STUDIES ON SOIL TEST BASED NUTRIENT MANAGEMENT APPROACHES IN DRY DIRECT SEEDED RICE - MUSTARD CROPPING SYSTEM

RAGHAVENDRA

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF AGRICULTURE, RAICHUR

UNIVERSITY OF AGRICULTURAL SCIENCES

RAICHUR – 584 104

AUGUST, 2017

STUDIES ON SOIL TEST BASED NUTRIENT MANAGEMENT APPROACHES IN DRY DIRECT SEEDED RICE-MUSTARD CROPPING SYSTEM

Thesis submitted to the
University of Agricultural Sciences, Raichur
in partial fulfillment of the requirement for the

Doctor of Philosophy

in

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

By

RAGHAVENDRA

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF AGRICULTURE, RAICHUR

UNIVERSITY OF AGRICULTURAL SCIENCES

RAICHUR – 584 104

AUGUST, 2017

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF AGRICULTURE, RAICHUR

UNIVERSITY OF AGRICULTURAL SCIENCES

RAICHUR – 584 104

CERTIFICATE

This is to certify that the thesis entitled **" STUDIES ON SOIL TEST BASED NUTRIENT MANAGEMENT APPROACHES IN DRY DIRECT SEEDED RICE-MUSTARD CROPPING SYSTEM"** submitted by **Mr. RAGHAVENDRA** for the degree of **DOCTOR OF PHILOSOPHY** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the University of Agricultural Sciences, Raichur, is a record of research work carried out by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

RAICHUR

JUNE, 2017

_____
(K. NARAYANA RAO)
CHAIRMAN

Approved by
Chairman:

_____
(K. NARAYANA RAO)

Co-Chairman: _____
(SUHAS P. WANI)

Members: 1.

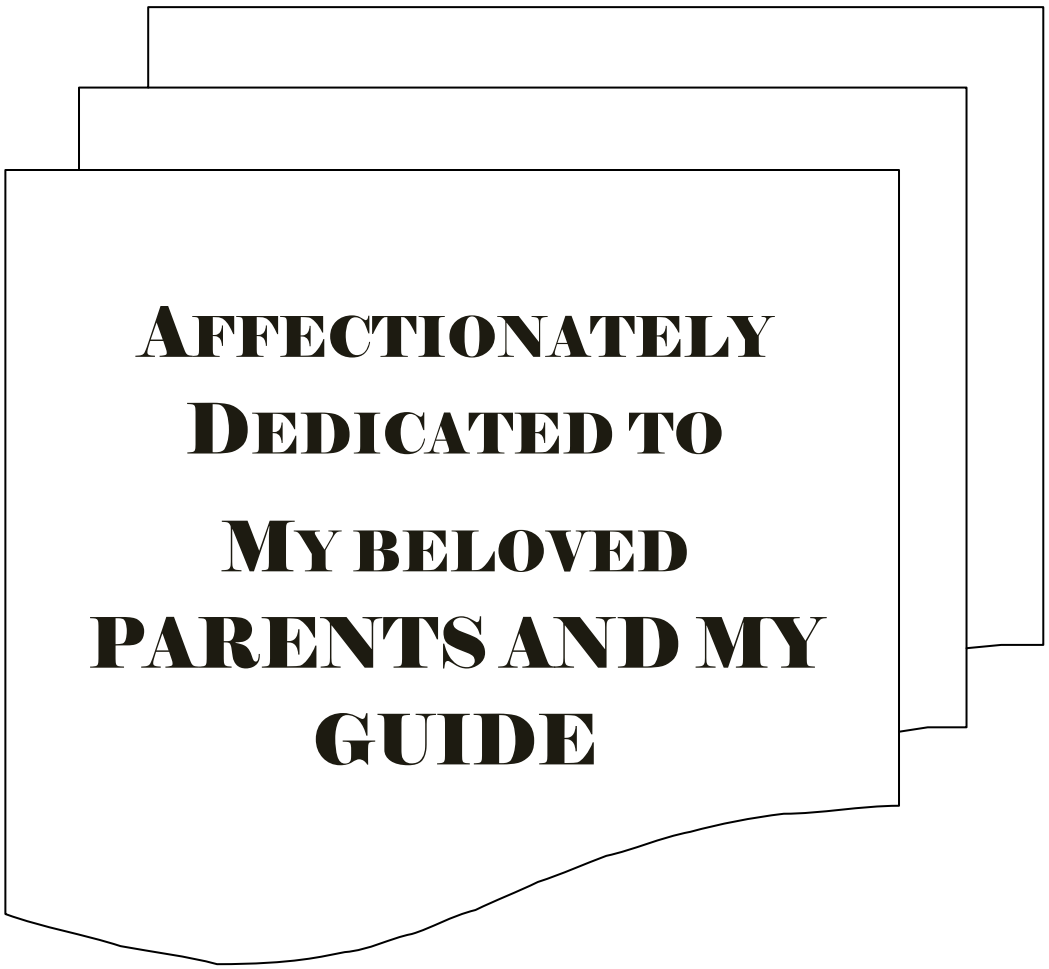
_____
(M. V. RAVI)

2.

_____
(VEERESH H.)

3. _____
(A. S. CHANNABASAVANNA)

4. _____
(MAHADEVA SWAMY)


Affectionately
Dedicated to
My beloved
PARENTS AND MY
GUIDE

ACKNOWLEDGEMENT

It is a matter of pleasure to glance back and recall the path one traverses during the days of hard work and pre-perseverance. It is still great at this juncture to recall all the faces and spirit in the form of teachers, friends, near and dear one's. I would consider this work nothing more than incomplete without attending to the task of acknowledging the overwhelming help I received during this endeavor of mine.

It is always immense and immeasurable pleasure to applaud the auspicious personality who has the character of benevolence, consummate and care taking in others welfare. Here I am in hunt for words to express my pleasurable feelings and thankfulness to my well-wisher cum chairman of my advisory committee ***Dr. K, Narayana Rao,*** *Professor and Head, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Raichur for his level of guidance, lively encouragement and constructive criticism at every stage of my research work, is far beyond the call of duty.*

I express my sincere gratitude and thanks to the members of my advisory committee, ***Dr. M. V. Ravi,*** *Programme Co-ordinator KVK, Raichur,* ***Dr. Veeresh H,*** *Assistant Professor Department of Soil Science and Agricultural Chemistry,* ***Dr. A.S Channabasavanna,*** *Professor Agronomy & Head of ARS, Malnoor and* ***Dr. Mahadeva Swamy,*** *Professor Department of Agricultural Microbiology, College of Agriculture Raichur for their constant encouragement, valuable suggestions, sensible criticism and constructive guidance during the course of this investigation.*

I am very much thankful to my Co-chairman of my advisory committee ***Dr. Suhas P. Wani*** *Research Program Director – Asia and Theme Leader- ICRISAT Development Center for his constant guidance and suggestions during the course of research work. And also I convey my heartful thanks to* ***ICRISAT (LSU team)*** *for the financial support during the research period.*

I also thankful to ***Dr. M. G. Patil*** *, Dean (PGS),* ***Dr. B. S. Golasangi,*** *(Technical Officer) and Sri. Veeresh Gouda, Personal Secretary,, Directorate of Post Graduate Studies, UAS, Raichur for the excellent technical support and guidance.*

This thesis must severely bear the imprint of insightful entries and ideas of ***Dr. M. K, Naik,*** *Director of Research, UAHS, Shivamogga, Dr. S. R. Balanagoudar, Dr. S. N. Bhatt, Sri. R. V. Beladhadi, Sri. N. L. Rajesh, Dr. H. S. Latha, and the staff of Department of Soil Science and Agricultural Chemistry, UAS, Raichur. I also thankful to Dr. A. G shrinivas, Dr. Dhanoji and Dr. Ashok Gaddi their constant help during the course period College of Agriculture, Raichur.*

I ever remain grateful to my teachers of pre and post matriculation, undergraduate and post-graduate studies, as their dedication in teaching along with affection and love showered brought me to this stage.

I wish to place record my heartfelt thanks to my parents and their persistent encouragement, blessings and affections of my father ***Sri. Anjaneya,*** *mother* ***Smt. Laxmidevi*** *and my sister* ***Veena*** *with whose undemanding, selfless scarifies, unwearing support, love and blessings in these days of testing and toiling, stand in an immaculate, may I be worthy to be upto their desires and expectations.*

I also I wish to place record my heartfelt thanks to Mr. Haribabu, Sathynarayana and Dorababu farmers of Vijayanagar camp, their constant help and suggestions during the experimentation period.

Friends are invaluable treasures, it is because of their precious help, constant support and encouragement. I completed this daunting task. I take this opportunity to express my heartfelt gratitude to my friends. Few such memorable junior friends are Umesh, Bheemaraya and Mareppa and junior friends like Geethanjali (M. Sc Maize), Meenakshi, Soumya, Kumar Naik and Rajesh and my senior friend like, B,V Shreenivas, Ravi sir, Sudharshan, Bharathkumar, Rajesh (Dhada) who helped me directly and indirectly of course a long chain I remember always.

I express deep sense of gratitude to non-teaching staff members viz., Somashekar, Sreenivas, Krishnamurthi, Veenodha, Shreedevi, Huligemma, Laxmi and Sujala staff for their kind and selfless help all throughout during the analytical works and making me successful.

Finally, I thank library authorities and teachers of UAS, Raichur for providing facilities during my study.

One last word; since it is practically impossible to list all the names who contributed contributions to my work, it seems proper to issue a blanket of thanks for those who helped me directly or indirectly during the course of study.

Raichur

June, 2017

(Raghavendra)

CONTENTS

Sl. No.	Chapter Particulars	Page No.
	CERTIFICATE	**iii**
	ACKNOWLEDGEMENT	**iv**
	LIST OF ABBREVIATIONS	**vi**
	LIST OF TABLES	**ix**
	LIST OF FIGURES	**xii**
	LIST OF PLATES	**xiii**
	LIST OF APPENDICES	**xiv**
I.	**INTRODUCTION**	**1-5**
II.	**REVIEW OF LITERATURE**	**6-44**
	2.1 Nutrient management approaches for enhancing growth and production potentials of various crops/cropping system.	7
	2.2 Nutrient availability, uptake and use efficiencies in crops/cropping system as influenced by nutrient management approaches.	26
	2.3 Residual nutrient effect of various nutrient management approaches on growth and yield of mustard/other crops.	34
	2.4 Effect of nutrient supply on biological properties of soil.	37
	2.5 Economic analysis of different nutrient management approaches in crops/cropping system.	40
III.	**MATERIAL AND METHODS**	**45-74**
	3.1 Location of the experimental site	45
	3.2 Soil characteristics	46
	3.3 Climatic condition	46
	3.4 Cropping history of the experimental site	48
	3.5 Field experiment details	52
	3.6 Fertilizer calculation for Dry DSR	57
	3.7 Crop management practices for Dry DSR	61
	3.8 Collection of experimental data	63
	3.9 Observation on yield parameters and yield of Dry DSR	65
	3.10 Residual effects of different nutrient management approaches on the growth and yield of mustard	66

Contd...

Sl. No.	Chapter Particulars		Page No.
	3.11	Chemical analysis of soil samples	70
	3.12	Collection of soil samples for microbial activity	71
	3.13	Uptake pattern and use efficiencies of different nutrients	71
	3.14	Balance of NPK status in soil (kg ha^{-1})	72
	3.15	Rice equivalent yield (REY)	73
	3.16	Economic analysis	73
	3.17	Statistical analysis of data	74
IV.	**EXPERIMENTAL RESULTS**		**75-144**
	4.1	Growth parameters of Dry DSR	75
	4.2	Yield and yield attributing parameters of Dry DSR as influenced by different nutrient management approaches	84
	4.3	Nutrient uptake by Dry DSR	92
	4.4	Nutrient use efficiency (NUE) of Dry DSR	102
	4.5	Microbial population at harvest of the Dry DSR as influenced by different nutrient management approaches	107
	4.6	Soil enzyme activities at harvest of the Dry DSR as influenced by different nutrient management approaches	109
	4.7	Economics of Dry DSR as influenced by nutrient management approaches	111
	4.8	Growth parameters of mustard	114
	4.9	Yield and yield attributing parameters of mustard	116
	4.10	Nutrient uptake by mustard	120
	4.11	Economics of mustard as influenced by residual effect of different nutrient management approaches	126
	4.12	Soil chemical properties after harvest of mustard crop in Dry DSR-Mustard cropping sequence	129
	4.13	Soil fertility status after harvest of mustard crop in Dry DSR -Mustard cropping sequence	129
	4.14	Nitrogen, phosphorus and potassium balance in soil after harvest of mustard crop in Dry DSR-Mustard cropping sequence	133
	4.15	Rice-equivalent yield and economics of Dry DSR-Mustard cropping sequence	141

Contd...

Sl. No.	Chapter Particulars		Page No.
V.	**DISCUSSION**		**146-191**
	5.1	Soil characteristics	147
	5.2	Effect of weather parameters on crop growth	147
	5.3	**DRY DIRECT SEEDED RICE**	**149-173**
	5.3.1	Effect of different nutrient management approaches on yield, yield attributes and growth parameters of Dry DSR	149
	5.3.2	Influence of different nutrient management approaches on nutrient uptake by Dry DSR	164
	5.3.3	Influence of different nutrient management approaches on nutrient use efficiency (NUE) of Dry DSR	165
	5.3.4	Microbiological properties of rhizospheric soil of rice as influenced by different nutrient management approaches	170
	5.3.5	Economics of Dry DSR as influenced by different nutrient management approaches	173
	5. 4	**MUSTARD**	**175-180**
	5.4.1	Residual effect of different nutrient management approaches on growth, yield and yield parameters of mustard	175
	5.4.2	Residual effect of different nutrient management approaches on nutrient uptake and economics of mustard	180
	5. 5	**DRY DSR - MUSTARD CROPPING SEQUENCE**	**182-192**
	5. 5.1	Influence of different nutrient management approaches on soil fertility status after harvest of mustard crop in Dry DSR-Mustard cropping sequence	182
	5. 5.2	Influence of different nutrient management approaches on balance of N, P_2O_5 and K_2O after harvest of mustard crop in Dry DSR-Mustard cropping sequence	186
	5. 5.3	Influence of different nutrient management approaches on rice equivalent yield and economics of Dry DSR-Mustard cropping sequence	188
VI.	**SUMMARY AND CONCLUSIONS**		**192-197**
VII.	**REFERENCES**		**198-218**
	APPENDICES		**219-229**

LIST OF TABLES

Table No.	Title	Page No.
1	Initial physico-chemical and biological properties of soil from the experimental site	47
2	Monthly meteorological data for the year 2015-16 and 2016-17 recorded at Meteorological Observatory, Main Agricultural Research Station, UAS, Raichur	49
3	Plant height of Dry DSR at different growth stages as influenced by different nutrient management approaches	76
4	Number of tillers m^{-2} of Dry DSR at different growth stages as influenced by different nutrient management approaches	78
5	Leaf area per plant of Dry DSR at different growth stages as influenced by different nutrient management approaches	81
6	SPAD values of Dry DSR at different growth stages as influenced by different nutrient management approaches	83
7	Total dry matter production of Dry DSR at different growth stages as influenced by different nutrient management approaches	85
8	Number of panicles m^{-2}, number of grains $panicle^{-1}$ and panicle length of Dry DSR as influenced by different nutrient management approaches	87
9	Filled grains per panicle, unfilled grains per panicle and sterility per cent of Dry DSR as influenced by different nutrient management approaches	89
10	Test weight, grain yield and straw yield of Dry DSR as influenced by different nutrient management approaches	91
11	Effect of different nutrient management approaches on nitrogen uptake by Dry DSR	93
12	Effect of different nutrient management approaches on phosphorous uptake by Dry DSR	95
13	Effect of different nutrient management approaches on potassium uptake by Dry DSR	97
14	Effect of different nutrient management approaches on sulphur uptake by Dry DSR	99
15	Effect of different nutrient management approaches on zinc uptake by Dry DSR	101
16	Effect of different nutrient management approaches on iron uptake by Dry DSR	103

Contd...

Table No.	Title	Page No.
17	Nutrient use efficiency of Dry DSR as influenced by different nutrient management approaches	105
18	Agronomic efficiency of Dry DSR as influenced by different nutrient management approaches	106
19	Microbial population at harvest stage of Dry DSR as influenced by different nutrient management approaches	108
20	Soil enzyme activities at harvest stage of Dry DSR as influenced by different nutrient management approaches	110
21	Economics of Dry DSR as influenced by different nutrient management approaches	113
22	Residual effect of different nutrient management approaches on growth parameters of mustard at harvest	115
23	Residual effect of different nutrient management approaches on yield attributing parameters of mustard	117
24	Residual effect of different nutrient management approaches on seed yield, stover yield, oil content and oil yield of mustard	119
25	Residual effect of different nutrient management approaches on nitrogen uptake by mustard	121
26	Residual effect of different nutrient management approaches on phosphorous uptake by mustard	123
27	Residual effect of different nutrient management approaches on potassium uptake by mustard	125
28	Residual effect of different nutrient management approaches on economics of mustard	128
29	Physico-chemical properties of soil after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches	130
30	Available N, P_2O_5 and K_2O in soil after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches	132
31	Available sulphur, zinc and iron in soil after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches	134
32	Nitrogen balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2015-16	136

Contd...

Table No.	Title	Page No.
33	Nitrogen balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2016-17	137
34	Phosphorus balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2015-16	139
35	Phosphorus balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2016-17	140
36	Potassium balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2015-16	142
37	Potassium balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by nutrient management approaches during 2016-17	143
38	Rice equivalent yield and economics of Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches	145

LIST OF FIGURES

Figure No.	Title	Page No.
1.	Monthly meteorological data recorded at Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Raichur for the year 2015-16.	50
2.	Monthly meteorological data recorded at Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Raichur for the year 2016-17.	51
3.	Plan of experimental layout	56
4.	Influence of different nutrient management approaches grain yield and straw yield of Dry-DSR	151
5.	Number of panicles m^{-2}, number of grains $panicle^{-1}$, panicle length and test weight of Dry-DSR as influenced by different nutrient management approaches	157
6.	Total dry matter production of Dry DSR at different growth stage as influenced by different nutrient management approaches	161
7.	Leaf area per plant of Dry DSR at different growth stages as influenced by different nutrient management approaches	161
8.	Number of tillers m^{-2} of Dry DSR at different growth stage as influenced by different nutrient management approaches	163
9.	Plant height of Dry DSR at different growth stages as influenced by different nutrient management approaches	163
10.	Effect of different nutrient management approaches on total nutrient uptake (N, P, K and S) by Dry DSR	166
11.	Effect of different nutrient management approaches on total Zn and Fe uptake by Dry DSR	167
12.	Effect of different nutrient management approaches on NPK use efficiency by Dry DSR	169
13.	Agronomic efficiency of NPK by Dry DSR as Influenced by different nutrient management approaches	169
14.	Microbial population at harvest of Dry DSR as influenced by different nutrient management approaches	171
15.	Soil enzyme activities at harvest of Dry DSR as influenced by different nutrient management approaches	171

Contd…..

Figure No.	Title	Page No.
16.	Economics of Dry DSR as influenced by different nutrient management approaches	174
17.	Yield parameters of mustard as influenced by residual nutrient effect of different nutrient management approaches	178
18.	Growth parameters of mustard as influenced by residual nutrient effect of different nutrient management approaches	178
19.	Residual effect of different nutrient management approaches on total nutrient uptake (N, P and K) by mustard after harvest	181
20.	Economics of mustard as influenced by residual effect of different nutrient management approaches	181
21.	Available N, P_2O_5 and K_2O in soil after harvest of second crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches	186
22.	Available Sulphur, Zinc and Iron in soil after harvest of mustard in Dry-DSR-Mustard cropping sequence as influenced by different nutrient management approaches	186
23.	Economics of Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches	190

LIST OF PLATES

Plate No.	Title	Page No.
1.	Over view of the experimental site at 75 DAS during, 2015	53
2.	Over view of the experimental site at maturity during, 2016	54
3.	General view of experiment on mustard during 2016 and 2017	68
4.	Comparative view of soil test based nutrient management approaches in Dry DSR, at milking stage	152
5.	Comparative view of soil test based nutrient management approaches in Dry DSR, at harvesting stage	153
6.	Comparative view of soil test based nutrient management approaches in Dry DSR, at milking stage	158
7.	Comparative view of different nutrient management approaches in Dry DSR, at harvesting stage	159
8.	Comparative view of residual nutrient effect of various nutrient management approaches on mustard	179

LIST OF APPENDICES

Appendix No.	Title	Page No.
I	Nitrogen and phosphorous concentration (%) in dry direct seeded rice after harvest during 2015 and 2016	219
II	Potassium and sulphur concentration (%) in dry direct seeded rice after harvest during 2015 and 2016	220
III	Zinc and iron concentration (ppm) in dry direct seeded rice after harvest during 2015 and 2016	221
IV	Nitrogen and phosphorous concentration (%) in mustard after harvest during 2016 and 2017	222
V	Potassium concentration (%) in mustard after harvest during 2016 and 2017	223
VI	Details of cost of cultivation of dry direct seeded rice in different treatments (₹ ha^{-1}) during *kharif* 2015	224-225
VII	Details of cost of cultivation of dry direct seeded rice in different treatments (₹ ha^{-1}) during *kharif* 2016	226-227
VIII	Details of cost of cultivation of mustard (₹ ha^{-1}) during *rabi* 2015-16	228
IX	Details of cost of cultivation of mustard (₹ ha^{-1}) during during *rabi* 2016-17	229

Introduction

I. INTRODUCTION

Rice is a vital food to more than half of the world's population. It is the most important food grain in the diets of hundreds of millions of peoples in Asia, Africa and Latin America living in the tropics and subtropics. In these areas, population growth rate is rapid and will likely remain high at least for the next decade. Rice will continue to be their primary source of food. In India, it continues to hold the key to sustain food production by contributing 20 to 25 per cent and assures food security for more than half of the total population. Rice accounts for 55 per cent of total cereal production in the country. The per capita food intake in India is 2234 calories per day of which 30 per cent comes from rice. In India, rice is grown in an area of 43.86 m ha with an annual production of about 104.84 million tonnes and the productivity is about 2.39 tonnes per ha (Anon., 2015). In Karnataka, rice is cultivated in command areas of Cauvery, Tungabhadra and Upper Krishna, where conventional puddling and transplanting are the major system of cultivation. In Western Ghats and high rainfall areas, the rice is cultivated as drill sown. The total area under rice in Karnataka is 1.30 m ha with an annual production of 3.66 million tonnes and the productivity is 2.83 tonnes per ha (Anon., 2015).

In spite of all the achievements of the green revolution, serious food problems still exist in the world. For every 3.6 seconds an individual dies of hunger. Chronic hunger takes the lives of 2400 people every day. Currently, there are more than 800 million undernourished people in the developing world. Three hundred million children under the age of five die because of hunger and malnutrition and one out of five babies is born underweight. It is necessary to produce 40 per cent more rice by 2025 to satisfy the growing demand without adversely affecting the resource base. This increased demand will have to be met from shrinking land, water and labour. If we are not able to produce more rice from the existing land resources, land-hungry farmers will destroy forest and move into more fragile lands, such as hillsides and wetlands, with disastrous consequences for biodiversity and watersheds.

Asia's population is projected to increase from 3.7 billion in 2000 to 4.6 billion in 2025. About 530 million tonnes of rough rice was produced from 135 million ha from irrigated rice area (average yield is 3.9 tonnes ha^{-1}) in 2002. Further, intensification of

irrigated rice farms is necessary to feed the growing population and maintain food security in the near future. Rice farmers, however, face several problems: stagnating yield: declining profit (due to rising input costs and lower rice prices); less land, water and labour for rice cultivation. So, there must be integrated use of compatible technologies that meet farmers needs and improve their productivity and income (Balasubramanian *et al*., 2005).

In India, rice is grown under 4 major ecosystems *viz.,* irrigated (21 m ha), rainfed lowland (14 m ha), rainfed upland (6 m ha) and flood prone (3 m ha). More than half of rice area (55 %) is rainfed in which 80 per cent of the rainfed rice area is in eastern India, making its cultivation vulnerable to vagaries of monsoon (Anon., 2006).

Rice is generally cultivated by transplanting or direct seeding methods. Transplanting method is extensively used, but it is laborious, cumbersome, time-consuming and expensive than direct seeding method. Non availability of labour in time and increase in cost of land preparation and transplanting are the problems in the major rice growing areas. While, the scarcity of labour at peak demand period results in increased cost of operation and delay in transplanting. Higher productivity is achieved by making certain changes in the management of rice and the resources depending on soil nutrients, water, soil biota and solar energy (Cessay *et al*., 2006, Lin *et al*., 2009 and Thakur *et al*., 2009).

Dry direct seeded rice (Dry DSR) is one such method of establishing rice with limited water supply, labour requirement and optimum nutrients. It has become a boon for tail-end farmers of command areas of Tungabhadra (TBP) and Upper Krishna Project (UKP) where, water supply is limited. The tail end farmers do not get sufficient water at right time and faced with ON-OFF canal water supply. Due to declining resources, farmers of tail end get water once in 10 days in Upper Krishna (UKP) and 20 days in Tungabhadra Project (TBP) forcing farmers to complete transplanting within this period which is not possible with limited labours, machinery *etc*. Under late onset of monsoon conditions and insufficient water in barrages, canal water may become erratic and untimely leading to delayed transplanting (beyond August). water scarcity and in spite of shortage of water in *kharif*, many farmers in tail-end still willing go either for early dry seeding or take advantage of early rains received nearly one and half month before canal

supplies was imminent success with farmers. This establishment/germination of rice could very well survive drought for one month before switching over to canal water as and when available. Thus, taking advantage of early showers and Dry DSR over transplanting caught the attention of farmers. Dry DSR has become boon for such farmers in the tail-end command area of Koppal, Raichur, Bellary and Yadagir districts.

The actual yield potentiality of Dry DSR had not been achieved because of existing fertilizer recommendation, as it consist of fixed rates and timing of N, P and K for vast areas of production. Such recommendations are in practice over the years in large areas. But crop growth and crop need for supplemental nutrients are strongly influenced by genotype, soil type and climate which can vary greatly among fields, seasons and years. A judicious use of fertilizers is essential since the cost of fertilizers has gone up very high in recent years. At present, the state or regional recommendations are very general and does not consider site-specific crop nutrient requirements. The nutrient requirement of direct-seeded rice is probably lower than that of transplanted rice during early growth stages. However, with higher planting densities used in direct seeding, a higher fertilizer rate may be required, particularly for later growth stages (Dingkuhn *et al.*, 1991). In addition, most existing fertilizer spreaders were not adjustable (Attanandana, *et al.*, 2002). These factors result in unbalanced and inefficient fertilizer use that results in poor economic returns. Furthermore, when N and P are used in unbalanced nutrient programs, they may be in excess of crop demand and result in losses from the soil-crop system, contributing to the nutrient load in streams, rivers, and other water bodies. TBP command area farmers in Karnataka are known for using imbalanced dose of nutrients with higher tendency for N and P fertilizers application. This also causes environmental damage and increase the total cost of production as heavy N use makes the rice crop more susceptible to pest and disease and thus increases cost of protection. This is aggravated under direct-seeding conditions where canopy density is invariably high. Unbalanced fertilizer use also causes soil degradation, particularly when N fertilizer use drives the removal of P and K that are not replenished by the addition of fertilizer nutrients. Fertilizer requirements of different crops vary due to their differential production potential and ability to mine nutrients from native and fertilizer sources. Therefore, the quantity of fertilizer to be applied to crops depends upon the initial nutrient status of the soil and thereby, soil test value need considerable attention. The fertilizer requirement of crop also depends upon the yield targets to be

achieved. For achieving a definite yield target of a crop, a definite quantity of nutrients must be applied to the crop and this requirement of nutrients can be calculated by taking into consideration the contribution of native soil available nutrients and applied fertilizer nutrients. This forms the basis for the fertilizer recommendation for targeted yield of crops (Subba Rao and Srivastava, 2000).

Among the various methods of fertilizer applications approaches, the one based on 'yield targeting' (SSNM and STCR) are unique in the sense that these methods not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve if good nutrient management practices are followed in raising the crop. For a given soil plant system located in a climatic belt, these approaches are unique because it provides a scientific basis for balanced fertilization not only among the fertilizer nutrient themselves but also soil available nutrients. Thus, there is an urgent need for more site specific nutrient recommendations that can be readily transferred and can meet farmer's production goals and resources. The site specific nutrient management (SSNM) approaches does not significantly aim to either reduce or increase fertilizer use. Instead, it aims on timely application of nutrients at optimal rates in order to achieve higher yields and higher nutrient use efficiency by the crops. SSNM approach provides the scientific basis for balanced fertilization based on soil available nutrient ratings.

The SSNM, STCR and NE approaches provide principles and tools for supplying crop nutrients as and when needed to achieve higher yield. These approaches not specifically aim to either reduce or increase fertilizer use. Instead, they aim to apply nutrients at optimal rates and time to achieve higher yield and high efficiency of nutrient use by the crop, leading to more net returns per unit of fertilizer invested. The targeting of crop yields is of importance so as to obtain varying production levels and to monitor the stress on soil fertility, since exhaustion of the nutrients from the soil is directly proportional to the yield level obtained. This also ensures judicious use of fertilizers and allows altering the profit per unit investment of fertilizers. The appropriate timing and rate of fertilizer application helps to increase higher yield and fertilizer use efficiency under Dry DSR.

Dry DSR-Mustard cropping system is most prominent and popular double cropping system under tail-end farmers of command areas of Tungabhadra (TBP) where

water supplies are limited during summer. Mustard crop cultivated as winter *rabi* crop with the available residual soil moisture and nutrients of Dry DSR. Indian mustard (*Brassica juncea* L.), locally known as "Sasive", belongs to *Cruciferae* family. It is introduced as an oily herb (38 - 40 per cent oil content), which is appropriate for zones with short seasons and less rainfall (Burton *et al*., 1999). Mustard is the major oilseed crop of India. Among the seven annual edible oilseeds cultivated in India, rapeseed-mustard contributed 28.6 per cent of the total production of oilseeds. India holds a premier position in rapeseed-mustard economy of the world with 2nd and 3rd rank in area and production, respectively. This group of oilseed crops is gaining wide acceptance among the farmers because of adaptability for both irrigated as well as rainfed areas and suitability for sole as well as mixed cropping. Besides, it offers higher return with low cost of production and low water requirement. Being a major *rabi* oilseed crop and having an advantage of soil moisture conserved during monsoon, it has greater potential to increase the availability of edible oil from the domestic production. Its wide adaptability for varied agro-climatic conditions, the area, production and yield of mustard in India have been fluctuating due to various biotic and abiotic stresses coupled with India's domestic price support programme. Nevertheless, the crop has potential to ensure the nutritional security and contribute to livelihood security. The highest productivity is in Gujarat (1396 kg ha^{-1}), Haryana (1343 kg ha^{-1}) and Rajasthan (1185 kg ha^{-1}) with overall national yield of 1151 kg ha^{-1}.

Nutrient requirement of Dry DSR varies from field to field due to high variability in soil fertility across farmers field and single homogenous nutrient recommendations may not be very useful in improving Dry DSR yields and maintain soil fertility. Increased fertilizer prices and escalating fuel prices in international market will make fertilizer input one of the costliest components in agriculture. Fertilizer best management practices with due importance to indigenous sources of nutrients such as organic manures, use of nutrient efficient genotypes *etc*., will be required for sustainable management of emerging Dry DSR-Mustard cropping system in the country. This research provides a synthesis of current information on Dry DSR-Mustard production systems, pros and cons of existing nutrient management strategies and the fertilizer best management practices for bridging yield gaps in current and emerging Dry DSR-Mustard sequence cropping systems in the tail end of TBP command area.

In view of the above, the present investigation was undertaken to study the "Soil Test Based Nutrient Management Approaches in Dry DSR-Mustard cropping system" in the farmer field of Vijayanagara Camp, Tq. & Dist: Raichur, during *kharif* and *rabi* seasons of 2015-16 and 2016-17 with the following objectives.

1) To identify the suitable nutrient management approach for enhancing production potential of Dry Direct Seeded Rice.
2) To study the nutrient uptake pattern and nutrient use efficiency of Dry Direct Seeded Rice under various nutrient management approaches.
3) To study the residual nutrient effect of nutrient management approaches on growth and yield of succeeding mustard.
4) To assess the economics of different nutrient management approaches on Dry DSR-Mustard sequence cropping system.

Review of Literature

II. REVIEW OF LITERATURE

Soil test calibration which is intended to establish a relationship between the levels of soil nutrients determined in the laboratory and crop response to fertilizer application in the field permits balanced fertilization through right kind and amount of fertilizers. In this regard, targeted yield approach had been found to be beneficial which recommends balanced fertilization considering the soil available nutrient status and crop needs.

The performance of suitable nutrient management approaches *viz.*, Site Specific Nutrient Management (SSNM), Soil Test Crop Response (STCR), Nutrient Expert (NE) and Soil Test Laboratory (STL) practices includes nutrient availability, uptake, targeted yield are required to increase productivity, quantity, profitability and nutrient use efficiency in rice-mustard cropping system. The work done in this regard particularly on rice-mustard cropping system is limited. Hence the work done on different crops in addition to the work on the same crops has been reviewed and the available literatures on sustainable nutrient management approaches are presented in this chapter under the following headings.

2.1 Nutrient management approaches for enhancing growth and production potentials of various crops/cropping system.

- 2.1.1 Growth and yield of rice as influenced by SSNM
- 2.1.2 Growth and yield of rice as influenced by STCR
- 2.1.3 Growth and yield of rice as influenced by nutrient expert
- 2.1.4 Growth and yield of rice as influenced by STL

2.2 Nutrient availability, uptake and use efficiencies in crops/cropping system as influenced by nutrient management approaches.

2.3 Residual nutrient effect of various nutrient management approaches on growth and yield of mustard/other crops.

2.4 Effect of nutrient supply on biological properties of soil.

2.5 Economic analysis of different nutrient management approaches in crops/cropping system.

2.1 Nutrient management approaches for enhancing growth and production potentials of various crops/cropping system.

The application of graded levels of major nutrients based on targeted yield approaches influences the growth and yield of many crops. In the present study an effort has been made to maximize the productivity and profitability of rice-mustard cropping system in Vertisol through sustainable nutrient management approaches.

2.1.1 Growth and yield of rice as influenced by SSNM

The performance of Site Specific Nutrient Management (SSNM) practices that include soil and season specific knowledge of crop nutrient supply are required to increase productivity, quantity, profitability and nutrient use efficiency in rice and mustard.

The main features of SSNM are;

- Site-specific application of all the essential nutrients based on soil tests.
- Optimal use of existing sources of nutrients, such as soil, crop residues and manures.
- SSNM further provides guidelines for selection of the most economic combination of nutrients.
- Advocates intelligent and optimal use of indigenous sources of nutrients such as crop/animal residues and manures.

Tandon (1976) revealed that fertilizer levels based on soil test and crop needs for 50 q ha^{-1} yield target increased the wheat yield by 12 q ha^{-1} over farmer's practice and this increase was obtained at 11.7 kg grain per kg of N + P_2O5 + K_2O.

Prasad and Prasad (1994) stated that application of fertilizer for a target yield of 30 and 40 q ha^{-1} along with different levels of compost to rice. There was a lower application of fertilizer with increase in the availability of compost and lowered the target yield. In that study application of 5 t ha^{-1} compost and 55, 41 and 27 kg NPK ha^{-1} recorded 31.1 q ha^{-1} and 135, 85 and 68 kg NPK ha^{-1} resulted in yield of 42.8 q ha^{-1}.

The potential benefits cited most frequently for site-specific nutrient management include increased profitability through higher yields and crop quality or through lower

costs of nutrient management and improved quality of the soil, water and air resources upon which agriculture and society depend and increased accountability for agriculture (Fixen, 1998).

Bhatti *et al.* (1998) created site specific N management units based on crop productivity. Site specific N management reduced N fertilizer application up to 70 per cent without a reduction in wheat grain yield compared to a grower's practice.

Singh and Singh (2000) compared SSNM in rice and wheat with farmer's practice and found an average increase of 0.56 and 0.58 t ha^{-1} in rice and wheat yields respectively.

Wang (2001) evaluated the performance of rice under SSNM practice with farmers practice. The results indicated that average grain yield of rice increased from 5.9 t ha^{-1} to 6.4 t ha^{-1} while plant N, P and K uptake increased by 8 to 14 per cent. The gross return over fertilizer cost was about 10 per cent greater with SSNM than farmers practice.

Site-specific approach to nutrient management was evaluated in 179 on-farm experiments with irrigated rice in China, India, Indonesia, Thailand, Philippines and Vietnam. The average grain yield of rice increased to 0.36 t ha^{-1} or 7 per cent greater with SSNM compared to the farmers practice. The increase ranged from 0.31 t ha^{-1} in the first year (+6 %) to 0.41 t ha^{-1} in the second year (+8 %). Plant uptake of N, P and K was greater with SSNM compared with farmers practice. The total amount of fertilizer N applied was initially similar in the two treatments, but N rates were about 7 per cent lower in SSNM in the second year (Doberman *et al.,* 2002).

Verma *et al.* (2002) found that prescription based fertilizer recommendation for the yield targets could be integrated with additional 5 t FYM ha^{-1}, would not only increase rice, maize and wheat yields by 4.2 to 5.7 q ha^{-1} but also build up soil fertility in terms of available N, P_2O_5 and K_2O and DTPA extractable micronutrients.

Mishra *et al.* (2003) conducted experiment on SSMM in hybrid rice at Pantnagar revealed that the highest grain yield of 9.7 t ha^{-1} was obtained with 150:60:120 N, P_2O_5, K_2O kg ha^{-1} with 6 kg Zn ha^{-1} and 7 kg Mn ha^{-1}. The state recommendation (SR) is 120:60:40 kg ha^{-1} with 6 kg Zn ha^{-1}, which produced 7.2 t ha^{-1}, indeed on farm experiments on SSNM in hybrid rice were established at three sites in the Udham Singh

Nagar district and reported that rice yields in SSMM plots ranged between 6.8 to 7.1 t ha^{-1} which were 0.7 to 0.8 t ha^{-1} greater than state recommendation (SR) and 0.2 to 0.3 t ha^{-1} greater than common farmers practice (FP).

Forty-one field verification trials were conducted with maize, rice and wheat at farmers' field to ascertain the validity of soil test based fertilizer prescription for achieving specific yield targets in wet-temperate zone of Himachal Pradesh. The results revealed that fertilizer recommendation based on targeted yield concept were found more precise and dependable up to the yield targets of 5 t ha^{-1} for rice and maize and 4 t ha^{-1} for wheat respectively (Verma *et al*, 2005).

Dhillon *et al.* (2006) recorded higher grain yield (27.6 to 46.0 q ha^{-1}) in rice with the application of fertilizer based on targeted yield (45 q ha^{-1}) approach when compared to farmers practice, general recommendation and soil test based recommendation.

Witt *et al.* (2006) indicated that sufficiently large yield gaps and significant opportunities to increase yield and profitability, if crop and nutrient management are fine-tuned to site-specific conditions. Farmers will probably need to adjust both timing and amount of fertilizer N, P, and K and use split applications to better match crop demand for nutrients.

Biradar *et al.* (2006) conducted an experiment with nutrient application on the basis of SSNM principles resulted in significantly higher grain yield over FP (Farmer's Practice) and RDF (Recommended Dose of Fertilizer) in rice crop. The yield increases under SSNM shows the promise for yield improvement can be achieved in northern parts of Karnataka through SSNM approach. The rice yields ranged from 5 to 6 t ha^{-1} under SSNM, 3.7 to 4.5 t ha^{-1} in RDF, and 3.4 to 3.9 t ha^{-1} under FP, with an average yield of 5.5, 4.1, and 3.7 t ha^{-1}, respectively. The average yield increase due to SSNM over RDF was 35 per cent and was50 per cent over FP.

Mishra *et al.* (2006) evaluated the performance of SSNM over 11 on-farm sites for two rice and one wheat crop, compared with the current farmers' fertilizer practice. The results of this study showed that SSNM has potential for improving yield and nutrient efficiency in irrigated rice-wheat system by providing balanced nutrition tailored to the dynamic crop demand in the season. The average grain yield of rice increased from 6.22 to 6.80 Mg ha^{-1} and wheat grain yield increased from 5.1 to 5.5 Mg ha^{-1}. The

gross return over fertilizer cost was 11 % greater with SSNM than with FFP in rice and about 9 % greater in wheat. SSNM saved about 41 kg N ha^{-1} in rice and 32 kg N ha^{-1} in wheat but increased K application by 25 kg ha^{-1} in rice and 27 kg ha^{-1} in wheat. Balanced fertilization and improved timing and splitting of fertilizer N increased N recovery efficiency in rice from 0.43 kg kg^{-1} in FFP plots to 0.57 kg kg^{-1} in SSNM plots. In wheat SSNM increased N recovery from 0.54 kg kg^{-1} to 0.64 kg kg^{-1}. The agronomic N use efficiency was 59 % greater with SSNM than with FFP in rice and 42 % greater in wheat.

Bandara *et al.* (2007) conducted an experiment to study the effect of site specific recommendation for rice grown in imperfect drained reddish brown earth soils low country dry zone of Sri Lanka, results showed that nutrients rates provided by optimum treatment computed by using the site specific approach amounting 175 kg N, 60 Kg P, 120 Kg K, 25 kg Mg, 50 kg S and 2 Kg Zn per hectare gave significantly higher growth, number of panicle m^{-2}, panicle length and rice yield of 7.38 t ha^{-1}, dry matter and nutrient content for the two consequent years of 2004 and 2005 than other treatments including department of agriculture fertilizer recommendation.

On farm participatory research was conducted in Northern Karnataka with the main objective of demonstrating the effect of SSNM on productivity of crops. The study indicated potential increment in yield when nutrients application was based on target yields under SSNM. As against the recommended dose of 50: 25: 0 kg N, P_2O_5, K_2O ha^{-1} for maize, application of 75:35:65 kg N, P_2O_5, K_2O based on SSNM resulted in obtaining the targeted yield of 8 t ha^{-1} (Biradar and Aladakatti, 2007).

Jianmin *et al.* (2007) conducted a survey on farmer's practice of fertilizer N in 18 villages of four provinces in China. The average rate of N application for rice production was 190 kg ha^{-1} and 76 per cent to 100 per cent of the total fertilizer N which was applied within 10 days after transplanting resulted in leaching of nitrate. The effect of SSNM through farmer participatory trial, it maintained rice yields with significantly less N fertilizer loss and there was no increase in labour input and 31 per cent N fertilizer were saved with SSNM technology. A recently developed SSNM technology can reduce fertilizer N use while preventing the yield falling.

Based on soil test values application of NPK fertilizers at 116:17:40 kg ha^{-1} (site specific nutrient management) recorded higher grain yield (6.06 t ha^{-1}) as compared to

application of NPK at 121:24:41 kg ha^{-1} (farmer's fertilizer practice) (5.72 t ha^{-1}). Fertilizer rate as estimated by SSNM is almost met the requirement of crop, therefore it could save nutrients, especially nitrogen which was applied too high by farmers. SSNM is a simple technique that farmers can be easily applied (Chu & Tan 2007). Site specific nutrient management (99.8:43.4:36 kg NPK ha^{-1}) in rice recorded higher grain yield (6.09 t ha^{-1}) as compared to farmer's fertilizer practice of 108.7: 48.6: 52.3 kg NPK ha^{-1} (4.99 t ha^{-1}) (Trinh *et al*., 2007).

Wang *et al.* (2007) conducted field experiments for seven years (1998–2004) to evaluate the agronomic performance of SSNM in farmers' fields. With SSNM, average grain yield increased by about 0.5 t ha^{-1} over the farmers' practice, while N use efficiency increased significantly. About 30 % of fertilizer N could be reduced through adoption of SSNM, which would effectively eliminate an unnecessary source of pollution in the rice ecosystem.

Field experiments were conducted by Singh *et al.* (2008) for 3 years to evaluate the effect of SSNM in rice-wheat cropping system at 9 locations of north-west India. Results of the study reported that the average mean grain yield of rice obtained with SSNM was 8.20 t ha^{-1} compared to 6.95 t ha^{-1} with the state recommendation and 6.03 t ha^{-1} with the farmer practice and the grain yield of the succeeding wheat crop was 4.86 t ha^{-1} with SSNM against 3.56 t ha^{-1} under farmer practice. The productivity of the entire rice-wheat system was highest under SSNM (12.79 t ha^{-1}), which was 35 % more than FP (9.49 t ha^{-1}).

Khurana *et al.* (2008) site-specific approach to nutrient management was evaluated in 56 on-farm experiments with irrigated wheat and transplanted rice crops in Northwest India. Compared with FFP, SSNM significantly increased grain yield in all regions in wheat and rice crops. On an average, SSNM generated a yield gain of at least 0.9 (17 %) and 0.5 t ha^{-1} (12 %) in rice and wheat crops, respectively, compared with FFP in approximately 48 % of the sites studied. Maximum increases in rice and wheat grain yields were obtained at sites with low fertility soils, while the regions with high fertility soils had minimum, but significant, increases in grain yields of rice and wheat crops with SSNM. Field-specific management of macronutrients increased yields of rice and wheat crops by 12 and 17 % and profitability by 14 and 13 %, respectively, in Northwest India.

Application of fertilizers based on SSNM in rainfed *Alfisols* conditions resulted in increasing the economic yield of maize crop as compared to recommended dose. It also recorded significantly higher nutrient uptake, nutrient balance and available nutrients in SSNM based nutrient management (Umesh, 2008).

Greta and Roland (2009) site-specific nutrient management (SSNM) is an approach that enables farmers to dynamically apply fertilizer to the rice crop as and when needed. On-farm field trials were conducted on 22 farms in the Philippines to verify and refine the SSNM guidelines for irrigated direct wet-seeded rice for the wet and dry seasons. The use of SSNM resulted in positive added net benefits, significantly higher yields, and higher gross return above fertilizer cost for farmers. Good crop management and assured availability of irrigation water helped to achieve targeted yields.

Gill *et al.* (2009) reported that higher grain yield of wheat grown after *kharif* crops under SSNM fixed plots on without application of secondary and micronutrients. The highest wheat yield under SSNM (6.57 t ha^{-1}) was registered after maize harvest, while the lowest production (5.81 t ha^{-1}) was recorded after sorghum fodder harvest.

Peng *et al.* (2010) field experiments and demonstration trials were conducted in China and other major rice-growing countries. On average, SSNM reduced N fertilizer by 32 % and increased grain yield by 5 % compared with farmers' N practices. The yield increase was associated with the reduction in insect and disease damage and improved lodging resistance of rice crop under the optimal N inputs. The main reason for poor fertilizer N use efficiency of rice crop in China is that most rice farmers apply too much N fertilizer, especially at the early vegetative stage. Furthermore, yield response of rice crop to N fertilizer application is low in China, around 1.5 t ha^{-1} on average. SSNM in China and other Asian rice-growing countries, we believe SSNM is a matured technology for improving both fertilizer N use efficiency and grain yield of rice crop.

Mukopadhaya and Majumdar (2010) conducted field experiments for evaluating the impact of soil test-based fertilization on rain fed rice. The results indicated significant yield increase with balanced use of nutrients. Omission of nutrients caused yield loss between 33 to 50 per cent (- P), 20 to 32 per cent (- K), 15 to 28 per cent (- S), 33 to 35per cent (-Zn), and 31 to 34 per cent (- B) in the Terai alluvial soils of West Bengal.

Uptake of all the nutrients significantly correlated with yield, suggesting interdependence of nutrient uptake that influenced yield.

Police Patil (2011) revealed that application of 169:32:113 NPK kg ha^{-1} (SSNM) for targeted yield of 6.5 t ha^{-1} in aerobic rice recorded significantly higher plant height (90.6 cm), higher number of tillers $hill^{-1}$ (40.1), dry weight (99.16 g $hill^{-1}$), leaf area (2943.10 cm^2 $hill^{-1}$), filled grains (165.92), panicle length (16.2 cm), 1000 seed weight (27.27 g) productive tillers $hill^{-1}$ (31.92), grain yield (5903 kg ha^{-1}) and straw yield (7279 kg ha^{-1}) as compared to application of 118: 22:78 NPK kg ha^{-1} for targeted yield of 4.5 t ha^{-1} (81.5 cm, 32.25, 86.71g $hill^{-1}$, 2075.05 cm^2 $hill^{-1}$, 153.63, 13.86 cm, 20.25 g, 27.25, 5685 and 7047 kg ha^{-1}, respectively).

Satyanarayana *et al.* (2011) reported that SSNM is not only a potential to increase profits but also shown increasing evidence of environmental friendliness owing to its balanced and crop need based nutrient application.

Alagesan and Babu (2011) revealed that the application of graded levels of N (40,80, 120, 160 and 200 kg N ha^{-1}) significantly increased the grain yield and yield attributing characters *viz.*, number of tillers, filled grains per panicle, percentage of unfilled grains per panicle and test weight. The effect was significant up to a level of 120 kg N ha^{-1}. Nitrogen application at 160 kg ha^{-1} did not bring any distinct effect on the yield parameters over 120 kg ha^{-1} level. Application of N in four equal splits at seedling, active tillering (AT), panicle initiation (PI) and flowering enhanced the growth and yield attributes when compared to the recommended practice of three equal splits of 1/3 each at seedling, AT and PI. In dry as well as SWM season, application of 120 kg N ha^{-1} produced higher grain yield of 5409 kg ha^{-1} and 5185 kg ha^{-1} respectively. Application of 160 kg N ha^{-1} failed to bring significant yield advantage over 120 kg N ha^{-1} level. The grain yield of wet seeded rice started declining when N was applied at 200 kg ha^{-1}.

Keram *et al*. (2012) findings showed that inorganic fertilizer application based on targeted yield along with organic manure (FYM) *i.e.,* integrated plant nutrient system (IPNS) approach, that consisted of application of 98 N: 103 P_2O_5: 27 K_2O kg ha^{-1} through chemical fertilizers + 46 N: 36 P_2O_5: 45 K_2O kg ha^{-1} through 5 t FYM ha^{-1} as organic manure, resulted in higher number of panicles m^{-2} (310.67) and grain yield 4.04 t ha^{-1} of rice. Thus the practice of fertilizing a crop on the basis of target is precise, meaningful and ecofriendly which needs to be among farmers to increase the yields.

Mauriya *et al.* (2013) field study was conducted during two consecutive years, to evaluate the response of site-specific nutrient management (SSNM) on productivity and economics of rice-wheat cropping system. The total productivity of the cropping system in terms of rice yield equivalent (14.8 t $ha^{-1}annum^{-1}$) was the highest with the application of SSNM treatment *i.e.* $N_{150}P_{60}K_{120}S_{40}B_5Mn_{20}Zn_{25}$ in rice and $N_{150}P_{60}K_{120}$ in wheat, which was 66.4 per cent higher over farmer's practice and 28.2 per cent over state recommended practice. All the yield attributing characters as well as yield of both rice and wheat showed beneficial effects of site-specific nutrient management. Highest net returns of 67,033 Rs $ha^{-1}annum^{-1}$ obtained with SSNM treatment, which was 31,681 and 16,905 Rs ha^{-1} $annum^{-1}$ higher over that of farmer's practice and state recommended doses, respectively. Thus, nutrients in rice–wheat cropping system may be applied on site-specific soil test basis including micronutrients along with major nutrients for higher productivity and profitability.

Upendra *et al.* (2013) revealed that among all the fertilizer doses, application of site specific nutrient management package *i.e.,* NPK B @ 100-90-90-0 kg ha^{-1} resulted the highest number of tillers m^{-2} (410), filled grains per panicle(123), panicle length (24.9 cm), 1000-grain weight, dry matter production at harvest(10632 kg ha^{-1}), grain yield (4961 kg ha^{-1}), net returns (17,711 Rs ha^{-1}), the highest N, P and K uptake at harvest (102.56, 24.76 and 85.45 kg ha^{-1}). Ignoring the application of P & K fertilizers for rice resulted in significant yield loss besides mining the very precious nutrient base of soil. Site-specific nutrient management involved balanced nutrition to rice crop showed its positive impact on yield and economics of rice-rice system. Boron application was found to be not useful in improving rice yields in flood plains of Godavari delta.

Jat *et al.* (2013) showed that highest yield of both rice and maize and also the highest system productivity were obtained with SSNM, further indicated that application of SSNM principles, aided by nutrient balance studies, can help improve nutrient management in rice maize systems towards improving yield and profitability.

Singh *et al.* (2014) revealed that targeted yield of rice (45 q ha^{-1}) and (50 q ha^{-1}) have been achieved by using the plant nutrients on the basis of targeted yield concept. The per cent increase in yield was 46.2 per cent in first location, 46.5 per cent in second location, 45.9 per cent in third location and 46.6 per cent in fourth location over farmers practice.

Umesh *et al*. (2014) reported that targeted yield based fertilizer application either by SSNM or STCR approach recorded significantly higher grain yield, oil and crude protein yield, starch and phenol content over state recommendation. Significantly higher grain (39.8 %) and straw yield (48.4 %) were obtained with the application of fertilizer based on SSNM for 8 t ha^{-1} target yield (6,491 kg ha^{-1}) over RDF (3,810 kg ha^{-1}) 100-50-25 kg N-P-K ha^{-1}. The stover yield was also responded lesser extent than did in grain yield.

Shreenivas (2016) conducted field experiments to study the sustainable nutrient management approaches for maximizing productivity and profitability of maize-chickpea cropping system in Vertisol of Upper Krishna Project (UKP) command area. Application of nutrients through SSNM approach for targeted yield of 8.0 t ha^{-1} of maize grain registered significantly higher grain and seed yield (7.74 t ha^{-1} and 2.99 t ha^{-1}, respectively) over farmers practice, RDF and STL method.

Paradkar *et al*. (2016) conducted experiment on site specific nutrients management and conservation tillage practices in maize-mustard relay cropping under rainfed conditions**.** SSNM (140:34:71 kg ha^{-1}) compared with NPK treatments of 50 per cent RDF (60:30:20 kg ha^{-1}), 100 per cent RDF (120:60:40 kg ha^{-1}). Results reveals that the grain yield of the crops, maize and mustard found highest in SSNM than 50 per cent RDF and 100 per cent RDF. In addition, conventional method of sowing showed significantly higher grain yield, 4573 kg $ha^{-1}$of maize, whereas, mustard gave high grain yield, 1002 kg ha^{-1} under zero tillage practices.

Application of nutrients based on site specific nutrient management approach increased the yield of rice crop; resource use efficiency and reduced the ill effect of imbalanced application of fertilizers.

2.1.2 Growth and yield of rice as influenced by STCR approach

The application of fertilizers on STCR method involves the information on the amount of the nutrient removed by the crop, initial level of soil fertility and contribution of nutrients from the soil and added fertilizers. This method is designed to maintain soil fertility and to increase the yield levels.

With the introduction of fertilizer responsive high yielding varieties and hybrids and intensification of cropping under irrigation during 1960’s, the general fertilizer

recommendations were being on the higher order. These fertilizer recommendations by soil test laboratories needed to be reoriented to suit the modern agricultural technology by generating soil test calibration research work. Keeping this in view, ICAR initiated the AICRP on STCR during the fourth five year plan (1967-68). The studies under the project provide quantitative relationship for adjusting fertilizer doses based on soil test values for obtaining maximum yield and profit per hectare, and targeted yields of crops/multiple cropping.

The experiment conducted by Milapchand *et al.* (1984) to test the validity of targeted yield concept for rice crop in the cultivators field showed that the actual yields obtained against different targets were within ± 5 and ± 10 per cent range for 70 and 23 per cent of the cases, respectively. The results of demonstration cum field verification trials in farmers fields conducted by different soil testing laboratories at IARI, New Delhi and analysis of follow up trials indicated that the yields achieved by following the generalized fertilizer recommendations could be obtained with even much lower levels of fertilizers when applied on STCR basis.

The average yield of cereals obtained using STCR technique was 4446 kg ha^{-1} with fertilizer nutrient application of 143 kg ha^{-1} and the yield obtained with general recommendation was 4421 kg ha^{-1} with fertilizer nutrient application of 213 kg ha^{-1} (Sonar *et al.,* 1984).

Dev *et al.* (1985) stated that the results on actual grain yield obtained against the 35 q ha^{-1} and 45 q ha^{-1} showed a variation of 27.7 to 47.4 and 28.3 to 56.5 q ha^{-1} and with state level general recommended doses, the yield obtained was 27 to 56.6 q ha^{-1}. The mean grain yield obtained was 35.0, 37.5 and 43.3 q ha^{-1} against the target of 35, 40 and 45 q ha^{-1}, respectively and the average yield obtained in 56 experiments for general recommendation was 39.6 q ha^{-1}. These results showed that soil test based yield targets of wheat were obtained with in ±10 per cent of the deviations of the target in majority of the experiment. Further, the results suggest that adjustment equation for knowing soil test based fertilizer application holds good and they can be safely used to advise farmers on fertilizer usage in wheat.

Ramamoorthy *et al.* (1985) established the theoretical basis and experimental proof for the fact that Liebig's law of minimum operates equally well for N, P and K.

This formed the basis of fertilizer application for achieving targeted yields, first advocated by Troug (1960).

Dhillon *et al.* (1987) reported that the nutrient requirement of crops increased with increase in yield target and decreased with increase in soil test value of the nutrient. They also calculated the quantity of fertilizer which produced the actual yield within ± 5 per cent of the target in 85 per cent cases and for targets greater than 40 q ha^{1}. The actual yields deviated by ± 10 per cent in 50 per cent and up to ± 20 per cent in 17 per cent cases.

Selvakumari (1998) showed that addition of NPK for a yield target of 65 q ha^{-1} based on STCR technology through fertilizers and green manure along with coal fly ash @ 40 t ha^{-1} recorded 73.7 q ha^{-1} grain yield in rice compared to 65.8 q ha^{-1} with fertilizer alone.

Sharma *et al.* (1989) compared three rates of fertilizer application, *viz.*, recommendation of the state department, rates as per soil test and farmers practice and observed that fertilizer doses as per soil test method gave significantly higher yields in rice.

STCR studies on the rice in the red laterite soil of the regional research station, Vridhachalam in India was carried out by Loganathan *et al.* (1995) to test validation of the fertilizer prescription equations for their applicability. They observed that these fertilizer prescription equations hold good at lower levels of yield target up to 2 t ha^{-1}, beyond which there is diminished response to applied nutrients. Fertilizer adjustment equations developed for wheat, rice, pearl, millet, Indian mustard and green gram were tested in fields conducting follow up trails for eight years in Punjab. The results showed that in all these crops, yield targets were achieved with ±10 per cent deviation from the target (Dhillon *et al.,* 1999).

Santhi and Selvakumari (1999) developed fertilizer adjustment equations inclusive of organic sources for rice both in *kharif* and *rabi* reasons in lower Bhavani project area of Tamilnadu. The quantity of fertilizer that could be adjusted to the levels and sources of organic manures was evaluated to be 38 kg N ha^{-1}, 13 kg P_2O_5 ha^{-1} and 33 kg K_2O ha^{-1} fertilizers with GM (*Sesbania rostrata*), 10 kg P_2O_5 ha^{-1} for fertilizers with

(*Bacillus megaterium* var. *phosphaticum)* 40 kg N, 26 kg P_2O_5 and 33 kg K_2O ha^{-1} for fertilizers with GM plus PB.

Suri and Verma (1999) reported that fertilization based on targeted yield concept in maize-wheat system was superior to both state level general recommendation and soil test based approaches.

Subba Rao and Sanjay Srivastava (2000) stated that in majority (80 %) of the cases, the yield target were achieved within ± 10 per cent variation by applying fertilizers based on STCR approach. Farmer's practice of fertilizer application was inferior to soil test based fertilizer recommendation.

Ray *et al*. (2000) conducted field experiments with different fertility gradients in Gangetic alluvial soil (Typic Ustochrept), of Nilganj series. The study revealed that the yield targets were achieved for jute 25-30 q ha^{-1}, coarse rice 35-50 q ha^{-1} and wheat 30-35 q ha^{-1} with + 10 per cent deviation from desired yield targets. Validity of the yield targets was tested at farmers' fields through follow-up trials as frontline demonstrations which revealed that prescription based fertilizer application was found profitable as compared to general recommendation.

Milapchand *et al.* (2004) modified a fertilizer adjustment equation for phosphorus for rice crop ($F.P_20_5$ =1.78 T - 8.4 Sp). Fertilizer P requirement at any soil test value of P for 7 t ha^{-1} rice yield target was lower when calculated using modified equation compared to that of calculated using earlier equation ($F.P_20_5$ =1.78 T -5.99 Sp).

Berra *et al.* (2006) carried out soil test crop response correlation studies in IR-36 to quantify rice production in the context of the variable use of balanced fertilizers based on targeted yield concept. Soil fertility status for N was low to medium (224-348 kg ha^{-1}), P was medium to high (87-320 kg ha^{-1}) and K ranged from medium to high (158-678 kg ha^{-1}). Nutrient requirement (NR) in kg ha^{-1} of grain produce, the per cent contribution from the soil available nutrients (CS %) and the per cent contribution from the applied fertilizers (CF %) were computed for calibrating and formulating fertilizer recommendations. The per cent achievement of targets aimed at different levels was more than 90 per cent, indicating that soil test based fertilizer recommendation approach was reasonably reliable.

Soil test crop response correlation studies conducted with mustard and rapeseed on Typic Haplustept soil at Ludhiana provided high correlations of high predictability between grain yield and soil available nutrients and fertilizer nitrogen. Fertilizer application based on the yield target, gave higher yields over farmer's practice. Grain yield of mustard was found between 550 and 1850 kg ha^{-1} with a mean value 1267 kg ha^{-1}. For rapeseed it was between 698 and 2720 kg ha^{-1} with a mean value of 2108 kg ha^{-1} (Chand *et al.*, 2006).

Sanjay *et al*. (2006) reported that application of double the dose of recommended fertilizer for targeted paddy yield of 10 t ha^{-1} through 100 per cent inorganic sources recorded significantly higher grain yield (10330 and 10262 kg ha^{-1}).

Prabhuraj *et al.* (2006) reported that targeted and actual yields obtained agree with each other. These were positive up to 40 t ha^{-1} and become negative above these yield targets. However, the per cent deviations were within $\pm$ 10 up to yield target of 50 t ha^{-1} per year. These results showed very close correlation between targeted yields and the yields actually obtained and an evidence of usefulness of soil testing within limits of variations under field condition.

Field experiments were conducted at farmers' fields to check the validity of the fertilizer adjustment equations for different crops. (maize, wheat, greengram, raya and gobhi sarson). The results of the study revealed the superiority of targeted yield concept over the other practices in farmers' fields as it gave higher yields and optimal economic returns. The targets were achieved within reasonable limits when the fertilizer was applied on soil test basis (10 + deviation from the target) in majority of crops (Dhillon *et al.*, 2006).

Maheswari *et al.* (2007) conducted an experiment at Coimbatore, (TN) to ascertain the optimum nitrogen (100, 125, 150 and 175 kg ha^{-1}) dose to enhance aerobic rice productivity with PMK-3 cultivar. They reported that significantly higher grain yield was recorded at 175 N kg ha^{-1}, N levels followed the quadratic response (R^2>0.973), with 150 and 175 kg N ha^{-1} produced on par growth and yield (4.03 and 4.1 t ha^{-1}) and also increased number of productive tillers (301.5, 308.4, 326.6 and 333.9 respectively) significantly with increase in N levels. Hence, 150 kg N ha^{-1} will be optimum to realize the maximum productivity with PMK-3 cultivar under aerobic rice.

Ramesh and Chandrasekaran (2007) conducted field experiment and reported that by application of nitrogen based on STCR approach as the targeted yield of 7 t ha^{-1} recorded higher plant height, leaf area index, dry matter production, total tillers m^{-2}, panicle length, productive tillers m^{-2} and grain yield as compared to blanket recommendation.

Soil test based fertilizer prescription equations under Integrated Plant Nutrition System (STCR-IPNS) were developed by Gayathri *et al*., 2009, for potato on Ultisols. Making use of these equations, monograms were formulated for a range of soil test values and desired yield targets of potato. These equations were validated on farmer's fields and it was found that the per cent achievement of the targets aimed was more than 90 and STCR-IPNS for 40 t ha^{-1} recorded relatively higher response ratio (38.05 kg kg^{-1}) and benefit-cost ratio (15.3) over other treatments indicating the validity of the equations for prescribing fertilizer doses for potato.

Apoorva *et al.* (2010) reported that the application of fertilizers on STCR basis along with dual microbial inoculation recorded higher grain yield (3740.5 kg ha^{-1}) and straw yield (9485.9 kg ha^{-1}) of finger millet. Further, a higher gross returns, net returns; microbial population, enzyme activities like phoshatase and dehydrogenase activities were observed when compared to the other treatment combinations carried out during the experiment *viz*., Control, GRD (General Recommended Dose) and STL (Soil Test Laboratory). The targeted yield in finger millet could be achieved within ± 10 per cent deviation with integrated plant nutrient supply using STCR approach.

A field experiment carried out to assess the soil test based fertilizer recommendation under rice-wheat cropping sequence. The results revealed that inorganic fertilizer application based on targeted yield along with FYM resulted in higher grain yield 4.04 t ha^{-1} in rice and 6.94 t ha^{-1} in wheat. STCR approach was more superior in soil fertility build-up in rice and wheat cropping sequence. (Keram *et al.*, 2012).

Raghu (2013) field experiment was conducted at ARS, Dadesugur, UAS, Raichur to study the existing recommended level of N, P and K fertilizer in package of practice by comparing with STCR approach, STL method and increased level by 25 to 50 per cent N, P and K based on soil fertility category (LMH) and also modified STL method along with PSB on growth, yield, nutrient uptake and soil fertility status at harvest stage of paddy. The results indicated that STCR approach produced significantly higher plant

height, number of leaves per hill, number of productive tillers per hill, grain and straw yield (88.96 cm, 52.85, 23.05, 5856 kg ha^{-1} and 7067 kg ha^{-1}, respectively) at harvest stage as compared to RDF (42.18 cm, 32.80, 11.65, 3900 kg ha^{-1} and 5310 kg ha^{-1}, respectively).

Kanhaiya and Singh (2014) the nutrient requirement of N, P_2O_5 and K_2O for producing one quintal of rice yield in *Inceptisol* were found to be 2.56, 0.56 and 2.21 kg ha^{-1} respectively. The per cent contributions of nutrient from soil, fertilizers and FYM were 26.35, 51.17 and 26.14; 54.03, 36.35 and 75.68; and 18.59, 3.10 and 8.56 of N, P and K nutrients, respectively. The fertilizer adjustment equations and a ready reckoner of optimum fertilizer doses at varying soil test values for attaining yield target of 40 and 50 q ha^{-1} of rice yield have been calibrated based on the targeted yield concept.

Sharma and Singhal (2014) ascertain the validity of developed fertilizer adjustment equations based on soil test crop response for targeted yield of pearl millet, rice, wheat and mustard crops. These equations were compared with other fertilizer use practices such as farmer's practice and general recommendation. The use of fertilizer based on soil test for targeted yield has increased by 28.6, 12.7 16.5, and 29.9 % to obtain average pearl millet yield of 26.8, rice yield of 55.1, wheat yield of 59.4 and mustard yield of 24.3 q ha^{-1} from 30, 55, 60 and 25 q ha^{-1} targeted yield of the crops over general fertilizer recommendation respectively. Among the different fertilizer practices, STCR based fertilizer recommendations were found more economically viable within the agro-ecological zone and achieved more than 95 % of targeted yield of different crops except pearl millet.

Sharma *et al.* (2015) conducted an experiment to study the impact of STCR based integrated fertilizer application for targeted yield of pearl millet-wheat Cropping sequence. The result showed that STCR based integrated use of fertilizer with FYM produced significantly higher grain and straw yields of pearl millet-wheat crops as compared to other treatments. The highest average grain and straw yield of pearl millet (2.85 and 6.59 t ha^{-1}) and wheat (5.38 and 7.17 t ha^{-1}) was recorded with the application STCR based integrated fertilizer recommendation.

The targeted yield in rice was achieved with integrated nutrient supply through organic and inorganic sources using STCR approach. It was inferred from the study that the STCR technology may be the appropriate approach for optimum nutrient supply

which improves the soil properties especially the soil health and productivity in a long run in comparison to other nutrient management technologies (Singh *et al*., 2015)

2.1.3 Growth and yield of rice and other crops as influenced by Nutrient expert (NE)

Nutrient expert – a decision tool for nutrient management in hybrid maize, wheat and rice crops. This will help a farmers increase his yield and profit by suggesting a meaningful yield goal for his location and by providing a fertilizer management strategy required to attain the yield goal. The guidelines provided by this software are consistent with the scientific principles of SSNM.

Kumar *et al.* (2012) reported that site-specific nutrient recommendations for wheat based on nutrient expert. It increased wheat yields and profits over existing farmer fertilizer practices and generalized recommendations. It also indicated that better understanding of indigenous nutrient supplying capacity of soils under varying growing environments (tillage, residue management practices *etc*.). It utilizes the information to guide nutrient management in wheat can improve yields and economics over existing practices. The nutrient expert decision tool can be an effective tool for farmers, industry agronomists and government extension personnel to provide field-specific nutrient recommendation to individual wheat farmers for improved yields and farm profits.

Mirasol *et al.* (2012) Nutrient expert is a computer-based decision support tool that uses the principles of site-specific nutrient management for developing fertiliser recommendations tailored to a specific field or growing environment. Results of field evaluation have shown that NE is effective in providing recommendations that can increase yields and profits compared with farmers' current practices. NE is an excellent tool for providing tactical information to crop advisors and farmers as well as strategic information to high level decision makers.

Jat *et al.* (2013) showed that the 4R principles of applying right source of nutrients, right rate, right time and right place is expected to increase nutrient use efficiency, productivity and farm profit from maize production. Adaption of 4R principle-based site-specific nutrient management decision support tools provides the opportunity for large-scale adoption of improved nutrient management across maize ecologies. Yield improvement with NE-based fertilizer recommendation could primarily

be attributed to a balanced application of nutrients based on SSNM principles. It revealed balanced use of all the essential nutrients thereby improving yields and optimizing nutrient use in the maize growing areas of Southern India.

Limin *et al*. (2013) indicated that principles of nutrient recommendations were formed and incorporated as part of the nutrient expert for wheat decision support system. Field validation based on yield response and agronomic efficiency showed a trend to increase both grain yield and gross profit, and agronomic efficiency, recovery efficiency and partial factor productivity of nitrogen were all improved in most sites. It was concluded that nutrient expert for wheat could be used as an alternative method of soil testing when making fertilizer recommendation.

Satyanarayana *et al*. (2013) used nutrient expert based field-specific fertilizer recommendations offered solutions to the farmers of southern India for better nutrient use in maize. Results from validation trials, comparing NE-based recommendations with farmer practice and the state recommendation in 82 farmer fields of southern India, demonstrated the utility of the decision support system tool in improving the yield and profitability of maize farmers in the region. Also showed that NE-based fertilizer recommendations generated on the principles of SSNM performed better than FP and SR for maize. Besides providing location-specific nutrient recommendations rapidly, the tool has options to tailor recommendations based on resource availability to the farmers.

Sapkota *et al.* (2014) reported that wheat production with NE-based recommendation supplemented with green seeker guided nutrient management under no tillage system can be carbon neutral. This combination of tillage and nutrient management strategy can be recommended for wheat production in Northwest Indo gangetic plain to increase yield, efficiency and profitability as well as to reduce agriculture's contribution to climate change.

Xinpeng Xu *et al*. (2014) showed that fertilizer recommendation based on nutrient expert method could maintain grain yield and profitability and improve nutrient use efficiency through 4R nutrient stewardship and it is proved to be a promising approach for fertilizer recommendation when soil testing is not available.

The research work carried out by using nutrient expert as a tool for fertilizer recommendation to maize, wheat as shown improved growth and yield of maize and

wheat but in case of rice, still research work is going on rice to achieve the attainable yield.

2.1.4 Soil Test Laboratory (STL) approach for fertilizer application

The pedestal of nutrient management is soil testing. To get maximum yield and to know about available nutrient status, soil testing is a pre-requisite. Based on soil testing one can go for required fertilizer application and it is gaining more importance in modern agriculture.

Subramoney and Padmanabhan (1969) reported that the yield increase in paddy due to fertilizer application based on recommendation of soil test value ranged from 7.22 to 69 per cent compared to the farmer's usual practice.

Mallarino *et al.* (1991) conducted a study during 1979 to 1981 on corn and soybean growing loamy soils of north eastern states with low and high testing values for available P and K (28 ppm and 170 ppm, respectively) to determine the effect of P and K fertilization and soil test values and yield of corn and soybean. The greatest rates and the smallest rates of application of fertilizers caused increase and decrease in soil test values, respectively.

Giri *et al*. (1999) conducted an experiment at Parabani during *kharif* season and concluded that application of $FeSO_4$ and $ZnSO_4$ along with NPK fertilizers resulted in higher number of filled grains, effective tillers and grain yield (1718 kg ha^{-1}) of rice over the NPK fertilizers alone (1640 kg ha^{-1}).

Ravi and Rao (1992) conducted a field experiment to study the effect of graded levels of potassium (0, 60 and 120 kg ha^{-1}) and time of application (all basal, half as basal + half at 30 DAT, half as basal + half at PI stage and 1/3 equally as basal, at 30 DAT and at PI stage). They reported that higher test weight, number of filled grains per panicle and yield were obtained due to application of potassium at 120 Kg ha^{-1} in two equal splits as basal and at PI stage.

Patel *et al*. (2001) evaluated the validity of the targeted yield relationship for pigeon pea through follow up trials at the experimental farm. The data showed that soil test based yield targets of 10, 12, 16 and 20 q ha^{-1} were obtained within ± 10 per cent variation of targets.

Subhendumandal and Swamy (2003) reported that application of N (120 kg ha^{-1} as urea in equal splits during transplanting, filleting, panicle initiation and 50 per cent flowering resulted in the highest number of panicles (365 m^2), number of filled grains $panicle^{-1}$ (89.8), 1000 grain weight (22.57 g), grain yield (5024 kg ha^{-1}), straw yield (5198 kg ha^{-1}) and harvest index (49.18 %). The variety MTU-101 recorded the highest number of filled grains $panicle^{-1}$ (86.2), 1000 grain weight (24.64 g), grain yield (5052 kg ha^{-1}), straw yield (5322 kg ha^{-1} and harvest index (48.60).

Dhillon *et al.* (2006) stated that farmer's practice produced grain yield almost comparable to that of soil test based fertilizer recommendations. It was observed that for the yield target of 55 q ha^{-1} in wheat, application of fertilizer calculated on the basis of targeted yield approach produced the yield within 5 per cent of the target in most of the sites.

Mollah *et al.* (2008) conducted an experiment at Nandi gram during 2003-04, 2004-05, 2005-06 to determine the optimum fertilizer dose for mustard- rice cropping pattern which enhancing total production and profit. The average of three years results indicated that the highest grain yield and gross margin were obtained from (T_2) soil test base (STB) fertilizer dose for high yield goal (HYG) in all crops and it was followed by IPNS (T_3). The lowest grain yield and gross margin from T_6 (absolute control) in all crops.

Rajesh (2015) conducted field experiment on performance of rice genotypes as influenced by different levels of nitrogen under transplanting and direct seeding methods and their residual effects on succeeding sesame at UAS farm Raichur. Results revealed that among the methods of planting TPR recorded significantly higher grain yield 5644 kg ha^{-1} due to higher yield parameters such as number of filled grains $panicle^{-1}$ (153), number of panicles m^{-2} (361.4) and test weight (23.6 g) and growth parameters like number of tillers m^{-2} (596.4), leaf area (845.4 cm^2 $hill^{-1}$) and dry matter production (68.3 g $hill^{-1}$) with nitrogen levels 125 % RDN compared to DSR.

2.2 Nutrient availability, uptake and use efficiencies in crops/cropping system as influenced by nutrient management approaches

Poor utilization of fertilizer by crops is mainly due to imbalanced nutrition or losses into the environment particularly of N that occurs because fertilizer N application

is not fine tuned to synchronize the supply and plant demand. For increasing nutrient use efficiency and with nutrient availability is essential to match the dynamic crop demand with nutrient supply.

2.2.1 Nutrient availability

Chatterjee *et al.* (1996) reported that application of N, K and Zn caused a significant increase in Zn uptake. This was associated with increased dry matter yield of rice with N and K and increased Zn concentration with Zn and K application. Synergistic effect of Zn on N and K were also observed.

Chaudhary *et al.* (1998) observed higher dry matter in chickpea at higher application of nutrients. It was also seen from the data that, varieties combined with nutrients based on SSNM increased the nutrient status in the soil and resulted in better nutrient availability and uptake by the crop.

Reddy and Reddy (1999) found that the available macronutrients (N, P_2O_5 and K_2O) were significantly increased with the integrated use of manures and fertilizers. Nutrient availability was highest in treatments with vermicompost closely followed by poultry manure and FYM.

Initial low level of organic carbon rose to medium level only in treatments with green manure or FYM. Continuous cropping with 100 per cent or 150 per cent NPK levels showed a significant increase in organic carbon (0.18 to 0.37%) but the change in status from low (0.18%) to medium (0.38%) was observed only in green manure or FYM treatments under rice-wheat cropping system (Rekhi *et al*., 2000).

Tolanur and Badanur (2003) reported that there was no change in pH of soil due to the application of 100 per cent RDF through inorganic and 50 per cent RDF through inorganic + 50 per cent RDF through FYM. But they noticed a change in EC and there was increase in organic carbon (0.47 %) content in soil with the application of 50 per cent RDF through FYM and 50 per cent RDF through fertilizer as compared to 100 per cent RDF through inorganic alone (0.44 %).

Mahala *et al*. (2006) reported that grain and stover yield of maize was significantly increased upto 60 kg P_2O_5 ha^{-1}, whereas the available N and P status of the soil after maize harvest increased upto 80 kg P_2O_5 ha^{-1}. The residual effect of increasing P levels up to 80 kg P_2O_5 ha^{-1} significantly increased the seed and straw yield, nutrient

uptake and the available N and P status of soil after mustard harvest. Increasing P levels significantly increased yield attributes, grain and stover yield of maize upto 60 kg P_2O_5 ha^{-1}. While N and P uptake was increased significantly upto application of 80 kg P_2O_5 ha^{-1} and FYM application at 10 t ha^{-1} also had significant, positive effect on growth and yield of maize.

Kumar *et al*. (2007) conducted the experiment to study the effect of levels of N @ 0, 50, 100 and 150 kg ha^{-1} on NPK concentration and uptake by high yielding variety and a hybrid of rice. They revealed that though the N, P and K concentration increased though non-significantly, their uptake increased significantly with increase in N levels which was attributed to maintenance of relatively large amounts of N in the ammonium form for longer period and the increased yield of dry matter at higher levels of N.

Wijebandara (2007) conducted a field experiment to know the response of rice to different methods of cultivation and nutrient levels and reported that significantly higher concentration and uptake of plant N, P, K and Zn and residual available N, P and Zn in soil were recorded in treatment receiving 75 per cent RDF + biofertilizer with 25 kg $ZnSO_4$ per ha. The 75 per cent RDF + biofertilizer with 25 kg $ZnSO_4$ per ha under SRI method of cultivation was found to be the best treatment which recorded the highest yield of rice.

Soil pH may be affected significantly if fertilizer salts are present; the lower pH is often referred to as salt depression of pH. Salts may depress pH slightly (0.1 pH unit) or by as much as 1.0 pH unit. The average pH depression of about 0.6 pH unit (David, 2008).

Singh *et al.* (2008) reported that application of 100 per cent RDF + FYM @ 2 t ha^{-1} to soybean (previous crop) and 50 per cent RDF to chickpea recorded at the end of two years of cropping sequence resulted in significant improvement in post harvest soil quality as evident by increased in organic matter and available N, P, K content in soil.

Katkar *et al.* (2011) reported that application of inorganic fertilizers slightly increased EC of soil under sorghum. The highest value of EC (0.341 d Sm^{-1}) was recorded in 150 per cent NPK, followed by 100 per cent NPK + FYM at 10 t ha^{-1} (0.336 d Sm^{-1}) while lowest EC (0.270 d Sm^{-1}) was recorded in control.

Tetarwal *et al.* (2011) reported that significant built up of organic carbon (0.74%), available N (316.0 kg ha^{-1}) and available P (10.8 kg ha^{-1}) was registered with RDF + FYM 10 t ha^{-1}. Maximum P balance (3.3 kg ha^{-1}) was recorded under application of FYM 10 t ha^{-1} alone and Zn content (0.45 mg kg^{-1}) was recorded under RDF + Zn.

Devi *et al*. (2012) conducted experiment to study the influence of levels (100, 125, 150 and 175 kg ha^{-1}) and time of N application nutrient uptake and post harvest N status of soil in aerobic rice. The results revealed that uptake of P, K and post harvest soil available N of rice recorded significantly highest with the application of 150 kg N ha^{-1}, whereas highest N uptake by rice was recorded in 175 kg N ha^{-1}.

Ram *et al.* (2012) reported that continuous adoption of rice-rice cropping system has led to deterioration of soil quality resulting in a serious threat to its sustainability in high rainfall zone of south Gujarat, India. Therefore crop diversification with wider choice in the production of a variety of crops is being promoted to restore the soil quality.

Jansi *et al*. (2013) conducted a field experiment during *kharif* 2011 at Agriculture College farm, Naira to study the response of semi-dry rice for nitrogen level to its time of application on nutrient uptake, yield and economics of semi dry rice. Application of 120 kg N ha^{-1} resulted in highest grain yield and nutrient uptake. With the time application, highest nutrient uptake, yield and returns were recorded at harvesting stage with the application of nitrogen in four splits ¼ each at basal, conversion to wet panicle initiation and flowering leading to higher productivity.

Dhaliwal *et al.* (2013) reported that the content of available S, Zn, Cu, Fe, Mn and B levels in calcareous soil of all treatments ranged from 0.84-1.20, 1.20-3.50, 0.82-3.17, 31.7-49.6, 3.52-7.12 and 1.02-1.15 mg kg^{-1}, respectively by combined application of varied levels of NPK, sulphur, zinc sulphate, copper sulphate, manganese sulphate and borax in site specific nutrient management experiment in rice-wheat cropping system.

Ramachandrappa *et al*. (2014) reported that the soil available nitrogen and potassium was low and phosphorus was medium in SSNM for a targeted finger millet yield of 4000 kg ha^{-1} with the application of 155:45:203 kg N, P_2O_5, K_2O ha^{-1} could achieve the yield of 3971 kg ha^{-1} during 2008-09.

Sharma and Jain (2014) studied highest available N and P status, lowest available S and Zn status, actual N and P gains, apparent positive P balance, actual losses of S and Zn and maximum negative N, K and S balance were observed in groundnut-wheat cropping system and the highest available K status and actual K gain were recorded in cluster bean-wheat cropping system. Maximum actual grains in N, P, K, S and Zn and apparent negative balance of N, P and K were obtained with the application of 100 % N, P, K, S, Zn, while negative balance of S and Zn in 100% NPK and 100 % NPKS, respectively. Application of 125 % NPK to wheat recorded maximum actual gains in N, P, K and Zn, actual S loss and apparent negative balance of N, K and S while positive P and Zn balance in 75 per cent NPK treatment.

2.2.2 Nutrient uptake

The nitrogen and phosphorus uptake increased significantly with increasing levels of nitrogen and iron and their interaction effect was significant (Dahiya and Bhatia, 1982). Velayutham *et al*. (1992) reported that the split application of potassium increased the NPK uptake and the yield of low land rice. The uptake of potassium and grain yield were found to be maximum under the treatment receiving K_2O @125 kg ha^{-1} for three equal splits at basal, maximum tillering and panicle primordial initiation stages.

Dubey and Bisen (1989) reported that N uptake increased significantly with increased levels of N in grain and straw. Sharma and Mittra (1989) reported that uptake of N, P and K increased significantly with increasing N levels. Further, Sagar and Reddy (1995) reported that the uptake of P and K in grain and straw of rice was significantly increased with the split application of higher levels of N and K.

Rao *et al*. (1998) reported that there was an increase of 16.9 per cent and 15.6 |per cent of N-uptake by straw and grain, respectively in direct seeded rice over transplanted rice. Phosphorus and potassium uptake by rice grain was not influenced significantly by methods of planting but P and K uptake by straw of direct seeded crop was significantly higher than transplanted rice. Increase in total N of shoot due to *Azospirillum* inoculation and the magnitude of increase being 7.5 to 16.7 per cent over un- inoculated control.

Thakur *et al.* (1998) found that the nitrogen uptake by plants increased significantly upto 150 kg N ha^{-1}, whereas N uptake by baby corn recorded significant increase upto 200 kg N ha^{-1}.

Riazeddin Ahamed *et al.* (1999) reported that fertilizer application based on STCR significantly increased uptake of nitrogen (61.9-153.1 kg ha^{-1}), phosphorus (8.6-32.8 ha^{-1}) and potassium (84.1-263.6 ha^{-1}) by rice.

Pal *et al.* (2000) reported that significant differences were recorded in K uptake by rice grain due to splitting of K levels over basal and these followed the same trend in the case of rice yield.

Doberman *et al.* (2000) reported that Site Specific Nutrient Management (SSNM) improved the plant uptake of N, P and K by 10-20 per cent and N use efficiency by 40 per cent. Similarly, SSNM approach was developed to increase mineral fertilizer use efficiency and to achieve balanced plant nutrition.

Hossain *et al.* (2001) reported that uptake of N, P, S, Zn and B by mustard crop (grain + straw) were markedly influence by different treatments. The lowest uptake of N, P, S, Zn and B were observed in the treatment which received combination of zinc, boron and molybdenum. The total uptake of N, P, S, Zn and B ranged from 64.4-94.9 kg ha^{-1}, 7.98-11.07 kg ha^{-1}, 8.04-11.00 kg ha^{-1}, 8.13-11.84 kg ha^{-1}, 0.22-0.42 kg ha^{-1} and 0.08-0.15 kg ha^{-1}, respectively.

Surendra Singh and Sarkar (2001) indicated that application of 210:90:150 kg NPK ha^{-1} as per SSNM approach recorded significantly higher NPK uptake 158:13:160.7 kg ha^{-1} compared to state recommended dose of 100:60:40 kg NPK ha^{-1} under wheat-maize cropping system.

The N and P uptake by grain and straw in maize increased significantly with the application of 150 and 80 kg N and P, respectively. These levels recorded N uptake of 52.89 and 33.76 kg ha^{-1} in grain and straw respectively. The higher phosphorus uptake by grain was found to be 12.6 kg ha^{-1} and straw 20.8 kg ha^{-1} with N_{150} and P_{80} combination. The higher K uptake by straw and grain was recorded 9.89 and 80.94 kg ha^{-1}, respectively and it increased with increasing levels of nitrogen and phosphorus (Manoj Kumar and Singh, 2003).

Anilkumar and Thakur (2004) found that application of 150 per cent recommended fertilizer resulted in higher uptake of nutrients followed by recommended fertilizer + 10 t FYM ha^{-1} and also found reduced nutrient loss when inorganic and organic fertilizers were applied in combination.

Application of 60 kg P_2O_5 enabled the rice crop to produce 3.1 and 5.9 per cent more yield than 30 kg P_2O_5 ha^{-1} and control (without P), respectively. The potash application @ 50 kg ha^{-1} gave 5.0 per cent more yield over control. The total N P K uptake under SSNM was 463 kg ha^{-1} whereas the corresponding value for recommended and farmers practices were 421.6 and 436.7 kg ha^{-1}. The nitrogen uptake under SSNM was 10.01 per cent and 5.5 per cent more than the farmers and recommended practices. The corresponding increase in phosphorus and potash was 8.5, 3.5 per cent and 9.9, 7.0 per cent respectively (Gill, 2006).

Bharathi and Poongothai (2008) conducted a field experiment with maize and green gram to study the direct and residual effect of S nutrient uptake and S use efficiency. The main crop treatments constituted application of S at 0, 15, 30 and 45 kg ha^{-1}. Higher nutrient uptake of S (15.71 kg ha^{-1}), N (244.2 kg ha^{-1}), P (70.6 kg ha^{-1}) and K (254.5 kg ha^{-1}) recorded in the treatment receiving 45 kg S ha^{-1} and also the availability of S (24 mg kg^{-1}) recorded in the same treatment.

Sharma *et al.* (2008) reported that the rice-potato–onion+maize relay cropping system removed the maximum quantity of N (371.6 kg ha^{-1}), P (110.4 kg ha^{-1}) and K (451.4 kg ha^{-1}), followed by rice-berseem-maize+cowpea (F), having corresponding values 352.0, 88.2 and 361.0 kg ha^{-1} $year^{-1}$. Heavy removal of NPK by rice-berseem-maize+cowpea (F) resulted in maximum negative balance of nitrogen (152.9 kg ha^{-1}), phosphorus (31.4 kg ha^{-1}) and potassium (304.6 kg ha^{-1} $year^{-1}$). Potassium balance was negative in all the cropping systems, indicating that K was the most removable nutrient by the crops, which results in mining of soil K and thus calls for adequate K fertilization.

Yadav and Alok kumar (2009) long-term studies revealed that crop productivity is declining even after applying recommended doses of NPK fertilizers. Responses to N reduced greatly in rice and almost zero in wheat in the absence of P fertilizer over 20 years. But the responses to P and K emerged after 8-10 and 20-22 years respectively, when their availability soil reached below the critical limits. The response (kg grain kg^{-1} nutrients applied) to N was higher in rice than in wheat, while that to P and K was higher in wheat than in rice. Amongst the nutrients, maximum response was noted with P followed by N and K. Experiments conducted on farmers' fields revealed that 8-12 per cent of the total increase in grain yield of various crops could be attributed to K application only.

Madhusudhan (2013) concluded that application of nutrients through SSNM approach for target yield of 8 t ha^{-1} exhibited the higher NPK uptake (290.55, 75.83 and 203.30 kg N, P_2O_5 and K_2O ha^{-1} at harvest) as compared to RDF and control.

2.2.3 Nutrient use efficiency

Prasad *et al.* (1998) found that average nutrient requirement for the production of one quintal of wheat grains were 2.01 kg N, 0.54 kg P_2O_5 and 2.63 kg K_2O. Fertilizer use efficiency were 40.8 per cent for N, 12.3 per cent for P_2O_5 and 64.3 per cent for K_2O and those of soil were 9.5 per cent for N, 32.9 per cent for P_2O_5 and 24.3 per cent for K_2O.

Ferguson *et al.* (2002) reported that recovery efficiency of fertilizer N (REN) in rice increased significantly with SSNM. On an average REN increased by about 29 per cent with SSNM compared to farmers fertilizer practice. Similarly, agronomic use efficiency was greater with SSNM (14.8 kg grain kg^{-1} fertilizer N than 11.5 kg grain kg^{-1} fertilizer P) due to greater REN in SSNM treatment.

Abdulrahaman *et al.* (2002) reported that increase in fertilizer efficiency of N (12 to 36 %), P (8 to13 %) and K (>100 %) and average rice yield in the SSNM (5.6 to 6.4 t ha^{-1}) over farmers' practice. The yield goal achieved in SSNM approach was 78 to 83 per cent.

Majumdar *et al.* (2002) revealed that interaction effects of nitrogen and sulphur and nitrogen and pig manure significantly influenced nutrient uptake by both maize and mustard crops. Nitrogen use efficiency (NUE) estimated as agronomic efficiency, physiological efficiency and also apparent N recovery were found to be higher at 50 kg N in comparison to 100 kg N ha^{-1} for both the crops. Application of 100 kg N, 20 kg S and 5 t pig manure ha^{-1} was found suitable to get maximum grain yields and better quality for both the crops.

Khuong *et al.* (2007) showed the remarkable difference in grain yield and nutrient use efficiency among three fertilizer application methods. The grain yield of SSNM was similar or higher than those of EFP (Extension's Fertilizer Practice) and FFP (Farmer's Fertilizer Practice) about 0.17 t ha^{-1}. The SSNM supported to increase the nutrient use efficiency of N, P and K. The agronomic efficiency and recovery efficiency of NPK of SSNM plot were higher than those of EFP and FFP. The SSNM supported to

remarkable decrease of fertilizer doses. It reduced at average of 11 kg N ha^{-1}, 5.2 kg P_2O_5 ha^{-1}and 16 kg K_2O ha^{-1}.

Sourov and Sanyal (2007) evaluated site-specific K management was evaluated in three selected rice growing areas of West Bengal in four farmers fields. At all the sites, a statistically significant increase in grain yield of 3.65 t ha^{-1} and 4.07 t ha^{-1} recorded under SSKM treatments of 100 % and 150 % respectively, over state recommended doses and farmers practice. The relative agronomic efficiency and agronomic use efficiency of K (AEK) was found to be highest for the treatment SSKM 150 per cent.

The performance of SSNM was tested for two rice crops compared with the current Farmers Fertilizer Practice (FFP), average grain yield was increased under SSNM practice. The agronomic N use efficiency was 83 per cent greater with SSNM than FFP (Khurana *et al.,* 2007).

Rutkowska *et al*. (2014) conducted a field experiment to study the effect of potassium on yield, N use efficiency, recovery efficiency and agronomic efficiency in maize and barley. The factors of the experiment were potassium fertilization (K plus and K minus treatment) and increasing nitrogen rates. The results revealed that higher N uptake (201 kg ha^{-1}), K uptake (135 kg ha^{-1}), highest apparent nitrogen recovery 75 per cent in K plus treatment and 57 per cent in K minus one and agronomic efficiency which amounted to 26 and 23 kg grain kg^{-1} N applied, respectively.

Paradkar *et al*. (2016) conducted experiment on site specific nutrients management and conservation tillage practices in maize-mustard relay cropping under rainfed conditions. The status of NPK after harvest mustard increased significantly with successive increase in fertilizer level. Treatment with site specific nutrient management 140:34:71 N P K kg ha^{-1} exhibited highest NPK (192 N, 22.2 P, 307 K kg ha^{-1}) status that was significantly higher than 100 % RDF (135 N, 16.8 P, 281 K kg ha^{-1}) and 50 % RDF (126 N, 14.8 P, 256 K kg ha^{-1}).

2.3 Residual nutrient effect of various nutrient management approaches on growth and yield of mustard/other crops.

Dudhat *et al.* (1997) conducted an experiment by growing wheat in *rabi* season using 5 m t castor cake or 15 m t FYM and/or the recommended chemical fertilizer rates

of 120 kg N + 60 kg P_2O_5 ha^{-1} or half dose NP rates. Green gram was grown in summer on residual effect of these fertilizers and reported that wheat yield was highest with castor cake plus recommended NP fertilizers, while green gram seed yield was higher from the residual effect of FYM and inorganic fertilizers.

Sharma *et al.* (1999) conducted an experiment on nutrient management in soybean – mustard crop sequence and observed that the residual effect of different levels of fertilizer applied to soybean, showed significant variation in growth and seed yield of mustard. The highest yield of 2,109 kg ha^{-1} was observed when N_{40} (½N through urea + ½N through FYM) was applied to soybean. In another experiment on nutrient management in soybean– mustard crop sequence inferred that during *rabi* season, maximum uptake of NPK nutrients was recorded where mustard crop received recommended dose (80:40:20) of fertilizers, preceeded by the treatment receiving 50 per cent through inorganic sources applied to *kharif* season crop (soybean).

Thakur *et al.* (1999) while studying the response of french bean (*Phaseolus vulgaris*) varieties to fertilizer levels, *rhizobium* inoculation and their residual effect on onion (*Allium cepa*) in mid-hills of north-western Himalayas at Palampur (H.P.) concluded that *rhizobium* inoculation in french bean registered a significant residual effect and resulted in higher onion bulb yield.

Trivedi and Singh (1999) during their study on response of blackgram - Indian mustard cropping sequence to fertilizer application at Gwalior (M.P.) observed that Indian mustard responded significantly up to 45 kg N ha^{-1}, beyond which there was no significant increase in the yield. Possibly this may be due to better buildup of N in the soil by the preceding blackgram crop and regular use of nitrogen levels.

Singh *et al.* (2001) while studying the response of brown sarson to residual effect of organic manure, nitrogen and transplanting dates of rice (*Oryza sativa*) at Kashmir observed that the number of siliquae per plant and seed, oil yield increased with increasing N rates. The value for 1000-grain weight was highest at 100 and 150 kg N ha^{-1}. Siliquae per plant was highest with FYM application. They further observed that P uptake increased with increasing residual N rates from 100 to 150 kg N ha^{-1} whereas N and K uptake increased only up to 100 kg N ha^{-1}.

Gawai and Pawar (2005) studied that the residual effect of application of 5 t FYM ha^{-1} to preceding sorghum crop resulted in significantly higher seed and *bhusa*

yield of chickpea due to 100 per cent RDF to chickpea on par with that of 50 per cent RDF showing 50 per cent saving nutrients. The sorghum equivalent yield was also the highest due to 75 per cent RDF + FYM + biofertilizer. The fertiliser levels to chickpea showed the highest net monetary returns due to 100 per cent RDF and highest BC ratio due to 50 per cent RDF.

Mahala *et al.* (2006) carried out a field experiment at Udaipur (Rajasthan) to study the direct and residual effects of sources and levels of phosphorus and FYM in maize-mustard cropping sequence and reported that the seed and straw yield of mustard were significantly increased due to residual effect of P levels up to 80 kg P_2O_5/ha applied to maize. The residual effect of 80 kg P_2O_5 ha^{-1} increased the seed yield of mustard by 5.16 and 6.89 % over 60 kg P_2O_5 $ha^{-1}$and 11.47 and 13.00 % over 40 kg P_2O_5 ha^{-1}. It was further observed that N and P uptake and available N and P in soil increased significantly due to residual effect of increasing P levels. Also observed that the residual effect of FYM 10 t ha^{-1} significantly improved the seed and straw yields of mustard and uptake of N and P over no FYM application.

Rana *et al.* (2007) while working on direct and cumulative residual effect of phosphorus and sulphur on Indian mustard-sunflower-urdbean cropping system observed the positive response to residual P applied to sunflower on the yield and yield attributes of urdbean.

Gangwar *et al.* (2008) revealed that the system-wise soil analysis undertaken after three crop cycles indicated that organic carbon increased positively over initial status in rice-chickpea system; however, the magnitude of increase was largest under mechanical transplanting (puddled), and negative balances were found in rice-wheat system. Available P and K balance was generally positive in rice-wheat, rice-chickpea and rice-indian mustard crop sequences except for P in rice-wheat and rice-mustard crop sequences under direct seeding. The drum or direct seeded rice based cropping system not only produced higher grain yield of hybrid rice but also resulted in greater productivity of the subsequent crops.

Chandrapala *et al.* (2010) observed uptake of nutrients. Based on the systems productivity (11.72 t ha^{-1}), net returns (58,983 ha^{-1}), and BCR, NPK + Zn + S treatment excelled all other nutrient combinations. SRI method used 23 and 25 per cent less water compared to conventional tillage and dry seeding. NPK + FYM application to rice crop

recorded significantly highest quantity of available soil N, P and K content after crop harvest. While, highest available soil S and Zn content was recorded by the treatments where in respective nutrients were applied in the previous season to rice. Thus it is concluded that SRI rice – maize is more productive, beneficial and efficient water user. Both Zn and S should be applied to rice to raise the productivity of subsequent maize.

Pankaj *et al.* (2013) conducted an experiment to evaluate nutrient management in direct seeded rice and its residual effect on uptake, translocation and recovery of nutrients in rainfed lentil. The experimental findings indicated that crops grown under 100% N through FYM was significantly superior in increasing grain, stubble yield as well as protein yield of lentil. A significantly higher yield and economic return (B: C=0.72) was noted when the crop was grown under 100 % N through FYM followed by 50 % RDF + 50 % N through FYM (B:C=0.62) and 100 % RDF (B:C=0.54). Application of FYM (50 % or 100 %) in *kharif* rainfed rice induced significantly higher residual contribution of nutrients N, P, K and S coupled with agronomic efficiency in succeeding *rabi* lentil crop when compared to equivalent supplementation by peer inorganic fertilizers.

Chavan *et al*. (2014) reported that the increasing dose of fertilizers up to 125 % recommended dose of fertilizers (RDF) significantly increased pod yield by 79.7 per cent and haulm yield by 63.3 per cent of groundnut over the control. Succeeding rice showed significant response to residual fertilizer levels up to 100 % RDF in grain yield and up to 125 per cent in straw yield and registered 16.9 and 25.4 per cent increase over the control, respectively in groundnut-rice cropping system.

Bandana *et al.* (2014) studied that the growth, yield attributes and yields of succeeding maize were maximum at the residual fertility of 150 kg + 20 kg S + 10 t FYM ha^{-1} closely followed by 150 kg N + 5 kg Zn + 10 t FYM ha^{-1}. The uptake of N, P, K and S by wheat (200, 23.8, 184 and 30.4 kg ha^{-1}) and maize (104, 16.7, 182 and 20.2 kg ha^{-1}) was the highest at 150 kg N + 20 kg S + 10 t FYM ha^{-1} and the lowest in control. The Zn uptake by both the crops was highest at 150 kg N + 5 kg Zn + 10 t FYM ha^{-1}.The residual available N, P, K and S in the soil after harvest of maize were maximum at 150 kg N +20 kg S + 10 t FYM ha^{-1} and Zn (0.60 mg kg^{-1}) at 5 kg Zn + 20 t FYM ha^{-1} application.

Rajesh (2015) conducted field experiment on performance of rice genotypes as influenced by different levels of nitrogen under transplanting and direct seeding methods and their residual effects on succeeding sesame at UAS farm Raichur. Results revealed that succeeding sesame recorded higher REY, production efficiency, net returns and BC ratio under the genotype JKPH 3333 with 125 per cent RDN. To make the rice cultivation cost-effective, to ensure the rational use of water and to get rice best fit in different cropping systems on account of early maturity, cultivation of DSR seems to be the best option.

Shreenivas (2016) studied residual effect of different nutrient management approaches on growth and yield of chickpea. Application of nutrients through SSNM approach for targeted yield of 8.0 t ha^{-1} for maize registered significantly higher plant height, total number of branches per plant and total dry matter production, MEY, seed yield (2.99 t ha^{-1}) and 100 seed weight of chickpea followed by STCR, STL, and farmer practices.

2.4 Effect of nutrient supply on biological properties of soil

The enzymes produced by the proliferating microorganisms mediate many processes occurring in soil. These enzymes are substrate specific and act from either outside or inside the living cells. Any threat to microbial activity is reflected in the rate of biochemical transformation occurring in soils. Variations in the microbial population might result in an alteration of an enzyme activity. Enzymes have biological significance as they participate in the biological cycling of elements. They play a very important role in the initial phases of decomposition of organic residues and transformation of some of the mineral compounds and under unfavorable conditions for the proliferation of microorganisms (Kiss *et al*., 1975). The climatic and edaphic factors of soil may influence the microbial enzymes (Kiss *et al*., 1975; Harrison, 1979) and change the quantity and quality of substrates on which they act.

Halstead and Swoden (1986) in their study on the effect of various types of organic matter added for over 20 years noticed that in comparison with the untreated plots, the organic matter treated plots showed increased phosphatase activity in soil but its effect on soil phosphorus was less consistent. The phosphatases mediate the release of inorganic P from organically bound P returned to soil as litter and other organic debris (Dhruvakumar *et al*., 1992).

Kamaleshkukreja *et al*. (1991) noticed that the total microbial biomass and dehydrogenase activity of the soil was significantly increased in plots that received 90 t/ha of FYM continuously for over 20 years.

Shedzhen *et al*. (1991) found that urease activity in rice soils was inhibited by application of Mn and Zn and increase initially or at the end of 14 days by Mo, Co, B and Cu. Application of N, P, K, B, Co, Mo. Zn, Mn and Cu increased the phosphatase activity.

In Vertisol of Coimbatore, the dehydrogenase and phosphatase activities were found to be highest in FYM treated plots. With higher rates of NPK fertilization, the activities of soil enzymes were also found to be higher and the effect was more pronounced when FYM was applied in combination with fertilizers (Singaram and Kamalakumari, 1995).

Iqbal *et al*. (1998) reported that the activity of phosphatases was negatively correlated with soil pH and inversely correlated with electrical conductivity. The activity had a direct relationship between soil organic matter, nitrogen and bacterial population in both the soils.

Baligar *et al.* (1999) observed that there was no correlation between acid and alkaline phosphatase activities with extractable P, which was consistent with other studies. This lack of correlation between phosphatases and extractable P could be due to the suppression of soil phosphatase activity by the long-term application of phosphate fertilizer (about 125 kg P_2O_5 per ha per year).This suggests that phosphatases are stimulated when phosphate levels are low in soils.

Sneh *et al*. (1999) indicated that amounts of soil organic matter and mineralizable C and N increased with the application of inorganic fertilizers. However, there was greater increase in these parameters when farmyard manure, wheat straw or *Sesbania bispinosa* green manure was applied along with inorganic fertilizers. Microbial biomass C increased from 147 mg kg P soil in unfertilized soil to 423 mg kg P soil in soil amended with wheat straw and inorganic fertilizers.

Mamatha *et al.* (2001) found that the dehydrogenase activity was higher in the rhizosphere soil of grass compared to that of sandal wood rhizosphere.

Balota *et al*. (2004) showed that soil enzyme activities were significantly correlated with organic carbon and microbial biomass. This indicates that enzyme activities were associated with active microorganisms in soil which are the major source of soil enzymes. While a significant correlation between enzyme activities and organic C is likely due to higher C levels supporting greater microbial biomass.

Saraswathy and Bama (2004) reported that acid phosphotase and alkaline phosphotase enzyme activities were higher in unplanted soil (0.06 and 0.09 mg/min of incubation/g of soil, respectively) than in planted (root zone) soil (0.03 and 0.04 mg/min of incubation/g of soil) due to water logging and high nitrogen content.

Manna *et al*. (2005) studied the influence of FYM on the dynamics of microbial biomass and its turnover and activities of enzymes under a soybean wheat system. They observed, that the microbial biomass of soil was significantly higher under soybean than under wheat crop. All the three enzymes were positively correlated with microbial biomass N and P and there were also significant correlations between soil organic carbon and microbial biomass C, N and dehydrogenase activity.

Marinari *et al*. (2006) reported on increase in enzyme activity mainly to the steady use of animal manure on organic farms and several authors reported higher enzyme activities in soils richer in organic matter (Balota *et al*., 2004).

Dehydrogenases are an integral part of microorganisms and are involved in organic matter oxidation; nevertheless, this activity is not consistently correlated with other properties of biological systems such as O_2 consumption, CO_2 production or microbial biomass (Dick *et al.,* 1996). However, it has been considered as a soil quality indicator, because it is involved in electron transport systems of oxygen metabolism and requires an intracellular environment (viable cells) to express its activity (Kandeler *et al*., 2007).

Gheibi *et al.* (2009) revealed that enzyme activity was higher in the roots than in the shoots and was also higher in plants supplied with urea, compared to those fed on ammonium nitrate.

Moeskops *et al.* (2010) reported dehydrogenase activities 3.8–6.4 times higher in organic farms and suggested that higher soil organic carbon contents may potentially

explain increased enzyme activities. The differences between organically and conventionally managed soil remain surprisingly high.

Sunjingjing *et al.* (2015) showed that high soil microbial activity due to N fertilizer rate. The variance analysis results indicated N fertilizer rate and growth stage both can influence the soil urease activity and soil organic matter. It is concluded that proper N fertilizer rate is important for optimal microbial growth while topdressing N fertilizer at jointing stage of wheat is beneficial to the soil enzyme activity.

The review of literature related to influence fertilizer application rate on biological properties revealed that increased application rate reduces microbial load as compared to optimum levels. Further integrated approach of organic manures and fertilizers maintains microbial biomass and enzyme activity.

2.5 Economic analysis of different nutrient management approaches in crops/cropping system.

The goal of any agricultural practices is to obtain maximum returns per money invested. This also gives the information about the optimum level of input that could be recommended to obtain maximum profit. Some of the reviews pertaining to above aspects are given below.

The economic sustainability of wheat production was significantly higher with the application of fertilizer for a target yield of 45 q h^{-1}. Application of 209, 52 and 44 kg NPK ha^{-1} based on targeted yield (45 q h^{-1}) approach recorded significantly higher grain yield (48.27 q ha^{-1}). Further, the same treatment recorded higher monetary returns over control and return per rupee invested on fertilizer. The results evaluated in different locations showed that majority of cases the yield targets were achieved within ± 10 per cent variation (Tamboli *et al.* 1996).

Suri *et al.* (1999) reported that higher benefit cost ratio (3.97) was obtained owing to combined application of FYM @ 5 t ha^{-1} and 148 kg N + 26 kg P_2O_5 + 62 kg K_2O ha^{-1} with the yield target of 5 t ha^{-1} over control and lower yield targets of 3 and 4 t ha^{-1}. They further reported that, higher benefit cost ratio was obtained with application of FYM @ 2.5 t ha^{-1} and 148 kg N + 26 kg P_2O_5 + 62 kg K_2O ha^{-1} when compared to control.

Guanghuo Wang *et al*. (2001) reported that the site-specific nutrient management led to reduction of the average fertilizer cost by \$15 ha^{-1} $crop^{-1}$ and an increase in GRF by \$88 ha^{-1} $crop^{-1}$ compared with FFP.

Dobermann *et al.* (2002) revealed that across all sites and four successive irrigated rice domains of Asia, under SSNM practice profitability increased by 46 US \$ ha^{-1} per crop or 12 per cent of the total average net return. The average profitability increased from 32 US \$ ha^{-1} $crop^{-1}$ in the first year to 61 US \$ ha^{-1}. The profit increases ranged from 4 to 82 US \$ ha^{-1} among eight rice domains.

Abdulrachman *et al.* (2002) indicated that yield and profitability can be increased when improved crop management practices were introduced. The yields with SSNM were close to the yield goal and 16 per cent greater than the FFP. The fertilizer cost was about US \$ 40 ha^{-1} in both SSNM and FFP but the profitability (gross return over fertilizer cost) increased by US \$ 130 SSNM due to increase in yield.

Yadhav and Hira Nand (2004) reported SSNM practice increased net returns of 35 and 109 per cent in pigeonpea and pearlmillet over state recommendations.

Gawai and Pawar (2005) studied that the residual effect of application of 5 t FYM ha^{-1} to proceeding crop sorghum resulted in significantly higher grain and *bhusa* yield of chickpea due to 100 per cent RDF to chickpea on par with that of 50 per cent RDF showing 50 per cent saving nutrients. The sorghum equivalent yield was also the highest due to 75 per cent RDF +FYM+biofertilizer. The fertiliser levels to chickpea showed the highest net monetary returns due to 100 per cent RDF highest BC ratio due to 50 per cent RDF.

Fertilization of maize based on SSNM for targeted yield enhances the grain yield of maize by 5 to 15 per cent with an average yield increase of 1025 kg ha^{-1} net income improved by 1 to 23 per cent and the average being US \$ 100 ha^{-1} (Hongting Wang *et al.,* 2005).

Biradar *et al* (2006) showed that yield increases under SSNM resulted in an improvement in the economic feasibility of food crop production in Karnataka. The average additional net income under SSNM in rice, wheat, and chickpea was US \$ 53, 68, and 23 ha^{-1} over RDF, and US \$ 115, 101, and 24 ha^{-1} over farmers practice, respectively. The nutrient input costs resulting from implementation of SSNM approach will lessen in succeeding seasons as micronutrient applications are likely to require for

every 2 or 3 years. In such a circumstance, production will be profitable and sustainable in due course of time.

Berra *et al*. (2006) indicated that soil test based fertilizer recommendation approach was economically viable within the agro-ecological zone with relatively uniform cropping practices and socio-economic conditions.

Dhillon *et al.* (2006) noticed the superiority of the target yield concept over the other practices as it gave higher yields and optimal economic returns. The yield targets were achieved within reasonable limits when the fertilizer was applied on soil test basis in the majority of the crops thus establishing the utility of the adjustment equations for recommending soil test based fertilizer application to the farmers. The higher BC ratio of wheat (6.9), maize (5.12) and ray (6.19) and suggested that the target yield concept gave higher yield and hence better economic returns than farmers practice and general recommended dose.

Milp-Chand *et al.* (2006) reported that experimental results in *Typic Haplustalf* soils of Punjab for targeted yield approach, higher value of additional yield, BC ratio was obtained in 18 t ha^{-1} targeted yield as compared to soil test based fertilizer recommendation and farmers practices under mustard and rapeseed cropping system at 5 locations.

Pampolinoa *et al.* (2007) evaluated the economic benefits in farmer's fields in southern India, Philippines, and southern Vietnam. The results showed that net annual benefit due to use of SSNM was US $ 34 ha^{-1} per year in Vietnam, 106 US $ ha^{-1} per year in the Philippines, and US $ 168 ha^{-1} year in India. The increased benefit with SSNM was attributed to increased yield rather than reduced costs of inputs.

Khuong *et al* (2007) reported on economic efficiency, where SSNM helped to reduce fertilizer cost from 3.6 to 16.6 per cent. The SSNM contributed to increase income and profit for rice growing farmers through the decrease of fertilizer cost and increase of profit and fertilizer cost ratio. Indeed, SSNM is a new and efficient fertilizer application.

Sathyanarayana *et al.* (2011) reported that the SSNM is not only a potential to increase profits but also shown increasing evidence of environmental friendliness owing to its balanced and crop need based nutrient application.

Mirasol *et al*. (2012) reported that Nutrient Expert for Hybrid Maize (NEHM) increased yield and profit of farmers in Indonesia and the Philippines. In Indonesia, NEHM increased yield by 0.9 t $ha^{-1,}$ which increased profit by US$ 270 ha^{-1} over farmer's fertilizer practice (FFP). In the Philippines, NEHM increased yield by 1.6 t ha^{-1} and profit by US$ 379 ha^{-1} compared with FFP.

Mauriya *et al*. (2013) found that the highest net returns of ₹ 67,033 ha^{-1} $annum^{-1}$ obtained with SSNM treatment, which was ₹ 31,681 and ₹ 16,905 ha^{-1} $annum^{-1}$ higher over that of farmer's practice and state recommended doses, respectively in rice-wheat cropping system.

Jat *et al.* (2013) reported that Nutrient Expert (NE) maize increased yield and economic benefit over FP and SR. Compared to FP; it increased yield by 1.06 t ha^{-1} and GRF by 12,902 Rs. ha^{-1} with a significant reduction in fertilizer cost of 3,239 Rs. ha^{-1}, Recommendations from NE-Maize also increased yield (by 0.9 t ha^{-1}) and GRF (by 8,033 Rs. ha^{-1}) over SR with a moderate reduction in fertilizer cost (-1,041 Rs. ha^{-1}). This indicates that NE, in addition to suggesting the right rate of nutrients sufficient to meet the attainable yield targets, also helps in optimizing nutrient use through appropriate reductions in fertilizer application.

Madhusudhan (2013) studied that application of nutrients through SSNM for target yield 8 t ha^{-1} recorded maximum cost of cultivation, gross returns, net return and B:C ratio (28,811, 1,02,886 ha^{-1}, 74,075 ₹ ha^{-1} and 3.57, respectively) as compared to control and RDF.

Umesh *et al.* (2014) reported that SSNM based nutrient application resulted in improvement of economic returns of corn production. The net income obtained from corn production under SSNM was 28.94 x 103 Rs. ha^{-1} was much higher over RDF excepting N_{200} P_{75} K_{50} level.

From the above review of literatures, it is clear that application of graded levels of major nutrients based on targeted yield approaches influences the growth and yield of many crops. In the present study an effort has been made to maximize the Dry-DSR productivity and profitability of DSR-Mustard cropping system in Vertisol through sustainable nutrient management approaches.

Material and Methods

III. MATERIAL AND METHODS

The field experiments on "Soil test based nutrient management approaches in Dry DSR-Mustard cropping system" was conducted in the farmer field of Vijayanagar camp, Tq: Raichur, Dist: Raichur, during *kharif* and *rabi* seasons of 2015-16 and 2016-17. Details of materials used, procedures followed and methodologies adopted are presented in this chapter.

3.1 Location of the experimental site

The field experiments were conducted during *kharif* and *rabi* seasons of 2015-16 and 2016-17, in the farmer field of Vijayanagar Camp, Tq: Raichur, Dist: Raichur, which is the tail end of Tungabhadra Project (TBP) Command area, is situated on the latitude of 16^{o} $11^{'}$ North, longitude of 77^{o} $13^{'}$ East and at an elevation of 393 meters above mean sea level and is located in the North Eastern Dry Zone (Zone-2) of Karnataka.

3.1.1 Criteria for the selection of location for experimental site and yield target fix

Dry DSR is being grown extensively as rainfed and irrigated crop in different taluks of Koppal, Raichur, Bellary and Yadagir district, especially in the tail end farmers of TBP Command Area. The detailed survey was conducted by interviewing 100 farmers from Raichur, Sindhanur, Manvi, Siraguppa and Gangavathi for evaluating the yield and fertilizer levels from their fields and to study the production constraints. Based on survey, it was found that farmers of TBP command area, using imbalanced dose of nutrients with higher tendency for nitrogen and phosphorus fertilization (246 kg N and 166 kg P_2O_5 ha^{-1} with lower dose of potassium as per survey data, 2014) with an intention of getting higher yields. The chemical fertilizers used were mainly, urea as source of nitrogen and it was applied at the rate of 160 kg $acre^{-1}$ and DAP @145 kg $acre^{-1}$ as a source of phosphorus and murate of potash @ 40 kg $acre^{-1}$ as a source of potassium or other complex fertilizers like 10:26:26 or 20:20:0 were also used. The survey indicated that, 90 to 100 % of the farmers use the above recommended dose of fertilizer (200-250 % N and 180-220 % P fertilizers) and about 5-10 % farmers use recommended dose of fertilizer (100:50:50 NPK kg ha^{-1}). The major constraints found were imbalanced use of nutrients (N, P & K) along with water scarcity and faced with ON-OFF canal water supply. The average grain yield levels of Dry DSR crop were found to be 35 to 45 q ha^{-1} as per package of practice UAS, Raichur, 2015 with

recommendation of fertilizer, which was very low as compared to other rice growing areas. The other constraints that there was lack of soil testing methods for application of balanced fertilizer and lack of identification of causes for low yields of Dry DSR and remedial measures for the same. Potential yield of Dry DSR (BPT-5204) is up to 45-50 q ha^{-1} as observed in Bellary and Raichur districts. The crop was found to yield up to 55 q ha^{-1} for those using balanced nutrition along with proper irrigation. With this background, experiment was planned in the farmer field of Vijayanagara camp, to know the suitable nutrient management practice to attain the targeted yield in Dry DSR. Fertilizer was applied based on soil test result by considering different nutrient management principles.

3.2 Soil characteristics

Composite soil sample was collected from depth of 0-15 cm in the experimental site before initiation of the experiment. The soil was air-dried, powdered and allowed to pass through 2 mm sieve and was analyzed for physico-chemical and biological properties. Initial physico-chemical and biological properties of soil from the experimental site are furnished in Table 1.

The soil of the experimental site was deep black clay in texture (Sand 36.47 %, silt 10.75 % and clay 52.80 %) with a bulk density of 1.12 Mg m^{-3} and water holding capacity 60.45 per cent. The soil pH was 8.20 with electrical conductivity of 0.69 dS m^{-1}. The organic carbon content was medium (6.82 g kg^{-1}). The soil was low in available nitrogen (192.36 kg ha^{-1}), high in available phosphorus (74.68 kg ha^{-1}), potassium (348.00 kg ha^{-1}), sulphur (21.20 mg kg^{-1}), exchangeable calcium and magnesium 37.54 and 10.75 c mol (p^{+}) kg^{-1} and deficient in DTPA extractable Zn and Fe (0.46 and 4.39 mg kg^{-1}) and sufficient in DTPA extractable Mn and Cu (1.23 and 2.40 mg kg^{-1}).

3.3 Climatic condition

The research location comes under semi-arid tract with an average annual rainfall of 597 mm. The total amount of rainfall received during the crop growing period (July-December) was 479.6 mm and 561.1 mm during 2015 and 2016. Although, monsoon sets in early June, rains during September and October (North-east) being assured. Normally dry weather prevails over entire summer months.

Table 1. Initial physico-chemical and biological properties of soil from the experimental site

Sl. No.	Particulars	Value
I	**Physical properties**	
	Particle size distribution	
	Sand (%)	36.47
	Silt (%)	10.75
	Clay (%)	52.80
	Textural class	Clay
	Bulk density (Mg m^{-3})	1.12
	Water holding capacity (%)	60.45
II	**Chemical properties**	
	Soil pH	8.20
	Electrical conductivity (dS m^{-1})	0.69
	Organic carbon (g kg^{-1})	6.82
	Available nutrients (kg ha^{-1})	
	Nitrogen (N)	192.36
	Phosphorous (P_2O_5)	74.68
	Potassium (K_2O)	348.00
	Exchangeable calcium [c mol (p^+) kg^{-1}]	37.54
	Exchangeable magnesium [c mol (p^+) kg^{-1}]	10.75
	Sulphur (mg kg^{-1})	21.20
	DTPA extractable micronutrients (mg kg^{-1})	
	Zinc	0.46
	Iron	4.39
	Manganese	1.23
	Copper	2.40
III	**Microbiological parameters**	
	Bacteria (No. $\times 10^6$ cfu g^{-1} soil)	9.5 x 10^6
	Fungi (No. $\times 10^3$ cfu g^{-1} soil)	6.3 x 10^3
	Actinomycetes (No. $\times 10^4$ cfu g^{-1} soil)	3.3 x 10^4
	Phosphatase activity (µg PNP g^{-1} soil h^{-1})	3.75
	Dehydrogenase activity (µg TPF formed g^{-1} soil h^{-1})	0.82

The high rainfall in the month of August and September, prevalence of cloudy and humid weather. The mean maximum temperature varied from 23.3 to 35.10 ^{o}C during cropping period. The crop particularly at heading stage was subjected to lower temperature during October, 2015-16.

The monthly meteorological data for the year 2015-16 and 2016-17 as recorded at meteorological observatory, Main Agricultural Research Station, Raichur, and the mean data of last 2 years (2015-2017) of climatic parameters like rainfall, temperature and relative humidity are presented in Table 2 and depicted in Fig. 1 and 2.

Total annual rainfall was 677.5 mm and 868.8 mm during 2015-16 and 2016-17, respectively. The crop growth period was from July 2015 to February 2016 and July 2016 to February 2017 for Dry DSR-Mustard cropping sequence. During the crop growth period, September 2015 and 2016 received higher rainfall (316.6 and 292.5 mm, respectively) and there was deviation in the peak rainfall as compared to normal pattern.

The mean maximum temperature was higher in the month of May (39.9 ^{o}C) during 2016 and April (41.8 ^{o}C) during 2017. The mean minimum temperature was in the month of January (17.7 ^{o}C) during 2016 and December (15.6 ^{o}C) during 2017. The mean monthly relative humidity ranged from 69.0 and 88.0 per cent and 48.0 to 92.0 per cent during 2016 and 2017, respectively.

3.4 Cropping history of the experimental site

Dry direct seeded rice was cultivated in the experimental site during *kharif* 2014 with farmer practices of fertilizer application and mustard was raised as Rabi crop and left fallow during summer season of 2015.

Table 2. Monthly meteorological data for the years 2015-16 and 2016-17 and mean of the last 83 years (1932-2015) recorded at Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Raichur

Month	Rainfall (mm)			Temperature (°C)						Relative humidity (%)		
				Mean maximum			Mean minimum					
	1932-2015	2015-16	2016-17	1932-2015	2015-16	2016-17	1932-2015	2015-16	2016-17	1932-2015	2015-16	2016-17
April	70.7	114.2	0.0	39.9	37.3	41.8	22.6	24.4	28.3	77.0	68.0	48.0
May	71.5	18.7	87.2	39.7	39.9	39.6	22.5	26.8	26.6	80.0	66.0	66.0
June	182.7	38.7	194.1	35.3	36.3	33.8	22.3	24.9	24.2	82.0	77.0	84.0
July	62.5	42.0	143.2	33.4	36.3	31.8	20.5	24.6	23.5	79.0	77.0	86.0
August	21.2	51.4	78.0	32.9	34.6	32.4	19.1	24.3	23.1	79.0	80.0	86.0
September	4.0	316.6	292.5	32.2	39.1	29.2	16.2	23.4	22.6	76.0	88.0	92.0
October	1.2	65.4	39.2	31.5	33.4	31.2	16.8	23.0	19.7	77.0	80.0	84.0
November	1.1	2.0	0.0	31.3	31.9	34.2	18.5	21.1	22.3	62.0	79.0	82.0
December	44.3	2.2	8.2	30.5	32.0	30.2	22.6	18.4	15.6	56.0	83.0	81.0
January	13.0	1.4	0.0	31.3	31.2	30.6	24.4	17.7	16.2	53.0	75.0	76.3
February	42.9	0.0	0.0	32.5	35.5	33.9	25.3	21.6	19.2	60.0	62.0	61.0
March	113.8	24.9	26.4	36.5	37.9	38.5	23.3	22.7	23.4	79.0	66.0	72.0
Total	**628.9**	**677.5**	**868.8**	-	-	-	-	-	-	-	-	-

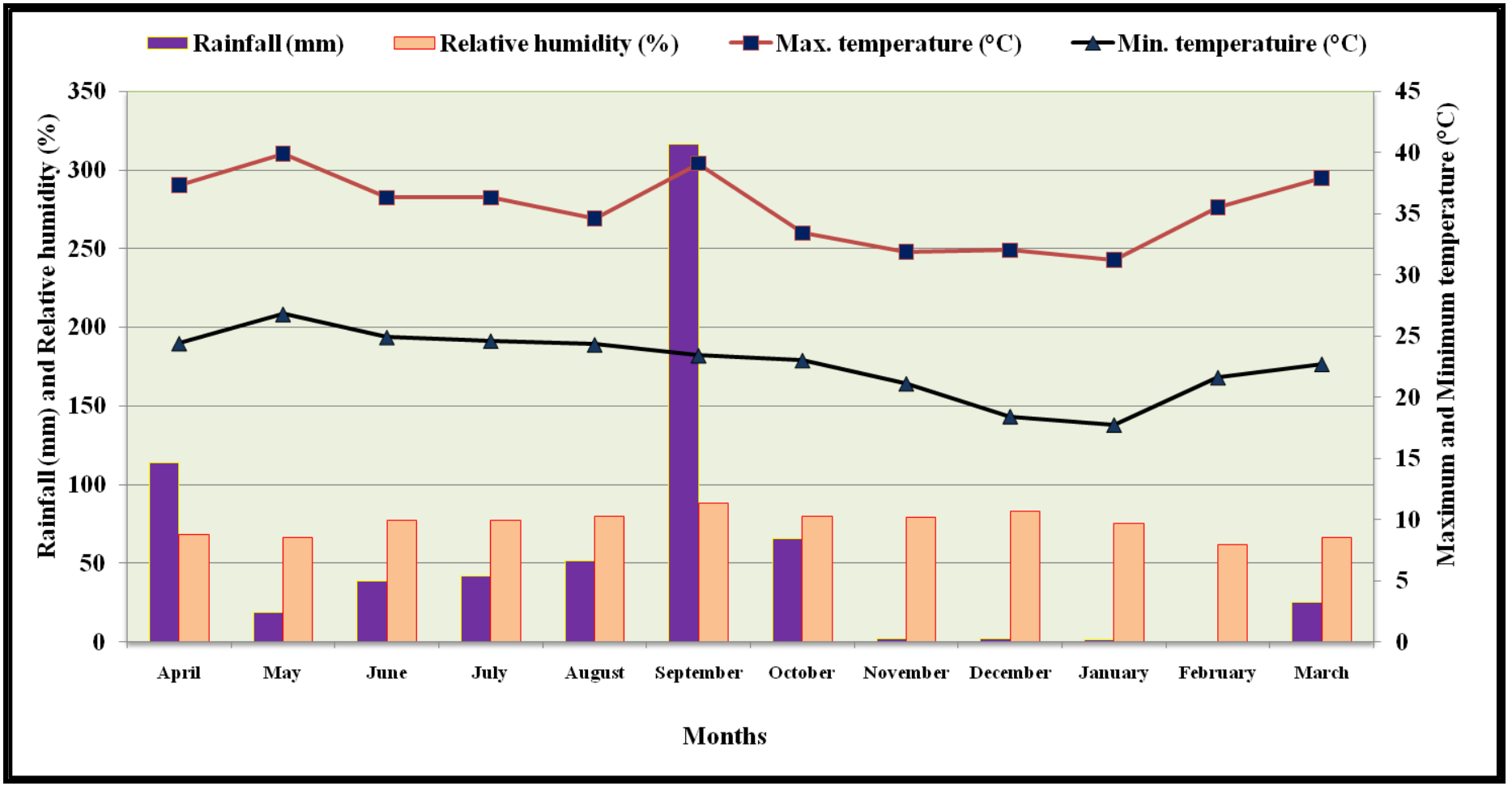


Fig. 1. Monthly meteorological data recorded at Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Raichur for the year 2015-16

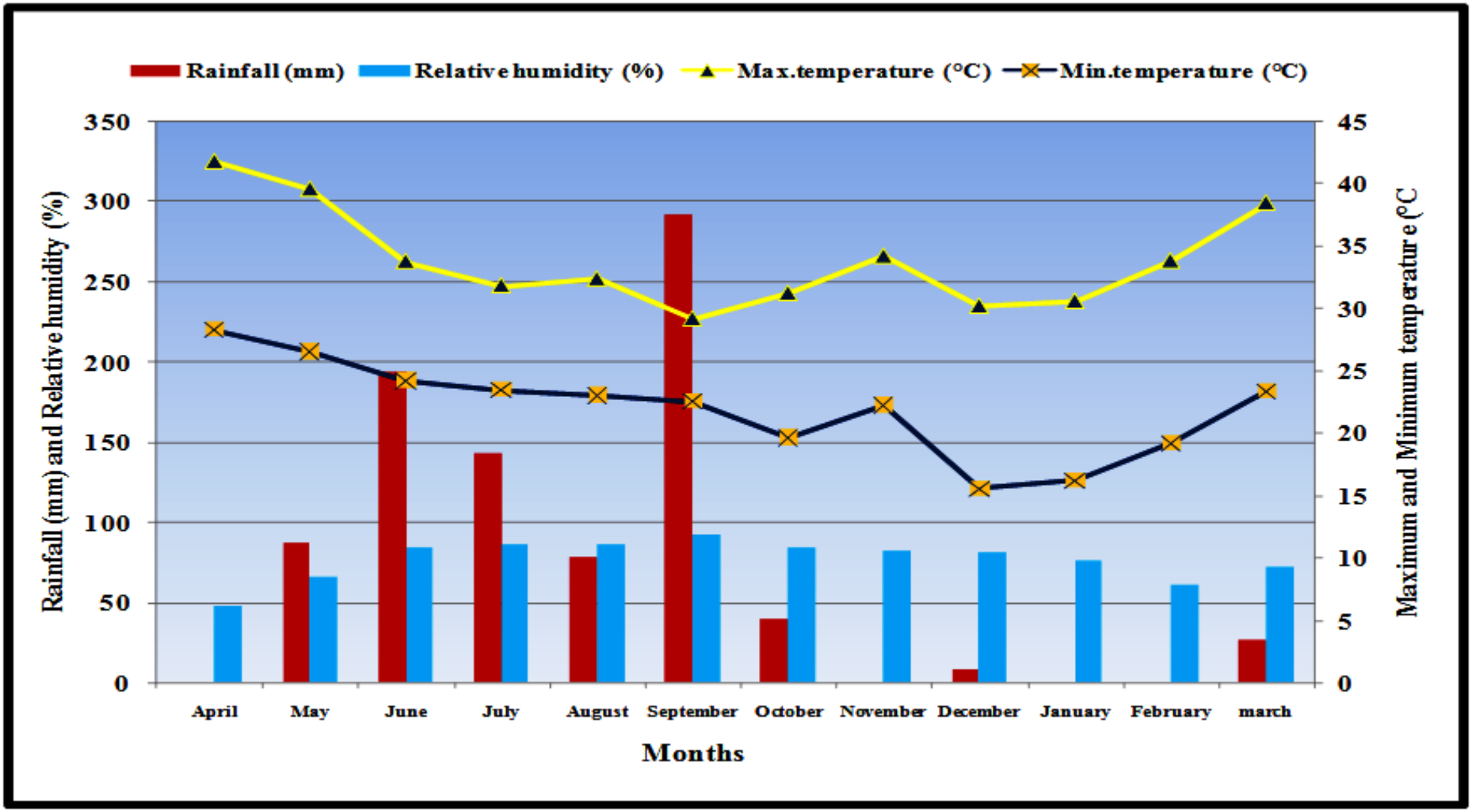


Fig. 2. Monthly meteorological data recorded at Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Raichur for the year 2016-17

3.5 Field experiment details

The details of the experiment with regard to treatments evaluated and the design adopted are given below.

Field investigations were carried out during 2015-16 and 2016-17 in the same location on "Soil test based nutrient management approaches in Dry DSR-Mustard cropping system" in Vertisol of TBP command area with following details. The experiment was conducted with ten treatments during *kharif* and *rabi* seasons of 2015-16 and 2016-17 (Plate 1 & 2 for Dry DSR and plate 3 for mustard).

3.5.1 Dry-Direct Seeded Rice

3.5.2 Treatment details

T_1: Absolute control

T_2: Recommended dose fertilizer
(100: 50: 50 kg :: N: P_2O_5: K_2O ha^{-1})

T_3: Farmers practice
(246: 166: 60 kg :: N: P_2O_5: K_2O ha^{-1})

T_4: Soil test laboratory method
(112.5: 37.5: 37.5 kg :: N: P_2O_5: K_2O ha^{-1})

T_5: STCR approach (Targeted yield 45 q ha^{-1})
(99: 00: 60 kg :: N: P_2O_5: K_2O ha^{-1})

T_6: STCR approach (Targeted yield 55 q ha^{-1})
(134: 28: 80 kg :: N: P_2O_5: K_2O ha^{-1})

T_7: SSNM approach (Targeted yield 45 q ha^{-1})
(118: 35: 95 kg :: N: P_2O_5: K_2O ha^{-1})

T_8: SSNM approach (Targeted yield 55 q ha^{-1})
(144: 43: 115 kg :: N: P_2O_5: K_2O ha^{-1})

T_9: Nutrient expert approach (Targeted yield 45 q ha^{-1})
(100: 22: 38 kg :: N: P_2O_5: K_2O ha^{-1})

T_{10}: Nutrient expert approach (Targeted yield 55 q ha^{-1})
(118: 28: 45 kg :: N: P_2O_5: K_2O ha^{-1})

Note: FYM @ 7 t ha^{-1} and deficient $ZnSO_4$ @ 25 kg ha^{-1} soil application + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

Plate 1: Over view of the experimental site at 75 DAS during, 2015

Plate 2: Over view of the experimental site during 2016

3.5.3 Plot size, spacing, variety, Seed rate, sowing and harvesting dates of DSR

Gross plot size	5.5 m x 3.4 m = 18.70 m²
Net plot size	4.5 m x 3.0 m =13.5 m²
Spacing	0.25 m x 0.10 m
Crop	Paddy
Variety	BPT -5204
Seed rate	30 kg ha $^{-1}$
Date of sowing	July 18th 2015 & July 7th 2016
Date of harvesting	December 12th 2015 & December 5th 2016
Crop duration	145-150 days

3.5.4 Salient features of the cultivar BPT-5204

The original name of BPT-5204 is Sonamasuri, grains are thin and medium size and grown largely in the south Indian states viz., Andhra Pradesh, Telangana and Karnataka. In Telugu, Sonamasuri rice is called *Bangaru Theegalu* (meaning Golden Ivy). Grains are light weight, aromatic and considered to be of premium quality. It matures in 145-150 days. Sonamasuri is largely considered to be a healthy dish as it contains little starch and is easily digestible**.**

3.5.5 Design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with ten treatments and were replicated thrice. The plan of layout of the experiments is shown in Fig. 3.

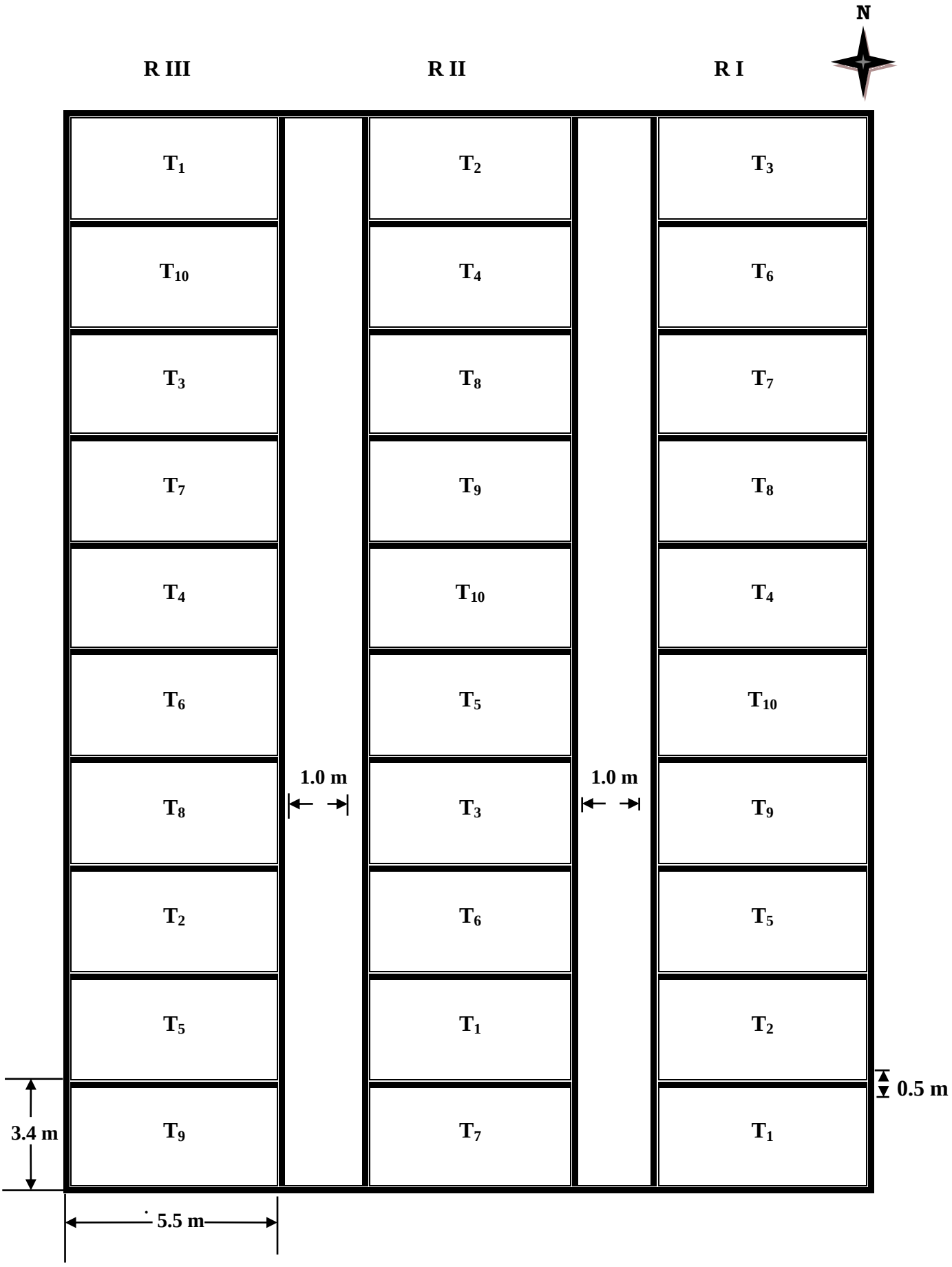


Fig. 3: Plan of experimental layout

3.6 Fertilizer calculation for Dry DSR

The quantity of fertilizer needed for each treatment was worked out as explained in the following paragraphs. FYM at the rate of 7 tonnes per hectare was applied 15-20 days before sowing to all pre-marked plots except absolute control and incorporated in soil.

3.6.1 Absolute control

No fertilizer and FYM were applied in control plot and proper care has been taken by raising 0.5 m strong bunds around each plot to avoid the movement of fertilizer and water from one plot to another.

3.6.2 Recommended dose fertilizer

The recommended dose of fertilizer for rice in the North Eastern Dry Zone (Zone-2) is 100: 50: 50 kg N: P_2O_5: K_2O ha^{-1} (Package of practice, UAS Raichur, 2015). Nitrogen, phosphorus and potassium in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP), respectively were applied. As per RDF, 50 per cent of N and full dose of P and K were applied at basal and remaining 50 per cent N in two equal splits were applied at 60 and 75 DAS.

3.6.3 Farmer's practice

Survey was conducted from DSR growing farmers of Raichur, Manvi, Sindhanur, Sirguppa, Gangavathi and surrounding areas of UAS Raichur for their nutrient management. Based on their nutrient management practices, average quantity of fertilizers for farmer's practice treatment was worked out *i.e* farmers apply an average of 246: 166: 60 kg ha^{-1} NPK in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP) or 10:26:26 or 20:20:0 complex fertilizers were applied. Farmers usually apply N in three to four splits, and P in two splits and K in one splits, mostly starting about 2 weeks after sowing. Almost all farmers regularly use herbicides and insecticides. In recent years, many farmers have also used foliar fertilizers containing some NPK plus micronutrients, often mixed with fungicides.

3.6.4 STL method

In soil test laboratory method, the amount of fertilizer dose was calculated on the basis of fertility ratings (Low, medium and high for N, P and K). The detail is as follows:

RDF (kg ha^{-1})	Addition to be made in RDF at low fertility rating (kg ha^{-1})	Deduction to be made in RDF at high fertility rating (kg ha^{-1})
Nitrogen		
<50	No changes	No changes
52.5-100	+ 12.5	- 12.5
102.5-175	+ 25.0	- 25.0
177.5-250	+ 37.5	- 37.5
251-325	+ 50.0	- 50.0
Phosphorous (P_2O_5)		
<25	No change	No change
27.5-75	+ 12.5	- 12.5
77.5-125	+ 25.0	- 25.0
Potassium (K_2O)		
<25	No change	No change
26-50	+ 12.5	- 12.5
51-100	+ 25.0	- 25.0

Note: No change in RDF at medium fertility level

As per the soil test rating in the experimental field, available nitrogen was low and it is < 100 kg ha^{-1} RDF, therefore, addition of 12.5 kg ha^{-1} to the recommended dose of fertilizer was made. For available phosphorous, the soil test rating is high and the recommended dose of phosphorous is 50 kg ha^{-1} and there is -12.5 kg ha^{-1} of RDF was made *i.e.* 37.5 kg ha^{-1} of P_2O_5. The available potassium content was high and the RDF is < 50 kg ha^{-1} and there is -12.5 kg ha^{-1} of recommended dose of fertilizer was made. Hence, the calculated fertilizer dose as per STL method was 112.5: 37.5: 37.5, N, P_2O_5 and K_2O kg ha^{-1}, respectively.

3.6.5 Calculation of fertilizer for STCR approach

The targeted yield equations developed for the rice under STCR scheme (Anon., 2007) were used for the calculation of fertilizer N, P_2O_5 and K_2O by considering the targeted yield 45 and 55 q ha^{-1}. The details of equations are given below:

- $FN=3.45T-0.29SN$ ($KMnO_4$-N)
- $FP_2O_5=2.82T-1.70SP_2O_5$(Olsen's P_2O_5)
- $FK_2O=2.00T-0.09SK_2O$ (NH_4OAC-K_2O)

Whereas,

T = Targeted yield (q ha^{-1})

FN = Nitrogen supplied through fertilizer (kg ha^{-1})

FP_2O_5 = Phosphorus supplied through fertilizer (kg ha^{-1})

FK_2O = Potassium supplied through fertilizer (kg ha^{-1})

This targeted yield equation were developed for rice crop variety *i.e.* IR-8 and other HYV for black clayey soil of Sirguppa, Bellary and Raichur regions of TBP command area. [**Source:** Prakash *et al.* (2007), *The Technical bulletin* on STCR - an approach for fertilizer recommendations based on yield target (A success story in Karnataka].

The initial soil test value for available N, P_2O_5 and K_2O, were 192.36, 74.68 and 348.00 kg ha^{-1}, respectively.

For targeted yield of 45 and 55 q ha^{-1}, the fertilizer calculation of N, P_2O_5 and K_2O was as follows.

For 45 q ha^{-1},

FN = 3.45 x 45 – 0.29 x 192.36= 99.4 kg nitrogen ha^{-1}

FP_2O_5 = 2.82 x 45 – 1.70 x 74.68= 00 kg phosphorus ha^{-1}

FK_2O = 2.00 x 45 – 0.09 x 348.00= 59.0 kg potash ha^{-1}

The calculated fertilizer dose was (99: 00: 59:: N, P_2O_5, K_2O kg ha^{-1}).

For 55 q ha^{-1},

FN = 3.45 x 55 – 0.29 x 192.36= 134.0 kg nitrogen ha^{-1}

FP_2O_5 = 2.82 x 55 – 1.70 x 74.68= 28.0 kg phosphorus ha^{-1}

FK_2O = 2.00 x 55 – 0.09 x 348.00= 78.7 kg potash ha^{-1}

The calculated fertilizer dose was (134: 28: 79:: N, P_2O_5, K_2O kg ha^{-1}).

3.6.6 Calculation of fertilizer for SSNM approach

The amount of fertilizer for SSNM treatments (T_7 and T_8) was calculated by using the formulae (IPNI, 2010). The average nutrient removal of N, P and K by rice crop per quintal grain production was 2.01, 1.12 and 3.00 kg ha^{-1}. According to the targeted yield, nutrient removal was calculated by multiplying targeted yield with nutrient removal.

For targeted yield of 45 and 55 q ha^{-1}, nutrient removal was as follows.

For 45 q ha^{-1}: N: (2.01 x 45=90.5 kg ha^{-1})

P_2O_5: (1.12 x 45=50.4 kg ha^{-1})

K_2O: (3.0 x 45= 135.0 kg ha^{-1})

For 55 q ha^{-1}: N: (2.1 x 55=110.5 kg ha^{-1})

P_2O_5: (1.12 x 55=61.6 kg ha^{-1})

K_2O: (3.0 x 55= 165.0 kg ha^{-1})

In SSNM, the soil nutrient ratings are considered for recommendation of fertilizers. If soil nutrient rating is medium, then application of nutrients exactly the removal quantity; If soil nutrient rating is low, then apply 30% more and if soil nutrient rating is high then apply 30% less.

In case of rice, soil test result of N, P_2O_5 and K_2O in the field were 192.36 74.68 and 348.00 kg ha^{-1}, respectively. Accordingly, soil fertility rating was low for N, and high P and K, respectively. Therefore, nutrient requirement are as follows.

For 45 q ha^{-1}: N: 90.5 x 130/100 = 117.50 kg ha^{-1}

P_2O_5: 50.4 x 70/100 = 35.28 kg ha^{-1}

K_2O: 135.45 x 70/100 = 94.50 kg ha^{-1}

For 55 q ha^{-1}: N: 115.5 x 130/100 = 144.0 kg ha^{-1}

P_2O_5: 61.6 x 70/100 = 43.12 kg ha^{-1}

K_2O: 165.0 x 70/100 = 115.50 kg ha^{-1}

The calculated fertilizer dose for 45 q ha^{-1} is 118: 35: 95: N, P_2O_5, K_2O kg $ha^{-1}$and for 55 q ha^{-1} is 144: 43 115: N, P_2O_5, K_2O kg ha^{-1}.

3.6.7 Nutrient expert approach

Nutrient expert is a nutrient decision support software that uses the principles of site-specific nutrient management (SSNM) and enables farm advisors to develop customized fertilizer recommendations tailored to a specific field or growing environment.

Nutrient expert estimates the attainable yield and yield response to fertilizer from site information using decision rules developed from on-farm trials. Specifically, NE uses characteristics of the growing environment: water availability (irrigated, fully rainfed and rainfed with supplemental irrigation) and soil fertility indicators: soil texture, soil color and organic matter content, soil test for P or K (if available), historical use of organic materials (if any) and problem soils (if any) crop residue management and fertilizer inputs for the previous crop; and farmers' current yields. Nutrient expert software were run in a system by feeding of necessary information of experimental location, such as current farmer practice like fertilizer inputs, crop residue management, yield, soil fertility indicators and other necessary in formations to run the nutrient expert. As per nutrient expert software fertilizer recommendation for the experimental site was as follows.

- For the yield target 45 q ha^{-1} the N:P:K dose were 100:22:38 kg ha^{-1}
- For the yield target 55 q ha^{-1} the N:P:K dose were 118:28:45 kg ha^{-1}

3.7 Crop management practices for Dry DSR

3.7.1 Land preparation

The land was ploughed twice with mould board plough and then harrowed twice to bring the soil into fine tilth and reveres blade operation taken once to make land level. The experiment was laid out as per the plan given in Fig. 1 and the plots were provided with bund of 0.5 m all around to avoid the contamination of fertilizer and water from other plots. Irrigation channels were also made to facilitate irrigation.

3.7.3 Seed and sowing

The sowing was done with help of tractor drawn seed drill at a spacing of 25 cm x 10 cm in a pre-marked field as per plan of layout. The seeds were sown at the depth of 2-3 cm.

3.7.3 Weed management

Weeds in the experimental plots were managed by application of Pendimethalin 30 EC @ 1.0 kg *a.i.* ha^{-1} at 3 days after sowing as pre-emergent and Bispyribac sodium 10 % SL @ 250 ml ha^{-1} was sprayed at 20 days after sowing as early post-emergent with the help of hand operated knapsack sprayer. Two hand weedings (60 and 90 DAS) were carried out during the crop growth in direct seeded rice.

3.7.4 After care

Thinning of excessive seedlings was done 15 days after sowing to maintain optimum plant population. Seedlings were spaced at 10 cm between plants within a row. Gap filling was also done simultaneously on the same day. Chloropyriphos, Coragen and Tricyclazole were sprayed (@ 2 ml L^{-1}, 0.5 g and 1 g L^{-1}), respectively to overcome minor incidence of leaf minor, leaf folder, stem borer and blast.

3.7.5 Irrigation management

Sowing was taken up immediately after receipt of optimum rainfall. Later on the crop was irrigated with pond water as and when ever required to maintain optimum moisture for better growth and development of crop during initial periods. Later on when canal water was available as per warabhandi alteration method of irrigation.

3.7.6 Application stages of fertilizer

The calculated NPK fertilizer as per nutrient management approaches, such as STL, STCR, SSNM and nutrient expert were applied as follows.

The total calculated nitrogen was applied in four splits during different nutrient demand stages of DSR. Nitrogen applications are fine-tuned using a chlorophyll meter (SPAD) *i.e* initial $1/4^{th}$ of nitrogen, entire dose of phosphorus and half dose of calculated potassium were applied at early, 25 to 30 days after sowing depending on moisture availability, in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP), later on $1/4^{th}$ of nitrogen, were applied at active tillering stage, and $1/4^{th}$ of

nitrogen were applied at early panicle initiation stage. 50 % potash and 1/4th of nitrogen were applied at heading stage according to the treatment details.

3.7.7 Micro nutrient application

As per soil test result the experimental site was deficient in zinc and iron, so that zinc was applied to experimental site in the form of $ZnSO_4$ at the rate of 25 kg ha^{-1} along with first dose of nitrogen application. Iron sulphate foliar sprayed (2-3 sprayings at 4-5 days intervals) at the rate of 0.5 per cent to correct iron deficiency in Dry-DSR during early growth stage except control.

3.7.8 Harvesting and threshing

The crop was harvested on 12th December, 2015 and 5th December, 2016 at its physiological maturity. Hand threshing and winnowing was done to separate the grains after thorough sun drying. Treatment wise for grain and straw yield was recorded separately and finally expressed in q ha^{-1}.

3.8 Collection of experimental data

Five plants from net plot were selected at random and tagged for the purpose of recording various observations. Observations on growth parameters at five distinct stages of crop growth *viz.*, 60, 90, 120 DAS and at harvest were recorded on observation plants. Data on yield parameters were recorded at harvest. Based on observations recorded on five tagged plants, average per plant was calculated.

3.8.1 Growth parameters

3.8.1.1 Plant height (cm)

The plant height of dry direct seeded rice was recorded at 60, 90, 120 DAS and at harvest from base of the plant up to the tip of the last sheath of main shoot. Five plants mean height was expressed in centimeter.

3.8.1.2 Number of tillers per square meter

Number of tillers per square meter were counted at randomly selected area and expressed as tillers per square meter.

3.8.1.3 SPAD meter readings

Chlorophyll meter readings were recorded at 60, 90 and 120 DAS. The top most fully expanded leaf was chosen for SPAD measurement, as described by Babu *et al*. (2000). The SPAD readings were taken at random for each plot and the average was noted.

3.8.1.4 Total dry matter accumulation (g plant $^{-1}$)

Five plants were uprooted at randomly from the net plot area excluding two border rows in the field. The root portion of the plant was discarded. The above ground portion of plant samples were washed in water and dried under the sun, then kept in hot air oven at 65 ^{o}C for further drying. The mean dry weight plant^{-1} was calculated and expressed in grams.

3.8.1.5 Leaf area per plant

For measuring leaf area, number of leaves per plant was counted. The length and maximum width of each leaf on the middle tiller was measured and leaf area of each leaf was computed as follows.

$$\text{Leaf area} = K \times L \times W$$

Where,

K = constant factor

L = length of leaf (cm)

W = maximum width of leaf (cm)

The value of constant K was taken as 0.75 up to 90 days and 0.67 during maturity stage (Gomez, 1972). The leaf area per plant was then calculated as follows.

Leaf area per plant = total leaf area of middle tiller x total number of tillers per plant.

It was recorded for five plants separately and averaged to get leaf area in cm^2 plant^{-1}.

3.9 Observation on yield parameters and yield of Dry DSR

3.9.1 Number of panicles per square meter

Number of panicles per square meter were counted at harvest from each treatment at random and expressed as number of panicles per square meter.

3.9.2 Panicle length (cm)

Length of panicle from five panicles selected at random in each plot was recorded from base to tip of panicles and the mean was computed and expressed in centimeters.

3.9.3 Number of filled, unfilled and total grains per panicle

Filled, unfilled and total number of grains panicle^{-1} was determined by counting the grains in five panicles of randomly selected plants and mean was calculated.

3.9.4 Sterility percentage

It is the proportion of number of unfilled grains per panicle to the total number of grains per panicle and expressed in percentage.

$$\text{Sterility percentage} = \frac{\text{Number of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \text{ X } 100$$

3.9.5 Test weight (g)

From the seed yield of each net plot, 1000 seeds were randomly counted and weight was recorded and expressed in grams.

3.9.6 Grain yield (q ha^{-1})

The crop in the net plot was harvested, threshed, dried in sun. The grains were cleaned and weight was recorded and converted into quintals per hectare.

3.9.7 Straw yield (q ha^{-1})

The straw from net plot after threshing was dried in sun, weighed and converted into quintals per hectare.

3.10 Experiment-II: Residual effects of different nutrient management approaches on the growth and yield of mustard

The residual effects of main crop treatments were studied using mustard as a test crop in the same plot during *rabi* season for the years of 2015-16 and 2016-17, respectively because the tail end farmers of TBP command area cultivate mustard in their field as *rabi* crop with available residual moisture and nutrients.

3.10.1 Crop management practices for mustard

3.10.1.1 Seeds and sowing

Sowing was done manually in wet soil immediately after harvest of main crop. Shallow furrows lines were opened at the distance of 45 cm and mustard seeds were sown in lines at 3-5 cm deep and covered immediately after sowing.

3.10.1.2 Gap filling and thinning

Gap filling was done after eight days of sowing to ensure uniform plant population. Thinning was done 15 days after sowing by maintaining one healthy and vigorous seedling.

3.10.1.3 Irrigation

Irrigation was done only once on 30 days after sowing in order to maintain enough moisture in the field.

3.10.1.4 Weed management

Hand weeding was done once 45 days after sowing to control weeds in the field.

3.10.1.5 Harvesting and threshing

The crop was harvested after attaining for maturity when all foliage turned yellow and leaf shedding initiated. The plants from net plot area were harvested, sun dried and threshed to separate seeds and weighed separately. The grain yield per plot was recorded. Then, the values were converted to per hectare and expressed in kg ha^{-1}.

3.10.1.6 Plot size, spacing, variety, sowing and harvesting dates of mustard

Gross plot size	5.4 m x 3.3 m = 18.70 m²
Net plot size	4.5 x 3.0 m =13.5 m²
Spacing	0.45 m x 0.15 m
Variety	PM-30
Date of sowing	December 24th 2015 & December 8th 2016
Date of harvesting	March 18th 2016 & March 3rd 2017
Crop duration	85 to 90 days

3.10.2 Growth and yield parameters of mustard

3.10.2.1 Plant height

Plant height from ground level up to the growing tip of the plant was recorded from five tagged plants and the mean plant height was worked out and expressed in centimeter.

3.10.2.2 Number of primary branches per plant

Number of primary branches were counted from five tagged plants and mean value was calculated.

3.10.2.3 Dry matter production per plant

Plant samples for dry matter studies were collected at harvest. Five plants were uprooted at random in each treatment these samples were dried in shade than oven dried in hot air oven till a constant weight. The total dry matter production per plant was obtained and was expressed on per plant basis (g plant^{-1}).

3.10.2.4 Siliquae per plant

The siliquae present on five randomly selected plants were separated and counted, average value was reported as number of siliquae per plant.

3.10.2.5 Seeds per siliquae

Seeds were collected by splitting five siliquae from each plant out of five plants and then counted the seeds expressed as seeds per siliquae.

3.10.2.6 Weight of 1000-seeds

Sample of seeds was drawn from the produce of each net plot and thousand seeds were counted from each treatment. The counted seeds were weighed and recorded as test weight in g.

3.10.2.7 Seed yield

The sun dried plants from net plot area were threshed, cleaned and the weight was recorded. Based on the yield from net plot, the grain yield per hectare was calculated and expressed in kilograms per hectare.

3.10.2.8 Oil content

Approximately 25 g of seeds drawn randomly from each treatment was oven dried at 50 ± 5 °C and estimation of per cent oil content in the grain was done by using N.M.R. (Nuclear Magnetic Resonance Spectrometer).

3.10.2.9 Oil yield

Oil yield per hectare was worked out by multiplying oil content and seed yield per hectare and was expressed in kg ha^{-1}.

2016

2017

Plate 3: General view of experiment on mustard during 2016 and 2017

3.11 Chemical analysis of soil samples

3.10.1 Collection of soil samples

During the field experiment, composite soil sample was collected from experimental site before sowing and soil samples were collected at 0-15 cm depth from each experimental plot after harvest of the Dry DSR-Mustard cropping sequence. The collected soil samples were dried under shade, powdered using wooden pestle and mortar and passed through 2 mm sieve and preserved for analysis. For organic carbon analysis, the 2 mm sieved soil samples were subjected for further grinding and passed through 0.2 mm sieve.

The standard methods followed and instruments used for the soil and plant analysis during the experiments are presented in the following table.

Methods used for analysis			
I. Soil analysis			
Sl.No.	**Parameters**	**Method**	**Reference**
1.	pH (1:2.5)	Potentiometric method	Piper (1966)
2.	EC (dSm^{-1})	Conductometry method	Jackson (1973)
3.	Organic carbon (%)	Wet oxidation method	Jackson (1973)
4.	Available N ($kg\ ha^{-1}$)	Alkaline potassium permanganate method	Subbiah and Asija (1956)
5.	Available P_2O_5 ($kg\ ha^{-1}$)	Olsen's method	Jackson (1973)
6.	Available K_2O ($kg\ ha^{-1}$)	Flame photometry method	Jackson (1973)
7.	Exchangeable Ca & Mg	Versanate titration method	Jackson (1973)
9.	Available S ($mg\ kg^{-1}$)	$CaCl_2$ extractable method	Jackson (1973)
10.	Available Zn,Fe, Cu and Mn ($mg\ ha^{-1}$)	DTPA extractable method	Lindsay & Norvell (1978)
II. Plant analysis			
1.	Nitrogen	Microkjeldhal method	Piper (1966)
2.	Phosphorus	Vanadomolybdic method	Piper (1966)
3.	Potassium	Flame photometer method	Piper (1966)
4.	Sulphur	Turbidometric method	Jackson (1973)
5.	Zinc, and Iron	Atomic Absorption Spectrophotometer method	Jackson (1973)

3.12 Collection of soil samples for microbial activity

For the purpose of analyzing the microbial activity, the soil samples were collected from experimental plot after the harvest of crop from each plot from rhizosphere of rice plant. Immediately after collecting, the soil samples were stored in refrigerator and these soil samples were used for enumeration of soil microflora, dehydrogenase activity and phosphatase activity.

3.12.1 Soil microflora estimation

The enumeration of total bacteria, fungi and actinomycetes in free rhizosphere was carried out after the harvest of crop by serial dilution and agar plate method (Pramer and Schmidt, 1964).

3.12.2 Dehydrogenase activity

Dehydrogenase activity in the soil samples was determined by following the procedure as described by Casida *et al.* (1964). The results are expressed as µg of triphenyl formazan (TPF) formed per gram of soil per day.

3.12.3 Phosphatase activity

Phosphatase activity of soil samples was determined by following the procedure of Evazi and Tabatabai (1979).

3.13 Uptake pattern and use efficiencies of different nutrients

The grain and straw samples were collected at harvest stages of Dry-DSR and analyzed for total N, P, K, S, Zn, & Fe and workout for total uptake and use efficiency of nutrients (N, P and K) in Dry-DSR during both the years are given in Appendix I to III. Similarly total N, P and K uptake of mustard workout for balance sheet of nitrogen, phosphorus and potassium status in soil during both the years are given in Appendix IV to V. The formulae used are as follows:

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient concentration in samples (\%)}}{100} \text{ X } \text{Biomass yield (kg ha}^{-1})$$

3.13.1 Nutrient use efficiency (NUE)

The nutrient use efficiency of applied nutrients *viz.*, nitrogen, phosphorous, potassium by DSR at harvest was calculated as explained below. It is the ratio of difference between uptake of nutrient by the crop in fertilized plot and uptake of nutrient by a crop in control to the quantity of respective nutrient applied.

$$\text{Nutrient use efficiency (NUE) (\%)} = \frac{NUf - NUc}{Na} \times 100$$

Where,

NUf: Amount of nutrient uptake by a crop in fertilized plot (kg ha^{-1})

NUc: Amount of nutrient uptake by a crop in control plot (kg ha^{-1})

Na: Amount of nutrient applied (kg ha^{-1})

3.13.2 Agronomic Efficiency (AE) (kg grain kg^{-1} nutrient applied)

Agronomic efficiency of nutrients is the ratio of difference between the grain yield in fertilized plot and grain yield in control plot to the amount of respective nutrient applied.

$$\text{Agronomic Efficiency (AE) (kg grain kg}^{-1}\text{ nutrient applied)} = \frac{Yf - Yc}{Na}$$

Where,

Yf: Grain yield in fertilized plot (kg ha^{-1})

Yc: Grain yield in control plot (kg ha^{-1})

Na: Amount of nutrient applied (kg ha^{-1})

3.14 Balance of nitrogen, phosphorus and potassium status in soil (kg ha^{-1})

Balance sheet of nitrogen, phosphorus and potassium was worked out at the end of each sequence by considering the initial soil available N, P_2O_5 and K_2O status and N, P_2O_5 and K_2O supplied through fertilizers and manures. Upon subtracting the crop uptake, the expected balance of nutrients was arrived. Net gain or loss of nutrients was worked by subtracting expected balance from initial N, P_2O_5 and K_2O status.

3.15 Rice equivalent yield (REY)

The rice equivalent yield of rice-mustard system was calculated by taking into account the grain/seed yield of both crops and the prevailing market price of both the crops. Finally rice equivalent yield was calculated as,

$$REY = \frac{\text{Yield of mustard X Price of mustard}}{\text{Price of rice}} + \text{Yield of rice}$$

3.16 Economic analysis

The price of inputs, labour cost and market price of the produce obtained that were prevailing at the time of experimentation (2015-16 and 2016-17) was considered for working out the cost of cultivation and returns. The details considered to work out the economics are given in Appendix VI to IX.

3.16.1 Cost of cultivation (₹ ha^{-1})

The cost of cultivation was worked out considering the materials input like seed, manure, fertilizer, plant protection chemicals, *etc*. and labour input for all the operations. The expenditure incurred from sowing to marketing including the field preparation were worked out and expressed in ₹ ha^{-1}. Treatment wise cost of cultivation was worked out.

3.16.2 Gross returns (₹ ha^{-1})

The total income obtained from the product (grain/seed and straw/stover) of unit cost of main products and its total yield and expressed in ₹ ha^{-1} (The price of the crop products prevailing in the market after the harvest was obtained from the Agriculture Produce Market Committee, Raichur and was used for the calculation of gross returns.)

3.16.3 Net returns (₹ ha^{-1})

Net returns obtained by subtracting cost of cultivation from gross returns and expressed in ₹ ha^{-1}

Net returns (₹ ha^{-1}) = Gross returns (₹ ha^{-1}) – Cost of cultivation (₹ ha^{-1})

3.16.4 Benefit cost ratio (BCR)

The benefit cost ratio was worked out by using the following formula.

$$\text{Benefit Cost ratio} = \frac{\text{Gross returns (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

3.17 Statistical analysis of data

The experimental data obtained were subjected to statistical analysis using Fisher's method of analysis of variance as out lined by Gomez and Gomez (1984). The level of significance used in 'F' and't' tests was p= 0.05. Critical difference values were calculated, wherever 'F' test was found significant. Results have been interpreted and discussed based on the pooled data of two years (2016 and 2017).

Experimental Results

IV. EXPERIMENTAL RESULTS

The experimental results on "Soil test based nutrient management approaches in Dry DSR-Mustard cropping system" conducted during *Kharif* and *Rabi* seasons of 2015-16 and 2016-17 at the farmer field of Vijayanagar camp, Dist/Tq: Raichur are explained in this chapter.

Experiment No. 1: To identify the suitable nutrient management approach in Dry DSR

The results of the experiment conducted during *kharif* seasons of 2015-16 and 2016-17 in the farmer field of Vijayanagar camp, to identify the suitable nutrient management approach in Dry DSR are explained below. The response of crop growth, yield parameters and yield were similar in both the years. Therefore, only pooled data of two years are explained in this chapter.

4.1 Growth parameters of Dry DSR

The data on growth parameters *viz*., plant height, number of tillers per square meter, leaf area, SPAD readings and dry matter production of Dry DSR as influenced by different nutrient management approaches at different growth stages are presented in Tables 3 to 7. The data on growth parameters were found be higher in second year as compared to first year in all the treatments except absolute control. However, the trend observed was similar during the both the years. Therefore, only pooled data of two years are explained below.

4.1.1 Plant height (cm)

Influence of different nutrient management approaches on plant height at different growth stages of Dry DSR are presented in Table 3 and the results were found to be significant at all the growth stages.

At 60 DAS, T_3: Farmer practice recorded highest plant height (20.2 cm) followed by SSNM approach for targeted yield of 55 q ha^{-1} (19.0 cm) and T_6:STCR approach targeted yield of 55 q ha^{-1} (17.4 cm) as compared to rest of the treatments. Whereas, the lowest plant height was observed in absolute control (11.7 cm).

Table 3. Plant height of Dry DSR at different growth stages as influenced by different nutrient management approaches

Treatments	Plant height (cm)											
	60 DAS			90 DAS			120 DAS			At Harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	12.8	10.6	11.7	20.7	18.2	19.4	40.1	38.7	39.4	48.6	45.3	47.0
T_2	14.6	15.5	15.1	25.3	29.0	27.7	48.3	50.0	49.2	56.7	60.1	58.4
T_3	19.6	20.4	20.2	34.6	37.5	37.0	59.3	61.8	60.2	74.0	75.3	74.7
T_4	15.2	16.5	15.9	25.4	30.7	29.1	49.0	51.2	50.1	59.9	61.1	60.5
T_5	12.4	12.8	12.6	21.0	23.8	22.9	46.1	44.4	45.3	51.7	52.3	52.0
T_6	17.1	17.7	17.4	30.3	33.1	32.5	54.9	56.6	55.8	67.4	69.2	68.3
T_7	16.7	17.5	17.1	29.9	31.0	30.5	50.7	53.2	52.0	63.9	67.0	66.5
T_8	18.2	19.7	19.0	33.2	36.7	35.5	57.6	59.7	58.7	72.5	73.0	72.8
T_9	14.4	14.9	14.7	24.0	28.9	27.5	46.6	48.3	47.5	53.7	54.4	54.1
T_{10}	15.0	16.1	15.6	26.1	30.4	28.8	50.4	52.1	51.3	60.1	63.3	61.7
S. Em.±	1.4	1.3	1.4	2.2	1.8	2.0	3.2	2.9	4.6	3.4	3.9	3.9
C.D. at 5 %	4.3	3.9	4.1	6.6	5.3	6.0	9.4	8.7	13.6	10.2	11.7	11.4

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

At 90 DAS, the treatment T_3: Farmer practice recorded highest plant height of (37.0 cm) as compared to T_1: Absolute control (19.4 cm), T_5: STCR approach targeted yield of 45 q ha^{-1} (22.9 cm), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (27.5 cm), T_2: RDF (27.2 cm), T_4: STL method (28.1 cm) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (28.8 cm) and it was found on par with the T_8: SSNM approach targeted yield of 55 q ha^{-1} (35.5 cm) followed by T_6: STCR approach targeted yield of 55 q ha^{-1} (32.5 cm) and T_7: SSNM approach targeted yield of 45 q ha^{-1}(30.5 cm).

Plant height at 120 DAS was recorded highest with T_3: Farmer practice (60.2 cm) followed by T_8: SSNM approach targeted yield of 55 q ha^{-1} (58.7 cm) as compared to T_1: Absolute control (39.4 cm), T_5: STCR approach targeted yield of 45 q ha^{-1} (45.3 cm), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (47.5 cm), T_2: Recommended dose of fertilizer (49.2 cm), T_4: STL method (50.1 cm) and it was found on par with the T_6:STCR approach targeted yield of 55 q ha^{-1} (55.8 cm) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (52.0 cm) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (51.3 cm).

Similarly at harvesting stage, farmer practice recorded taller plant (74.7 cm) and it was found on par with the SSNM approach targeted yield of 55 q ha^{-1} (72.8 cm) followed by STCR approach targeted yield of 55 q ha^{-1} (66.5 cm) and SSNM approach targeted yield of 45 q ha^{-1} (68.3 cm) and these treatments were significantly superior over rest of the treatments. Whereas lowest plant height was observed in the T_1: absolute control (47.0 cm).

4.1.2 Number of tillers per meter square

Significant variations were observed with regard to number of tillers per meter square as influenced by different nutrient management approaches at all the growth stages. The overall trend of the pooled data revealed that number of tillers per meter square increased progressively from 60 DAS to till harvest (Table 4).

Number of tillers per meter square of Dry DSR differed significantly at all the growth stages due to application of different levels of fertilizers. Number of tillers per meter square was recorded higher in second year as compared to first year except absolute control. However the trend observed similar during the both the years of study periods.

Table 4. Number of tillers per meter square of Dry DSR at different growth stages as influenced by different nutrient management approaches

Treatments	Number of tillers per meter square											
	60 DAS			90 DAS			120 DAS			At Harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	178.3	176.6	177.5	233.6	222.6	228.1	323.0	312.2	317.6	328.3	318.7	323.5
T_2	294.4	301.2	297.8	373.5	377.0	375.3	494.6	511.0	502.8	521.2	539.0	530.1
T_3	335.1	355.5	345.3	422.9	443.3	433.1	571.6	595.3	583.5	609.4	619.9	614.7
T_4	288.3	309.0	298.7	370.7	386.6	378.8	511.0	523.5	517.3	534.7	537.9	536.3
T_5	242.5	250.1	246.3	306.8	310.5	308.7	420.6	423.6	422.1	422.3	438.7	430.5
T_6	342.2	359.4	350.8	441.5	457.5	449.5	621.3	635.3	628.3	638.9	662.4	650.6
T_7	320.0	340.1	330.1	404.8	423.8	414.3	548.0	571.1	559.6	582.3	593.0	587.7
T_8	358.1	376.7	367.4	468.7	485.0	476.9	630.8	649.3	640.1	674.0	682.0	678.0
T_9	264.3	285.6	275.0	337.6	358.3	348.0	459.2	486.8	473.0	480.4	497.5	489.0
T_{10}	314.7	323.4	319.1	384.5	400.3	392.4	536.2	564.3	550.3	570.6	582.4	576.5
S. Em.±	18.5	18.1	16.7	30.4	29.7	30.6	33.8	32.4	35.8	37.2	39.5	38.6
C.D. at 5 %	53.8	52.7	49.6	90.1	88.1	91.0	100.3	96.1	106.5	110.5	117.6	114.6

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

Pooled data reveals that number of tillers per meter square at 60 DAS recorded significantly higher with T_8: SSNM approach targeted yield of 55 q ha^{-1} (367.4) as compared to T_1: Absolute control (177.5), T_5: STCR approach targeted yield of 45 q ha^{-1} (246.3), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (275.0) followed by T_2: Recommended dose of fertilizer (297.8) and T_4: STL method (298.6) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (350.8), T_3: Farmer practice (345.3), T_7: SSNM approach targeted yield of 45 q ha^{-1} (330.1) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (307.7).

At 90 DAS, SSNM approach targeted yield of 55 q ha^{-1} (476.9) recorded significantly highest number of tillers per meter square of and it was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1} (449.5), T_3: Farmer practice (433.1), T_7: SSNM approach targeted yield of 45 q ha^{-1}(414.3) and T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1} (389.1) as compared to absolute control (228.1), STCR approach targeted yield of 45 q ha^{-1} (308.6) followed by nutrient expert for attainable yield of 45 q ha^{-1} (348.0), RDF (375.3) and STL method (378.8).

Number of tillers per meter square at 120 DAS was recorded significantly highest with SSNM approach targeted yield of 55 q ha^{-1} (649.3) followed by STCR approach targeted yield of 55 q ha^{-1} (583.5), farmer practice (640.1), SSNM approach targeted yield of 45 q ha^{-1} (559.5) and nutrient expert for attainable yield of 55 q ha^{-1} (550.3). Whereas lowest number of tillers per meter square was recorded in absolute control (317.6), STCR approach targeted yield of 45 q ha^{-1} (422.1), nutrient expert for attainable yield of 45 q ha^{-1} (473.0), RDF (502.8) and STL method (517.3).

At harvesting stage, number of tillers per meter square recorded significantly highest with the SSNM approach targeted yield of 55 q ha^{-1} (678.0) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (650.6), T_3: Farmer practice (614.7) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (587.7) and T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1} (576.5). It was significantly superior over the T_1: Absolute control (323.5), T_5: STCR approach targeted yield of 45 q ha^{-1} (430.5), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (489.0), T_2: Recommended dose of fertilizer (530.1) and T_4: STL method (536.3).

4.1.3 Leaf area per plant (cm^2)

The data pertaining to leaf area per plant as influenced by different nutrient management approaches at different growth stages of Dry DSR is presented in Table 5 and the results were found to be significant. The overall trend of the data revealed that leaf area per plant was increased progressively from 60 to 120 DAS thereafter it decreased slightly at harvest.

Leaf area per plant at 60 DAS, T_8: SSNM approach targeted yield of 55 q ha^{-1} (429 cm^2) recorded significantly highest leaf area per plant and it was found on par with the T_3: Farmer practice (420 cm^2), T_6: STCR approach targeted yield of 55 q ha^{-1} (407 cm^2), T_7: SSNM approach targeted yield of 45 q ha^{-1} (376.0 cm^2) and T_{10}: Nutrient expert for attainable 55 q ha^{-1} (362 cm^2). It was significantly superior over the rest of the treatments. Whereas lowest leaf area per plant was recorded in T_1: Absolute control (210 cm^2).

At 90 DAS, T_8: SSNM approach targeted yield of 55 q ha^{-1} (816 cm^2) recorded significantly highest leaf area per plant and it was found on par with the T_3: Farmer practice (806 cm^2), T_6: STCR approach targeted yield of 55 q ha^{-1} (772 cm^2), T_7: SSNM approach targeted yield of 45 q ha^{-1} (738 cm^2) and T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1} (702 cm^2). And it was found significantly superior over the rest of the treatments. Whereas lowest leaf area per plant was recorded in T_1: Absolute control (393 cm^2).

Leaf area per plant at 120 DAS was recorded highest with T_8: SSNM approach targeted yield of 55 q ha^{-1} (1418 cm^2) recorded significantly highest leaf area per plant and it was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1} (1351 cm^2), T_3: Farmer practice (1323 cm^2), T_7: SSNM approach targeted yield of 45 q ha^{-1} (1292 cm^2) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (1240 cm^2). And it was found significantly superior over the rest of the treatments. Whereas lowest leaf area per plant was recorded in T_1: Absolute control (696 cm^2).

At harvesting stage, T_8: SSNM approach targeted yield of 55 q ha^{-1} (955 cm^2) recorded significantly highest leaf area per plant and it was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1} (921 cm^2), T_3: Farmer practice (882 cm^2), T_7: SSNM approach targeted yield of 45 q ha^{-1} (843 cm^2) and T_{10}: Nutrient expert for

Table 5. Leaf area per plant of Dry DSR at different growth stages as influenced by different nutrient management approaches

Treatments	Leaf area (cm^2 $plant^{-1}$)											
	60 DAS			90 DAS			120 DAS			At Harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	212	207	210	405	381	393	712	679	696	464	432	448
T_2	324	353	339	656	668	662	1140	1158	1149	764	757	761
T_3	417	422	420	793	818	806	1303	1342	1323	870	893	882
T_4	345	363	354	625	682	654	1171	1188	1180	745	787	766
T_5	248	285	285	536	548	542	933	964	949	609	629	619
T_6	396	418	407	758	786	772	1334	1368	1351	913	928	921
T_7	353	399	376	725	751	738	1275	1308	1292	832	854	843
T_8	425	432	429	809	823	816	1403	1432	1418	942	967	955
T_9	307	335	321	599	631	615	1053	1098	1076	695	706	701
T_{10}	350	374	362	694	710	702	1206	1274	1240	816	835	826
S. Em.±	26	24	25	39	40	40	72	68	72	44	54	49
C.D. at 5 %	77	71	74	117	118	118	213	203	212	130	160	147

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

attainable yield of 55 q ha^{-1} (826 cm^2), it was significantly superior over the rest of the treatments. Lowest leaf area per plant was recorded in T_1: Absolute control (448 cm^2).

4.1.4 SPAD readings

Application of different doses of fertilizers exerted significant influence on the chlorophyll content in healthy leaves at 60, 90 DAS and 120 DAS are presented in Table 6. The overall trend of the data revealed that SPAD readings increased progressively from 60 to 90 DAS and then it decreased slightly at harvest.

SPAD readings at 60 DAS was recorded highest with T_3: Farmer practice (41.23) as compared to T_1: Absolute control (24.85), T_5: STCR approach targeted yield of 45 q ha^{-1} (33.02), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (31.85), T_2: Recommended dose of fertilizer (31.16) and T_4: STL method (34.04), it was found on par with the T_8: SSNM approach targeted yield of 55 q ha^{-1} (39.30), T_6: STCR approach targeted yield of 55 q ha^{-1} (37.51), T_7: SSNM approach targeted yield of 45 q ha^{-1} (36.77) and T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1} (35.02).

SPAD readings at 90 and 120 DAS were recorded highest with T_8: SSNM approach targeted yield of 55 q ha^{-1} (45.91 and 44.55) and it was found on par with the T_3: Farmer practice (44.81 and 43.08), T_6: STCR approach targeted yield of 55 q ha^{-1} (42.87 and 41.86), T_7: SSNM approach targeted yield of 45 q ha^{-1} (41.43 and 40.07 respectively) and T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1} (39.00 and 37.22) as compared to the rest of other treatments and lowest SPAD readings were recorded with T_1: Absolute control (27.20 and 25.43).

4.1.5 Dry matter production (g $plant^{-1}$)

Dry matter production in Dry DSR at different growth stages as influenced by different nutrient management approaches was differed significantly at all the growth stages is presented in Table 7.

At 60 DAS, significantly higher (7.83 g $plant^{-1}$) dry matter production was found with farmer practice as compared to absolute control (3.59 g $plant^{-1}$), STCR targeted yield of 45 q ha^{-1} (4.90 g $plant^{-1}$) followed by nutrient expert for attainable yield of 45 q ha^{-1}(5.57 g $plant^{-1}$), RDF (6.02 g $plant^{-1}$) and STL method (6.03 g $plant^{-1}$) and it was found on par with the SSNM targeted yield of 55 q ha^{-1} (7.70 g $plant^{-1}$), STCR approach

Table 6. SPAD values of Dry DSR as influenced by different nutrient management approaches at different growth stages

Treatments	SPAD Values								
	60 DAS			90 DAS			120 DAS		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	26.03	23.67	24.85	27.87	26.53	27.20	24.80	26.17	25.43
T_2	31.90	30.43	31.16	38.89	37.51	38.20	34.27	35.64	34.96
T_3	40.43	42.03	41.23	45.84	43.78	44.81	42.37	43.78	43.08
T_4	34.73	33.30	34.04	40.12	38.81	39.46	37.57	36.94	37.26
T_5	32.10	33.93	33.02	36.20	37.57	36.15	35.41	34.89	35.88
T_6	36.73	38.30	37.51	42.37	43.38	42.87	41.17	42.54	41.86
T_7	36.43	37.10	36.77	41.59	41.27	41.43	39.90	40.25	40.07
T_8	38.67	39.93	39.30	46.89	44.93	45.91	43.30	45.80	44.55
T_9	32.13	31.57	31.85	35.89	34.49	35.19	34.80	32.17	33.48
T_{10}	34.23	35.80	35.02	39.36	37.98	39.00	38.67	35.77	37.22
S. Em.±	2.16	2.71	2.24	2.69	2.43	2.58	2.75	3.29	2.63
C.D. at 5 %	6.31	7.92	6.54	8.03	9.61	7.68	7.84	7.09	7.53

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

targeted yield of 55 q ha^{-1} (6.99 g $plant^{-1}$), SSNM targeted yield of 45 q ha^{-1} (6.68 g $plant^{-1}$) and nutrient expert for attainable yield of 55 q ha^{-1} (6.26 g $plant^{-1}$).

At 90 DAS, the treatment T_8: SSNM approach targeted yield of 55 q ha^{-1} (29.97 g $plant^{-1}$), recorded highest dry matter production of followed by T_3: Farmer practice (28.05 g $plant^{-1}$) and it was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1} (27.16 g $plant^{-1}$) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (25.97 g $plant^{-1}$) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (24.33 g $plant^{-1}$) as compared to rest of treatments and lowest dry matter production per plant was recorded with T_1: Absolute control (13.78 g $plant^{-1}$).

Dry matter production at 120 DAS, was recorded highest with T_8: SSNM approach targeted yield of 55 q ha^{-1} (47.55 g $plant^{-1}$) as compared to T_1: Absolute control (22.29 g $plant^{-1}$), T_5: STCR approach targeted yield of 45 q ha^{-1} (30.16 g $plant^{-1}$), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (34.23 g $plant^{-1}$), T_2: Recommended dose of fertilizer (37.06 g $plant^{-1}$), T_4: STL method (37.81 g $plant^{-1}$) and it was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1} (45.16 g $plant^{-1}$), T_3: Farmer practice recorded (42.49 g $plant^{-1}$) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (41.11 g $plant^{-1}$) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (40.50 g $plant^{-1}$).

At harvesting stage, T_8: SSNM approach targeted yield of 55 q ha^{-1} recorded highest dry matter production of (62.25 g $plant^{-1}$) as compared to T_1: Absolute control (28.13 g $plant^{-1}$), T_5: STCR approach targeted yield of 45 q ha^{-1} (38.88 g $plant^{-1}$), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (41.94 g $plant^{-1}$), T_2: Recommended dose of fertilizer (45.88 g $plant^{-1}$) and T_4: STL method (49.06 g $plant^{-1}$). And it was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1}(59.83 g $plant^{-1}$), T_3: Farmer practice (55.90 g $plant^{-1}$) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (52.89 g $plant^{-1}$) and T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1}(50.76 g $plant^{-1}$).

4.2 Yield and yield attributing parameters of Dry DSR as influenced by different nutrient management approaches

The influence of different nutrient management approaches on yield and yield attributing parameters *viz.*, number of panicles m^{-2}, panicle length, number of grains $panicle^{-1}$, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, per cent sterility, test weight,

Table 7. Total dry matter production of Dry DSR at different growth stages as influenced by different nutrient management approaches

Treatments	Total dry matter production (g plant^{-1})											
	60 DAS			90 DAS			120 DAS			At Harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	3.65	3.52	3.59	13.71	13.84	13.78	23.21	21.37	22.29	28.30	27.95	28.13
T_2	6.01	6.03	6.02	22.55	24.24	23.40	36.73	37.38	37.06	45.33	46.42	45.88
T_3	7.90	7.76	7.83	26.82	29.28	28.05	41.85	43.12	42.49	52.96	58.83	55.90
T_4	5.86	6.19	6.03	21.98	24.87	23.43	37.27	38.35	37.81	46.50	51.62	49.06
T_5	4.85	4.96	4.90	18.56	19.51	19.04	30.10	30.42	30.26	38.29	39.47	38.88
T_6	6.85	7.13	6.99	25.68	28.65	27.16	44.38	45.94	45.16	56.48	63.17	59.83
T_7	6.55	6.81	6.68	24.54	27.39	25.97	39.99	42.23	41.11	50.61	55.17	52.89
T_8	7.62	7.78	7.70	31.17	28.53	29.97	48.53	46.57	47.55	64.25	60.25	62.25
T_9	5.41	5.72	5.57	20.27	22.98	21.63	33.01	35.44	34.23	41.80	42.08	41.94
T_{10}	6.09	6.42	6.26	22.84	25.81	24.34	32.20	41.80	40.50	47.09	54.42	50.76
S. Em.±	0.43	0.36	0.48	1.48	1.37	1.93	2.34	2.16	2.95	3.41	3.16	3.87
C.D. at 5 %	1.26	1.05	1.44	4.31	3.99	5.73	6.84	6.31	8.77	9.96	9.22	11.51

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

grain yield and straw yield are presented in the Table 8, 9 and 10 and the results obtained were significant. The response of yield parameters and yield were similar in both the years. In general yield and yield attributing parameters were recorded higher in second year as compared to first year in all the treatments except absolute control. However, the trend observed was similar during the both the years. Therefore, only pooled data of two years are explained below.

4.2.1 Number of panicles per meter square

Application of different doses of fertilizers exerted significant influence on the number of panicles per meter square during both the years of study. Pooled data, revels that number of panicles per meter was noticed significantly higher with SSNM approach targeted yield of 55 q ha^{-1} (437.6) and it was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1} (423.5), T_3: Farmer practice (380.3) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (368.7) and T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1}(356.6). It was significantly superior over the absolute control (149.9), T_5: STCR approach targeted yield of 45 q ha^{-1} (293.8), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (317.9), T_2: Recommended dose of fertilizer (326.2) and T_4: STL method (340.6).

4.2.2 Number of grains per panicle

Number of grains per panicle was registered significantly higher with T_8: SSNM approach targeted yield of 55 q ha^{-1} (143.9) as compared to T_1: Absolute control (112.1) T_5: STCR approach targeted yield of 45 q ha^{-1} (122.9), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (125.0), T_2: Recommended dose of fertilizer (127.1), T_4: STL method (129.5) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(131.4). It was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1} (139.3), T_3: Farmer practice (136.0) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (134.3).

4.2.3 Panicle length (cm)

Higher panicle length (19.8 cm) was registered with SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with the STCR approach targeted yield of 55 q ha^{-1} (19.4 cm) followed by farmer practice (18.3 cm) and SSNM approach targeted yield of 45 q ha^{-1} (17.7 cm). Lower panicle length was registered in absolute control (15.7 cm), as compared to rest of the treatments.

Table 8. Number of panicles m^{-2}, number of grains $panicle^{-1}$ and panicle length of Dry DSR as influenced by different nutrient management approaches

Treatments	Number of panicles m^{-2}			Number of grains $panicle^{-1}$			Panicle length (cm)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	156.6	143.2	149.9	116.0	110.3	113.2	15.9	15.4	15.7
T_2	320.3	332.0	326.2	124.4	129.7	127.1	16.6	17.0	16.8
T_3	378.9	381.6	380.3	134.5	137.5	136.0	18.1	18.4	18.3
T_4	334.3	346.8	340.6	128.6	130.4	129.5	17.2	17.5	17.4
T_5	285.1	302.4	293.8	120.5	125.2	122.9	16.5	16.7	16.6
T_6	418.0	429.0	423.5	136.1	142.5	139.3	19.2	19.6	19.4
T_7	366.4	370.9	368.7	133.9	134.6	134.3	17.4	18.0	17.7
T_8	432.2	443.0	437.6	140.2	147.6	143.9	19.6	19.9	19.8
T_9	315.7	320.1	317.9	122.7	127.2	125.0	16.0	16.4	16.2
T_{10}	347.8	365.4	356.6	128.2	136.5	132.4	17.3	17.6	17.5
S. Em.±	30.33	31.76	28.31	4.30	4.80	4.56	0.76	0.78	0.74
C.D. at 5%	90.12	94.39	84.11	12.77	14.27	13.55	2.22	2.28	2.15

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

4.2.4 Filled grains per panicle

Application of different doses of fertilizers exerted significant influence on the number of number of filled grains per panicle during both the years of study. Pooled data, revels that higher number of filled grains panicle^{-1} registered with T_8: SSNM approach targeted yield of 55 q ha^{-1} (134.1). And it was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1} (127.4) followed by T_3: Farmer practice (121.3) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (118.8) as compared to T_1: Absolute control (88.4), T_5: STCR approach targeted yield of 45 q ha^{-1} (105.6), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (109.2), T_2: RDF (109.8), T_4: STL method (112.4) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(115.5).

4.2.5 Unfilled grains per panicle

The number of unfilled grains per panicle varied significantly among the treatments due to application of different levels of fertilizer and their combination. In general number of unfilled grains per panicle was ranged from 9.8 to 23.7

Pooled data, revels that significantly lower number of unfilled grains per panicle was noticed in with T_8: SSNM approach targeted yield of 55 q ha^{-1}(9.8) followed by T_6: STCR approach targeted yield of 55 q ha^{-1} (12.0), T_3: Farmer practice (14.7) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (15.5) as compared to T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(15.8), T_2: Recommended dose of fertilizer (17.3), T_4: STL method (17.2), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (16.9), T_5: STCR approach targeted yield of 45 q ha^{-1} (17.3) and T_1: Absolute control (24.8).

4.2.6 Sterility percentage

The sterility percentage was significantly influenced by different levels of fertilizers. Among the treatment significantly lowest sterility percentage was observed with T_8: SSNM approach targeted yield of 55 q ha^{-1} (6.8 %) followed by T_6: STCR approach targeted yield of 55 q ha^{-1} (8.6 %) and T_3: Farmer practice (10.8 %). Highest sterility percentage was noticed in absolute control (21.9 %) followed by rest of the treatments.

Table 9. Filled grains per panicle, unfilled grains per panicle and sterility per cent of Dry DSR as influenced by different nutrient management approaches

Treatments	Filled grains panicle^{-1}			Unfilled grains panicle^{-1}			Sterility percentage		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	91.7	85.1	88.4	24.3	25.2	24.8	20.9	22.8	21.9
T_2	107.3	112.3	109.8	17.1	17.4	17.3	13.7	13.4	13.6
T_3	119.4	123.2	121.3	15.1	14.3	14.7	11.2	10.4	10.8
T_4	109.6	115.1	112.4	19.0	15.3	17.2	14.8	11.7	13.3
T_5	100.8	110.4	105.6	19.7	14.8	17.3	16.3	11.8	14.1
T_6	124.0	130.7	127.4	12.1	11.8	12.0	8.9	8.3	8.6
T_7	116.6	120.9	118.8	17.3	13.7	15.5	12.9	10.2	11.5
T_8	130.0	138.2	134.1	10.2	9.4	9.8	7.3	6.4	6.8
T_9	105.4	113.0	109.2	17.3	14.2	15.8	14.1	11.2	12.6
T_{10}	112.3	118.7	115.5	15.9	17.8	16.9	12.4	13.0	12.7
S. Em.±	5.4	6.2	5.8	1.5	1.0	1.3	0.8	0.8	0.7
C.D. at 5%	16.0	18.5	17.3	4.3	2.9	3.8	2.4	2.2	2.0

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

4.2.7 Test weight (g)

Test weight (g) in Dry DSR was significantly influenced by application of different levels of N, P and K fertilizers.

Test weight of 1000 seeds was recorded significantly higher (13.98 g) with T_8: SSNM approach targeted yield of 55 q ha^{-1} as compared to T_1: Absolute control (11.8 g), T_5: STCR approach targeted yield of 45 q ha^{-1} (12.60 g), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (13.12 g), T_2: Recommended dose of fertilizer (13.32 g) and T_4: STL method (13.22 g) and it was found on par with the T_6: STCR approach targeted yield of 55 q ha^{-1} (13.90 g), T_3: Farmer practice (13.66 g) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (13.60 g) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(13.53 g).

4.2.8 Grain yield (q ha^{-1})

Application of different levels of N, P and K fertilizers and their combination exerted significant variation in the grain yield of Dry DSR. The grain yield obtained during second year were recorded higher than first year in all the treatments, except absolute control but, trend followed same during the both the years.

The grain yield was recorded significantly highest with SSNM approach targeted yield of 55 q ha^{-1} (54.29 and 55.15 q ha^{-1} during *karif* 2015 & 2016 respectively) and it was found on par with STCR approach targeted yield of 55 q ha^{-1} (51.03 and 52.54 q ha^{-1} during *karif* 2015 & 2016 respectively) followed by farmer practice of fertilization (49.16 and 51.61 q ha^{-1} during *karif* 2015 & 2016, respectively), SSNM approach targeted yield of 45 q ha^{-1} (47.95 and 49.01 q ha^{-1} during *karif* 2015 & 2016, respectively) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (47.29 and 48.34 q ha^{-1} during *karif* 2015 & 2016, respectively) and it was significantly superior over rest of the other treatments and lowest grain yield were recorded in absolute control (22.99 and 19.82 q ha^{-1} during *karif* 2015 and 2016, respectively).

The grain yield during the both the years followed same trend. Pooled data revealed that grain yield was recorded significantly highest with T_8: SSNM approach targeted yield of 55 q ha^{-1} (54.73 q ha^{-1}) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (51.79 q ha^{-1}), T_3: Farmer practice (50.39 q ha^{-1}), T_7: SSNM approach targeted yield of 45 q ha^{-1} (48.48 q ha^{-1}) and T_{10}:Nutrient expert for attainable

Table 10. Test weight, grain yield and straw yield of Dry DSR as influenced by different nutrient management approaches

Treatments	Test weight (g)			Grain yield (q ha^{-1})			Straw yield (q ha^{-1})		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	11.82	11.78	11.80	22.99	19.82	21.41	30.52	24.64	27.58
T_2	13.23	13.40	13.32	43.82	44.68	44.25	56.05	58.13	57.09
T_3	13.78	13.54	13.66	49.16	51.61	50.39	61.48	64.43	62.96
T_4	13.34	13.10	13.22	45.86	48.01	46.94	57.35	59.93	58.64
T_5	12.38	12.82	12.60	37.50	40.52	39.01	46.90	50.59	48.75
T_6	14.02	13.78	13.90	51.03	52.54	51.79	63.82	65.59	64.71
T_7	13.48	13.72	13.60	47.95	49.01	48.48	59.97	61.18	60.58
T_8	13.82	14.15	13.98	54.29	55.17	54.73	67.89	68.87	68.55
T_9	13.00	13.24	13.12	41.68	43.13	42.41	52.13	53.84	52.99
T_{10}	13.51	13.54	13.53	47.29	48.34	47.82	59.14	60.34	59.74
S. Em.±	0.14	0.25	0.20	2.54	2.42	2.50	2.30	3.07	3.05
C.D. at 5%	0.42	0.74	0.58	7.55	7.20	7.42	8.90	9.13	9.05

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

yield of 55 q ha^{-1}(47.82 q ha^{-1}) and it was significantly superior over T_1: Absolute control (21.41 q ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (39.01 q ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (42.41 q ha^{-1}), followed by T_2: RDF (44.25 q ha^{-1}) and T_4: STL method (46.94 q ha^{-1}).

4.2.9 Straw yield (q ha^{-1})

Straw yield of Dry DSR was significantly influenced by different nutrient management approaches. The trend was same during both the years (Table 10).

Pooled data reveals that, significantly highest straw yield was recorded in treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} (68.38 q ha^{-1}) as compared to T_1: Absolute control (27.58 q ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (48.74 q ha^{-1}),T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (52.98 q ha^{-1}) followed by T_2: Recommended dose of fertilizer (57.09 q ha^{-1}) and T_4 :STL method (58.64 q ha^{-1}) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (64.70 q ha^{-1}), T_3: Farmer practice (62.95 q ha^{-1}) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (60.57 q ha^{-1}) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (59.74 q ha^{-1}).

4.3 Nutrient uptake by Dry DSR

The effect of different nutrient management approaches on nitrogen, phosphorous, potassium, sulphur (kg ha^{-1}), zinc and iron uptake (g ha^{-1}) by Dry DSR after harvest were presented in the Tables 11, 12, 13, 14, 15 and 16 respectively and the results were found to be significant. The trend was recorded same during both the years. So, only pooled data of two years nutrient uptake are explained here.

4.3.1 Nitrogen uptake

The results on nitrogen uptake (kg ha^{-1}) by Dry DSR grain, straw and total as influenced by different nutrient management approaches are presented in Table 11 and the results were found to be significant.

Table 11. Effect of different nutrient management approaches on nitrogen uptake by Dry DSR

Treatments	Nitrogen uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	28.97	23.39	26.18	10.07	8.38	9.22	39.04	31.77	35.40
T_2	53.02	55.40	54.21	23.54	25.58	24.56	76.56	80.98	78.77
T_3	67.35	71.74	69.54	38.24	41.24	39.74	105.59	112.97	109.28
T_4	59.16	62.89	61.03	28.10	32.36	30.23	87.26	95.26	91.26
T_5	42.75	48.22	45.48	18.29	21.25	19.77	61.04	69.47	65.25
T_6	66.34	68.83	67.58	37.65	39.35	38.50	103.99	108.18	106.09
T_7	65.21	66.16	65.69	34.42	36.10	35.26	99.63	102.26	100.95
T_8	73.83	76.13	74.98	42.09	43.39	42.74	115.93	119.52	117.72
T_9	50.02	53.48	51.75	21.89	24.77	23.33	71.91	78.25	75.08
T_{10}	63.37	65.26	64.31	31.34	33.37	32.35	94.72	98.63	96.67
S. Em.±	4.30	4.74	4.61	2.76	3.02	2.82	7.59	7.13	8.50
C.D. at 5%	12.77	14.09	13.71	8.05	8.82	8.23	22.55	21.20	25.26

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

4.3.1.1 Nitrogen uptake by grain

Among the different treatments, significantly highest nitrogen uptake by grain was recorded with SSNM approach targeted yield of 55 q ha^{-1} (74.98 kg ha^{-1}) and it was found on par with farmer practice (69.54 kg ha^{-1}) followed by STCR approach targeted yield of 55 q ha^{-1} (67.58 kg ha^{-1}), SSNM approach targeted yield of 45 q ha^{-1} (65.69 kg ha^{-1}) and nutrient expert attainable yield of 55 q ha^{-1}(64.31 kg ha^{-1}) and they were significantly superior over rest of the treatments. Lowest nitrogen uptake by grain was recorded in absolute control (10.89 kg ha^{-1}).

4.3.1.2 Nitrogen uptake by straw

The data revealed that among the different treatments, significantly highest nitrogen uptake by rice straw was observed with treatment receiving SSNM approach targeted yield of 55 q ha^{-1} (42.74 kg ha^{-1}) and it was found on par with farmer practice (39.74 kg ha^{-1}) followed by STCR approach targeted yield of 55 q ha^{-1} (38.50 kg ha^{-1}) and SSNM approach targeted yield of 45 q ha^{-1} (35.26 kg ha^{-1}) as compared to absolute control (10.89 kg ha^{-1}) and rest of the treatments.

4.3.1.3 Total nitrogen uptake by Dry DSR

The data on total nitrogen uptake of Dry DSR showed that, T_8: SSNM approach targeted yield of 55 q ha^{-1} (117.72 kg ha^{-1}) recorded significantly higher nitrogen uptake and it was found on par with farmer practice (109.28 kg ha^{-1}) followed by STCR approach targeted yield of 55 q ha^{-1} (106.09 kg ha^{-1}), SSNM approach targeted yield of 45 q ha^{-1} (100.95 kg ha^{-1}) and nutrient expert attainable yield of 55 q ha^{-1}(96.67 kg ha^{-1}) and they were significantly superior over rest of the treatments. Lowest nitrogen uptake was recorded in absolute control (10.89 kg ha^{-1}).

4.3.2 Phosphorus uptake

The data on phosphorus uptake (kg ha^{-1}) by Dry DSR grain, straw and total as influenced by different nutrient management approaches are presented in Table 15.

4.3.2.1 Phosphorus uptake by grain

It is evident from the table that, significantly higher phosphorus uptake by grain was recorded with treatment receiving, SSNM approach targeted yield of 55 q ha^{-1} (30.92 kg ha^{-1}) and it was found on par with farmer practice (30.75 kg ha^{-1}), SSNM approach

Table 12. Effect of different nutrient management approaches on phosphorus uptake by Dry DSR

Treatments	Phosphorus uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	10.81	9.51	10.16	1.83	1.23	1.53	12.64	10.75	11.69
T_2	24.10	25.56	24.83	6.67	8.08	7.38	30.77	33.64	32.20
T_3	29.50	32.00	30.75	8.61	10.31	9.46	38.10	42.31	40.21
T_4	22.93	22.56	22.75	4.01	6.41	5.21	26.94	28.98	27.96
T_5	15.00	17.83	16.41	3.52	4.81	4.16	18.52	22.63	20.58
T_6	25.00	26.27	25.64	7.34	8.85	8.10	32.34	35.12	33.73
T_7	24.93	25.98	25.45	6.48	7.83	7.15	31.41	33.81	32.61
T_8	30.40	31.45	30.92	8.83	10.33	9.58	39.23	41.78	40.50
T_9	19.17	21.13	20.15	4.69	5.65	5.17	23.86	26.79	25.33
T_{10}	22.70	24.17	23.43	6.51	7.24	6.87	29.20	31.41	30.31
S. Em.±	2.06	2.17	2.13	0.79	0.75	0.75	2.85	2.90	2.87
C.D. at 5%	6.11	6.44	6.31	2.09	2.18	2.21	8.46	8.61	8.54

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

targeted yield of 45 q ha^{-1} (25.45 kg ha^{-1}) and STCR approach targeted yield of 55 q ha^{-1} (25.64 kg ha^{-1}) as compared to absolute control (9.71 kg ha^{-1}) and rest of other treatments.

4.3.2.2 Phosphorus uptake by straw

Among the different treatments, the significantly higher phosphorus uptake by straw was recorded with treatment T_8: SSNM approach targeted yield of 55 q ha^{-1} (9.58 kg ha^{-1}) and it was found on par with T_3: Farmer practice (9.46 kg ha^{-1}), T_6: STCR approach targeted yield of 55 q ha^{-1} (8.85 kg ha^{-1}) and T_2: Recommended dose of fertilizer (7.38 kg ha^{-1}). And lower phosphorus uptake by straw was recorded in absolute control (1.53 kg ha^{-1}) and rest of the remaining treatments.

4.3.2.3 Total phosphorus uptake by Dry DSR

The data on total phosphorus uptake by Dry DSR showed that, T_8: SSNM approach targeted yield of 55 q ha^{-1} (40.50 kg ha^{-1}) recorded higher phosphorus uptake followed by T_3: Farmer practice (40.21 kg ha^{-1}) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (33.73 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (32.42 kg ha^{-1}) lower phosphorus uptake was recorded with rest of treatments and absolute control (11.69 kg ha^{-1}).

4.3.3 Potassium uptake

The data on potassium uptake (kg ha^{-1}) by Dry DSR grain, straw and total as influenced by different nutrient management approaches are presented in Table 16.

4.3.3.1 Potassium uptake by grain

Among the different nutrient management approaches, the significantly higher (29.56 kg ha^{-1}) potassium uptake by grain was recorded with treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (27.45 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (25.21 kg ha^{-1}), it was significantly superior over the rest of other treatments and lower total potassium uptake was recorded in absolute control (8.55 kg ha^{-1}).

Table 13. Effect of different nutrient management approaches on potassium uptake by Dry DSR

Treatments	Potassium uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	8.97	8.13	8.55	33.88	28.09	30.98	42.84	36.22	39.53
T_2	18.40	19.21	18.81	73.99	78.48	76.23	92.39	97.69	95.04
T_3	21.63	23.74	22.69	76.85	83.11	79.98	98.48	106.86	102.67
T_4	18.34	18.24	18.29	63.09	60.53	61.81	81.43	78.77	80.10
T_5	17.63	21.07	19.35	69.41	78.41	73.91	87.04	99.48	93.26
T_6	26.54	28.37	27.45	102.11	106.26	104.18	128.65	134.63	131.64
T_7	24.45	25.98	25.21	96.55	99.72	98.14	121.01	125.70	123.35
T_8	28.77	30.34	29.56	118.81	126.72	122.76	147.58	157.06	152.32
T_9	17.51	18.55	18.03	58.39	62.45	60.42	75.89	81.00	78.45
T_{10}	20.33	21.27	20.80	79.25	82.06	80.66	99.58	103.33	101.46
S. Em.±	1.90	1.62	1.57	8.22	9.23	8.63	10.01	11.07	10.56
C.D. at 5%	5.64	4.80	4.85	24.41	27.41	25.67	29.75	32.89	31.37

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

4.3.3.2 Potassium uptake by straw

The data on the potassium uptake by straw as influenced by different nutrient management approaches revealed that, significantly higher (122.76 kg ha^{-1}) potassium uptake was recorded in treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (104.18 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (98.14 kg ha^{-1}) and it was significantly superior over the rest of other treatments and lower potassium uptake by straw was recorded in absolute control (30.98 kg ha^{-1}).

4.3.3.3 Total potassium uptake by Dry DSR

It was observed that, significantly higher (151.93 kg ha^{-1}) total potassium uptake was recorded with treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (130.36 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (122.14 kg ha^{-1}), it was significantly superior over the rest of other treatments and lower total potassium uptake was recorded in absolute control (39.53 kg ha^{-1}).

4.3.4 Sulphur uptake

The data on sulphur uptake (kg ha^{-1}) by Dry DSR grain, straw and total as influenced by different nutrient management approaches are depicted in Table 14.

4.3.4.1 Sulphur uptake by grain

The sulphur uptake by grain was significantly higher (6.57 kg ha^{-1}) with T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (5.81 kg ha^{-1}), T_3: Farmer practice (5.19 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (5.09 kg ha^{-1}) and it was significantly superior over the rest of other treatments and lower sulphur uptake by grain was recorded in absolute control (1.61 kg ha^{-1}).

4.3.4.2 Sulphur uptake by straw

The uptake of sulphur by dry direct seeded rice straw was recorded significantly higher (9.82 kg ha^{-1}) with T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (8.88 kg ha^{-1}), T_7: SSNM approach targeted yield of 45 q ha^{-1} (8.70 kg ha^{-1}) and T_3: Farmer practice (8.65 kg ha^{-1})

Table 14. Effect of different nutrient management approaches on sulphur uptake by Dry DSR

Treatments	Sulphur uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	1.84	1.39	1.61	2.75	2.71	2.73	4.59	4.10	4.34
T_2	3.64	4.60	4.12	5.66	7.03	6.34	9.30	11.63	10.46
T_3	4.54	5.83	5.19	7.89	9.41	8.65	12.43	15.24	13.83
T_4	3.90	4.59	4.24	5.51	6.38	5.94	9.40	10.97	10.18
T_5	2.99	4.05	3.52	4.46	5.56	5.01	7.45	9.60	8.53
T_6	5.31	6.30	5.81	8.19	9.58	8.88	13.49	15.88	14.69
T_7	4.80	5.39	5.09	7.80	9.61	8.70	12.59	15.00	13.79
T_8	5.97	7.17	6.57	9.17	10.47	9.82	15.14	17.64	16.39
T_9	3.41	3.88	3.64	5.00	6.09	5.55	8.41	9.97	9.19
T_{10}	4.26	4.83	4.55	6.13	7.46	6.80	10.39	12.30	11.34
S. Em.±	0.48	0.50	0.55	0.56	0.61	0.58	0.99	0.96	0.98
C.D. at 5%	1.44	1.49	1.64	1.66	1.81	1.73	2.95	2.85	2.92

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

and it was significantly superior over the rest of other treatments and lower sulphur uptake by grain was recorded in absolute control (2.73 kg ha^{-1}).

4.3.4.3 Total sulphur uptake by Dry DSR

The pooled data revealed that, significantly higher (16.39 kg ha^{-1}) total sulphur uptake by Dry DSR was registered with T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (14.69 kg ha^{-1}) and T_3: Farmer practice (13.83 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (13.79 kg ha^{-1}), It was significantly superior over the rest of other treatments and lower sulphur uptake was recorded in absolute control (4.34 kg ha^{-1}).

4.3.5 Zinc uptake

The data on zinc uptake (g ha^{-1}) by Dry DSR grain, straw and total as influenced by different nutrient management approaches are depicted in Table 15.

4.3.5.1 Zinc uptake by grain

It was observed that, significantly higher zinc uptake by grain was recorded with T_8: SSNM approach targeted yield of 55 q ha^{-1} (112.2 g ha^{-1}) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (108.2 g ha^{-1}), T_3: Farmer practice (99.6 g ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (92.9 g ha^{-1}). It was significantly superior over the rest of other treatments and lower zinc uptake by grain was recorded in absolute control (34.4 g ha^{-1}).

4.3.5.2 Zinc uptake by straw

The uptake of zinc by Dry DSR straw was recorded significantly higher (249.87 g ha^{-1}) with T_8: SSNM approach targeted yield of 55 q ha^{-1} (230.2 g ha^{-1}) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (222.9 g ha^{-1}), T_3: Farmer practice (209.6 g ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (197.9 g ha^{-1}). It was significantly superior over the rest of other treatments and lower zinc uptake by straw was recorded in absolute control (63.3 g ha^{-1}).

4.3.5.3 Total zinc uptake by Dry DSR

The results revealed that, significantly higher (342.4 g ha^{-1}) total zinc uptake by Dry DSR was recorded with T_8: SSNM approach targeted yield of 55 q ha^{-1} (342.4 g ha^{-1}) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (331.1 g

Table 15. Effect of different nutrient management approaches on zinc uptake by Dry DSR

Treatments	Zinc uptake (g ha^{-1})								
	Grain			Straw			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	37.0	31.9	34.4	70.2	56.3	63.3	107.2	88.2	97.7
T_2	62.1	63.3	62.7	136.3	159.4	147.9	198.4	222.7	210.6
T_3	97.2	102.0	99.6	195.0	224.2	209.6	292.1	326.3	309.2
T_4	70.1	73.4	71.8	164.9	190.8	177.9	235.0	264.3	249.6
T_5	59.4	64.2	61.8	106.5	130.6	118.5	165.9	194.8	180.3
T_6	106.6	109.8	108.2	209.8	236.0	222.9	316.4	345.7	331.1
T_7	91.8	93.9	92.9	186.5	209.2	197.9	278.4	303.1	290.7
T_8	110.3	114.1	112.2	217.9	242.4	230.2	329.2	355.5	342.4
T_9	60.1	62.2	61.1	143.3	164.7	154.0	203.4	226.9	215.1
T_{10}	88.3	90.2	89.2	182.1	204.5	193.3	270.5	294.7	282.5
S. Em.±	7.2	7.4	7.3	12.1	12.8	11.4	17.9	18.1	20.6
C.D. at 5%	21.3	21.9	21.6	35.9	38.1	33.9	53.2	53.8	61.3

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

ha^{-1}), T_3: Farmer practice (309.2 g ha^{-1}), T_7: SSNM approach targeted yield of 45 q ha^{-1} (290.7 g ha^{-1}) and T_7: Nutrient expert attainable yield of 55 q ha^{-1} (282.5 g ha^{-1}). It was significantly superior over the rest of the treatments and lower zinc uptake by straw was recorded in absolute control (97.7 g ha^{-1}).

4.3.6 Iron uptake

The data on iron uptake (g ha^{-1}) by Dry DSR grain, straw and total as influenced by different nutrient management approaches are depicted in Table 16.

4.3.6.1 Iron uptake by grain

The iron uptake by grain was significantly higher with T_8: SSNM approach targeted yield of 55 q ha^{-1} (1397.4 g ha^{-1}) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (1317.5 g ha^{-1}) and T_3: Farmer practice (1266.8 g ha^{-1}). It was significantly superior over the rest of other treatments and lower iron uptake by grain was recorded in absolute control (274.8 g ha^{-1}).

4.3.6.2 Iron uptake by straw

The uptake of iron by Dry DSR straw was recorded significantly higher with T_8: SSNM approach targeted yield of 55 q ha^{-1} (2224.7 g ha^{-1}) and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (2064.9 g ha^{-1}) and T_3: Farmer practice (1910.2 g ha^{-1}). It was significantly superior over the rest of other treatments and lower iron uptake by grain was recorded in absolute control (413.4 g ha^{-1}).

4.3.6.3 Total iron uptake by Dry DSR

The data on total iron uptake by Dry DSR revealed that, significantly higher value (3622.1 g ha^{-1}) was registered with T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (3382.4 g ha^{-1}) and T_3: Farmer practice (3177.0 g ha^{-1}). It was significantly superior over the rest of other treatments and lower iron uptake was recorded in absolute control (688.1 g ha^{-1}).

4.4 Nutrient use efficiency (NUE) of Dry DSR

Data on nutrient use efficiency and agronomic efficiency of nitrogen, phosphorus and potassium at harvest of dry direct seeded rice as influenced by different nutrient management approaches are presented in Table 17 and 18.

Table 16. Effect of different nutrient management approaches on iron uptake by Dry DSR

Treatments	Iron uptake (g ha^{-1})								
	Grain			Straw			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	295.1	254.4	274.8	461.5	365.3	413.4	756.6	619.7	688.1
T_2	643.0	655.6	649.3	1045.6	1145.3	1095.4	1688.5	1801.0	1744.7
T_3	1236.0	1297.6	1266.8	1832.4	1988.0	1910.2	3068.4	3285.6	3177.0
T_4	817.3	855.6	836.5	1253.3	1372.1	1312.7	2070.6	2227.7	2149.2
T_5	503.2	543.8	523.5	799.4	915.6	857.5	1302.7	1459.3	1381.0
T_6	1298.3	1336.7	1317.5	2029.5	2100.4	2064.9	3327.8	3437.1	3382.4
T_7	1184.9	1211.1	1198.0	1738.5	1868.7	1803.6	2923.5	3079.9	3001.7
T_8	1386.1	1408.6	1397.4	2173.8	2275.6	2224.7	3560.0	3684.2	3622.1
T_9	606.0	627.1	616.6	1049.1	1140.0	1094.5	1655.1	1767.1	1711.2
T_{10}	910.9	931.1	921.0	1309.5	1399.5	1354.5	2220.4	2330.6	2275.5
S. Em.±	71.7	70.7	64.8	161.6	140.0	151.7	239.4	188.6	218.8
C.D. at 5%	157.6	155.4	142.4	355.1	307.7	333.4	526.0	414.5	480.7

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

4.4.1 Nutrient use efficiency (% of nutrient taken up by a crop)

Data on nutrient use efficiency of nitrogen, phosphorus and potassium in Dry DSR as influenced by different nutrient management approaches are presented in Table 17 and the efficiencies were higher during second year as compared to first year of the study.

Application of fertilizers as per SSNM approach targeted yield of 55 q ha^{-1} noted higher nitrogen use efficiency of (54.88 %) followed by the application of fertilizers through STCR approach targeted yield of 55 q ha^{-1} (53.80 %) and SSNM approach targeted yield of 45 q ha^{-1} (51.54 %) as compared to rest of other treatments and lowest nitrogen use efficiency (29.39%) was noted with farmer practice. Similarly higher phosphorus use efficiency (65.56 %) was observed with treatment receiving in SSNM approach targeted yield of 55 q ha^{-1} followed by the application of fertilizers through STCR approach targeted yield of 55 q ha^{-1} (63.11 %), SSNM approach targeted yield of 45 q ha^{-1} (62.20 %) and nutrient expert attainable yield of 55 q ha^{-1} (60.05 %) as compared to rest of other treatments and lowest phosphorus use efficiency (16.87 %) was noted with farmer practice. Further, higher potassium use efficiency (130.94 %) was obtained with nutrient expert attainable yield of 55 q ha^{-1} followed by the application of fertilizers through STCR approach targeted yield of 55 q ha^{-1} (109.30 %) and STL method of fertilization (109.30 %) and as compared to rest of other treatments and lowest potassium use efficiency (84.38 %) was noted with farmer practice of fertilization.

4.4.2 Agronomic efficiency (AE) (kg grain kg^{-1} nutrient applied)

Data on agronomic efficiency of nitrogen, phosphorus and potassium in Dry DSR as influenced by different nutrient management approaches are presented in Table 18 and the efficiencies were higher during second year as compared to first year of the study.

Higher agronomic efficiency of nitrogen (22.60 kg grain kg^{-1} N applied) was found with the application of fertilizers as per STCR approach targeted yield of 55 q ha^{-1} followed by nutrient expert attainable yield of 55 q ha^{-1} (22.38 kg grain kg^{-1} N applied) and SSNM approach targeted yield of 55 q ha^{-1} (22.22 kg grain kg^{-1} N applied) and lowest agronomic efficiency of nitrogen (11.53 kg grain kg^{-1} N applied) was noted with farmer practice. Further STCR approach targeted yield of 55 q ha^{-1} resulted in higher

Table 17. Nutrient use efficiency of Dry DSR as influenced by different nutrient management approaches

Treatments	Nutrient use efficiency (%)								
	N			P			K		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	-	-	-	-	-	-	-	-	-
T_2	37.52	49.16	43.34	36.26	45.78	41.02	99.10	110.92	105.01
T_3	27.05	31.72	29.39	15.34	18.39	16.87	74.19	86.17	80.18
T_4	42.86	56.43	49.65	38.15	48.61	43.38	102.90	97.45	100.18
T_5	22.22	38.62	30.42	-	72.75	36.38	75.42	90.88	83.15
T_6	50.57	57.02	53.80	59.21	67.00	63.11	105.92	112.68	109.30
T_7	49.26	53.81	51.54	53.97	70.43	62.20	81.18	86.74	83.96
T_8	51.26	58.50	54.88	61.83	69.28	65.56	96.39	93.87	95.13
T_9	32.87	46.48	39.68	55.29	78.55	66.92	89.33	104.78	97.06
T_{10}	43.58	55.12	49.35	60.22	77.04	68.63	126.09	135.78	130.94
Mean	39.69	49.98	44.84	40.68	54.78	51.37	94.50	102.14	98.32

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

Table 18. Agronomic efficiency of Dry DSR as influenced by different nutrient management approaches

Treatments	Agronomic efficiency (kg grain kg^{-1} nutrient applied)								
	N			P			K		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	-	-	-	-	-	-	-	-	-
T_2	20.83	23.68	22.26	41.66	49.72	45.69	41.66	49.72	45.69
T_3	10.64	12.42	11.53	15.77	19.15	17.46	34.89	42.39	38.64
T_4	20.33	24.06	22.20	60.99	75.17	68.08	60.99	75.17	68.08
T_5	14.66	21.21	17.94	0.00	115.00	57.50	25.02	33.39	29.21
T_6	20.73	24.02	22.38	100.14	97.96	99.05	35.95	40.90	38.43
T_7	20.29	22.28	21.29	71.31	83.40	77.36	26.32	30.79	28.56
T_8	21.87	23.32	22.60	72.79	82.21	77.50	27.22	30.74	28.98
T_9	18.69	23.31	21.00	84.95	105.95	95.45	50.51	63.00	56.76
T_{10}	20.59	24.17	22.38	86.79	101.86	94.33	54.00	63.38	58.69
Mean	18.74	22.05	20.39	58.25	79.75	69.00	39.62	47.72	43.67

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

agronomic efficiency of phosphorus (99.05 kg grain kg^{-1} P_2O_5 applied) followed by nutrient expert for attainable yield of 55 q ha^{-1} (94.33 kg grain kg^{-1} P_2O_5 applied respectively) and SSNM approach targeted yield of 55 q ha^{-1}(77.50 kg grain kg^{-1} P_2O_5 applied) and lowest agronomic efficiency of phosphorus (17.46 kg grain kg^{-1} N applied) was noted with farmer practice. Further, higher agronomic efficiency of potassium (68.08 kg grain kg^{-1} K_2O applied) was obtained with STL method of fertilization followed by nutrient expert for attainable yield of 55q ha^{-1} and 45 q ha^{-1} (58.69 and 56.76 kg grain kg^{-1} K_2O applied respectively). However, the lower agronomic efficiency of potassium was recorded with treatment receiving SSNM approach targeted yield of 45 q ha^{-1} (28.56 kg grain kg^{-1} K_2O applied).

4.5 Microbial population at harvest of the Dry DSR as influenced by different nutrient management approaches

Enumeration of bacteria, fungi and actinomycetes in soil at harvest of the crop was significantly influenced by the different nutrient management approaches are presented in Table 19 and 20. The microbial populations during both the years of study followed similar trend. Therefore, only pooled data of two years are explained.

4.5.1 Bacteria (No. × 10^6 cfu g^{-1} of soil)

Different nutrient management approaches were found to be significant with respect to bacterial population at harvest of rice.

It was observed that, at harvest of crop enumerated bacterial population was significantly higher (25.73×10^6 cfu g^{-1} of soil) with treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_7: SSNM approach targeted yield of 45 q ha^{-1} and T_6: STCR approach targeted yield of 55 q ha^{-1} (23.70 and 23.11×10^6 cfu g^{-1} of soil respectively). It was significantly superior over the rest of other treatments and lowest enumerated bacterial population was observed in absolute control (14.84×10^6 cfu g^{-1} of soil).

4.5.2 Fungi (No. ×10^3 cfu g^{-1} of soil)

Different nutrient management approaches were found to be significant with respect to fungal population at harvest of rice.

It was observed that, after harvest of crop enumerated fungal population was significantly higher (8.62×10^3 cfu g^{-1} of soil) with treatment receiving T_8: SSNM

Table 19. Microbial population at harvest stage of Dry DSR as influenced by different nutrient management approaches

Treatments	Bacteria (No. $\times 10^6$cfu g^{-1} of soil)			Fungi (No. $\times 10^3$cfu g^{-1} of soil)			Actinomycetes (No. $\times 10^4$cfu g^{-1} of soil)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	15.24	14.44	14.84	5.96	4.72	5.34	6.23	5.08	5.66
T_2	18.55	19	18.77	7.54	8.13	7.83	7.87	8.36	8.11
T_3	19.28	19.83	19.55	7.13	7.89	7.51	8.61	8.92	8.76
T_4	17.12	18.22	17.67	7.03	7.52	7.28	8.14	8.49	8.31
T_5	17.31	17.93	17.62	6.74	6.78	6.76	6.83	7.09	6.96
T_6	22.68	23.54	23.11	7.28	7.40	7.34	9.21	9.69	9.45
T_7	23.28	24.11	23.70	8.17	8.19	8.18	9.83	9.66	9.74
T_8	24.51	26.95	25.73	8.44	8.80	8.62	10.08	10.2	10.14
T_9	17.72	18.56	18.14	6.27	7.16	6.72	7.06	8.24	7.65
T_{10}	20.92	21.19	21.05	7.02	8.32	7.67	8.35	8.71	8.53
S. Em.±	1.11	1.16	1.13	0.44	0.23	0.35	0.34	0.21	0.29
C.D. at 5%	3.29	3.45	3.37	1.30	0.68	1.05	1.01	0.61	0.85

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

approach targeted yield of 55 q ha^{-1} and it was found on par with T_7: SSNM approach targeted yield of 45 q ha^{-1} and T_2: Recommended dose of fertilizer (8.18 and 7.83 $\times 10^3$ cfu g^{-1} of soil, respectively). It was significantly superior over the rest of treatments and lowest enumerated fungal population was observed in absolute control (5.34×10^3 cfu g^{-1} of soil).

4.5.3 Actinomycetes (No. $\times 10^4$ cfu g^{-1} of soil)

Actinomycetes population varied significantly due to different nutrient management approaches in both the years as well as in pooled data.

In general, the actinomycetes population ranged from 5.66 to 10.14×10^4 cfu g^{-1} of soil due to different nutrient management approaches. Significantly higher actinomycetes population (10.14×10^4 cfu g^{-1} of soil) was noticed in treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_7: SSNM approach targeted yield of 45 q ha^{-1} and T_6: STCR approach targeted yield of 55 q ha^{-1} (9.74 and 9.45×10^4 cfu g^{-1} of soil, respectively) it was significantly superior over the rest of treatments and lowest actinomycetes population was observed in absolute control (5.66×10^4 cfu g^{-1} of soil).

4.6 Soil enzymes activities at harvest of the Dry DSR as influenced by different nutrient management approaches

Phosphatase and dehydrogenase activities in soil at harvest of the crop was significantly influenced by nutrient management approaches are presented in Table 19.

4.6.1 Phosphatase activity (µg PNP g^{-1} of soil hr^{-1})

Year wise and pooled data on phosphatase activity differ significantly due to different nutrient management approaches.

Significantly highest (14.91 µg PNP g^{-1} of soil hr^{-1}) phosphatase activity was noticed in treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1}, T_3: Farmer practice and T_7: SSNM approach targeted yield of 45 q ha^{-1} (13.84,13.23 and 12.61 µg PNP g^{-1} of soil hr^{-1}, respectively) it was significantly superior over the rest of treatments and lowest phosphatase activity was observed in absolute control (9.47 µg PNP g^{-1} of soil hr^{-1}).

Table 20. Soil enzyme activities at harvest stage of Dry DSR as influenced by different nutrient management approaches

Treatments	Alkaline phosphatase (µg PNP g^{-1} soil hr^{-1})			Dehydrogenase (µg TPF formed g^{-1} soil hr^{-1})		
	2015	2016	Pooled	2015	2016	Pooled
T_1	9.13	9.82	9.47	5.17	6.19	5.68
T_2	11.24	11.95	11.60	9.14	9.87	9.51
T_3	12.83	13.62	13.23	10.14	11.06	10.60
T_4	10.81	11.71	11.26	7.05	7.88	7.46
T_5	10.13	10.82	10.47	6.17	7.19	6.68
T_6	13.03	14.65	13.84	11.52	12.15	11.84
T_7	12.39	12.83	12.61	11.23	12.02	11.63
T_8	14.77	15.06	14.91	11.80	12.39	12.09
T_9	10.62	11.44	11.02	7.73	8.41	8.07
T_{10}	11.46	12.05	11.75	7.93	8.38	8.16
S. Em.±	1.01	0.80	0.02	0.26	0.18	0.23
C.D. at 5%	3.00	2.37	0.05	0.78	0.55	0.68

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended Dose Fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

4.6.2 Dehydrogenase activity (µg TPF formed g^{-1} of soil hr^{-1})

Year wise and pooled data on dehydrogenase activity differ significantly due to different nutrient management approaches.

Significantly highest (12.09 µg TPF formed g^{-1} of soil hr^{-1}) dehydrogenase activity was noticed in treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} and T_7: SSNM approach targeted yield of 45 q ha^{-1} (11.84 and 11.63 µg TPF formed g^{-1} of soil hr^{-1}, respectively) and it was significantly superior over rest of the treatments and lowest dehydrogenase activity was observed in absolute control (5.68 µg TPF formed g^{-1} of soil hr^{-1}).

4.7 Economics of Dry DSR as influenced by different nutrient management approaches

Data pertaining to cost of cultivation, gross returns, net returns and benefit cost ratio (₹ ha^{-1}) of Dry DSR as influenced by different nutrient management approaches are presented in Table 21.

4.7.1 Cost of cultivation (₹ ha^{-1})

The cost of cultivation of Dry DSR under different nutrient management approaches varied from treatment to treatment due to varied amount of fertilizers application and their cost. Cost of cultivation was recorded higher during second year as compared to first year of the study. The pooled data reveals that highest cost of cultivation (₹ 45,851 ha^{-1}) was observed with T_3: Farmer practice followed by application of T_8: SSNM approach targeted yield of 55 q ha^{-1} (₹ 39,021 ha^{-1}), T_7: SSNM approach targeted yield of 45 q ha^{-1} (₹ 38,289 ha^{-1}), T_6: STCR approach targeted yield of 55 q ha^{-1} (₹ 37,865 ha^{-1}), T_2: Recommended dose of fertilizer (₹ 37,426 ha^{-1}), T_4: STL method (₹ 36,808 ha^{-1}), T_{10}:Nutrient expert for attainable 55 q ha^{-1} (₹ 36,600 ha^{-1}), T_9: Nutrient expert for attainable 45 q ha^{-1} (₹ 35,983 ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (₹ 35,758 ha^{-1}) and lowest cost of cultivation found with absolute control (₹ 24,310 ha^{-1}).

4.7.2 Gross returns (₹ ha^{-1})

Higher gross returns in Dry DSR was obtained with the nutrients application as per SSNM approach targeted for yield of 55 q ha^{-1} during both the years as well as in pooled means (₹ 1,20,668 ha^{-1}) followed by STCR approach for targeted yield of 55 q ha^{-1}(₹ 1,14,168 ha^{-1}), Farmer practice (₹ 1,11,072 ha^{-1}), SSNM approach targeted yield of 45 q ha^{-1} (₹ 1,06,886 ha^{-1}), Nutrient expert for attainable 55 q ha^{-1} (₹ 1,05,419 ha^{-1}), STL method (₹ 1,03,468 ha^{-1}), Recommended dose of fertilizer (₹ 97,741 ha^{-1}), Nutrient expert for attainable 45 q ha^{-1} (₹ 93,487 ha^{-1}) and STCR approach targeted yield of 45 q ha^{-1} (₹ 85,985 ha^{-1}).

While, lowest gross returns was obtained with absolute control treatment (₹ 47, 312 ha^{-1}), where no farm yard manure and fertilizers were applied.

4.7.3 Net returns (₹ ha^{-1})

Significantly higher net returns (₹ 81,647 ha^{-1}) was received from the nutrients application as per T_8: SSNM approach targeted yield of 55 q ha^{-1} it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (₹ 76,303 ha^{-1}) followed by T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1} (₹ 68,819 ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (₹ 68,597 ha^{-1}), it was significantly superior over T_4: STL method (₹ 66,660 ha^{-1}), T_3: Farmer practice (₹ 65,221 ha^{-1}), T_2: Recommended dose of fertilizer, (₹ 60,315 ha^{-1}), T_9:Nutrient expert for attainable yield of 45 q ha^{-1} (₹ 57,504 ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (₹ 68,819 ha^{-1}) and absolute control (₹ 23,002 ha^{-1}).

4.7.4 Benefit Cost ratio

Pooled data reveals that significantly higher benefit cost ratio (3.10) was obtained with the application of fertilizers through T_8: SSNM approach targeted yield of 55 q ha^{-1} it was on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (3.02), T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1} (2.89), T_4: STL method (2.82) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (2.79). And it was found significantly superior over T_5: STCR approach targeted yield of 45 q ha^{-1} (2.41), T_3: Farmer practice (2.43), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (2.60) and T_2: Recommended dose of fertilizer (2.62). However, lowest BC ratio was observed with absolute control (1.96).

Table 21. Economics of Dry DSR as influenced by different nutrient management approaches

Treatments	Cost of Cultivation (₹ ha^{-1})			Gross Returns (₹ ha^{-1})			Net Returns (₹ ha^{-1})			BC Ratio		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	23265	25355	24310	51331	43293	47312	28066	17938	23002	2.21	1.71	1.96
T_2	36596	38255	37426	97627	97854	97741	61031	59599	60315	2.67	2.56	2.62
T_3	44913	46789	45851	109384	112760	111072	64471	65971	65221	2.44	2.41	2.43
T_4	35853	37763	36808	102041	104894	103468	66188	67131	66660	2.85	2.78	2.82
T_5	34477	37039	35758	83440	88530	85985	48963	51491	50227	2.42	2.39	2.41
T_6	37012	38718	37865	113545	114791	114168	76533	76073	76303	3.07	2.96	3.02
T_7	37636	38942	38289	106692	107079	106886	69056	68137	68597	2.83	2.75	2.79
T_8	38993	39049	39021	120798	120537	120668	81805	81488	81647	3.10	3.09	3.10
T_9	35034	36931	35983	92741	94232	93487	57707	57301	57504	2.65	2.55	2.60
T_{10}	35706	37494	36600	105223	105614	105419	69517	68120	68819	2.95	2.82	2.89
S. Em.±	-	-	-	-	-	-	4427	4585	4507	0.11	0.11	0.12
C.D. at 5%	-	-	-	-	-	-	12923	13384	13392	0.31	0.32	0.37

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control (No NPK & FYM)
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

Experiment No. 2: To assess the residual nutrient effect of various nutrient management approaches on growth and yield of mustard as subsequent *rabi* crop

The results of the experiment conducted during *rabi* seasons of 2015-16 and 2016-17 in the farmer field of Vijayanagar camp, Tq: Raichur, Dist: Raichur to assess the residual nutrient effect of different nutrient management approaches on mustard are explained below. The response of crop growth, yield parameters and yield of mustard were slightly better in first year (2015-16) than second year (2016-17) but, response of crop growth, yield parameters and yield were similar in both the years. Therefore, only pooled data of two years are explained in below.

4.8 Growth parameters of mustard

The data on growth parameters *viz*., plant height (cm), number of primary branches per plant, total dry matter production (g plant^{-1}) of mustard at the time of harvest as influenced by residual nutrient effect of different nutrient management approaches are presented in Table 22.

Residual nutrient effect of different nutrient management approaches on plant height at harvest stages of mustard are furnished in Table 22 and the results were found to be significant.

Plant height was significantly higher with treatment T_8: SSNM approach targeted yield of 55 q ha^{-1} (123.7 cm) it was found on par with T_3: Farmer practice (120.2 cm) followed by T_6: STCR approach targeted yield of 55 q ha^{-1} (117.9 cm) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (113.3 cm). It was significantly superior over rest of other treatments and lowest plant height was observed with absolute control (80.7 cm).

Residual effect of different nutrient management approaches on total number of primary branches per plant at harvest are furnished in Table 22 and the results were found to be non-significant. However the highest number of primary branches per plant were found with SSNM approach targeted yield of 55 q ha^{-1} (4.28) followed by farmer practice (4.09) and lowest number of primary branches per plant was observed with absolute control (2.81).

Influence of residual effect of different nutrient management approaches on total dry matter production at harvest stage furnished in Table 22 and the results were found to be significant. The total dry matter production was higher (67.1 g plant^{-1}) with SSNM

Table 22. Residual effect of different nutrient management approaches on growth parameters of mustard at harvest

Treatments	Plant height (cm)			Number of primary branches per plant			Dry matter production (g plant^{-1})		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	85.7	81.8	83.7	2.86	2.76	2.81	40.4	39.1	39.7
T_2	109.0	110.2	109.6	3.75	3.69	3.72	60.7	58.4	59.6
T_3	119.6	120.7	120.2	4.12	4.05	4.09	67.1	64.7	66.3
T_4	100.8	101.9	101.4	3.47	3.40	3.44	58.1	57.9	58.0
T_5	94.2	95.3	94.8	3.25	3.33	3.29	45.3	44.5	44.9
T_6	119.0	120.1	117.9	4.10	4.03	4.07	64.8	62.5	63.7
T_7	112.7	113.8	113.3	3.88	3.96	3.92	64.2	61.0	62.6
T_8	123.1	124.2	123.7	4.24	4.31	4.28	65.5	68.8	67.1
T_9	99.1	100.2	99.7	3.42	3.49	3.46	58.6	56.3	57.5
T_{10}	112.5	113.7	113.1	3.87	3.80	3.84	59.2	56.9	58.0
S. Em.±	4.21	3.85	4.04	0.13	0.15	0.13	1.77	1.65	1.88
C.D. at 5%	12.64	11.45	12.02	NS	NS	NS	5.25	4.90	5.58

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

approach targeted yield of 55 q ha^{-1} and it was found on par with farmer practice (66.3 g $plant^{-1}$), STCR approach targeted yield of 55 q ha^{-1} (63.7 g $plant^{-1}$) and SSNM approach targeted yield of 45 q ha^{-1} (62.6 g $plant^{-1}$). And it was found significantly superior over the absolute control (39.7 g $plant^{-1}$), STCR approach targeted yield of 45 q ha^{-1} (44.9 g $plant^{-1}$), Nutrient expert for attainable yield of 45 q ha^{-1} (57.5 g $plant^{-1}$) followed by RDF (59.6 g $plant^{-1}$), STL method (58.0 g $plant^{-1}$) and Nutrient expert for attainable yield of 55 q ha^{-1} (58.0 g $plant^{-1}$).

4.9 Yield and yield attributing parameters of mustard

The residual effect of different nutrient management approaches on yield attributing parameters and yield of mustard crop *viz.*, number of silique per plant, number of seeds per silique, 1000 seed weight (g), seed yield (kg ha^{-1}), Stover yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}), are presented in the Table 23 and 24.

It is evident from the table that, number of silique per plant was significantly higher with the residual effect of SSNM approach targeted yield of 55 q ha^{-1}(314.5), It was found on par with STCR approach targeted yield of 55 q ha^{-1}(310.7) followed by farmer practice (290.6) and SSNM approach targeted yield of 45 q ha^{-1} (286.4). It was significantly superior over rest of other treatments lowest number of silique per plant was observed with absolute control (180.5).

Influences of residual effect of different nutrient management approaches on number seeds per silique and the results were found to be non-significant. However the higher number seeds per silique were found with SSNM approach targeted yield of 55 q ha^{-1} (13.6) followed by STCR approach targeted yield of 55 q ha^{-1}(13.4), farmer practice (13.1) and lowest number seeds per silique was observed with absolute control (10.6).

Residual effect of different nutrient management approaches on test weight were found to be non-significant, however highest 1000 seeds weight of (4.35 g) were found with T_8: SSNM approach targeted yield of 55 q ha^{-1} followed by T_6: STCR approach targeted yield of 55 q ha^{-1}(4.29 g) and farmer practice (4.11 g). Lowest 1000 seeds weight was observed with absolute control (3.88 g).

Seed yield of mustard differed significantly due to the residual effect of different nutrient management approaches.

Table 23. Residual effect of different nutrient management approaches on yield attributing parameters of mustard

Treatments	Number of silique plant^{-1}			Number of seeds silique^{-1}			Test weight (g)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	187.6	173.4	180.5	10.9	10.2	10.6	3.90	3.85	3.88
T_2	285.4	274.5	280.0	12.7	12.7	12.7	4.05	4.02	4.04
T_3	304.9	295.0	290.6	13.0	13.1	13.1	4.10	4.12	4.11
T_4	276.2	269.1	272.7	12.3	12.2	12.3	4.15	4.13	4.14
T_5	242.6	237.4	240.0	12.0	11.8	11.9	4.08	4.01	4.05
T_6	317.4	304.0	310.7	13.5	13.4	13.4	4.28	4.31	4.29
T_7	290.0	283.1	286.4	12.8	13.2	13.0	4.18	4.15	4.17
T_8	323.1	305.9	314.5	13.4	13.7	13.6	4.37	4.33	4.35
T_9	266.7	253.3	260.0	12.2	12.1	12.2	4.00	3.99	4.00
T_{10}	279.7	272.6	276.2	12.6	12.5	12.6	4.10	4.13	4.12
S. Em.±	10.96	11.89	11.34	0.43	0.45	0.38	0.09	0.06	0.07
C.D. at 5%	31.76	35.34	33.69	NS	NS	NS	NS	NS	NS

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

Significantly higher seed yield was recorded with T_8: SSNM approach targeted yield of 55 q ha^{-1} (592 kg ha^{-1}) as compared to T_1: Absolute control (217 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (413 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (452 kg ha^{-1}) followed by T_4: STL method (486 kg ha^{-1}), T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (505 kg ha^{-1}) and T_2: Recommended dose of fertilizer (512 kg ha^{-1}) and it was found on par with T_3: Farmer practice (570 kg ha^{-1}), T_6: STCR approach targeted yield of 55 q ha^{-1} (544 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (531 kg ha^{-1}).

Among the different nutrient management approaches, significantly higher (1856 kg ha^{-1}) stover yield was recorded with the residual effect of treatment received SSNM approach targeted yield of 55 q ha^{-1} as compared to T_1: absolute control (660 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (1296 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (1420 kg ha^{-1}) followed by T_4: STL method (1525 kg ha^{-1}), T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(1585 kg ha^{-1}) and T_2: Recommended dose of fertilizer (1608 kg ha^{-1}) and it was found on par with T_3: Farmer practice (1810 kg ha^{-1}) followed by T_6: STCR approach targeted yield of 55 q ha^{-1}(1667 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (1667 kg ha^{-1}).

The results on oil content of mustard were found to be non significant, due to the residual effect of different nutrient management approaches. However, higher oil content were found with T_8: SSNM approach targeted yield of 55 q ha^{-1} (40.8 %) followed by T_3: Farmer practice (40.5 %) and T_6: STCR approach targeted yield of 55 q ha^{-1}(39.9 %) as compared to T_1: Absolute control (36.5 %), T_5: STCR approach targeted yield of 45 q ha^{-1} (37.4 %), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (37.9 %), T_4: STL method (38.6 %) followed by T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(39.0 %), T_2: Recommended dose of fertilizer (38.9 %) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (39.3%).

Significant differences in the oil yield of mustard were found due to residual effect of different nutrient management approaches. Significantly higher (240.6 kg ha^{-1}) oil yield was obtained with SSNM approach targeted yield of 55 q ha^{-1} as compared to T_1: Absolute control (79.2 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (154.1 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (170.9 kg ha^{-1}) followed by T_2: Recommended dose of fertilizer (198.7 kg ha^{-1}), T_4: STL method (187.5 kg ha^{-1}) and

Table 24. Residual effect of different nutrient management approaches on seed yield, stover yield, oil content and oil yield of mustard

Treatments	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})			Oil content (%)			Oil yield (kg ha^{-1})		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	231	203	217	710	609	660	37	35.9	36.5	85.5	72.9	79.2
T_2	535	488	512	1653	1562	1608	38.6	39.1	38.9	206.5	190.8	198.7
T_3	579	560	570	1828	1791	1810	40.1	40.8	40.5	232.2	229.3	230.7
T_4	518	453	486	1580	1470	1525	38.9	38.3	38.6	201.5	173.5	187.5
T_5	435	390	413	1343	1248	1296	37.5	37.2	37.4	163.1	145.1	154.1
T_6	576	511	544	1780	1635	1708	39.2	39.9	39.6	225.8	203.9	214.8
T_7	563	498	531	1740	1594	1667	39	39.5	39.3	219.6	196.7	208.1
T_8	615	566	592	1901	1811	1856	40.5	41.0	40.8	249.1	232.1	240.6
T_9	478	426	452	1476	1363	1420	37.2	38.5	37.9	177.8	164.0	170.9
T_{10}	527	482	505	1628	1542	1585	38.3	39.7	39.0	201.8	191.4	196.6
S. Em.±	19.1	25.3	21.4	60.9	77.4	70.3	0.94	1.08	0.78	8.4	11.0	12.0
C.D. at 5%	55.7	81.7	62.4	177.7	226.0	205.9	NS	NS	NS	24.6	32.2	34.5

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(196.6 kg ha^{-1}) and it was found on par with farmer practice (230.7 kg ha^{-1}), STCR approach targeted yield of 55 q ha^{-1} (214.8 kg ha^{-1}) and SSNM approach targeted yield of 45 q ha^{-1} (208.1 kg ha^{-1}).

4.10 Nutrient uptake by mustard

The residual effect of different nutrient management approaches on nitrogen, phosphorous and potassium uptake (kg ha^{-1}) by mustard after harvest are presented in the Table 25, 26 and 27 respectively and the results were found to be significant.

4.10.1 Nitrogen uptake

The data of nitrogen (kg ha^{-1}) uptake by mustard seed, stover and total as influenced by residual effect of different nutrient management approaches are presented in Table 25 and the results were found to be significant.

4.10.1.1 Nitrogen uptake by seed

Among the different treatments, significantly highest nitrogen uptake by seed was recorded with the residual effect of T_8: SSNM approach targeted yield of 55 q ha^{-1} (15.62 kg ha^{-1}) as compared to T_1: Absolute control (4.20 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (8.30 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (9.28 kg ha^{-1}) followed by T_4: STL method (11.00 kg ha^{-1}), T_2: Recommended dose of fertilizer (11.48 kg ha^{-1}) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(11.65 kg ha^{-1}) and it was found on par with farmer practice (13.99 kg ha^{-1}) followed by STCR approach targeted yield of 55 q ha^{-1} (11.96 kg ha^{-1}) and SSNM approach targeted yield of 45 q ha^{-1} (11.76 kg ha^{-1}).

4.10.1.2 Nitrogen uptake by stover

The data revealed that among the different treatments, significantly highest nitrogen uptake by mustard stover was observed with the residual effect of treatment T_8: SSNM approach targeted yield of 55 q ha^{-1} (11.78 kg ha^{-1}) as compared to T_1: Absolute control (3.21 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (6.99 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (7.79 kg ha^{-1}) followed by T_4: STL method (8.63 kg ha^{-1}), T_2: Recommended dose of fertilizer (8.76 kg ha^{-1}) and T_{10}:Nutrient expert for attainable 55 q yield of ha^{-1}(9.01 kg ha^{-1}) and it was found on par with farmer practice

Table 25. Residual effect of different nutrient management approaches on nitrogen uptake by mustard

Treatments	Nitrogen uptake (kg ha^{-1})								
	Seed			Stover			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	4.92	3.47	4.20	3.86	2.56	3.21	8.78	6.03	7.40
T_2	12.57	10.39	11.48	10.00	7.53	8.76	22.57	17.92	20.25
T_3	14.94	13.04	13.99	12.85	10.50	11.67	27.79	23.53	25.66
T_4	12.54	9.47	11.00	9.88	7.38	8.63	22.41	16.85	19.63
T_5	9.57	7.02	8.30	8.04	5.94	6.99	17.61	12.96	15.29
T_6	13.65	10.27	11.96	11.36	8.55	9.95	25.01	18.82	21.91
T_7	13.06	10.46	11.76	10.93	8.24	9.58	23.99	18.70	21.34
T_8	15.62	12.96	14.29	13.06	10.50	11.78	28.68	23.47	26.07
T_9	10.76	7.80	9.28	8.78	6.43	7.61	19.54	14.23	16.88
T_{10}	12.60	10.70	11.65	10.22	7.79	9.01	22.82	18.49	20.65
S. Em.±	0.84	0.90	1.10	0.85	0.79	0.83	1.79	1.80	1.90
C.D. at 5%	2.45	2.67	3.26	2.53	2.53	2.45	5.32	5.34	5.65

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

(11.67 kg ha^{-1}) followed by STCR approach targeted yield of 55 q ha^{-1} (9.95 kg ha^{-1}) and SSNM approach targeted yield of 45 q ha^{-1} (9.58 kg ha^{-1}).

4.10.1.3 Total nitrogen uptake by mustard

The data on total nitrogen uptake of mustard showed that, T_8: SSNM approach targeted yield of 55 q ha^{-1} (26.07 kg ha^{-1}) recorded significantly higher nitrogen uptake as compared to T_1: Absolute control (7.40 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (15.29 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (16.88 kg ha^{-1}) followed by T_2: Recommended dose of fertilizer (20.25 kg ha^{-1}), T_4: STL method (19.63 kg ha^{-1}) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(20.00 kg ha^{-1}) and it was found on par with T_3: Farmer practice (25.66 kg ha^{-1}) followed by T_6: STCR approach targeted yield of 55 q ha^{-1} (21.91 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (21.34 kg ha^{-1}).

4.10.2 Phosphorus uptake

The data on phosphorus uptake (kg ha^{-1}) by mustard seed, stover and total as influenced by the residual effect of different nutrient management approaches are presented in Table 26.

4.10.2.1 Phosphorus uptake by seed

It is evident from the table that, phosphorus uptake by seed among different treatments, farmer practice recorded significantly higher (3.40 kg ha^{-1}) phosphorus uptake and it was found on par with SSNM approach targeted yield of 55 q ha^{-1} (3.22 kg ha^{-1}) as compared to other treatments such as T_1: absolute control (0.98 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (1.89 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (2.14 kg ha^{-1}) followed by T_2: Recommended dose of fertilizer (2.49 kg ha^{-1}), T_4: STL method (2.41 kg ha^{-1}), T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(2.42 kg ha^{-1}),T_6: STCR approach targeted yield of 55 q ha^{-1} (2.75 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (2.69 kg ha^{-1}).

4.10.2.2 Phosphorus uptake by stover

Among the different treatments, the significantly higher phosphorus uptake by straw was recorded with T_3: Farmer practice (2.70 kg ha^{-1}) and it was found on par with T_8: SSNM approach targeted yield of 55 q ha^{-1} (2.57 kg ha^{-1}), T_6: STCR approach targeted yield of 55 q ha^{-1} (2.13 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q

Table 26. Residual effect of different nutrient management approaches on phosphorus uptake by mustard

Treatments	Phosphorus uptake (kg ha^{-1})								
	Seed			Stover			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	1.16	0.81	0.98	0.64	0.52	0.58	1.79	1.33	1.56
T_2	2.89	2.10	2.49	1.98	1.72	1.85	4.87	3.82	4.34
T_3	3.53	3.26	3.40	2.91	2.49	2.70	6.44	5.75	6.10
T_4	2.75	2.08	2.41	1.90	1.62	1.76	4.64	3.70	4.17
T_5	2.22	1.56	1.89	1.34	1.12	1.23	3.56	2.68	3.12
T_6	3.00	2.50	2.75	2.21	2.04	2.13	5.20	4.55	4.88
T_7	2.98	2.39	2.69	2.24	2.01	2.14	5.23	4.40	4.81
T_8	3.38	3.06	3.22	2.57	2.39	2.48	5.95	5.45	5.70
T_9	2.49	1.79	2.14	1.77	1.53	1.65	4.26	3.32	3.79
T_{10}	2.80	2.02	2.42	1.90	1.79	1.85	4.70	3.81	4.26
S. Em.±	0.17	0.24	0.26	0.14	0.18	0.25	0.31	0.35	0.33
C.D. at 5%	0.49	0.71	0.75	0.40	0.52	0.74	0.91	1.04	0.96

Note FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

ha^{-1} (2.14 kg ha^{-1}) as compared to other treatments such as absolute control (0.58 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (1.23 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (1.65 kg ha^{-1}) followed by T_4: STL method (1.76 kg ha^{-1}), T_2: Recommended dose of fertilizer (1.85 ha^{-1}) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(1.85).

4.10.2.3 Total phosphorus uptake by mustard

The data on total phosphorus uptake by mustard showed that, farmer practice recorded higher phosphorus uptake (6.10 kg ha^{-1}) and it was found on par with T_8: SSNM approach targeted yield of 55 q ha^{-1} (5.70 kg ha^{-1}) and T_6: STCR approach targeted yield of 55 q ha^{-1} (4.88 kg ha^{-1}) as compared to absolute control (1.56 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (3.12 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (3.79 kg ha^{-1}), T_2: Recommended dose of fertilizer (4.34 kg ha^{-1}), T_4: STL method (4.17 kg ha^{-1}), T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (4.26 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (4.81 kg ha^{-1}).

4.10.3 Potassium uptake

The data on potassium uptake (kg ha^{-1}) by mustard seed, stover and total as influenced by the residual effect of different nutrient management approaches are presented in Table 27.

4.10.3.1 Potassium uptake by seed

Among the different nutrient management approaches, the significantly higher (3.89 kg ha^{-1}) potassium uptake by seed was recorded with treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} as compared to absolute control (1.19 kg ha^{-1}), T_4: STL method (2.84 kg ha^{-1}), T_9: Nutrient expert for attainable 45 q ha^{-1} (2.60 kg ha^{-1}),T_2: Recommended dose of fertilizer (3.09 kg ha^{-1}), T_{10}:Nutrient expert for attainable 55 q ha^{-1}(3.05 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (2.44 kg ha^{-1}). It was found on par with T_3: Farmer practice (3.42 kg ha^{-1}), T_6: STCR approach targeted yield of 55 q ha^{-1} (3.32 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (3.33 kg ha^{-1}).

4.10.3.2 Potassium uptake by stover

The data on the potassium uptake by stover as influenced by different nutrient management approaches revealed that, significantly higher (31.09 kg ha^{-1}) potassium uptake was recorded in treatment receiving SSNM approach targeted yield of 55 q ha^{-1}

Table 27. Residual effect of different nutrient management approaches on Potassium uptake by mustard

Treatments	Potassium uptake (kg ha^{-1})								
	Seed			Stover			Total		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	1.29	1.10	1.19	11.22	9.38	10.30	12.51	10.47	11.49
T_2	3.21	2.98	3.09	26.94	24.84	25.89	30.15	27.81	28.98
T_3	3.53	3.32	3.42	29.80	28.66	29.23	33.33	31.97	32.65
T_4	3.06	2.63	2.84	25.44	23.23	24.33	28.49	25.85	27.17
T_5	2.61	2.26	2.44	21.76	19.72	20.74	24.37	21.98	23.17
T_6	3.57	3.07	3.32	29.19	26.16	27.68	32.76	29.23	30.99
T_7	3.56	3.09	3.33	28.71	25.82	27.27	32.26	28.91	30.58
T_8	4.00	3.79	3.89	31.94	30.24	31.09	35.93	34.04	34.99
T_9	2.77	2.43	2.60	23.47	21.40	22.43	26.24	23.83	25.03
T_{10}	3.16	2.94	3.05	26.37	24.83	25.60	29.54	27.77	28.65
S. Em.±	0.22	0.24	0.18	1.45	1.36	1.35	1.45	1.59	1.44
C.D. at 5%	0.65	0.71	0.54	4.22	4.09	3.95	4.22	4.78	4.20

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

and it was significantly superior over the absolute control (10.30 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (20.74 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (22.43 kg ha^{-1}), T_4: STL method (24.33 kg ha^{-1}) followed by T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(25.60 kg ha^{-1}) and T_2: Recommended dose of fertilizer (25.89 kg ha^{-1}). It was found on par with T_3: Farmer practice (29.23 kg ha^{-1}), T_7: SSNM approach targeted yield of 45 q ha^{-1} (27.27 kg ha^{-1}) and T_6: STCR approach targeted yield of 55 q ha^{-1} (27.68 kg ha^{-1}).

4.10.3.3 Total potassium uptake by mustard

It was observed that, significantly higher (34.99 kg ha^{-1}) total potassium uptake was recorded with the treatment receiving residual effect of T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_3: Farmer practice (32.65 kg ha^{-1}), T_7: SSNM approach targeted yield of 45 q ha^{-1} (30.58 kg ha^{-1}) and T_6: STCR approach targeted yield of 55 q ha^{-1} (30.99 kg ha^{-1}) and it was significantly superior over the T_1: Absolute control (11.49 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (23.18 kg ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (25.03 kg ha^{-1}),T_4: STL method (27.17 kg ha^{-1}) followed by T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (28.65 kg ha^{-1}) and T_2: Recommended dose of fertilizer (28.98 kg ha^{-1}).

4.11 Economics of mustard as influenced by residual effect of different nutrient management approaches

Data pertaining to cost of cultivation, gross returns, net returns (₹ ha^{-1}) and benefit cost ratio of mustard as influenced by residual nutrient effect of different nutrient management approaches are presented in Table 28.

4.11.1 Cost of cultivation (₹ ha^{-1})

The prices of the inputs that were prevailing at the time of their use were taken into account to work out the cost of cultivation. The cost of cultivation for the succeeding mustard crop was same in all the treatments of preceding Dry- DSR (₹ 6,050 ha^{-1}, ₹ 7,030 ha^{-1} and ₹ 6,540 ha^{-1}) during *Rabi,* 2016 and *Rabi,* 2017 both the years of study and in pooled means respectively.

4.11.2 Gross returns (₹ ha^{-1})

Gross returns of succeeding mustard crop differed due to residual effects of different nutrient management approaches.

Higher gross returns (₹ 26,886 ha^{-1}) was obtained with the SSNM approach targeted yield of 55 q ha^{-1} followed by farmer practice (₹ 25,998 ha^{-1}), T_6: STCR approach targeted yield of 55 q ha^{-1} (₹ 24,735 ha^{-1}), T_7: SSNM approach targeted yield of 45 q ha^{-1} (₹ 24,143 ha^{-1}), T_2: Recommended dose of fertilizer (₹ 23,286 ha^{-1}), T_{10}:Nutrient expert for attainable 55 q ha^{-1} (₹ 22,968 ha^{-1}), T_4: STL method (₹ 22,092 ha^{-1}), T_9: Nutrient expert for attainable 45 q ha^{-1} (₹ 20,572 ha^{-1}) and T_5: STCR approach targeted yield of 45 q ha^{-1} (₹ 18,775 ha^{-1}).While, lowest gross returns was obtained with T_1: Absolute control (₹ 9,864 ha^{-1}).

4.11.3 Net returns (₹ ha^{-1})

Significantly higher net returns (₹ 20, 346 ha^{-1}) was received from the application of T_8: SSNM approach targeted yield of 55 q ha^{-1} followed by T_3: Farmer practice (₹ 19,458 ha^{-1}) it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (₹ 18,195 ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (₹17,603 ha^{-1}). It was significantly superior over T_{10}: Nutrient expert for attainable 55 q ha^{-1} (₹ 15,431 ha^{-1}), T_4: STL method (₹ 15,552 ha^{-1}), T_2: Recommended dose of fertilizer (₹ 16,746 ha^{-1}), T_9:Nutrient expert for attainable 45 q ha^{-1} (₹ 14,032 ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (₹ 12,235 ha^{-1}) and T_1: Absolute control (₹ 3,324 ha^{-1}).

4.11.4 Benefit Cost ratio

Significantly higher benefit cost ratio was obtained with the residual nutrient effect of T_8: SSNM approach targeted yield of 55 q ha^{-1}(4.14). It was found on par with T_3: Farmer practice (4.00), T_6: STCR approach targeted yield of 55 q ha^{-1} (3.81) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (3.72) and it was significantly superior over T_2: Recommended dose of fertilizer (3.59), T_{10}: Nutrient expert for attainable 55 q ha^{-1} (3.54), T_4: STL method (3.41), T_9:Nutrient expert for attainable 45 q ha^{-1} (3.17) and T_5: STCR approach targeted yield of 45 q ha^{-1} (2.89). However, lowest BC ratio was observed with T_1: Absolute control (1.52).

Table 28. Residual effect of different nutrient management approaches on economics of mustard

Treatments	Cost of Cultivation (₹ ha^{-1})			Gross Returns (₹ ha^{-1})			Net Returns (₹ ha^{-1})			BC Ratio		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	6050	7030	6540	10288	9440	9864	4238	2410	3324	1.70	1.34	1.52
T_2	6050	7030	6540	23832	22741	23286	17782	15711	16746	3.94	3.23	3.59
T_3	6050	7030	6540	25811	26186	25998	19761	19156	19458	4.27	3.72	4.00
T_4	6050	7030	6540	23064	21120	22092	17014	14090	15552	3.81	3.00	3.41
T_5	6050	7030	6540	19377	18174	18775	13327	11144	12235	3.20	2.59	2.89
T_6	6050	7030	6540	25658	23813	24735	19608	16783	18195	4.24	3.39	3.81
T_7	6050	7030	6540	25079	23207	24143	19029	16177	17603	4.15	3.30	3.72
T_8	6050	7030	6540	27396	26376	26886	21346	19346	20346	4.53	3.75	4.14
T_9	6050	7030	6540	21292	19852	20572	15242	12822	14032	3.52	2.82	3.17
T_{10}	6050	7030	6540	23475	22461	22968	17425	15431	16428	3.88	3.20	3.54
S. Em.±	-	-	-	-	-	-	1054	1086	949	0.13	0.16	0.14
C.D. at 5%	-	-	-	-	-	-	3076	3170	2769	0.39	0.48	0.42

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

4.12 Soil chemical properties after harvest of mustard crop in Dry DSR-Mustard cropping sequence

Results on soil chemical properties *viz.,* pH, electrical conductivity and organic carbon after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches are presented in Tables 29.

4.12.1 Soil pH

Application of different nutrient management approaches did not influence significantly on the pH of soil. However, it was ranged from 8.22 in farmer practice to 7.86 in absolute control.

4.12.2 Electrical conductivity

There was no significant difference in electrical conductivity (EC) of soil by adaptation of different nutrient management approaches. The higher (0.82 dS m^{-1}) electrical conductivity was recorded in farmer practice followed by SSNM approach targeted yield of 55 q ha^{-1}(0.75 dS m^{-1}), STL method (0.74 dS m^{-1}) and STCR approach targeted yield of 55 q ha^{-1} (0.73 dS m^{-1}) and lower electrical conductivity was noticed with absolute control, STCR approach targeted yield of 45 q ha^{-1}, Nutrient expert for attainable 45 q ha^{-1}, Nutrient expert for attainable 55 q ha^{-1} (0.63, 0.70, 0.70 and 0.72 dS m^{-1}, respectively).

4.12.3 Organic carbon

There was no significant difference in the organic carbon of soil was observed with the adaptation of different nutrient management approaches. Among them, higher organic carbon was resulted with treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} (6.88 g kg^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (6.84 g kg^{-1}) as compared to other treatments and lowest organic carbon of soil was noticed in absolute control (6.79 g kg^{-1}).

4.13 Soil fertility status after harvest of mustard crop in Dry DSR-Mustard cropping sequence

Nutrient availability in soil after harvest of mustard crop in Dry DSR-Mustard cropping sequence are presented in Table 30 and 31. Significant differences were observed in the soil available nutrients status after harvest of mustard crop due to the

Table 29. Physico-chemical properties of soil after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches

Treatments	pH			EC (dS m^{-1})			Organic carbon (g kg^{-1})		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	7.82	7.90	7.86	0.62	0.64	0.63	6.80	6.77	6.79
T_2	8.09	8.14	8.11	0.71	0.74	0.73	6.82	6.83	6.83
T_3	8.21	8.23	8.22	0.80	0.84	0.82	6.85	6.87	6.86
T_4	8.01	8.12	8.07	0.72	0.75	0.74	6.83	6.85	6.84
T_5	7.89	7.95	7.92	0.68	0.72	0.70	6.81	6.83	6.82
T_6	8.10	8.15	8.13	0.70	0.71	0.71	6.84	6.86	6.85
T_7	8.12	8.16	8.14	0.72	0.74	0.73	6.83	6.85	6.84
T_8	8.10	8.18	8.14	0.75	0.73	0.75	6.86	6.89	6.88
T_9	7.98	8.09	8.04	0.69	0.70	0.70	6.82	6.83	6.83
T_{10}	8.11	8.12	8.12	0.71	0.73	0.72	6.84	6.86	6.85
S. Em.±	0.31	0.35	0.37	0.03	0.05	0.04	0.13	0.13	0.13
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control

T_2: Recommended dose fertilizer

T_3: Farmers practice

T_4: STL method

T_5: STCR approach (Targeted yield : 45 q ha^{-1})

T_6: STCR approach (Targeted yield : 55 q ha^{-1})

T_7: SSNM approach (Targeted yield : 45 q ha^{-1})

T_8: SSNM approach (Targeted yield : 55 q ha^{-1})

T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})

T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

application different levels of fertilizers during the both the years of the study as well as in pooled means. There was no definite trend was observed in the available soil nutrients status during first and second year of the study.

4.13.1 Available nitrogen

Available nitrogen was significantly higher (232.40 kg ha^{-1}) with the application of fertilizers as per farmer practice of nitrogen fertilization followed by T_8: SSNM approach targeted yield of 55 q ha^{-1} (230.8 kg ha^{-1}) and it was found on par with T_7: SSNM approach targeted yield of 45 q ha^{-1} (222.9 kg ha^{-1}) and T_6: STCR approach targeted yield of 55 q ha^{-1} (225.5 kg ha^{-1}). It was significantly superior over T_1: absolute control (135.52 kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (201.2 kg ha^{-1}), T_2: Recommended dose of fertilizer (208.6 kg ha^{-1}), T_9: Nutrient expert for attainable 45 q ha^{-1} (211.9 kg ha^{-1}) followed by T_4: STL method (212.5 kg ha^{-1}) and T_{10}:Nutrient expert for attainable 55 q ha^{-1}(215.7 kg ha^{-1}).

4.13.2 Available phosphorus

Available phosphorus was significantly higher (130.5 kg ha^{-1}) with T_3: Farmer practice fertilization followed by T_8: SSNM approach targeted yield of 55 q ha^{-1} (82.60 kg ha^{-1}), T_4: STL method (80.0 kg ha^{-1}), T_2: Recommended dose of fertilizer (81.5 kg ha^{-1}) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (74.5 kg ha^{-1}). It was significantly superior over absolute control (41.1 kg ha^{-1}), STCR approach targeted yield of 45 q ha^{-1} (56.7 kg ha^{-1}), Nutrient expert for attainable 45 q ha^{-1} (66.9 kg ha^{-1}), STCR approach targeted yield of 55 q ha^{-1} (68.5 kg ha^{-1}) and nutrient expert for attainable yield of 55 q ha^{-1} (68.0 kg ha^{-1}).

4.13.3 Available potassium

Available potassium was significantly higher (329.3 kg ha^{-1}) with the application of fertilizers as per the T_8: SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with T_7: SSNM approach targeted yield of 45 q ha^{-1} (323.6 kg ha^{-1}). It was significantly superior over T_1: Absolute control (259.2 kg ha^{-1}), T_9: Nutrient expert for attainable 45 q ha^{-1} (266.7kg ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (285.5 kg ha^{-1}), T_2: Recommended dose of fertilizer (286.0 kg ha^{-1}) followed by T_{10}:Nutrient expert for attainable 55 q ha^{-1}(276.9 kg ha^{-1}), T_6: STCR approach targeted yield of 55 q ha^{-1} (291.9 kg ha^{-1}) and T_4: STL method (287.1 kg ha^{-1}).

Table 30. Available N, P_2O_5 and K_2O in soil after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches

Treatments	N (kg ha^{-1})			P_2O_5 (kg ha^{-1})			K_2O (kg ha^{-1})		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	152.4	118.6	135.5	51.2	30.9	41.1	285.8	232.5	259.2
T_2	206.6	210.5	208.6	82.5	80.5	81.5	312.5	259.5	286.0
T_3	222.4	242.4	232.4	112.5	148.5	130.5	305.1	258.4	281.8
T_4	209.5	215.5	212.5	79.5	80.4	80.0	310.6	263.6	287.1
T_5	198.7	203.7	201.2	61.1	52.3	56.7	300.4	270.6	285.5
T_6	218.5	232.5	225.5	71.6	65.3	68.5	309.4	274.4	291.9
T_7	214.6	231.2	222.9	76.6	72.3	74.5	332.6	314.6	323.6
T_8	219.5	242.1	230.8	82.1	83.1	82.6	337.5	321.1	329.3
T_9	207.6	216.3	211.9	70.3	63.4	66.9	290.8	242.5	266.7
T_{10}	212.5	219.0	215.7	73.5	62.4	68.0	301.4	252.4	276.9
S. Em.±	2.94	7.58	5.42	4.49	6.40	5.31	8.90	11.59	9.75
C.D. at 5%	8.59	22.13	15.83	13.11	18.69	15.49	25.97	33.84	28.46

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control

T_2: Recommended dose fertilizer

T_3: Farmers practice

T_4: STL method

T_5: STCR approach (Targeted yield : 45 q ha^{-1})

T_6: STCR approach (Targeted yield : 55 q ha^{-1})

T_7: SSNM approach (Targeted yield : 45 q ha^{-1})

T_8: SSNM approach (Targeted yield : 55 q ha^{-1})

T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})

T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

4.13.4 Available sulphur

Available sulphur was significantly higher (17.55 mg kg^{-1}) with treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} as compared to absolute control (13.83 mg kg^{-1}), T_9: Nutrient expert for attainable 45 q ha^{-1} (14.71 mg kg^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (14.85 mg kg^{-1}) followed by T_2: Recommended dose of fertilizer (285.95 mg kg^{-1}) and T_{10}:Nutrient expert for attainable 55 q ha^{-1}(14.97 mg kg^{-1}) and it was found on par with T_7: SSNM approach targeted yield of 45 q ha^{-1} (15.85 mg kg^{-1}), T_6: STCR approach targeted yield of 55 q ha^{-1} (15.44 mg kg^{-1}) and T_4: STL method (15.14 mg kg^{-1}).

4.13.5 Available zinc

Available zinc was significantly higher (0.64 mg kg^{-1}) with treatment receiving STL method as compared to absolute control, farmer practice, RDF, STCR and Nutrient expert approach targeted yield of 45 q ha^{-1} (0.30, 0.55, 0.55, 0.56 & 0.56 mg kg^{-1} respectively) it was found on par T_8: SSNM approach targeted yield of 55 q ha^{-1} (0.59 mg kg^{-1}) followed by STCR approach targeted yield of 55 q ha^{-1} (0.58 mg kg^{-1}) and Nutrient expert for attainable 55 q ha^{-1}(0.61 mg kg^{-1}).

4.13.6 Available iron

Available iron was significantly higher (5.87 mg kg^{-1}) with treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1} as compared to absolute control (3.40 mg kg^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (3.74 mg kg^{-1}), T_4: STL method (3.90 mg kg^{-1}), T_2: Recommended dose of fertilizer (3.95 mg kg^{-1}), T_6: STCR approach targeted yield of 55 q ha^{-1} (4.08 mg kg^{-1}) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (4.91 mg kg^{-1}) and T_9: Nutrient expert for attainable 45 q ha^{-1} (4.93 mg kg^{-1}). It was found on par with T_{10}: Nutrient expert for attainable 55 q ha^{-1}(5.23 mg kg^{-1}) and T_3: Farmer practice (5.23 mg kg^{-1}).

4.14 Nitrogen, phosphorus and potassium balance in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence

Results on balance of nitrogen, phosphorus and potassium after harvest of second crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches are presented in Table 32 to 38. Which showed the account of initial soil nutrients applied, uptake by a crop and residual nutrient status. After harvest of

Table 31. Available sulphur, zinc and iron in soil after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches

Treatments	Sulphur (mg kg^{-1})			Zinc (mg kg^{-1})			Iron (mg kg^{-1})		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	15.60	12.06	13.83	0.31	0.28	0.30	4.23	2.56	3.40
T_2	16.45	13.49	14.97	0.50	0.59	0.55	4.29	3.61	3.95
T_3	15.74	12.63	14.19	0.48	0.62	0.55	5.57	4.89	5.23
T_4	17.37	12.90	15.14	0.59	0.68	0.64	4.24	3.56	3.90
T_5	17.52	12.18	14.85	0.52	0.59	0.56	3.82	3.55	3.74
T_6	17.61	13.27	15.44	0.61	0.54	0.58	4.82	3.44	4.08
T_7	17.67	14.04	15.85	0.57	0.64	0.61	5.25	4.57	4.91
T_8	19.21	15.88	17.55	0.62	0.56	0.59	6.02	5.74	5.87
T_9	16.20	14.38	15.29	0.49	0.62	0.56	5.23	4.63	4.93
T_{10}	16.06	13.36	14.71	0.53	0.69	0.61	5.57	4.89	5.23
S. Em.±	0.57	0.65	0.61	0.02	0.02	0.02	0.35	0.36	0.32
C.D. at 5%	1.66	1.89	1.77	0.06	0.07	0.06	1.01	1.06	0.94

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

crop, nutrient balance was worked out. Net gain or net loss due to application of higher amount of nutrient had resulted in buildup of nutrients in soil after crop harvest. The positive value of a particular nutrient element indicates the quantity of nutrient present in soil after harvest of crop; negative value indicated that actual loss of particular nutrient element during the course of crop season.

4.14.1 Nitrogen balance in soil

Results on balance of nitrogen after harvest of second crop in dry direct seeded rice-mustard sequential cropping system as influenced by different nutrient management approaches during 2015-16 and 2016-17 are presented in Tables 32 and 33, respectively.

The initial soil available nitrogen of experimental site was 192.36 kg ha^{-1}, the amount of nitrogen is added through fertilizers was highest in farmer practice 281.0 kg ha^{-1}.

During first and second year of the experimentation (2015 and 2016), adaptation of different nutrient management practices were resulted in net loss of nitrogen. However, maximum net loss of nitrogen (-117.58 kg ha^{-1} and -124.5 kg ha^{-1}, respectively) was found with treatment receiving T_3: Farmers practice of fertilizer application. Whereas, minimum net loss of nitrogen (-7.15 and -19.32 kg ha^{-1}, respectively) was observed with treatment receiving T_8: SSNM approach targeted yield of 55 q ha^{-1}. Net gain of nitrogen (7.86 and 4.0 kg ha^{-1}, respectively) was observed with absolute control during first and second year of the experimentation. The highest net loss of nitrogen was found in the order: T_3: Farmers practice (-117.58 kg ha^{-1}) > T_5:STCR approach targeted yield of 45 q ha^{-1} (-48.7 kg ha^{-1}) > T_9: Nutrient expert for attainable yield of 45 q ha^{-1}(-28.29 kg ha^{-1}) > T_4: STL method (-20.69 kg ha^{-1}) > T_2: Recommended dose of fertilizer (-21.60 kg ha^{-1}) > T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (-19.62 kg ha^{-1}) > T_6: STCR approach targeted yield of 55 q ha^{-1} (-14.91 kg ha^{-1}) > T_7: SSNM approach targeted yield of 45 q ha^{-1} (-12.4 kg ha^{-1}) during first year of experimentation (2015-16). Further, during second year of experimentation (2016-17) net loss of nitrogen was followed the order: T_3: Farmers practice (-124.5 kg ha^{-1}) > T_5:STCR approach targeted yield of 45 q ha^{-1} (-45.17 kg ha^{-1}) > T_9: Nutrient expert for attainable yield of 45 q ha^{-1}(-35.88 kg ha^{-1}) > T_2: Recommended dose of fertilizer (-32.20 kg ha^{-1}) > T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (-31.18 kg ha^{-1}) > T_4: STL method (-29.39 kg ha^{-1}) > T_6: STCR approach

Table 32. Nitrogen balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2015-16

Treatments	Initial soil N (kg ha^{-1})	Applied N through FYM/Ferti (kg ha^{-1})	Total N (kg ha^{-1})	Total N uptake by DSR and mustard (kg ha^{-1})	Estimated N (kg ha^{-1})	Soil nitrogen status after harvest of mustard	Net gain/ loss (+/-) of N in soil
	1	2	3=1+2	4	5=3-4	6	7=6-5
T_1	192.36	0.0	192.36	47.82	144.54	152.40	7.86
T_2	192.36	135.0	327.36	99.13	228.23	206.63	-21.60
T_3	192.36	281.0	473.36	133.38	339.98	222.40	-117.58
T_4	192.36	147.5	339.86	109.67	230.19	209.50	-20.69
T_5	192.36	134.0	326.36	78.65	247.71	198.74	-48.97
T_6	192.36	170.0	362.36	129.00	233.36	218.45	-14.91
T_7	192.36	158.0	350.36	123.62	226.74	214.60	-12.14
T_8	192.36	185.0	377.36	144.61	232.75	225.60	-7.15
T_9	192.36	135.0	327.36	91.45	235.91	207.62	-28.29
T_{10}	192.36	153.0	345.36	113.28	232.08	212.46	-15.36

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended Dose Fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

Table 33. Nitrogen balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2016-17

Treatments	Initial soil N (kg ha^{-1})	Applied N through FYM/Ferti (kg ha^{-1})	Total N (kg ha^{-1})	Total N uptake by DSR and mustard (kg ha^{-1})	Estimated N (kg ha^{-1})	Soil nitrogen status after harvest of mustard	Net gain/ loss (+/-) of N in soil
	1	2	3=1+2	4	5=3-4	6	7=6-5
T_1	152.40	0.00	152.40	37.80	114.60	118.64	4.04
T_2	206.63	135.00	341.63	98.90	242.73	210.53	-32.20
T_3	222.40	281.00	503.40	136.50	366.90	242.40	-124.50
T_4	209.50	147.50	357.00	112.11	244.89	215.50	-29.39
T_5	198.74	132.60	331.34	82.43	248.91	203.74	-45.17
T_6	218.45	169.00	387.45	127.00	260.45	232.45	-28.00
T_7	214.60	166.00	380.60	120.96	259.64	231.15	-28.49
T_8	225.60	185.00	404.45	142.99	261.46	242.14	-19.32
T_9	207.62	135.00	344.62	92.48	252.14	216.26	-35.88
T_{10}	212.46	153.00	365.46	117.12	248.34	218.97	-29.37

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

targeted yield of 55 q ha^{-1} (-28.62 kg ha^{-1}) > T_7: SSNM approach targeted yield of 45 q ha^{-1} (-28.49 kg ha^{-1}).

4.14.2 Phosphorus (P_2O_5) balance in soil

Data on balance sheet of phosphorus after harvest of mustard crop in dry direct seeded rice-mustard cropping sequence as influenced by different nutrient management approaches during 2015-16 and 2016-17 are presented in Tables 34 and 35, respectively.

Adaptation of different nutrient management practices are resulted in net loss of phosphorus during first and second year of experimentation. However, maximum net loss (-101.1 and -99.4 kg ha^{-1}, respectively) of phosphorus was observed with farmers practice and minimum net loss (-7.9 and -8.1 kg ha^{-1}, respectively) was recorded with treatment receiving SSNM approach targeted yield of 55 q ha^{-1} during first and second year of experimentation. Maximum net loss of phosphorus was followed the order T_3: Farmers practice (-90.7 kg ha^{-1}) > T_2: Recommended dose of fertilizer (-34.9 kg ha^{-1}) > T_4: STL method (-21.8 kg ha^{-1}) > T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (-21.5 kg ha^{-1}) > T_5:STCR approach targeted yield of 45 q ha^{-1} (-21.2 kg ha^{-1}) > T_6: STCR approach targeted yield of 55 q ha^{-1} (-19.7 kg ha^{-1}) > T_9: Nutrient expert for attainable yield of 45 q ha^{-1}(-17.9 kg ha^{-1}) > T_7: SSNM approach targeted yield of 45 q ha^{-1} (-14.0 kg ha^{-1}) during fist year (2015-16). Further, during second year of experimentation (2016-17) net loss of phosphorus was found in the order of T_2: Recommended dose of fertilizer (-34.2 kg ha^{-1}) >T_5:STCR approach targeted yield of 45 q ha^{-1} (-22.9 kg ha^{-1}) > T_4: STL method (-21.4 kg ha^{-1}) > T_6: STCR approach targeted yield of 55 q ha^{-1} (-19.4 kg ha^{-1}) > T_7: SSNM approach targeted yield of 45 q ha^{-1} (-19.0 kg ha^{-1}) > T_9: Nutrient expert for achievable yield 45 q ha^{-1}(-18.0 kg ha^{-1}) > T_1: Absolute control (-8.2 kg ha^{-1}).

4.14.3 Potassium (K_2O) balance in soil

Data on balance of potassium after harvest of second crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2015-16 and 2016-17 are presented in Tables 36 and 37, respectively.

Adaptation of different nutrient management practices are resulted in net gain/loss of potassium, application fertilizer as per T_8: SSNM approach targeted yield of 55 q ha^{-1} resulted in net gain of potassium (27.9 and 17.8 kg ha^{-1}, respectively) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (6.3 and 5.6 kg ha^{-1}) during first year and

Table 34. Phosphorus balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2015-16

Treatments	Initial soil P_2O_5 (kg ha^{-1})	Applied P through FYM/Ferti (kg ha^{-1})	Total P (kg ha^{-1})	Total P uptake by DSR and mustard (kg ha^{-1})	Estimated P_2O_5 (kg ha^{-1})	Soil P_2O_5 status after harvest of mustard	Net gain/ loss (+/-) of P_2O_5 in soil
	1	2	3=1+2	4	5=3-4	6	7=6-5
T_1	74.68	0.00	74.68	14.43	60.25	51.20	-9.05
T_2	74.68	67.50	142.18	35.64	106.54	82.46	-24.08
T_3	74.68	183.50	258.18	44.54	213.64	112.54	-101.10
T_4	74.68	55.00	129.68	31.58	98.10	79.45	-18.65
T_5	74.68	17.50	92.18	22.08	70.10	61.06	-9.04
T_6	74.68	45.50	120.18	37.54	82.64	71.56	-11.08
T_7	74.68	52.50	127.18	36.64	90.54	76.56	-13.98
T_8	74.68	60.50	135.18	45.18	90.00	82.14	-7.86
T_9	74.68	39.50	114.18	28.12	89.06	70.27	-15.79
T_{10}	74.68	45.50	120.18	33.90	86.28	73.46	-12.82

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

Table 35. Phosphorus balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2016-17

Treatments	Initial soil P_2O_5 (kg ha^{-1})	Applied P through FYM/Ferti (kg ha^{-1})	Total P (kg ha^{-1})	Total P uptake by DSR and mustard (kg ha^{-1})	Estimated P_2O_5 (kg ha^{-1})	Soil P_2O_5 status after harvest of mustard	Net gain/ loss (+/-) of P_2O_5 in soil
	1	2	3=1+2	4	5=3-4	6	7=6-5
T_1	51.20	0.00	51.20	12.08	39.12	30.92	-8.20
T_2	84.58	67.50	152.08	37.46	114.62	80.45	-34.17
T_3	112.54	183.50	296.04	48.06	247.98	148.54	-99.44
T_4	79.45	55.00	134.45	32.68	101.77	80.42	-21.35
T_5	65.06	35.50	100.56	25.31	75.25	52.32	-22.93
T_6	71.56	50.90	122.46	39.67	82.79	65.32	-17.47
T_7	76.56	52.50	129.06	38.21	90.85	72.30	-18.55
T_8	77.92	60.50	138.42	47.23	91.19	83.12	-8.07
T_9	70.27	42.50	109.77	30.11	79.66	63.43	-16.23
T_{10}	73.46	45.50	118.96	35.22	83.74	62.35	-21.39

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

second year of the experimentation. Further T_6: (6.6 kg ha^{-1}), T_2: (1.4 kg ha^{-1}) and T_{10}: (1.90 kg ha^{-1}) resulted in gain of potassium during the first year of the experimentation, whereas during second year T_6 : (13.8 kg ha^{-1}) resulted in gain of potassium. Further in soil during first year loss of potassium followed order of T_5: STCR approach targeted yield of 45 q ha^{-1} (-29.8 kg ha^{-1}) > T_9: Nutrient expert for attainable 45 q ha^{-1}(-27.7 kg ha^{-1}) >T_3: Farmers practice (-21.7 kg ha^{-1}) >T_4: STL method (-0.4 kg ha^{-1}). Further during second year of the experimentation loss of potassium followed order of T_3: Farmers practice (-17.9 kg ha^{-1}) > T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (-15.4 kg ha^{-1}) > T_4: STL method (-14.9 kg ha^{-1}) > T_2: Recommended dose of fertilizer (-12.5 kg ha^{-1}) > T_1: Absolute control (-6.7 kg ha^{-1}) > T_5: STCR approach targeted yield of 45 q ha^{-1} (-5.6 kg ha^{-1}).

4.15 Rice-equivalent yield and economics of Dry DSR-Mustard cropping sequence

4.15.1 Rice-equivalent yield (REY) of Dry DSR-Mustard cropping sequence

Equivalent yield is the best indicator of system productivity of sequence cropping system. Maximum REY of Dry DSR-Mustard cropping sequence was recorded with SSNM approach targeted yield of 55 q ha^{-1} (67.65 q ha^{-1}) followed by STCR approach targeted yield of 55 q ha^{-1} (63.67 q ha^{-1}) (Table 38) and which were superior over absolute control (26.15 q ha^{-1}), recommended dose of fertilizer (55.44 q ha^{-1}), STL method (57.55 q ha^{-1}), farmers practice (62.89 q ha^{-1}) and nutrient expert (58.86 q ha^{-1}).

4.15.2 Economics of Dry DSR-Mustard cropping sequence

Data pertaining to cost of cultivation, gross returns, net returns and benefit cost ratio (₹ ha^{-1}) of Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches are presented in Table 38.

method (₹ 43,348 ha^{-1}), T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (₹ 43,140 ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (₹ 42,523 ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (₹ 42,298 ha^{-1}) and T_1: Absolute control (₹ 30,850 ha^{-1}).

4.15.2.2 Gross returns (₹ ha^{-1})

Higher gross returns was obtained with T_8: SSNM approach targeted yield of 55 q ha^{-1} (₹ 1,47,554 ha^{-1}) followed by application of T_6: STCR approach targeted yield of 55

Table 36. Potassium balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2015-16

Treatments	Initial soil K_2O (kg ha^{-1})	Applied K through FYM/Ferti (kg ha^{-1})	Total K (kg ha^{-1})	Total K uptake by DSR and mustard (kg ha^{-1})	Estimated K_2O (kg ha^{-1})	Soil K_2O status after harvest of mustard	Net gain/ loss (+/-) of K_2O in soil
	1	2	3=1+2	4	5=3-4	6	7=6-5
T_1	348.60	0.00	348.60	55.35	293.25	285.80	-7.45
T_2	348.60	85.00	433.60	122.54	311.06	312.45	1.39
T_3	348.60	110.00	458.60	131.81	326.79	305.12	-21.67
T_4	348.60	72.50	421.10	109.92	311.18	310.64	-0.54
T_5	348.60	93.00	441.60	111.41	330.19	300.41	-29.78
T_6	348.60	113.00	461.60	161.41	300.19	309.35	9.16
T_7	348.60	129.82	478.42	153.27	325.15	332.62	7.48
T_8	348.60	150.00	498.60	183.51	315.09	337.45	22.36
T_9	348.60	72.00	420.60	102.13	318.47	290.75	-27.72
T_{10}	348.60	80.00	428.60	129.12	299.48	301.40	1.92

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

Table 37. Potassium balance sheet in soil (kg ha^{-1}) after harvest of mustard crop in Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during 2016-17

Treatments	Initial soil K_2O (kg ha^{-1})	Applied K through FYM/Ferti (kg ha^{-1})	Total K (kg ha^{-1})	Total K uptake by DSR and mustard (kg ha^{-1})	Estimated K_2O (kg ha^{-1})	Soil K_2O status after harvest of mustard	Net gain/ loss (+/-) of K_2O in soil
	1	2	3=1+2	4	5=3-4	6	7=6-5
T_1	285.80	0.00	285.80	46.69	239.11	232.45	-6.66
T_2	312.45	85.00	397.45	125.50	271.95	259.45	-12.50
T_3	305.12	110.00	415.12	138.83	276.29	258.39	-17.90
T_4	310.64	72.50	383.14	104.62	278.52	263.62	-14.90
T_5	300.41	97.16	397.57	121.46	276.11	270.56	-5.55
T_6	309.35	115.06	424.41	163.86	260.55	274.40	13.85
T_7	332.62	129.82	462.44	154.61	307.83	314.60	6.78
T_8	337.45	150.00	487.45	191.10	296.35	321.06	24.71
T_9	290.75	72.00	362.75	104.83	257.92	242.50	-15.42
T_{10}	301.40	80.00	381.40	131.10	250.30	252.37	2.07

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

q ha^{-1} (₹ 1,38,904 ha^{-1}), T_3: Farmer practice (₹ 1,37,071 ha^{-1}), T_7: SSNM approach targeted yield of 45 q ha^{-1} (₹ 1,31,029 ha^{-1}), T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1} (₹ 1,28,387 ha^{-1}), T_2: Recommended dose of fertilizer (₹ 1,21,085 ha^{-1}), T_4: STL method (₹ 1,25,560 ha^{-1}), T_9: Nutrient expert for attainable yield of 45 q ha^{-1} (₹ 1,14,059 ha^{-1}) and T_5: STCR approach targeted yield of 45 q ha^{-1} (₹ 1,04,761 ha^{-1}).While, lowest gross returns was obtained with T_1: Absolute control treatment (₹ 57,176 ha^{-1}).

4.15.2.3 Net returns (₹ ha^{-1})

Significantly higher net returns (₹ 1,01,993 ha^{-1}) was received from the application of T_8: SSNM approach targeted yield of 55 q ha^{-1} it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (₹ 94,499 ha^{-1}) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (₹ 86,200 ha^{-1}) and T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1} (₹ 85,247 ha^{-1}) and it was significantly superior over T_4: STL method (₹ 82,212 ha^{-1}), T_2: Recommended dose of fertilizer(₹ 77,062 ha^{-1}), T_3: Farmer practice (₹ 84,680 ha^{-1}), T_9:Nutrient expert for attainable yield of 45 q ha^{-1} (₹ 71,536 ha^{-1}), T_5: STCR approach targeted yield of 45 q ha^{-1} (₹ 62,463 ha^{-1}). However, lowest net returns were obtained with absolute control (₹ 26,326 ha^{-1}).

4.15.2.4 Benefit Cost ratio

Significantly higher benefit cost ratio (3.24) was obtained with the application of fertilizers through T_8: SSNM approach targeted yield of 55 q ha^{-1} it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (3.13) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (2.93), it was significantly superior over T_3: Farmer practice (2.62), T_{10}: Nutrient expert for attainable yield of 55 q ha^{-1} (2.98), T_4: STL method (2.90), T_9:Nutrient expert for attainable yield of 45 q ha^{-1} (2.69), T_2: Recommended dose of fertilizer (2.76) and T_5: STCR approach targeted yield of 45 q ha^{-1} (2.48). However, lowest BC ratio was observed with absolute control (1.87).

Table 38. Rice equivalent yield and economics of Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches

Treatments	REY (q ha^{-1})			Cost of Cultivation (₹ ha^{-1})			Gross Returns (₹ ha^{-1})			Net Returns (₹ ha^{-1})			BC ratio		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	27.89	24.40	26.15	29315	32385	30850	61619	52733	57176	32304	20348	26326	2.10	1.63	1.87
T_2	55.17	55.72	55.44	42646	45285	43966	121459	120595	121027	78813	75310	77062	2.85	2.66	2.76
T_3	61.45	64.32	62.89	50963	53819	52391	135195	138946	137071	84232	85127	84680	2.65	2.58	2.62
T_4	56.84	58.26	57.55	41903	44793	43348	125105	126014	125560	83202	81221	82212	2.98	2.80	2.89
T_5	46.73	49.34	48.03	40527	44069	42298	102817	106704	104761	62290	62635	62463	2.54	2.42	2.48
T_6	63.25	64.10	63.67	43062	45748	44405	139203	138604	138904	96141	92856	94499	3.23	3.03	3.13
T_7	59.89	60.28	60.08	43686	45972	44829	131771	130286	131029	88085	84314	86200	3.02	2.83	2.93
T_8	67.34	67.97	67.65	45043	46079	45561	148194	146913	147554	103151	100834	101993	3.29	3.19	3.24
T_9	51.82	52.77	52.29	41084	43961	42523	114033	114084	114059	72949	70123	71536	2.78	2.60	2.69
T_{10}	58.47	59.24	58.86	41756	44524	43140	128698	128075	128387	86942	83551	85247	3.08	2.88	2.98
S. Em.±	-	-	-	-	-	-	-	-	-	5477	5742	5664	0.10	0.13	0.11
C.D. at 5%	-	-	-	-	-	-	-	-	-	15988	16760	16828	0.30	0.37	0.34

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield : 45 q ha^{-1})
T_6: STCR approach (Targeted yield : 55 q ha^{-1})
T_7: SSNM approach (Targeted yield : 45 q ha^{-1})
T_8: SSNM approach (Targeted yield : 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield : 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield : 55 q ha^{-1})

Discussion

V. DISCUSSION

Nutrient management is the careful monitoring and amending of soil fertility to meet crops needs with emphasis on maintaining productivity and profitability. At present, the state or regional fertilizer recommendations are very general which are equated to the medium soil fertility level of nutrients and does not consider soil test values and crop nutrient requirements. Such recommendations are constant over the years over large areas. On the other hand, the soil nutrient levels, crop growth and crop needs for supplemental nutrients are strongly influenced by crop and soil management and can vary greatly among fields, seasons and years. Farmers of TBP Command Area, in Karnataka state are known for using imbalanced dose of nutrients with higher tendency for nitrogen and phosphorus fertilization (246 kg N and 166 kg P ha^{-1} with lower dose of potassium as per survey data, 2014) with an intention of getting higher yields, it leads to increase in cost of cultivation, lower profits and fertilizer losses from the soil-crop system, contributing to the nutrient load in streams, rivers and other water bodies and it leads to deterioration of soil health.

Identification of good nutrient management approaches for application of adequate quantities of plant nutrients is a key for increasing productivity and production in cropping system. A systematic approach in Dry DSR-mustard cropping system to optimize the fertilizer recommendation based on the soil test results is essential to maintain the nutrient balance as well as crop production and profitability. The identification of best approach is helpful to address the sustainable nutrient management in Dry DSR-Mustard cropping system.

Among the various methods of fertilizer applications, the one based on ‘yield targeting’ is unique in the sense this method not only indicates soil test based fertilizer doses but also the level of yield the farmer can hope to achieve if good agronomic practices are followed in raising the crop. This approach provides a scientific basis for balanced fertilization not only among the fertilizer nutrient themselves but also soil available nutrients. SSNM demonstrated a potential to increase crop yields and profits. There is also increasing evidence of the environmental-friendliness of SSNM as it focused on balanced and crop need-based nutrient application. The study on sustainable nutrient management approach based on the soil test results in SSNM and STCR under field situation is more essential for maximizing the yield by maintaining the nutrient

balance and explore the possibility of improving productivity of Dry DSR-mustard cropping system through yield target in a Vertisol. In view of the above, field studies were conducted under tail end of TBP command area in the farmer field at Vijayanagar camp, Tq: Raichur, Dist: Raichur, during *kharif* and *rabi* seasons of 2015-16 and 2016-17 to study the "Soil Test Based Nutrient Management Approaches in Dry DSR-Mustard cropping system".

The crop growth yield and yield parameters of Dry DSR were slightly better in the second year (2016-17) than first year (2015-16) and it might be due to better crop establishment and congenial weather conditions during crop growth period. However, the pattern of response was similar in both the years. Therefore, only pooled data of two years are discussed in this chapter.

5.1 Soil characteristics

The soil of the experimental site was clay in texture (Vertisol) with a bulk density of 1.12 Mg m^{-3} and water holding capacity of 60.45 per cent. The soil pH was slightly alkaline (8.20) with an electrical conductivity of 0.69 dS m^{-1}. The organic carbon content was medium (6.80 g kg^{-1}). The soil was low in available nitrogen (192.36 kg ha^{-1}), high in available phosphorus (74.68 kg ha^{-1}), potassium (348.00 kg ha^{-1}), sulphur (21.20 mg kg^{-1}), exchangeable calcium and magnesium 37.54 and 10.75 c mol (p^{+}) kg^{-1} and deficient in DTPA extractable Zn and Fe (0.46 and 4.39 mg kg^{-1},respectively) and sufficient in DTPA extractable, Mn and Cu (1.23 and 2.40 mg kg^{-1}) (Table 1).

5.2 Effect of weather parameters on crop growth

The environmental factors such as rainfall, temperature and relative humidity during the crop growth period affect quantity and quality of plant growth and yield parameters.

The annual rainfall received during 2016 and 2017 was 677.5 mm and 868.8 mm, respectively (Table 2 and Fig. 1 & 2) which were 80.7 and 271.8 mm higher than average rainfall of 81 years (1932-2015). The rain received during June helped for land preparation. Sowing of crop was taken on 18th July 2015 and 7th July 2016. The germination was good due to favourable rainfall situation during early stages. The rainfall during rice cropping period (18-07-2015 to 12-12-2015 and 7-07-2016 to 5-12-2017) was 677.5 mm and 868.8 mm, respectively. The rainfall received in the month of

July (42.0 and 143.2 mm) and August (51.4 and 78.0 mm) ensured adequate moisture for germination, emergence and early establishment of seedlings. Further, the adequate and uniform distribution of rainfall during September (316.6 and 292.5 mm) ensured proper growth and development of Dry DSR. A relatively higher rainfall was received in the month of August and September compared to normal which encouraged the vigorous growth of the crop. The rainfall during cropping season was higher than normal and was well distributed and hence rice crop did not suffer from moisture stress. The mean maximum temperature recorded during the period of crop growth was in the range of 31.2º C to 39.9º C during 2015-16 and 30.2º C to 41.8º C during 2016-17. While, the minimum temperature range during crop growth period was in the range of 17.7º C to 26.8º C during 2015-16 and 16.2º C to 28.3º C during 2016-17.

During cropping season, the relative humidity was maximum (88.0 and 92.0 % during 2015 and 2016, respectively) during establishment stage (September). The relatively higher RH recorded during September and October also favoured the insects such as leaf minor, leaf folder, stem borer and blast disease. These insect and disease were effectively controlled by spraying Chloropyriphos, Coragen and Tricyclazole were sprayed (@ 2 ml L^{-1}, 0.5 g and 1 g L^{-1}), respectively. The temperature and relative humidity existed during the experimentation period were conducive for growth and development of rice.

5.3 DRY DIRECT SEEDED RICE

The results of the field experiments influencing the different nutrient management approaches on growth, yield and yield parameters, nutrient uptake, NUE and economics of dry direct seeded rice production are discussed under the following headings:

5.3.1 Effect of different nutrient management approaches on yield, yield attributes and growth parameters of Dry DSR

5.3.2 Influence of different nutrient management approaches on nutrient uptake by Dry DSR

5.3.3 Influence of different nutrient management approaches on nutrient use efficiency (NUE) of Dry DSR

5.3.4 Microbiological properties of rhizospheric soil of rice as influenced by different nutrient management approaches

5.3.5 Economics of Dry DSR as influenced by different nutrient management approaches

5.4 MUSTARD

The influence of residual effect of different nutrient management approaches on growth, yield, nutrient uptake and economics of mustard are discussed under the following headings:

5.4.1 Residual effect of different nutrient management approaches on growth, yield and yield parameters of mustard

5.4.2 Residual effect of different nutrient management approaches on nutrient uptake and economics of mustard

5.5 DRY DIRECT SEEDED RICE - MUSTARD CROPPING SEQUENCE

The results of the field experiments on influence of different nutrient management approaches on soil fertility status, nutrient balance and total economics per year after harvest of mustard crop in Dry DSR-mustard cropping sequence are discussed under the following headings:

5. 5.1 Influence of different nutrient management approaches on soil fertility status after harvest of mustard crop in Dry DSR-mustard cropping sequence

5. 5.2 Influence of different nutrient management approaches on nutrient balance after harvest of mustard crop in Dry DSR-mustard cropping sequence

5. 5.3 Influence of different nutrient management approaches on total economics per year in Dry DSR-mustard cropping sequence

5.3 DRY DIRECT SEEDED RICE

5.3.1 Effect of different nutrient management approaches on yield, yield attributes and growth parameters of Dry DSR

The performance of Dry DSR was significantly influenced by different nutrient management approaches during both the years of study as well as on pooled basis. The yield and growth parameters of Dry DSR were significantly higher with SSNM and STCR treatments as compared to RDF, STL, FFP and NE. The better growth and yield parameters with SSNM may be due to the application of balanced use of nutrients as per the crop requirement. Yield and yield attributing parameters like number of panicles m^{-2}, panicle length, number of grains $panicle^{-1}$, filled grains $panicle^{-1}$, test weight, grain yield

and straw yield recorded higher were with SSNM and STCR treatments over absolute control, RDF, STL method, Nutrient Expert and farmers practice (From Table 8 to 10 and Fig. 4).

In the present study pooled data showed that, the effect of nutrient application through targeted yield approach exerted significant influence on the grain and straw yield of Dry DSR. The grain yield of Dry DSR was higher (54.73 q ha^{-1}) with treatment receiving SSNM approach for targeted yield of 55 q ha^{-1} and it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (51.79 q ha^{-1}) followed by T_3: Farmer practice (50.38 q ha^{-1}), T_7: SSNM approach targeted yield of 45 q ha^{-1} (49.01 q ha^{-1}) and T_{10}:Nutrient expert for attainable yield of 55 q ha^{-1}(47.81 q ha^{-1}). The lowest grain yield was recorded in absolute control (21.40 q ha^{-1}). (Table 10 and Fig.4 and Plate 7 & 4). The significantly higher straw yield was recorded in T_8: SSNM approach targeted yield of 55 q ha^{-1} (68.38 q ha^{-1}) followed by T_6: STCR approach targeted yield of 55 q ha^{-1} (64.70 q ha^{-1}) and T_3: Farmer practice (62.95 q ha^{-1}). The lowest straw yield was recorded in T_1: Absolute control (27.58 q ha^{-1}).The higher grain yield can be attributed to the ability of targeted yield approaches to satisfy the nutrient demand of crop more efficiently. The higher grain yield of Dry DSR was also due to better translocation of photosynthates from source to sink and higher growth attributing characters like plant height, number of tillers m^{-2}, leaf area per plant cm^{-2} (Table 5) and dry matter production (Table 7) and higher yield attributing characters like, number of panicles m^{-2}, panicle length, number of grains $panicle^{-1}$(Table 8), filled grains $panicle^{-1}$, lower number unfilled grains $panicle^{-1}$, low per cent sterility, (Table 9) and higher test weight due to supply of nutrients as per the demand of the crop by targeted yield approach. The results are in confirmation with the findings of Police Patil (2011), that application of 169:32:113 NPK kg ha^{-1} (SSNM) for targeted yield of 6.5 t ha^{-1} in aerobic rice recorded significantly higher filled grains (165.92), panicle length (16.2 cm), 1000 seed weight (27.27 g), productive tillers $hill^{-1}$ (31.92), grain yield (5903 kg ha^{-1}) and straw yield (7279 kg ha^{-1}). Similarly Dhillon *et al.* (2006) reported higher grain yield (46.0 q ha^{-1}) with the application of fertilizer based on targeted yield (45.0 q ha^{-1}) approach when compared to farmers practice, RDF and soil test based applications. These results are also coroborated with the findings of Doberman *et al.* (2000), Biradar *et al.* (2006), Keram *et al*. (2012), Umesh *et al*. (2014) and Singh *et al.* (2014). SSNM approach provides a scientific basis for the balanced fertilization not only among the fertilizer nutrient themselves but also

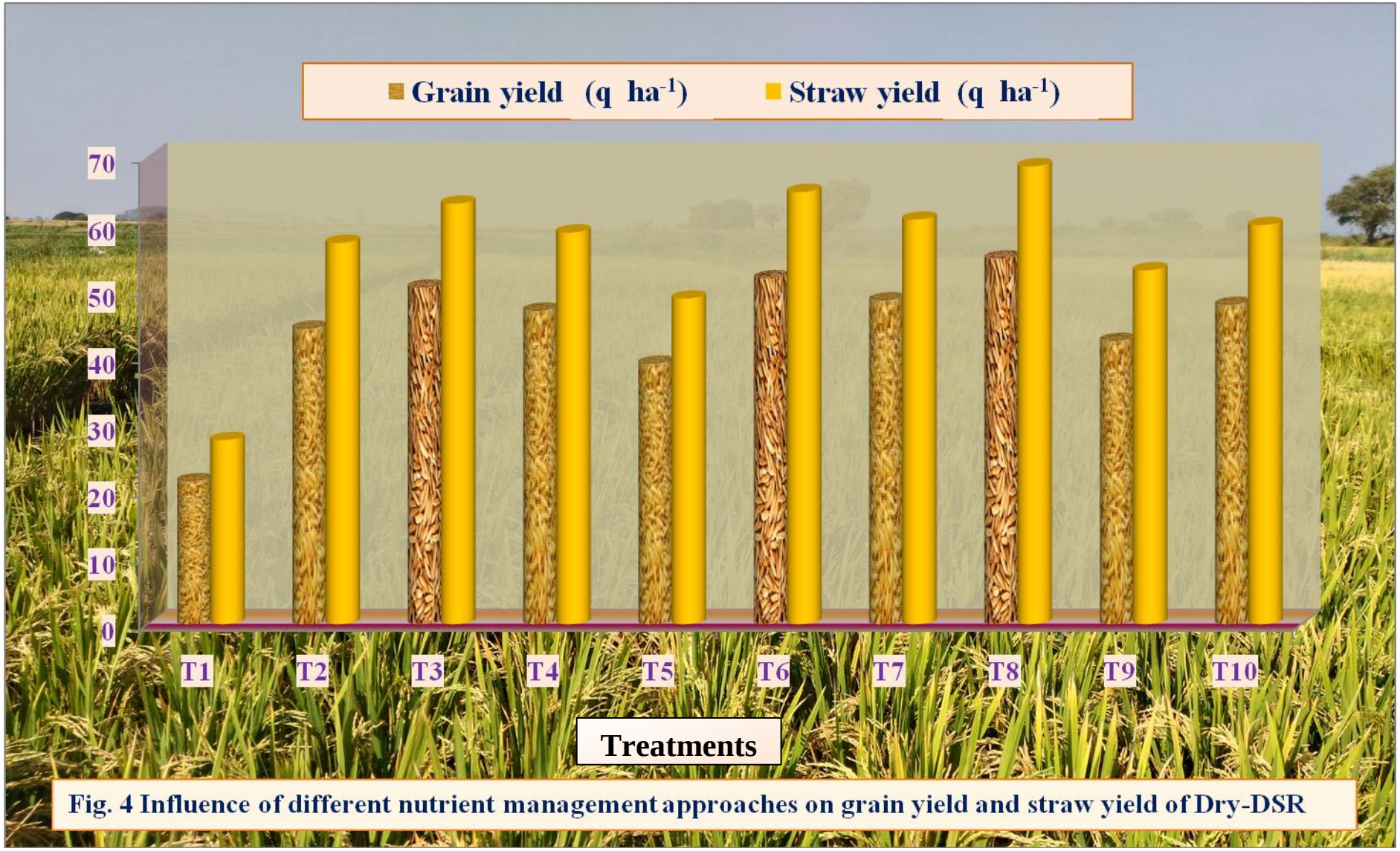


Fig. 4 Influence of different nutrient management approaches on grain yield and straw yield of Dry-DSR

T_7: SSNM approach (Targeted yield 45 q ha^{-1})

T_6: STCR approach (Targeted yield: 55 q ha^{-1})

T_8: SSNM approach (Targeted yield: 55 q ha^{-1})

T_{10}: Nutrient expert (Targeted yield 55 q ha^{-1})

Plate 4: Comparative view of Soil Test Based Nutrient Management Approaches in Dry DSR, at milking stage

T_6: STCR approach (Targeted yield: 55 q ha^{-1})
(134: 28: 80 kg:: N: P_2O_5: K_2O ha^{-1}

T_7: SSNM approach (Targeted yield 45 q ha^{-1})
(118: 35: 95 kg:: N: P_2O_5: K_2O ha^{-1})

T_8: SSNM approach (Targeted yield: 55 q ha^{-1})
(144: 43: 115 kg:: N: P_2O_5: K_2O ha^{-1})

T_{10}: Nutrient Expert (Targeted yield 55 q ha^{-1})
(118: 25: 45 kg :: N: P_2O_5: K_2O ha^{-1})

Plate 5: Comparative view of Soil Test Based Nutrient Management Approaches in Dry DSR, at harvesting stage

Soil available nutrients to achive targed yield (Satyanarayana *et al.* 2011). The absolute control recorded lower grain and straw yields of Dry DSR, which might be due to poor crop growth as well as lower values of yield attributes (Table 10). Lower grain yield of Dry DSR may also be attributed to lower leaf area (Table 5) which ultimately affected plant foliage cover, interception of light energy for photosynthesis, production and accumulation of dry matter. These results are in conformity with the findings of Ramesh and Chandrasekaran (2007).

Further farmer practice of fertilization involves higher doses of N & P_2O_5 fertilizer (246 & 166 kg ha^{-1}, respectively) with low dose of potassium, which recorded 4.30 q ha^{-1} less grain yield as compared to SSNM approach targeted yield 55 q ha^{-1}. These results are in conformity with the findings of Mishra *et al.* (2003) who reported that application of 150:60:120 N, P_2O_5, K_2O kg ha^{-1} with 6 kg Zn ha^{-1} and 7 kg Mn ha^{-1} as per SSMM approach in hybrid rice recorded significantly higher grain yield of 9.7 t ha^{-1} which were 0.7 to 0.8 t ha^{-1} more than state recommendation (SR) and 0.2 to 0.3 t ha^{-1} more than farmers practice of fertilization (FPF).

Further, application of fertilizer as per the site-specific nutrient management approach there was a saving of 30 % N as compared to farmers practice. These results are in conformity with the findings of Wang *et al.* (2007) and Shaobing *et al.* (2010) they reported that on average SSNM reduced N fertilizer by 32 % and increased grain yield by 5% compared with farmers' N practices in China and other major rice-growing countries of South East Asia.

Grain yield is governed by the factors which have direct or indirect impact. The factors which have direct influence on the grain yield are the yield components *viz.,* number of panicles m^{-2}, panicle length, number of grains $panicle^{-1}$ (Table 8), filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, per cent sterility, (Table 9) test weight and total dry matter production per plant (Table 7) have an indirect influence on grain yield through the yield components, which intern depends on different growth components *viz.,* plant height (Table 3) leaf area per plant and number of tillers per plant. All these growth components could have been promoted by more quantity of nutrients made available by the treatments to Dry DSR and evidenced through higher uptake of nutrients *viz.,* nitrogen, phosphorous and potassium (Table 11, 12 and 13, respectively).

The number of panicles m^{-2} is important yield attribute which is significantly higher (438.1) in SSNM approach targeted yield of 55 q ha^{-1} followed by STCR approach targeted yield of 55 q ha^{-1} (423.7) over absolute control (149.9), RDF (326.2), STL (330.6) and FFP (380.3) (Table 8 and Fig. 5). Yield increases over farmer practice were mainly attributed to a 13.09 % increase in the average number of panicles per m^2 (438.1 in SSNM vs 380.3 in FFP). Similar results were reported by Nagarajan *et al*. (2003). Inorganic fertilizer application based on targeted yield along with organic manure (FYM @ 5t ha^{-1}) resulted in higher number of panicles m^{-2} (310.67) and grain yield 4.04 t ha^{-1} of rice (Keram *et al*. 2012). Thus the practice of fertilizing a crop on the basis of targeted yield is precise, meaningful and eco-friendly. Raghu (2013) also reported that practice of STCR approach resulted higher number of tillers m^{-2}, panicle length, productive tillers m^{-2} and grain yield in rice as compared to RDF and STL method. These results also coroborates with the findings of Ramesh and Chandrasekaran (2007) and Upendra *et al.* (2013) in hybrid rice.

The number of grains per panicle is another important yield parameters which differed significantly due to application of nutrients through SSNM approach targeted yield of 55 q ha^{-1} (143.9) followed by STCR approach targeted yield of 55 q ha^{-1} (139.3) over absolute control (112.1), RDF (127.1) and STL method (129.5) (Table 10 and Plate 5 & 6). Significant difference in the number of grains per panicle of Dry DSR obtained by higher amounts of nutrients supplied through targeted yield approaches as evidenced by their nutrient content and higher number of grains per panicle. Lesser number of grains per panicle was recorded in absolute control (112.2) it might due to the inadequate supply of plant nutrients. Filled grains per panicle were significantly higher with SSNM approach targeted yield of 55 q ha^{-1} (134.1) followed by STCR approach targeted yield of 55 q ha^{-1} (127.4) and least sterility percentage and unfilled grains per panicle were recorded with SSNM approach targeted yield of 55 q ha^{-1} (6.8 % and 9.8, respectively) followed by STCR approach targeted yield of 55 q ha^{-1} (8.6 % and 12.0, respectively) this might be due to adequate supply of potassium fertilizer during early and panicle initiation stage which helped in proper filling of grains which resulted in higher number of plump grains and thus increased the number of grains $panicle^{-1}$ and reduced sterility percentage. The improved grain filling with potassium application was due to increased photosynthetic activity which stimulated some vital biochemical processes. The present findings are in agreement with findings of Venkateshwarlu and Singh (1980).

Similar results were also reported by Esfehani *et al.* (2005) showed that potassium fertilizer has positive effect on filled grains in rice while its deficiency caused pollen sterility and decreased the number of filled grains panicle^{-1}. Whereas, highest sterility percentage and unfilled grains per panicle registered with absolute control (21.9 % and 24.8) this may be due to inadequate supply of plant nutrients resulted in poor crop growth and yield attributes.

The test weight is another important yield attribute in the present investigation. However, higher 1000 seed weight of Dry DSR grain (13.98 g) was recorded with SSNM approach targeted yield of 55 q ha^{-1} over absolute control (11.8 g) and STCR approach targeted yield of 45 q ha^{-1} (12.6 g) and it was found on par with STCR approach targeted yield of 55 q ha^{-1} (13.90 g), farmers practice (13.66 g) and SSNM approach targeted yield of 45 q ha^{-1} (13.72 g) (Table 10 and Fig. 5). Higher 1000 seed weight of Dry DSR was mainly attributed to higher leaf area per plant (Table 5) and dry matter production in plants (Table 7) which might have supplied required photosynthates to the reproductive parts more precisely to the seed. Thus, due to availability of photosynthates the seed might have developed fully and resulted in plump grains and hence recorded higher test weight. These results are in accordance with the findings of Ravi and Rao (1992) they reported that maximum test weight, number of filled grains per panicle and yield were obtained due to application of higher potassium in two equal splits as basal and at panicle initiation stage. These results also coroborates with the findings of Police Patil (2011). Application of nutrients by SSNM approach targeted yield of 55 q ha^{-1} and STCR approach targeted yield of 55 q ha^{-1} was recorded significantly higher panicle length (19.8 cm and 19.4 cm, respectively) as compared to absolute control, RDF, STL method nutrient expert and farmer practice (Table 10 and Plate 7). It might be due to better growth attributes *viz.,* plant height (Table 3), leaf area per plant (Table 5) and total dry matter production (Table 7). The higher leaf area per plant was responsible for tapping of more solar radiation resulting in high photosynthetic rate which intern resulted in higher dry matter production. All these factors associated with leaf area which contributed towards significant improvement in growth and yield attributes and ultimately resulted in higher panicle length (Table 8 and Fig. 5). Similar interpretations were also reported by Ramesh and Chandrasekaran (2007), Bandara *et al.* (2007) and Upendra *et al.* (2013).

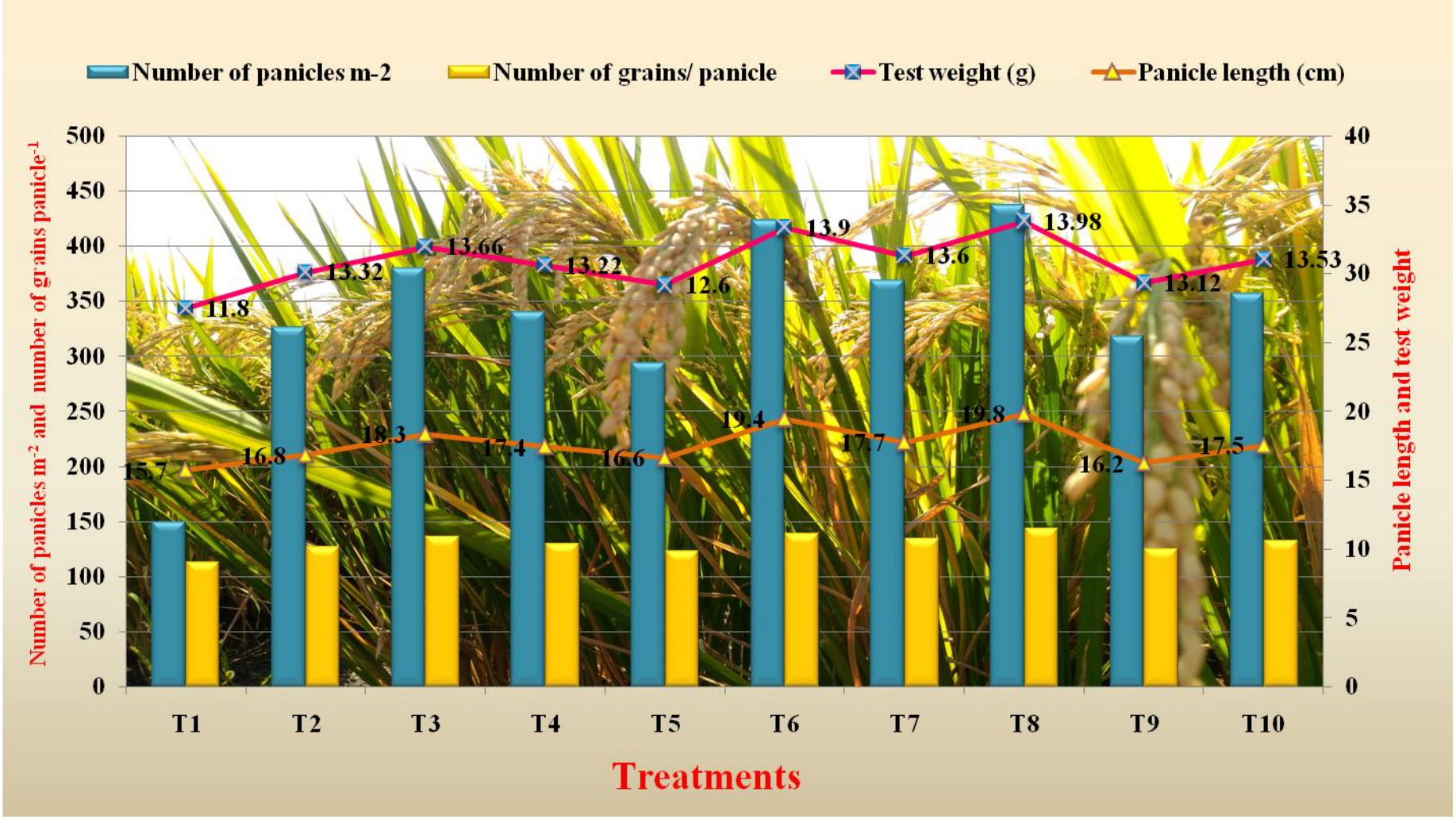
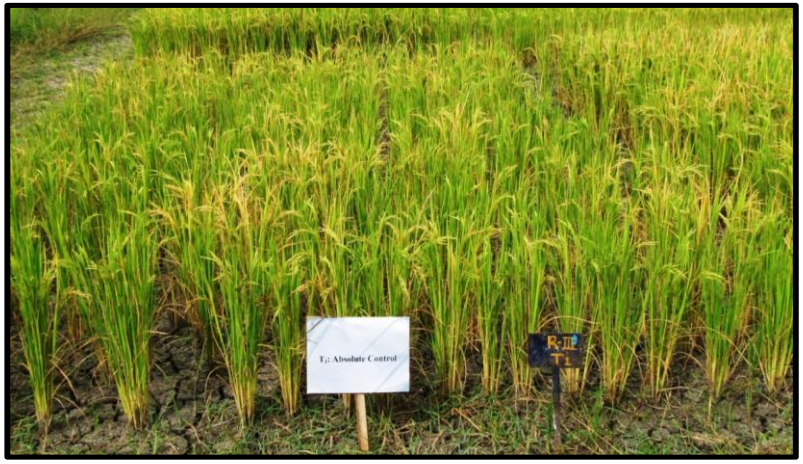


Fig. 5 Number of panicles m^{-2}, number of grains $panicle^{-1}$, panicle length and test weight of Dry-DSR as influenced by different nutrient management approaches



T_1: Absolute control

T_3: Farmers practice

T_2: Recommended dose fertilizer

T_4: STL method

Plate 6: Comparative view of Soil Test Based Nutrient Management Approaches in Dry DSR, at milking stage

T1: Absolute control
(00:00:00 kg:: N: P_2O_5: K_2O ha^{-1})

T2: Recommended dose fertillizer
(100:50:50 kg:: N: P_2O_5: K_2O ha^{-1})

T3: Farmers practice
(246: 166: 60 kg:: N: P_2O_5: K_2O ha^{-1})

T4: STL method
(112.5: 37.5: 37.5 kg:: N: P_2O_5: K_2O ha^{-1})

Plate 7: Comparative view of different nutrient management approaches in Dry DSR, at harvesting stage

The total dry matter produced in Dry DSR differed significantly due to target yield approach at different stages of crop growth. The total dry matter produced per plant was higher in SSNM approach targeted yield of 55 q ha^{-1} (6.68, 28.05, 47.55 and 62.25 g $plant^{-1}$ at 60, 90, 120 DAS and at harvest, respectively) which was on par with STCR approach targeted yield of 55 q ha^{-1} (6.99, 27.16, 45.16 and 59.83 g $plant^{-1}$, respectively) (Table 7 and Fig. 6) and these are significantly higher as compared to control, RDF, STL method and nutrient expert. The increased dry matter was usually associated with height of the plant (Table 3), more number of tillers per plant (Table 4) and intern higher leaf area per plant (Table 5) which led to greater accumulation of photosynthates. These results are in accordance with the findings of Upendra *et al.* (2013) reported that nutrient application nutrients through SSNM in hybrid rice resulted in significantly higher dry matter production at harvest (10632 kg ha^{-1}).

The leaf area of Dry DSR varied significantly due to targeted yield approaches and it was significantly higher in SSNM approach targeted yield of 55 q ha^{-1} (420, 816, 1418, and 955 followed by STCR approach targeted yield of 55 q ha^{-1} (407, 738, 1351 and 921 cm^2) at 60, 90, 120 DAS and at harvest, respectively (Table 5 and Fig. 7). Less leaf area per plant (Table 5) of Dry DSR was registered in absolute control (210, 393, 696 and 448 cm^2, respectively) followed by STCR approach targeted yield of 45 q ha^{-1} (267, 542, 949 and 619 cm^2, respectively) was attributed to significantly less number of tillers (Table 4). All these factors together caused significant reduction in dry matter production and its accumulation in reproductive parts and finally the grain yield. These results are in accordance with the findings of Mandal and Mahapatra (1983) quoted that grain yield of rice was positively correlated with leaf area duration from flowering to maturity and number of spikelets per m^2, per cent filled grains and test weight of grain. The leaf area duration was improved by the application of 160 kg N + 120 kg K_2O ha^{-1} during dry season and 120 kg N + 80 kg K_2O ha^{-1} during wet season with adequate phosphorus (60 Kg P_2O_5 ha^{-1}). These results are also in accordance with the findings Police Patil (2011), Rajesh (2015) and Umesh *et al.* (2014).

The SPAD readings differed significantly with the different fertilizer levels. Among the different nutrient management approaches higher chlorophyll content of 45.91 and 44.55 was recorded with SSNM approach targeted yield of 55 q ha^{-1} at 90 and 120 DAS respectively, due to adequate supply of nitrogen four in split doses, maintained

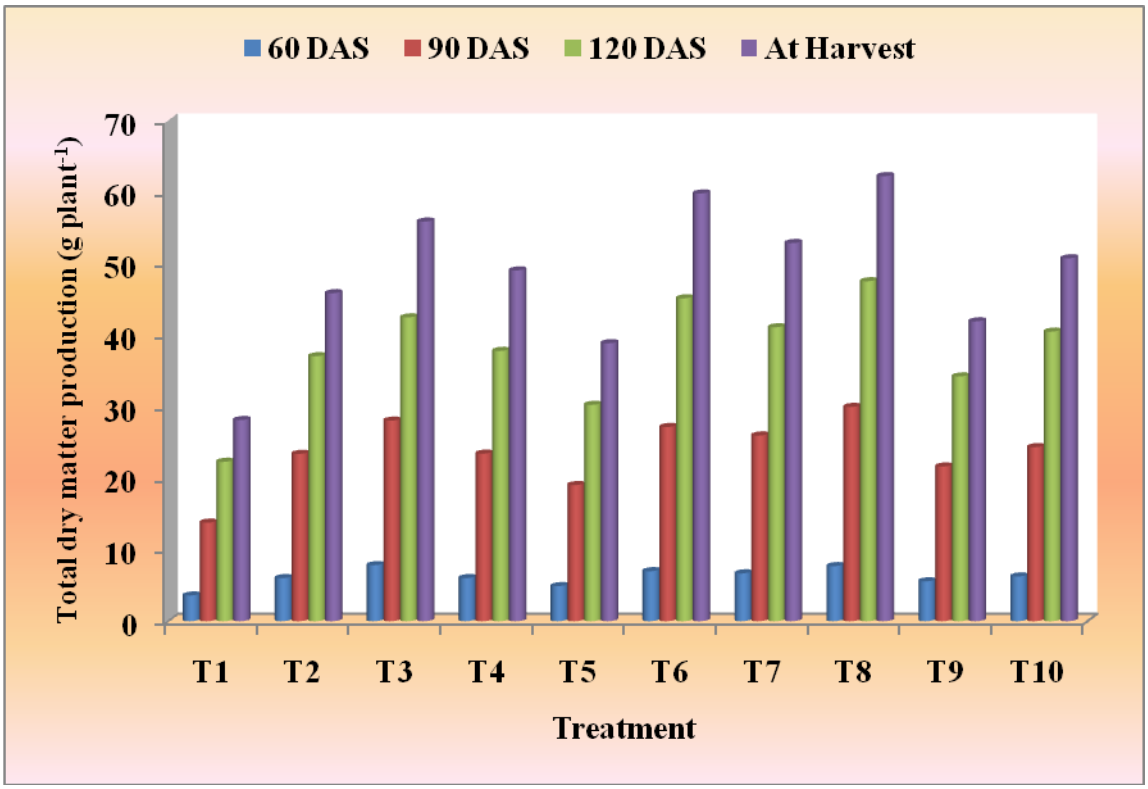


Fig 6.Total dry matter production of Dry DSR at different growth stage as influenced by different nutrient management approaches

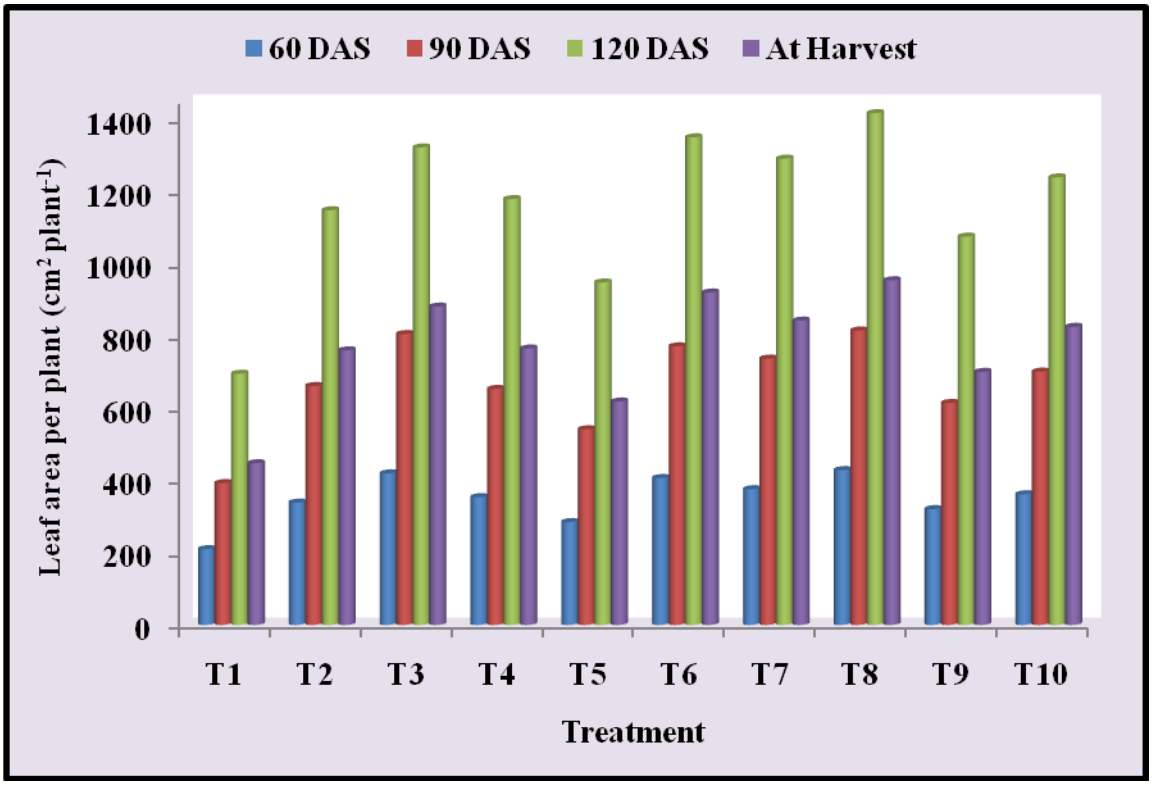


Fig. 7 Leaf area per plant of Dry DSR at different growth stages as influenced by different nutrient management approaches

plant required N throughout crop growing period. Low chlorophyll content resulted in decreased nitrogen doses (Gholizadeh *et al.,* 2009) (Table 6).

The number of tillers m^{-2} which is also a contributing factor for total dry matter production and finally to the grain yield. The significantly higher number of tillers m^{-2} was observed with SSNM approach targeted yield of 55 q ha^{-1} (367.4, 476.9, 640.1 and 678.0) followed by STCR approach targeted yield of 55 q ha^{-1} (350.8, 449.5, 628.3 and 650.6) and farmers practice (345.3, 433.1, 583.5 and 614.6) at 60, 90, 120 DAS and at harvest, respectively (Table 4 and Fig. 8). This has helped in accumulation of higher dry matter in stem and also helped in obtaining higher number of panicles per plant, grains per panicle and finally higher grain yield. These results are in accordance with the findings of Upendra *et al.* (2013) revealed that among all the fertilizer doses, application of SSNM package *i.e.* NPK B @ 100-90-90-0 kg ha^{-1} resulted the more number of tillers m^{-2} (410), filled grains per panicle (123), panicle length (24.9 cm), dry matter production at harvest (10632 kg ha^{-1}) and grain yield (4961 kg ha^{-1}). These results were also in conformity with the findings of Bandara *et al.* (2007) and Police Patil (2011).

The plant height also contributed for total dry matter was significantly higher in application of nutrients through SSNM approach targeted yield of 55 q ha^{-1} (19.7, 58.7 and 72.8 cm) at 60, 90, 120 DAS and at harvest, respectively followed by STCR approach targeted yield of 55 q ha^{-1} (17.4, 31.5, 55.8 and 68.3 cm) at 60, 90, 120 DAS and at harvest, respectively. However, there was slight increase plant height was registered with farmer practice at different stages as compared to SSNM and STCR approaches; it may be due to higher vegetative growth because of higher levels of N fertilization. The reduction in the plant height observed in absolute control (11.0, 19.9, 39.4 and 47.0 cm) at 60, 90, 120 DAS and at harvest, respectively (Table 3 and Fig. 9) might be due to inadequate supply of nutrients resulting in the reduction of growth and yield parameters (Table 3 to 7 and 8 to 10, respectively) which ultimately produced lesser grain yield as well as straw yield. The results were in conformity with the findings of Bandara *et al.* (2007) who reported that the application of site specific nutrients 175 kg N, 60 kg P, 120 kg K, 25 kg Mg, 50 kg S and 2 kg Zn per hectare gave significantly higher plant height, number of tillers m^{-2}, leaf area per plant and dry matter production and seed yield in rice as compared to RDF and other lower doses. Similar results was reported by Jemal Abdulahi (2010) that morphological characters like plant height and number of leaves were improved substantially due to the application of nutrients based

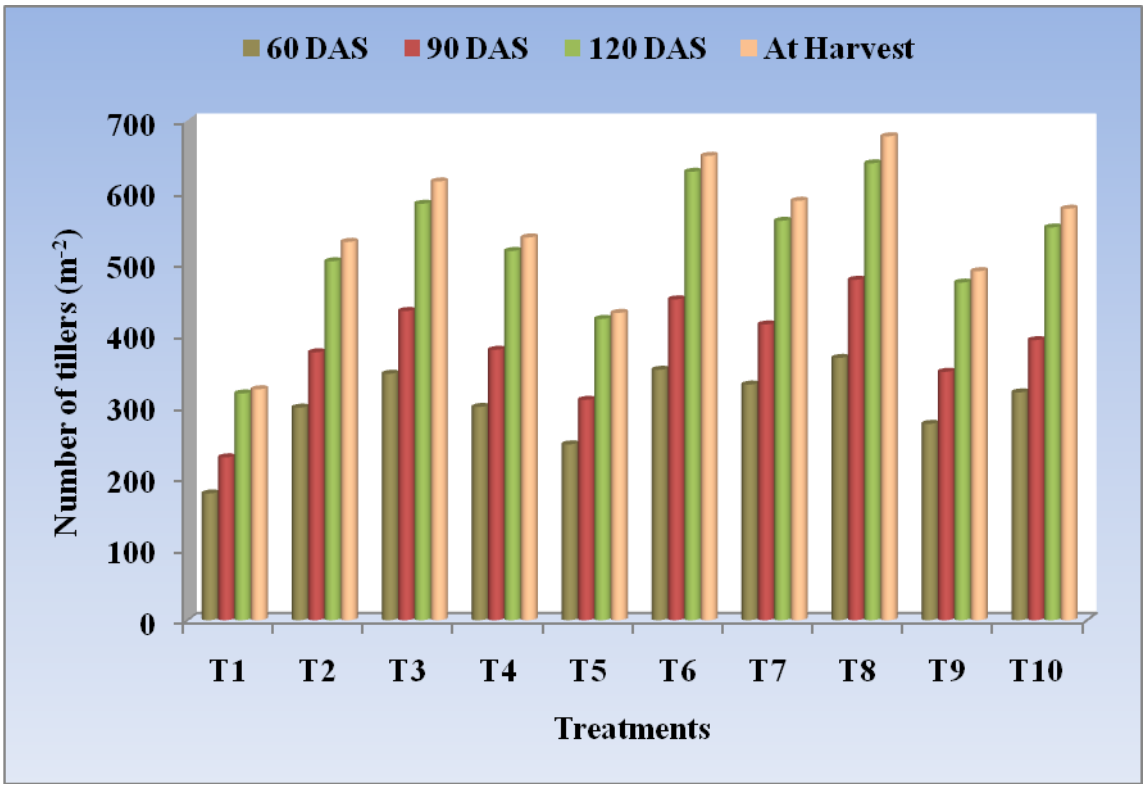


Fig 8. Number of tillers m^{-2} of Dry DSR at different growth stage as influenced by different nutrient management approaches

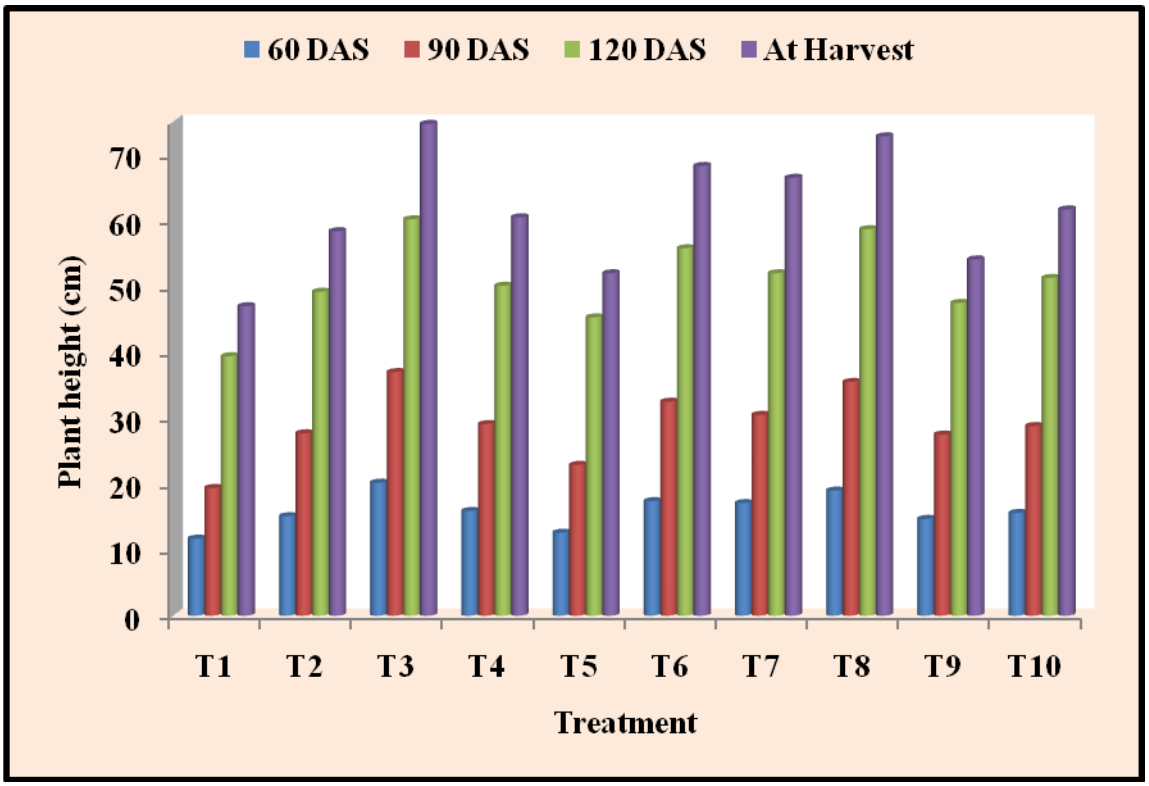


Fig 9. Plant height of Dry DSR at different growth stages as influenced by different nutrient management approaches

on SSNM approach. Raghu (2013) reported that STCR approach produced significantly higher plant height, more number of leaves per hill, number of productive tillers per hill, dry matter production, grain and straw yield as compared to RDF and STL method in rice.

5.3.2 Influence of different nutrient management approaches on nutrient uptake by Dry DSR

Nutrient uptake also plays an important role in the determination of yield potential in Dry DSR. Application of inorganic fertilizer through different nutrient management approaches based on targeted yield along with FYM improved the uptake of NPK over other treatments. The increased N, P and K uptake might be due to the higher nutrient supply as compared to RDF, STL method and NE. The nutrient retained in the soil after harvest of the crop mainly depends on both supply of nutrients through various sources and uptake by the crop. The results are in conformity with outcome of Umesh *et al*. (2014) who reported that the targeted yield based fertilizer application either by SSNM or STCR approach recorded significant improvement in uptake of N, P, K, S, Zn and Fe.

It has been proved that, application of nutrients through different nutrient management approaches along with recommended FYM improves the absorption and utilization of major nutrients. Total uptake (grain + straw) of nutrients was significantly higher with treatment receiving SSNM for targeted yield of 55 q ha^{-1} (117.72, 40.50, 151.93 and 16.11 kg N, P, K and S ha^{-1}, respectively) followed by STCR approach targeted yield of 55 q ha^{-1} (106.09, 31.19, 130.36 and 14.42 kg N, P_2O_5, K_2O and S ha^{-1}, respectively) as compared to other treatments (Table 11, 12, 13 & 14 and Fig. 10). It might be due to application of balanced fertilization based on target yield resulting in higher total NPK & S uptake. The higher nutrient uptake is well reflected in terms of higher grain and straw yield of Dry DSR (Table 10). Obviously this could be due to application of nitrogen in four splits, potash in two splits and along with required phosphatic fertilizers; this might be the reason for higher uptake of nutrients by the rice crop. The results are in line with the different research workers *viz.,* Sharma and Mittra (1989) reported that uptake of N, P and K increased significantly with increasing N levels. Further, Sagar and Reddy (1995) reported that the uptake of P and K in grain and straw of rice was significantly increased with the split application of higher levels of N

and K. Surendra Singh and Sarkar (2001) indicated that application of 210:90:150 kg NPK ha^{-1} as per SSNM approach recorded significantly higher NPK uptake 158:13:160.7 kg ha^{-1} compared to state recommended dose of 100:60:40 kg NPK ha^{-1} under wheat-maize cropping system. Riazeddin Ahamed *et al.* (1999) reported that fertilizer application based on STCR significantly increased uptake of nitrogen (61.9-153.1 kg ha^{-1}), phosphorus (8.6-32.8 ha^{-1}) and potassium (84.1-263.6 ha^{-1}) by rice.

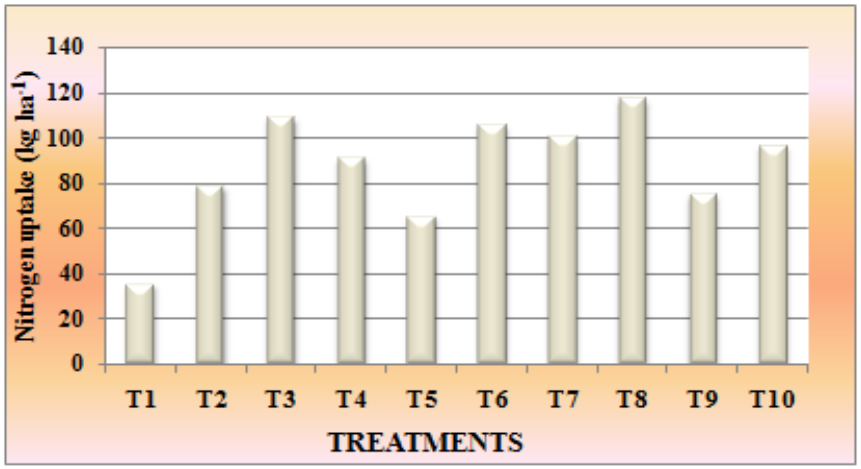
Application of nutrients through different nutrient management approaches improves the absorption and utilization of micronutrients. Total uptake of zinc and iron was significantly higher with treatment receiving SSNM for targeted yield of 55 q ha^{-1} (342.4 and 3622.1 g ha^{-1}, respectively) followed by STCR approach targeted yield of 55 q ha^{-1} (331.1 and 3382.4 g ha^{-1}, respectively) over other treatments (Table 14, 15 and Fig.11). This might be attributed to higher dry matter production of Dry DSR (Table 7) and also attributed to enhanced nutrient availability with the application of optimum rate of nutrients deficient in soil. These nutrients play an identical role in case of N content and uptake of zinc. This is because, Zn had equal role in N metabolism. Similar result reported by Chatterjee *et al.* (1996). Higher uptake of nutrients *viz*., nitrogen (183.10 kg ha^{-1}), phosphorus (71.41 kg ha^{-1}), potassium (169.84 kg ha^{-1}), zinc (413.8 g ha^{-1}) and Iron (3125.2.8 g ha^{-1}) were recorded with nutrients application through SSNM approach over RDF and other soil test methods Madhusudhan (2013).

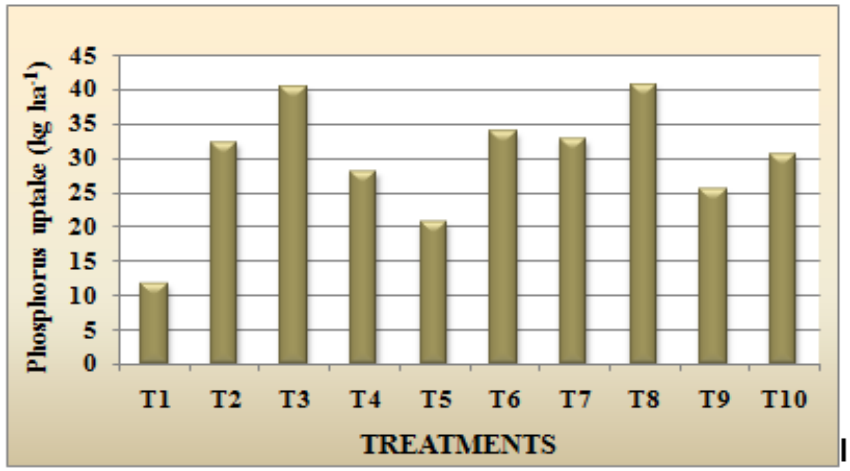
5.3.3 Influence of different nutrient management approaches on nutrient use efficiency (NUE) of Dry DSR

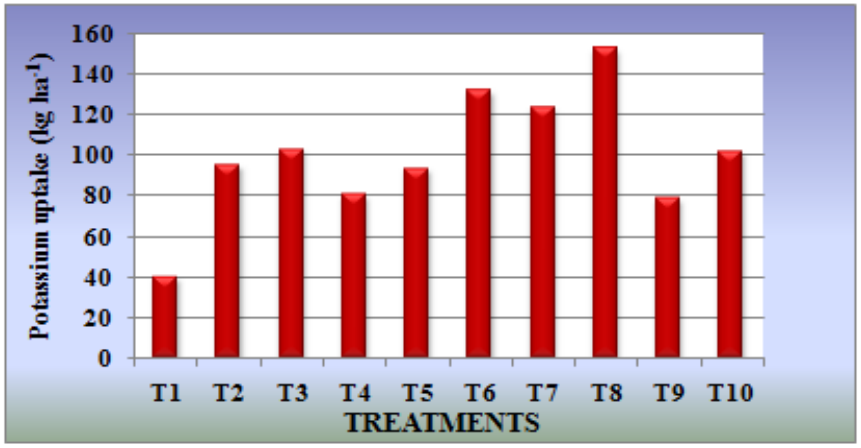
In the present study, influence of different nutrient management approaches has helped in meeting the rhythmatic demand of the crop. Obviously, all these could have contributed for higher nutrient use efficiency and agronomic efficiency of different nutrients.

5.3.3.1 Nutrient use efficiency (NUE)

Nutrient use efficiency is the ratio of difference between the nutrient uptake by a crop in fertilized plot and nutrient uptake by a crop in control plot to the amount of nutrient applied. Hence, the nutrient use efficiency depends on nutrient uptake by crop in control and fertilized plot and the amount of nutrient supplied to the respective plots. The higher nitrogen use efficiency (54.88 %) was recorded in SSNM approach targeted yield







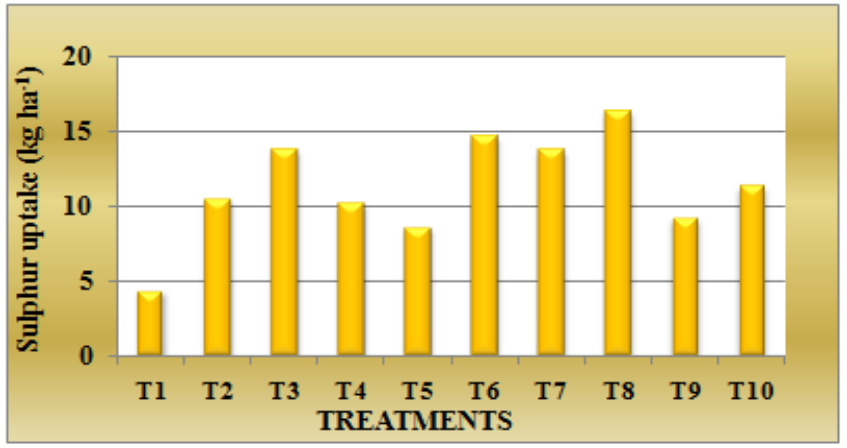
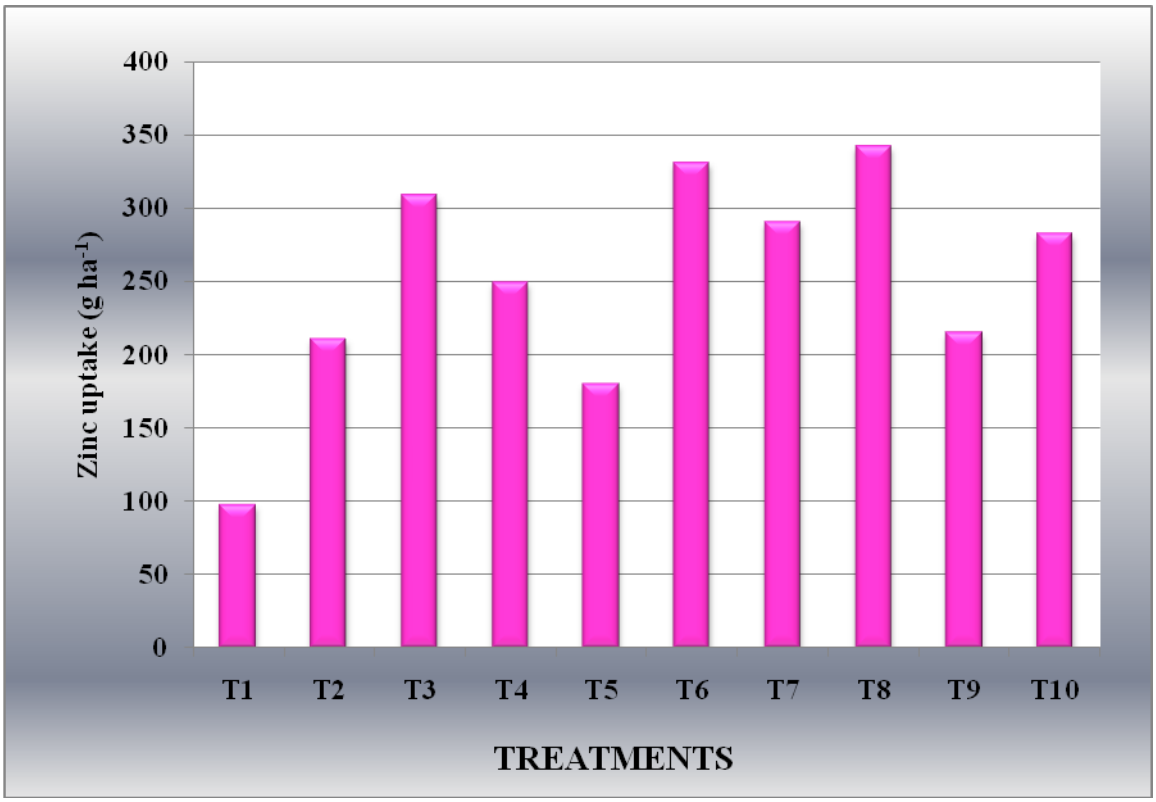


Fig. 10: Effect of different nutrient management approaches on total nutrient uptake (N, P, K and S) by Dry DSR



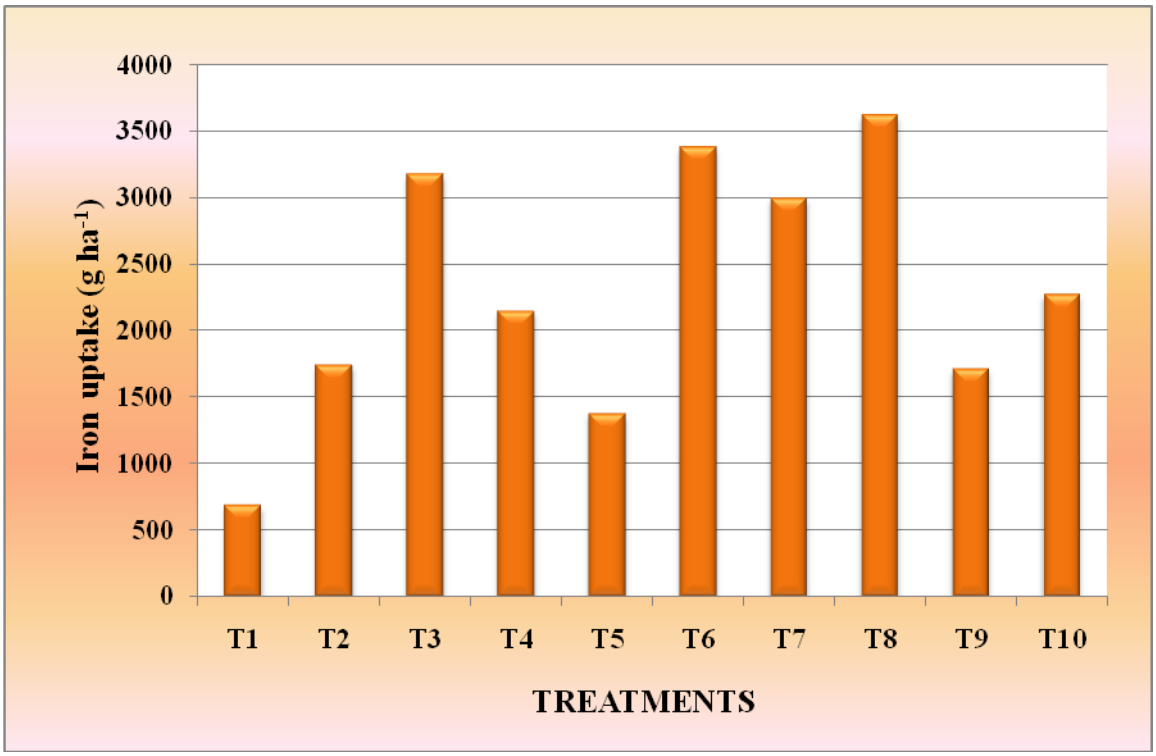


Fig. 11: Effect of different nutrient management approaches on total Zn and Fe uptake by Dry DSR

of 55 q ha^{-1} followed by the application of fertilizers through STCR approach targeted yield of 55 q ha^{-1} (53.80 %) and SSNM approach targeted yield of 45 q ha^{-1} (51.54 %). Whereas, lowest nitrogen use efficiency (29.39 %) was observed in farmer practice. The higher use efficiency of phosphorus (65.56 %) was observed with treatment receiving SSNM approach targeted yield of 55 q ha^{-1}, followed by the application of fertilizers through STCR approach targeted yield of 55 q ha^{-1} (63.11 %). Lowest phosphorus use efficiency (16.87 %) was observed in farmer practice. The higher potassium use efficiency of (130.94 %) was obtained with nutrient expert attainable yield of 55 q ha^{-1} followed by the application of fertilizers through STCR approach targeted yield of 55 q ha^{-1} (109.30 %) as compared to rest of other treatments and lowest potassium use efficiency (80.18 %) was noted with farmer practice of fertilization (Table 17 and Fig.12). The higher nutrient use efficiency might be due to the higher uptake of nutrient with increase in the rate of application of fertilizers. The results are in conformity with the findings of Ferguson *et al.* (2002) reported that recovery efficiency of fertilizer N (REN) in rice increased significantly with SSNM. On an average REN increased by about 29 per cent high with SSNM compared to farmers fertilizer practice. Abdulrahaman *et al.* (2002) reported that application of nutrients through SSNM approach increased fertilizer use efficiency of N by (12 to 36 %), P (8 to 13%) and K (>100%) and average rice yield in the SSNM (5.6 to 6.4 t ha^{-1}) over farmers' practice. The "Agronomic Efficiency" and "Recovery Efficiency" of NPK of SSNM plot were higher than those of FFP as reported by Khuong *et al*. (2007).

5.3.3.2 Agronomic efficiency (AE)

Agronomic efficiency is the ratio of difference between the grain yield from the fertilized plot and grain yield from the control plot to the amount of nutrients added hence, agronomic efficiency completely influenced by the grain yield of crop. The higher agronomic efficiency of nitrogen by Dry DSR was found in SSNM for targeted yield of 55 q ha^{-1}(22.60 kg grain kg^{-1} N applied) followed by STCR approach targeted yield of 55 q ha^{-1} (22.38 kg grain kg^{-1} N applied) and lowest agronomic efficiency of nitrogen (11.53 kg grain kg^{-1} N applied) was noted with farmer practice. The results are in conformity with outcome of Mishra *et al.* 2006. The agronomic N use efficiency was 83 per cent greater with SSNM than FFP (Khurana *et al.,* 2007). The application of fertilizers through STCR approach targeted yield of 55 q ha^{-1} resulted in higher agronomic

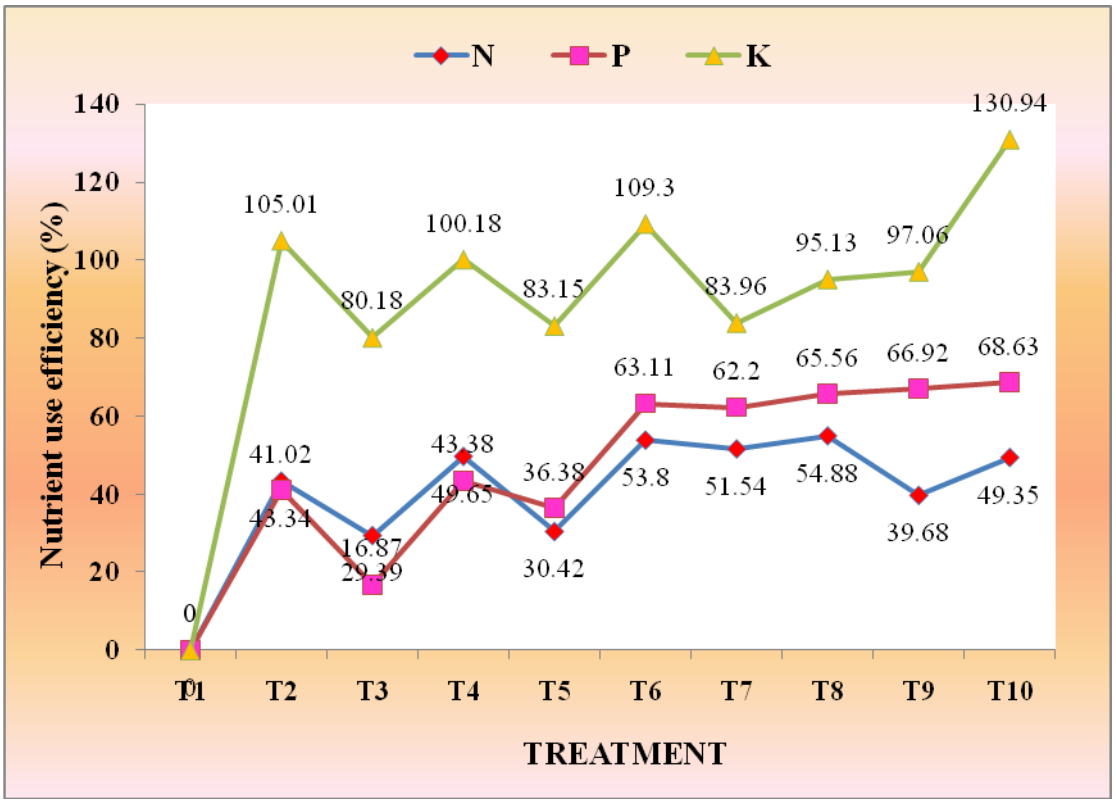


Fig. 12: Effect of different nutrient management approaches on NPK use efficiency in Dry DSR

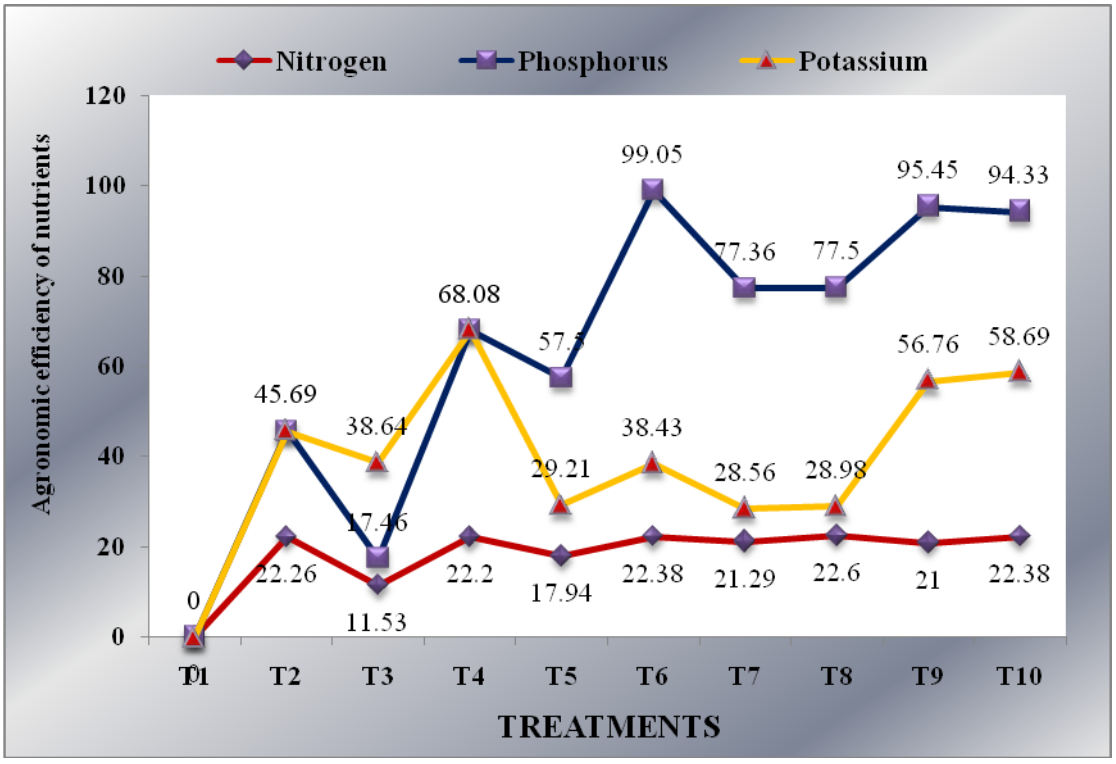


Fig. 13: Agronomic efficiency of NPK by Dry DSR as Influenced by different nutrient management approaches

efficiency of phosphorus (99.05 kg grain kg^{-1} P_2O_5 applied) followed by nutrient expert for attainable yield of 55 q ha^{-1} (94.33 kg grain kg^{-1} P_2O_5 applied respectively) and SSNM approach targeted yield of 55 q ha^{-1}(77.50 kg grain kg^{-1} P_2O_5 applied) and lowest agronomic efficiency of phosphorus (17.46 kg grain kg^{-1} P_2O_5 applied) was noted with farmer practice. Navin *et al*. (2006) reported that agronomic efficiency of phosphorous (115.3 kg kg^{-1} nutrient) was high upto 60 kg ha^{-1} phosphorous fertilization. Similarly, the higher agronomic efficiency of potassium (68.08 kg grain kg^{-1} K_2O applied) was obtained with STL method of fertilization followed by nutrient expert for attainable yield of 55q ha^{-1} (58.69 kg grain kg^{-1} K_2O applied respectively) (Table 18 and Fig.13). The higher agronomic efficiency might be due to the higher grain yield with increase in the rate of application of fertilizers. The results are in conformity with outcome of Sourov and Sanyal (2007) site-specific K management relatively increased agronomic use efficiency of K by treatment site specific K management of 150 per cent.

5.3.4 Microbiological properties of rhizospheric soil of rice as influenced by different nutrient management approaches

In pooled data, significantly higher bacterial population was recorded at harvest in SSNM approach targeted yield of 55 q ha^{-1} (25.73 cfu $\times 10^6$ g^{-1}) followed by SSNM for targeted yield of 45 q ha^{-1} and STCR for targeted yield of 55 q ha^{-1} (23.70 and 23.11 cfu $\times 10^6$ g^{-1}, respectively) (Table 19 and Fig. 14). This might be due to application of optimum quantity of fertilizers especially N and K along with FYM, which has resulted in more organic carbon accumulation and lead to more microbial activity. The results are in line with the earlier findings of Salinas-Garcia *et al*., 2002. The rise in the microbial populations after harvest could be due to favourable environment and the availability of food sources at that stage due to the residual organic materials (Gayathry, 2006).

Pooled data of two years revealed that the fungal and actinomycetes population was significantly higher with SSNM for targeted yield of 55 q ha^{-1} (8.62 cfu $\times 10^3$ g^{-1} and 10.14 cfu $\times 10^4$ g^{-1}, respectively) followed by SSNM for targeted yield of 45 q ha^{-1} (8.18 cfu $\times$103 g^{-1} and 9.74 cfu $\times 10^4$ g^{-1}, respectively) and STCR for targeted yield of 55 q ha^{-1} (7.34 cfu $\times 10^3$ g^{-1} and 9.45 cfu $\times 10^4$ g^{-1}, respectively), (Table 19 and Fig. 14). This may due to the positive influence of N and K from inorganic source at initial stages by masking the initial inhibitory effect of organic acids produced during decomposition which promoted the rapid multiplication of microflora in the soil. This is in line with the findings of Uphoff (2006).

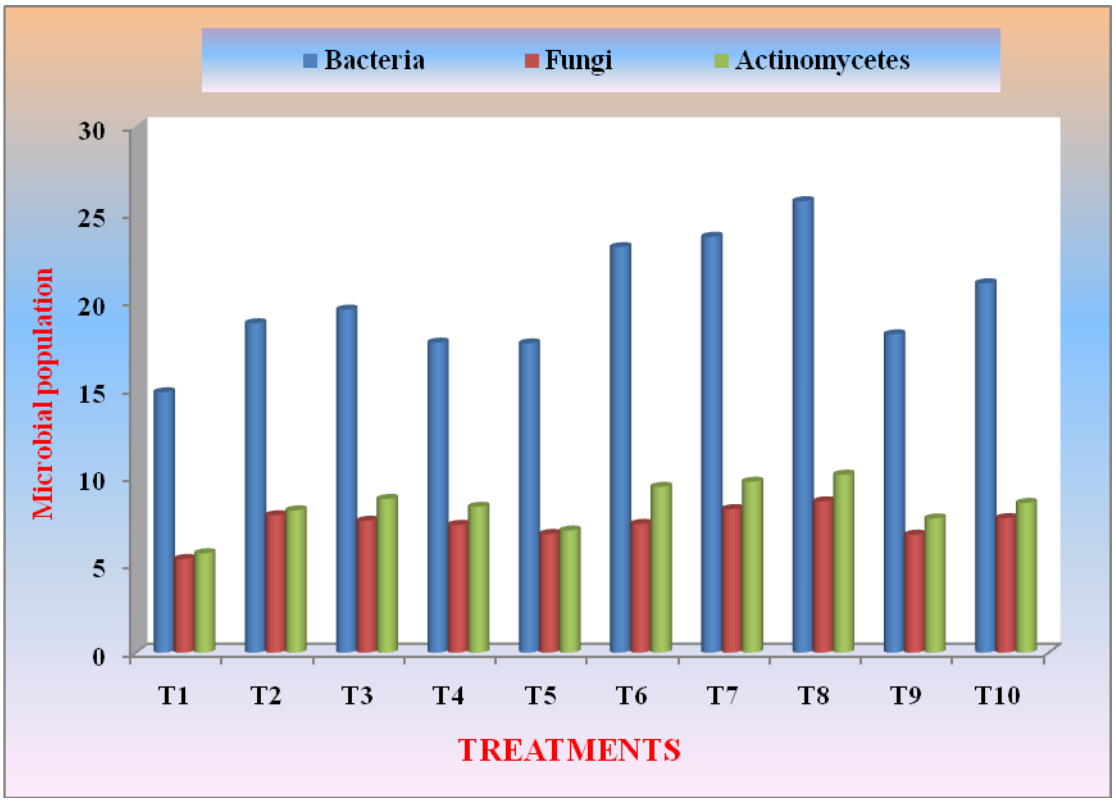


Fig. 14: Microbial population at harvest of Dry DSR as influenced by different nutrient management approaches

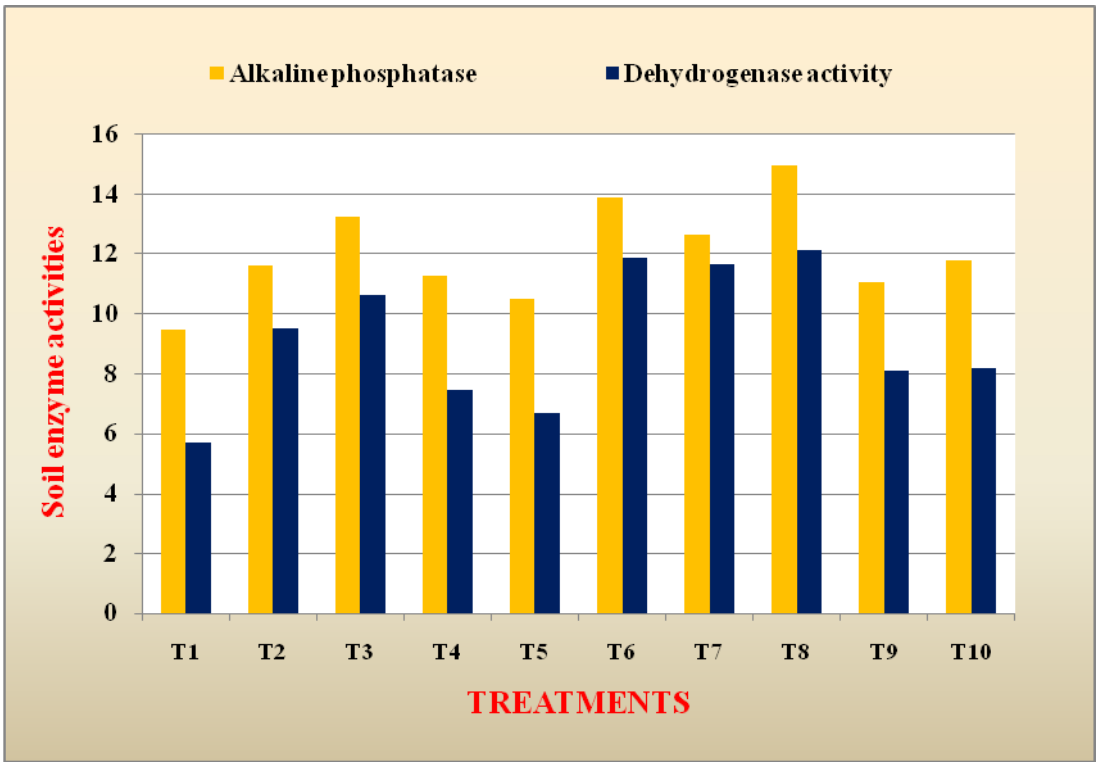


Fig. 15: Soil enzyme activities at harvest of Dry DSR as influenced by different nutrient management approaches

Higher microbial populations under reduced water condition could promote increased rate of decomposition that could result into better crop growth benefitting from favourable soil microbial properties. In general, there was a gradual change in the populations of microbes indicating phase changes in the soil environment. The nutrient level and environmental conditions could play a crucial role in the growth of microbes implying that healthy soils support microbial growth which has positive effects on the overall plant performance (Satyanarayana and Prasad, 2002).

In the present investigation the phosphatase and dehydrogenase enzymes activities in rhizosphere was significantly higher with the SSNM approach targeted yield of 55 q ha^{-1}. The highest phosphatase activity (14.91 µg PNP g^{-1} soil hr^{-1}) of soil was found with application of nutrients as per SSNM for targeted yield of 55 q ha^{-1} as compared to absolute control (9.47 µg PNP g^{-1} soil hr^{-1}) (Table 20 and Fig. 15). Shedzhen *et al*. (1991) found that application of N, P, K, B, Co, Mo. Zn, Mn and Cu increased the phosphatase activity. Similarly the higher dehydrogenase activity was recorded in the treatment receiving SSNM for targeted yield of 55 q ha^{-1} (12.09 µg TPF formed g^{-1} soil hr^{-1}) and lowest dehydrogenase activity was recorded in control (5.68 µg TPF formed g^{-1} soil hr^{-1}) (Table 20 and Fig. 15). This was mainly due to the application of balanced levels of NPK fertilizers as per SSNM approach in combination with FYM resulted in higher enzymatic activity. These results accordance with the findings of Singaram and Kamalakumari (1995) they found that activities of soil enzymes were found to be more pronounced with application higher levels of NPK fertilizers in combination with FYM. These results are also corroborates with the findings of Apoorva *et al.* (2010) and Salinas-Garcia *et al*. (2002).

The enzyme dehydrogenase is regarded as an indicator of total life in the soil and a strong indicator of biological activity. The enhancement of soil chemical, biological, and microbiological properties more in Dry DSR under organic and inorganic treatments due to nutrient level and environmental conditions could helps microbial growth which has positive effects on the overall plant performance. The presence of more microbial and biological activity in the rhizosphere leads to beneficial functions for crops such as plant growth promotion, phosphate solubilization, induced systemic resistance and protection against pathogens (Rao, 2005).

5.3.5 Economics of Dry DSR as influenced by different nutrient management approaches

Economics of any treatment is the deciding factor in many situation to judge its applicability in the field condition to recommend farming community to obtain better return with minimum investment in cultivation.

The cost of cultivation of Dry DSR was highest (₹ 45,851 ha^{-1}) with farmer practice fertilization due to higher quantity of fertilizers application rates as compared to other treatments. SSNM approach targeted yield of 55 q ha^{-1} registered (₹ 39,021 ha^{-1}) cost of cultivation and it reduced fertilizer cost by 14.9 per cent as compared to farmer practice and these results are confirmation with findings of Guanghuo Wang *et al*. (2001) reported that the site-specific nutrient management led to reduction of the average fertilizer cost by $15 ha^{-1} $crop^{-1}$ and an increase in GRF by $ 88 ha^{-1} $crop^{-1}$ compared with FFP.

Among the different treatments, the highest gross returns, net returns and BC ratio (₹ 1,20,668 ha^{-1}, ₹ 81,647 ha^{-1} and 3.10, respectively) were recorded with SSNM approach for targeted yield of 55 q ha^{-1} followed by STCR approach for targeted yield of 55 q ha^{-1} (₹ 1,14,168 ha^{-1}, ₹ 76,303 ha^{-1} and 3.02, respectively) and nutrient expert for attainable 55 q ha^{-1} (₹ 1,05,419 ha^{-1}, ₹ 68,819 ha^{-1} and 2.89, respectively) as compared to farmer practice (₹ 1,11,072 ha^{-1}, ₹ 65,221 ha^{-1} and 2.43, respectively) (Table 21 and Fig. 16) and rest of the other treatments. This is mainly due to higher grain and straw yield obtained with least investment in fertilizer brought lower cost of cultivation leads more gross returns, net returns and finally BC ratio. These results corroborated the findings of Dhillon *et al.* (2006) noticed the superiority of the target yield concept over the other practices as it gave higher yields and optimal economic returns. Pampolinoa *et al.* (2007) evaluated the economic benefits of SSNM in farmer's fields. The results showed that the net annual benefit due to use of SSNM was US $ 34 ha^{-1} per year in Vietnam, 106 US $ ha per year in the Philippines, and US $ 168 ha^{-1} year in India. The increased benefit with SSNM was attributed to increased yield rather than reduced costs of inputs. Abdulrachman *et al.* (2002) the yields with SSNM were close to the yield goal and 16 per cent greater than the FFP. The fertilizer cost was about US $ 40 ha^{-1} in both SSNM and FFP but the profitability (gross return over fertilizer cost) increased by US $130 with SSNM due to increase in yield. Lowest gross returns, net returns and BC ratio was

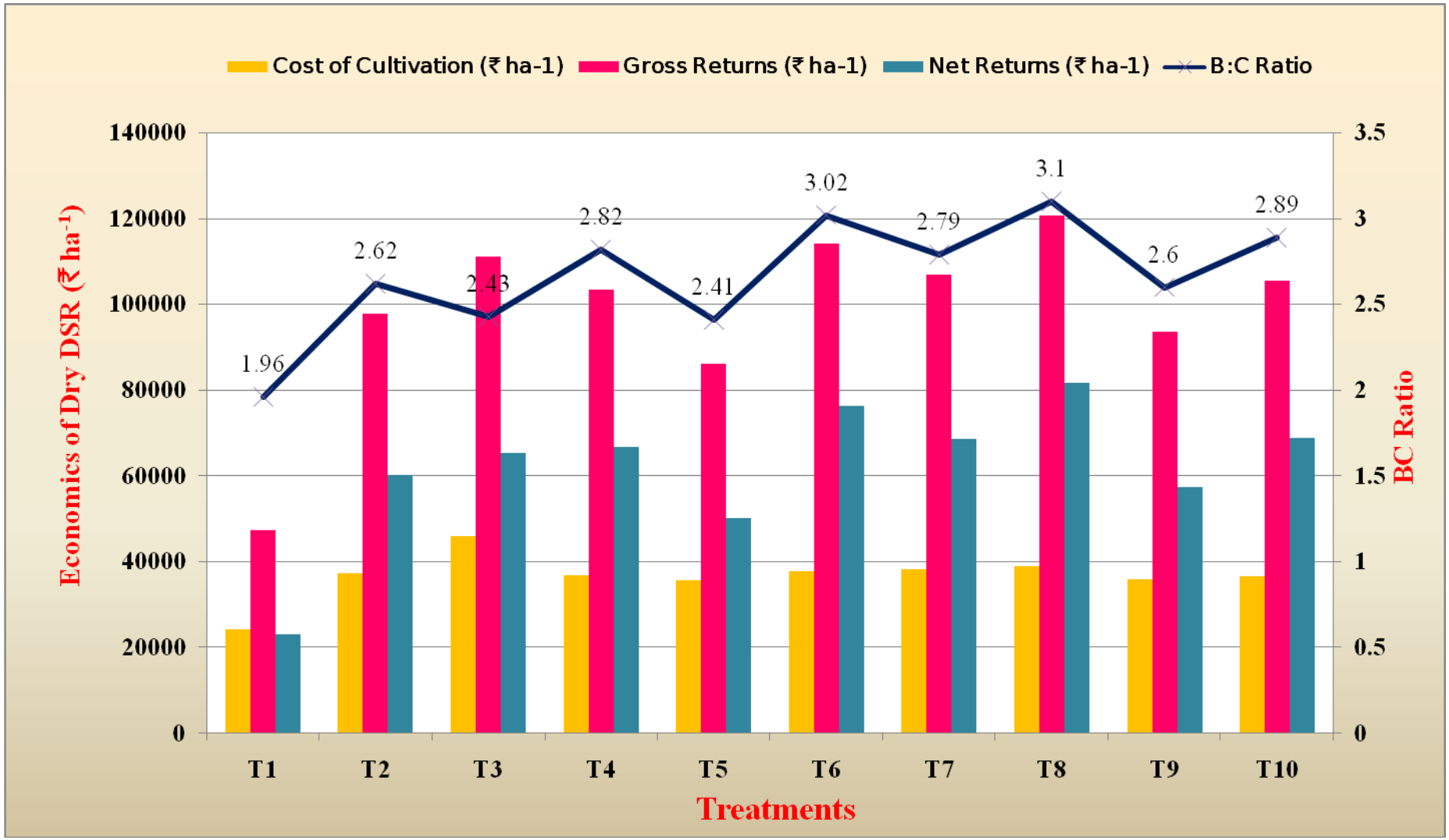


Fig. 16: Economics of Dry DSR as influenced by different nutrient management approaches

obtained with absolute control (₹ 47,312 ha^{-1}, ₹ 23,002 ha^{-1} and 1.96, respectively). This is due to lower grain yield and without application of chemical fertilizer. The results are in close proximity with the findings of Wang *et al.* (2005) and Milp-Chand *et al*.(2006)

5.4 MUSTARD

5.4.1 Residual effect of different nutrient management approaches on growth, yield and yield attributes of mustard

Mustard grown in succession after rice in Dry DSR-Mustard cropping sequence indicated significant variations in its performance due to residual effects of different nutrient management approaches. The response of crop growth, yield parameters and yield of mustard were slightly better in first year (2015-16) than second year (2016-17) but, response of crop growth, yield parameters and yield were similar in both the years. Therefore, only pooled data of two years are discussed below.

Pooled analysis showed that the residual effect of different fertilizer prescribed approaches to rice crop exerted significant influence by the seed yield of mustard during both the years of experimentation. Significantly higher seed yield (592 kg ha^{-1}) of mustard was obtained with the residual effect of nutrients through SSNM approach targeted yield of 55 q ha^{-1} and it was found on par with farmer practice (570 kg ha^{-1}), STCR approach targeted yield of 55 q ha^{-1} (544 kg ha^{-1}) and SSNM approach targeted yield of 45 q ha^{-1} (531 kg ha^{-1}). Whereas, lowest seed yield recorded in absolute control (217 kg ha^{-1}). Similar trend was noticed with stover yield, significantly higher (1856 kg ha^{-1}) stover yield of mustard was recorded with residual effect of nutrient through SSNM approach targeted yield of 55 q ha^{-1} followed by farmer practice (1810 kg ha^{-1}) and STCR approach targeted yield of 55 q ha^{-1} (1708 kg ha^{-1}). The lowest stover yield was recorded in absolute control (660 kg ha^{-1}) (Table 24, Fig. 17 and Plate 8). The better performance of succeeding mustard could be due to higher amount of available nitrogen, phosphorous and potassium after harvest of Dry DSR (Table 33). BPT-5204 being relatively medium duration one, removed lower amount nutrient from soil and made substantial build up in soil as reflected higher soil nutrient status after harvest of rice. Sharma *et al.* (1999) residual effect of different levels of fertility applied to soybean, showed significant variation in growth and seed yield of mustard. Gawai (2005) studied that the residual effect of application of 100 per cent RDF and 5 tone FYM ha^{-1} to

proceeding crop sorghum resulted in significantly higher grain and haulm yield of chickpea. Similar results reported by Pankaj *et al.* (2013) and Mahala *et al.* (2006).

The significantly higher (314.5) number of silique plant^{-1} of mustard was recorded with the treatment receiving residual effect of SSNM approach targeted yield of 55 q ha^{-1} followed by T_6: STCR approach targeted yield of 55 q ha^{-1} (310.7), T_3: Farmer practice (290.6) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (286.4). It was significantly superior over rest of the treatments. Lowest number of silique plant^{-1} was observed with absolute control (180.5) (Table 23 and Fig. 17). The higher number of seeds (13.6) per silique of mustard was mainly due to residual effect of nutrient application through SSNM for Dry DSR as compared to RDF and NE which showed the benefits of balanced fertilization. These results are in accordance with Singh *et al.* (2001) while studying the response of brown sarson to residual effect of organic manure, nitrogen and transplanting dates of rice observed that the number of siliquae per plant and seed yield of mustard increased with increasing N rates. The value for 1000-grain weight was highest at 150 kg N ha^{-1} and siliquae per plant was highest with FYM application.

The highest oil yield (240.6 kg ha^{-1}) obtained with SSNM approach targeted yield of 55 q ha^{-1}. The residual effect on oil content (40.8 %) was non significant statistically. However, higher oil content was recorded in SSNM approach targeted yield of 55 q ha^{-1}. This might be due to higher residual availability of applied nutrients. That leads to proper functioning of many enzymes, which aids in biochemical reaction within the plant which helps in bio-synthesis of oil. This might have resulted in higher oil content compared to control. SSNM approach targeted yield of 55 q ha^{-1} produced significantly higher oil yield (240.6 kg ha^{-1}) it might be due to higher seed yield and oil content resulted in production high oil yield. These results are in accordance with Singh *et al.* (2001)

The reason for higher seed yield of mustard was attributed to the higher values of yield components which intern depends on different growth components *viz.,* plant height, number of primary branches per plant and total dry matter (Table 22 and Fig 18). The total dry matter produced in the mustard plant was differed significantly due to target yield approach. The total dry matter produced at harvest was higher in residual effect of nutrients through SSNM approach targeted yield of 55 q ha^{-1} (67.1 g plant^{-1}), which was on par with STCR approach targeted yield of 55 q ha^{-1} (66.3 g plant^{-1}) (Table

22 and Fig. 18) and these are significantly higher as compared to other treatments. The increased dry matter was usually associated with higher number of branches per plant (Table 23) which led to greater accumulation of photosynthesis. Similar results reported by Shreenivas (2016) studied the residual effect of different nutrient management approaches on growth and yield of chickpea. Significantly higher plant height, total number of branches per plant, total dry matter production, seed yield (2.99 t ha^{-1}) and test weight (25.25 g) of chickpea were registered with the residual effect of nutrient application through SSNM approach targeted yield of 8.0 t ha^{-1} for maize as compared to STCR, STL and farmer practices.

The higher dry matter accumulation in seeds might be due to higher photosynthetic ability of the crop as reflected through higher total dry matter production (TDMP) in leaf and higher translocation of metabolites from leaf and stem to reproductive part during reproductive phase. Several research workers also reported higher TDMP and accumulation in reproductive part of residual crop with elevated fertility level of preceding crop. Rajesh (2015) reported that residual effect different levels of nitrogen application in Dry DSR lead to produced maximum number of capsules per plant, number of seeds $capsules^{-1}$ and test weight (g) in sesame. Seed weight per plant is reflected by the dry matter accumulation in grains and intern it largely depends upon on the number of pods per plant.

The plant height contributed for total dry matter production which was significantly higher in residual effect of nutrients through SSNM approach targeted yield of 55 q ha^{-1} (123.7 cm) followed by STCR approach targeted yield of 8.0 t ha^{-1} (117.9 cm) at harvest. The reduction in the plant height recorded in absolute control (80.7 cm) (Table 22 and Fig. 18). This might be due to inadequate supply of nutrients resulting in the reduction of growth and yield attributes which ultimately produce lesser seed yield. These results are in conformity with the findings of Shreenivas (2016) and Chavan *et al*. (2014).

The number of primary branches which was also a contributing factor for dry matter production and finally to the seed yield also differed due to targeted yield approaches. All these growth parameters could have been promoted by the higher residual quantity of nutrients made available by the different treatments to mustard crop. This was also evidenced through higher uptake of nutrients (Table 25 to 27).

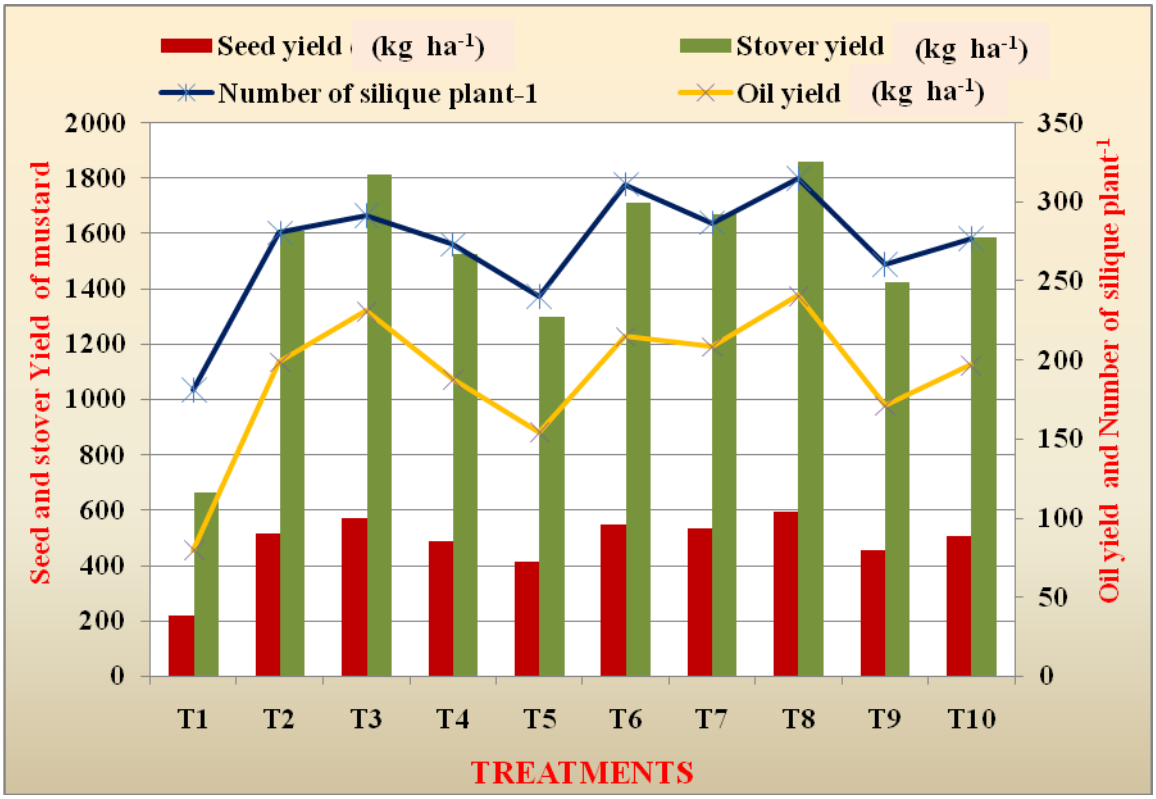


Fig. 17: Yield parameters of mustard as influenced by residual effect of nutrient applied by different nutrient management approaches to Dry DSR

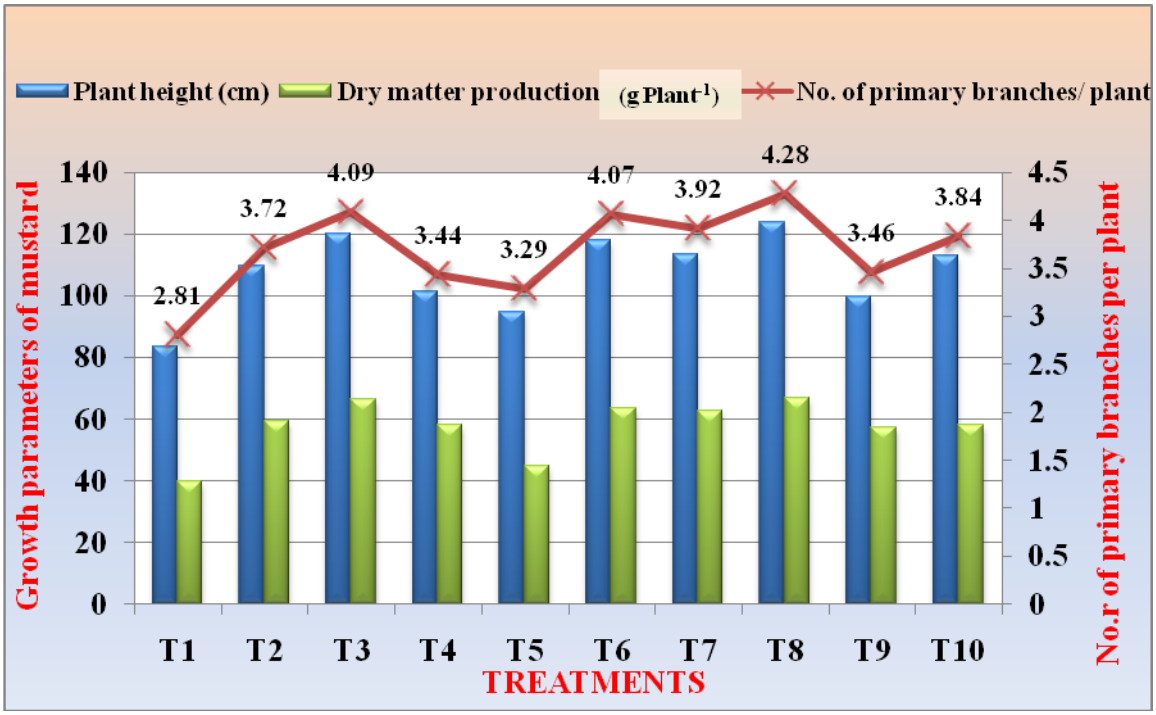


Fig. 18: Growth parameters of mustard as influenced by residual effect of nutrient applied by different nutrient management approaches to Dry DSR

T_8: SSNM approach (Targeted yield: 55 q ha^{-1})

T_3: Farmer practice

Plate 8: Comparative view of residual nutrient effect of various nutrient management approaches on mustard

5.4.2 Residual effect of nutrients applied as per different nutrient management approaches on nutrient uptake and economics of mustard

Total uptake (seed + stover) of nutrients are associated with the metabolic activities of plants and with the concentration and distribution of ions in the external medium. It has been proved that, application of nutrients at optimum dose improves the absorption and utilization of nutrients. Nutrient uptake by crop is the manifestation of biomass production and available nutrient status of soil. In the present study, mustard was sown in the plots where preceding direct seeded rice was cultivated. The total uptake of nutrients were significantly higher with the residual effect of nutrients through SSNM approach for targeted yield of 55 q ha^{-1} (26.07, 6.10 and 34.99 kg N, P_2O_5 and K_2O ha^{-1}, respectively) followed by STCR approach targeted yield of 55 q ha^{-1} (21.91, 4.88 and 30.99 kg N, P_2O_5 and K_2O ha^{-1}, respectively) over absolute control (7.40, 0.98 and 11.49 kg N, P_2O_5 and K_2O ha^{-1}, respectively). The higher uptake of nitrogen, phosphorous and potassium by mustard might be due to higher biomass production coupled with higher availability of nitrogen, phosphorous and potassium after harvest of Dry DSR (Table 25, 26 & 27 and Fig. 19). The higher availability of N, P and K in SSNM or STCR treated plot may be due to mineralization of organic manure applied for the previous crop and also root biomass. Pankaj *et al.,* (2013) opined that conjunctive use of organic and inorganic source of fertilizer *kharif* rainfed rice induced significantly higher residual contribution of nutrients N, P, K and S in the soil available pool thereby increased uptake by lentil plant at harvest. Similar results reported by Shreenivas (2016) reported that application of nutrients through SSNM on maize exerted significant influence on soil available NPK status after harvest of maize.

The increase in growth and yield of mustard further traced back to the improvement in nutrient uptake. Nitrogen, phosphorus and potassium uptake by mustard followed similar trends as that of seed and stover yields per hectare and TDMP. Singh *et al.* (2001) while studying the response of brown sarson to residual effect of organic manure, nitrogen and transplanting dates of rice. They observed that P uptake increased with increasing residual N rates from 100 to 150 kg N ha^{-1} whereas N and K uptake increased only up to 100 kg N ha^{-1}. Bandana Singh Chandel *et al.* (2014) studied that the growth, yield attributes and yields of succeeding maize were maximum uptake of N, P, K and S by wheat (200, 23.8, 184 and 30.4 kg ha^{-1}) was the highest at 150 kg N + 20 kg S + 10 t FYM ha^{-1} and the lowest uptake in control. Chaudhary *et al.* (1998) observed higher

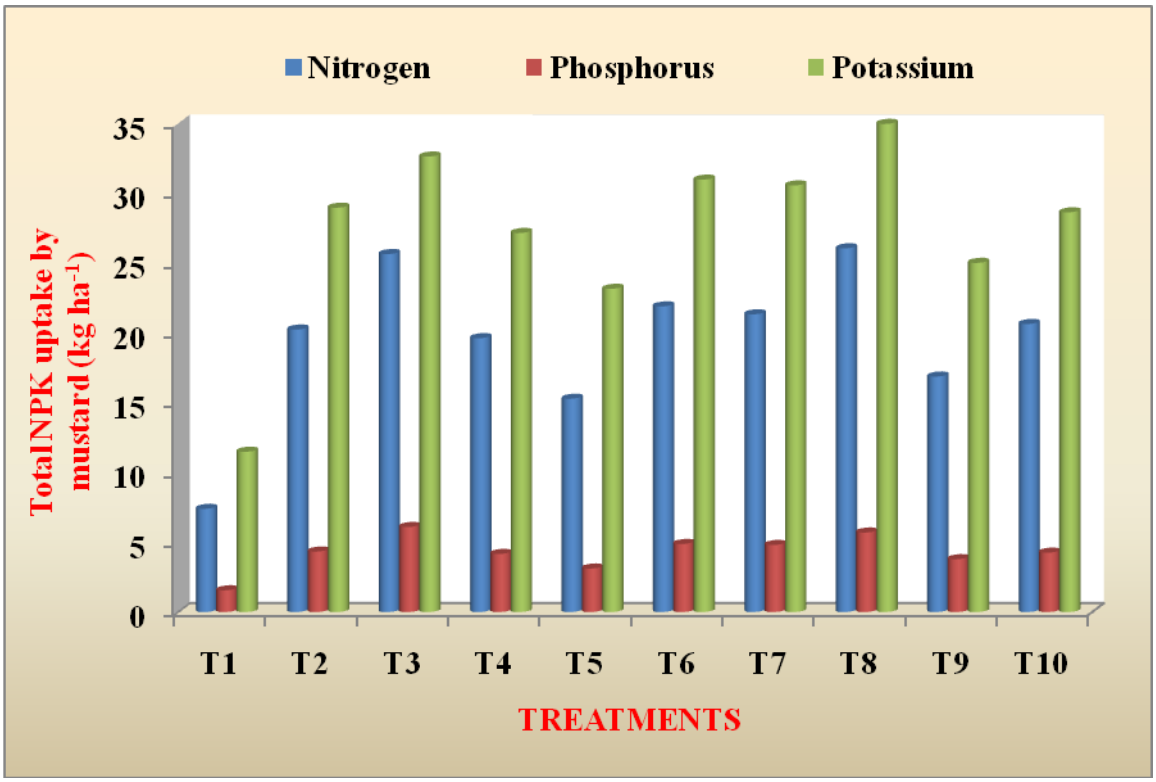


Fig. 19: Residual nutrients effect applied by different nutrient management approaches to rice on total nutrient (N, P and K) uptake by mustard

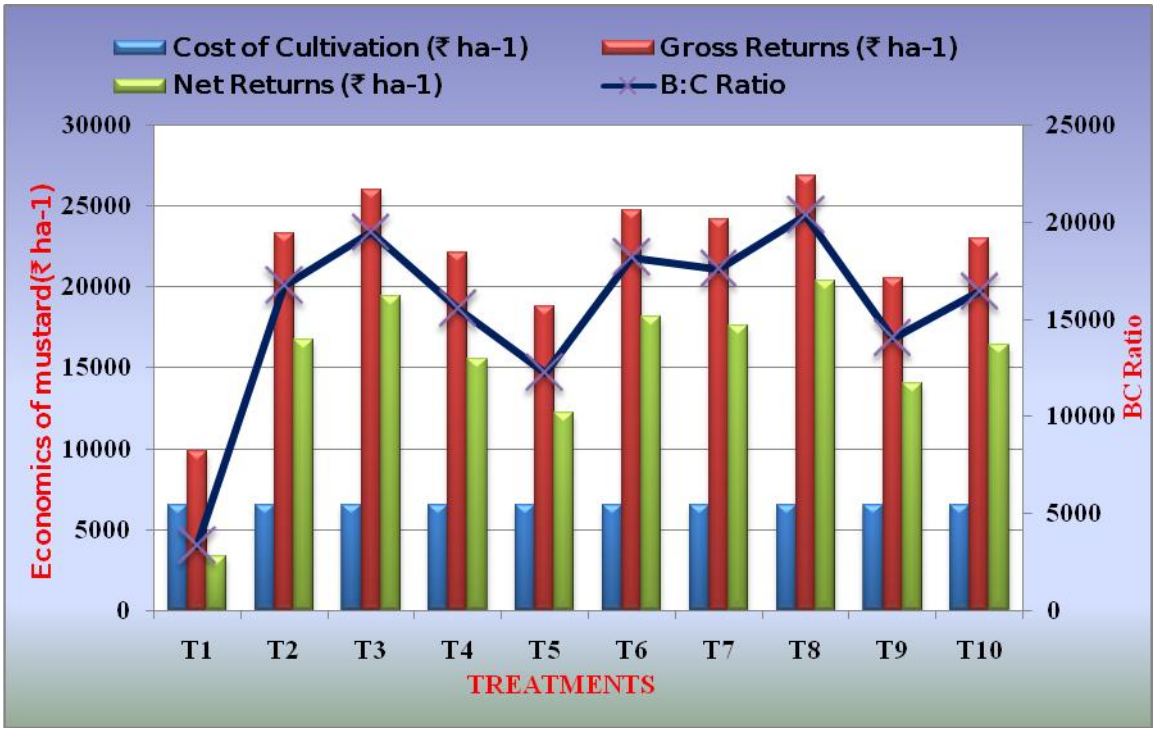


Fig. 20: Economics of mustard as influenced by residual effect of different nutrient management approaches

dry matter in chickpea resulted in higher uptake of nutrients in SSNM approach. Similar results reported by Shreenivas (2016).

The cost of cultivation for the succeeding mustard crop is same in all the treatments of preceding Dry-DSR (₹ 6,050 ha^{-1}, ₹ 7,030 ha^{-1} and ₹ 6,540 ha^{-1}) during both the years of study and in pooled means respectively. Higher gross returns obtained with SSNM approach targeted yield of 55 q ha^{-1} (₹ 26,886 ha^{-1}) followed by farmer practice (₹ 25,998 ha^{-1} and STCR approach targeted yield of 55 q ha^{-1} (₹ 24,735 ha^{-1}). This might be due to higher seed yield, stover yield with lowest cost of cultivation leads to higher gross returns as compared to rest of the treatments. Similarly net return and BC ratio was found highest with residual nutrients of SSNM approach targeted yield of 55 q ha^{-1} (₹ 20,346 ha^{-1} and 4.14, respectively) followed by farmer practice (₹ 19,458 ha^{-1} and 4.0, respectively) and STCR approach targeted yield of 55 q ha^{-1} (₹ 18,195 ha^{-1} and 3.81, respectively). Lowest net return and BC ratio was observed with absolute control (₹ 3,324 ha^{-1} and 1.52, respectively) (Table 28 and Fig. 20). This might be due to lower seed yield resulted in lower gross returns, net return and BC ratio as compared to rest of the treatments. Similar findings were reported by Pankaj *et al.* (2013) in DSR-Lentil cropping sequence a significantly higher yield and economic return (B:C=0.72) was noted when the crop was grown under the residual effect of 100% N through FYM followed by 50 % RDF + 50 % N through FYM (B:C=0.62) and 100% RDF (B:C=0.54). Similar results were also recorded by Rajesh (2015) in DSR-Sesamum cropping sequence and Shreenivas (2016) in maize-chickpea cropping sequence.

5.5 DRY DIRECT SEEDED RICE-MUSTARD CROPPING SEQUENCE

5.5.1 Influence of different nutrient management approaches on soil fertility status after harvest of mustard crop in Dry DSR-Mustard cropping sequence

Soil health in general refers to the soil productivity and sustainability in long range. It is measured in terms of improvement in physical, chemical and biological properties of soil. The better performance of Dry DSR-Mustard could be due to higher and balanced amount of available nitrogen, phosphorous and potassium after harvest of second crop in rice-mustard cropping system. The results obtained on chemical properties (Table 29) and soil fertility status (Table 30 and 31) after harvest of mustard crop in Dry DSR-Mustard cropping system is discussed below.

5.5.1.1 pH of soil

Soil pH is the single most important property which directly influences the soil fertility by controlling soil chemical reaction, ion exchange by altering surface charge of the colloids. The effect of soil test based nutrient management approach had no consequences in bringing any changes on soil chemical reaction. Non-significant differences were observed between treatments, however highest pH (8.22) was observed in treatment received farmer practice of fertilizers and lowest pH (7.86) was observed in absolute control (Table 31). Soil pH did not influenced significantly even if fertilizer salts are present and salts may depress pH slightly (0.1 pH unit). It might be due to buffering capacity of soil, which offered resistant against change in pH. Tolanur and Badanur (2003) reported that there was no change in pH of soil due to the application of 100 or 50 per cent RDF through inorganic + 50 per cent RDF through FYM as compared to 100 per cent RDF through inorganic alone. The results of present study are also in line with the findings of Singh *et al*. (2012).

5.5.1.2 Electric conductivity

Electric conductivity (EC) of soil is normally influenced by dissolution of salts which is accumulated by addition of organic residues. There was slight increase trend in EC of soil from initial level (0.69 dS m^{-1}) to after harvest (0.82 dS m^{-1}) (Table 32). However, lowest electric conductivity of soil was recorded in absolute control (0.63 dS m^{-1}) followed by nutrient expert (0.70 dSm^{-1}) and highest electric conductivity of soil after harvest of second crop was recorded with treatment receiving farmers practice fertilizer (0.82 dS m^{-1}) followed by SSNM approach targeted yield of 55 q ha^{-1} (0.75 dS m^{-1}). The results are in line with the different researchers. Katkar *et al.* (2011) reported that slightly increased EC of soil due to application of 150 per cent NPK followed by 100 per cent NPK + FYM at 10 t ha^{-1} and lower EC was recorded in control. Tolanur and Badanur (2003) noticed a slight change in EC in soil with the application of 50 per cent RDF through FYM and 50 per cent RDF through fertilizer as compared to 100 per cent RDF through inorganic alone. The results are also in conformity with the findings of Singh *et al*. (2012).

5.5.1.1.3 Organic carbon

Soil carbon is largely governed by the farming practice and climate. The net gain of organic carbon by soil determines soil productivity. Soil organic carbon is regarded as

soil quality indicator, especially organic carbon present in surface soil. In this layer, addition or removal of organic carbon takes place through farm practices. However, addition of organic matter through FYM increased per cent organic carbon in the soil and the highest organic carbon was recorded with treatment receiving SSNM approach targeted yield of 55 q ha^{-1} (6.88 g kg^{-1}) results are in line with the findings of Gangwar *et al.* (2008) and lowest organic carbon (6.79 g kg^{-1}) was noticed with absolute control (Table 31) this may be due to addition of low amount of biomass than rest of treatments. The results are in line with the findings of Shreenivas (2016) with the application for specific yield target along with FYM resulted in non significant change in soil organic carbon.

5.5.1.2 Available N, P_2O_5 and K_2O in soil

The nutrient status of different plots after the harvest was dependent on both supply of nutrients through various approaches and uptake by crops. Compared to initial soil status, addition of nutrients through organic and inorganic fertilizer tended to increase available nutrient status of soil. Available nutrients increased in the soil from first to second year of Dry DSR-Mustard cropping sequence indicating build up of nutrients in SSNM treated plots.

The available nutrients in soil differed significantly with different nutrient management approaches at the end of second (2016-17) year. The balance of N and P were highest with farmer practice (232.40, 130.54 and 281.76 kg N, P and K ha^{-1}, respectively) where as treatment receiving SSNM approach targeted yield of 55 q ha^{-1} (230.8, 82.6 and 329.3 kg N, P and K ha^{-1}, respectively) resulted in higher balance of K, N and P followed by STCR approach targeted yield of 55 q ha^{-1} (225.5, 68.5 and 291.9 kg N, P and K ha^{-1}, respectively) (Table 30 and Fig. 21). It could be due to enhanced nutrient pool at elevated fertility level which might have contributed to higher residual nutrient status of soil by retaining part of external applied nutrients in soil. Similar opinion of elevated fertility levels increased the available nutrient status of the soil after harvest of crop by several researchers. This might be due to release of nutrients from organic matter intern increases ‘N’ in soil was more with SSNM treatments. It was also in accordance with Wijebandara (2007) conducted a field experiment to know the response of rice to different methods of cultivation and nutrient levels and reported residual available N, P and Zn in soil were recorded in treatment receiving 75 per cent

RDF + biofertilizer with 25 kg $ZnSO_4$ per ha. The 75 per cent RDF + biofertilizer with 25 kg $ZnSO_4$ per ha under SRI method of cultivation. Ramachandrappa *et al*. (2014) reported that the soil available nitrogen and potassium is low and phosphorus is medium in SSNM for a targeted finger millet yield of 4000 kg ha^{-1} with the application of 155:45:203 kg N, P_2O_5, K_2O ha^{-1}. Similar, results reported by Shreenivas (2016) post harvest available nitrogen, phosphorus and potassium status increased in 125 % SSNM treated plots. Devi *et al*. (2012) reported influence of N levels (100, 125, 150 and 175 kg ha^{-1}) on nutrient uptake and post harvest N status of soil in aerobic rice. The results revealed that uptake of P, K and post harvest soil available N of rice recorded significantly highest with application of 150 kg N ha^{-1}.

5.5.1.3 Available sulphur

The available content of sulphur was significantly higher (17.55 mg kg^{-1}) in treatment receiving nutrients as per SSNM approach for targeted yield of 55 q ha^{-1} as compared to other treatments (Table 31 and Fig.22). The increase in available sulphur may be due to higher dose of NPK along with FYM which contributes higher availability sulphur. Further, the results are in line with the findings of Dhaliwal *et al.* (2013) that the content of available sulphur levels in black soil of all treatments ranged from 0.84-1.20 mg kg^{-1} by combined application of varied levels of NPK in site specific nutrient management experiment in rice-wheat cropping system. Bandana Singh Chandel *et al.* (2014) reported that the residual available of S in the soil after harvest of maize were maximum at 150 kg N + 10 ton FYM ha^{-1}.

5.5.1.4 DTPA extractable Zinc and Iron

The DTPA extractable Zn and Fe differed significantly due to nutrient management practices. There was slight increasing trend in Zn from initial level (0.46 mg kg^{-1}) to after harvest (0.64 g kg^{-1}). But, very slight decrease in Fe level from initial level (5.89 mg kg^{-1}) to after harvest (5.87 mg kg^{-1}) of second crop under different nutrient management practices (Table 31 and Fig. 22). The higher available Zn and Fe were observed with treatment receiving SSNM approach targeted yield of 55 q ha^{-1} as compared to other treatments. The results are in agreement with the findings of Dhaliwal *et al.* (2013) reported that the available Zn and Fe levels in calcareous soil ranged from 1.20 to 3.50 and 31.7 to 49.6 mg kg^{-1}, respectively by combined application of varied levels of NPK in site specific nutrient management experiment in rice-wheat cropping

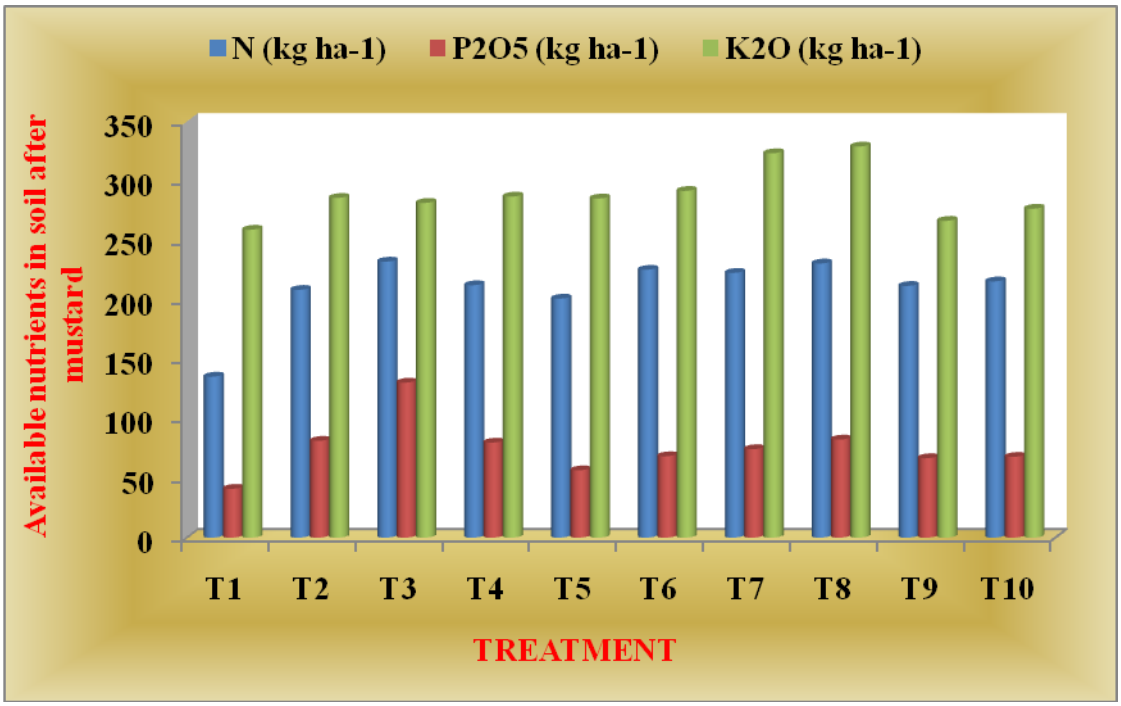


Fig. 21: Available N, P_2O_5 and K_2O in soil after harvest of second crop in Dry-DSR-mustard cropping sequence as influenced by different nutrient management approaches

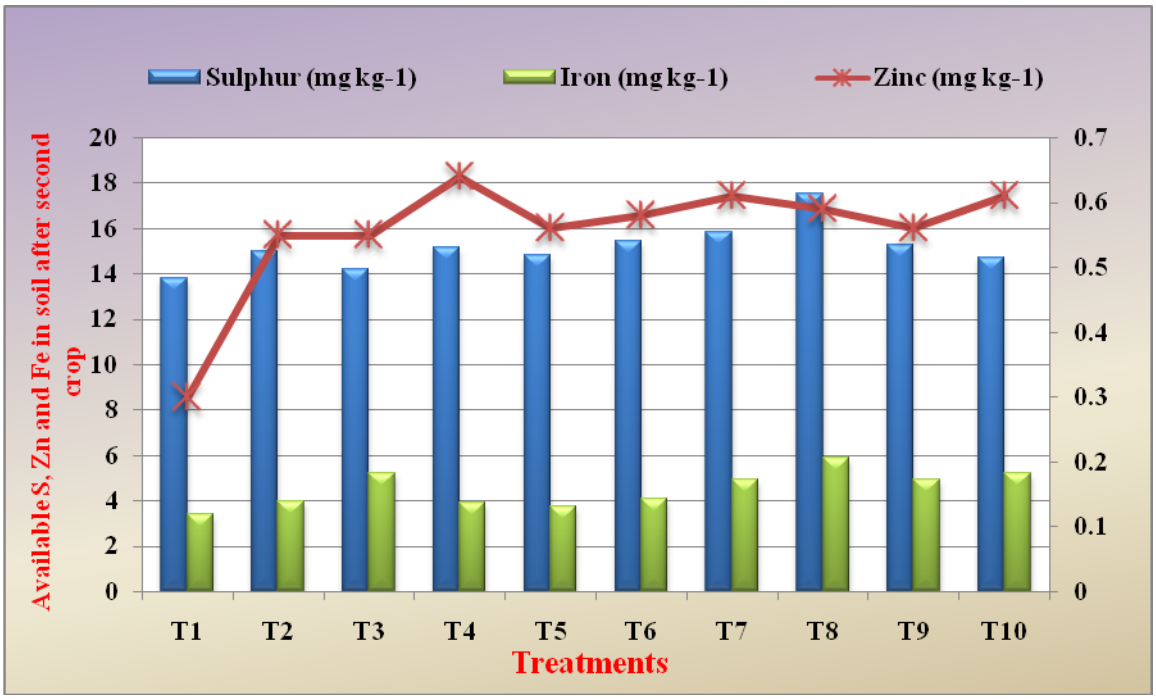


Fig. 22: Available Sulphur, Zinc and Iron in soil after harvest of mustard in Dry-DSR-mustard cropping sequence as influenced by different nutrient management approaches

system. Further, Kumar Ashok (2008) that combined application of 120 kg N along with 5 kg Zn and 10 ton FYM ha^{-1} registered higher residual zinc in maize-wheat cropping system.

5.5.2 Influence of different nutrient management approaches on balance of N, P_2O_5 and K_2O after harvest of mustard crop in Dry DSR-Mustard cropping sequence

In general, higher the uptake of nutrients by a crop lower will be the residual available nutrients in the soil. Further, higher the nutrient supplied, higher the residual soil nutrients. However, several factors influence the uptake and available nutrients.

Nutrient balance in soil is an indicator of sustainable soil fertility management. Data on nitrogen balance in soil after harvest of Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches during first and second year of the experimentation (2015-16 and 2016-17, respectively) revealed that negative balance of nitrogen in all treatments, except absolute control plot during 2016. Minimum net loss (-7.15 and -19.32 kg ha^{-1}) was found with treatment receiving SSNM approach targeted yield of 55 q ha^{-1} during first and second year of the experimentation, respectively. However, soil nitrogen greater over the initial soil N status. This may be due to split application of nitrogen leads to efficient uptake of nitrogen by crop and minimum loss of nitrogen. While net gain (7.8 and 4.0 kg ha^{-1}) of nitrogen was observed with absolute control during both the years. The highest net loss of nitrogen was found in farmers practice (-117.6 and -124.5 kg ha^{-1}) during first and second year of experimentation (Tables 32 and 33). This could be due to addition of large amount of nitrogenous fertilizers in farmers practice leads to more loss of N through leaching, volatilization and other losses.

Actual balance of phosphorus in soil was net negative (net loss in soil over initial status) over initial soil status during 2015-16 and 2016-17 (Tables 34 and 35). Maximum net loss (-101.1 and -99.4 kg ha^{-1}) of phosphorus was observed with farmers practice and minimum net loss (-7.9 and -8.1 kg ha^{-1}) was recorded with treatment receiving SSNM approach targeted yield of 55 q ha^{-1} during first and second year of experimentation (2015-16 and 2016-17). The negative balance/loss might be attributed to addition of more phosphorus into the soil and the added phosphorus might have not been mineralized and/or solubilised effectively during the crop growth period and less removal in

proportion to the quantity applied and some might have got converted to unavailable form in the soil or leached out.

Adaptation of different nutrient management practices are resulted in net gain/loss of potassium, application fertilizer as per SSNM approach targeted yield of 55 q ha^{-1} resulted in net gain of potassium (28.5 and 17.8 kg ha^{-1}) followed by T_7: SSNM approach targeted yield of 45 q ha^{-1} (6.3 and 5.6 kg ha^{-1}) during first year and second year of the experimentation. Further T_6 :(6.6 kg ha^{-1}), T_2: (1.4 kg ha^{-1}), and $T_{10:}$ (1.90 kg ha^{-1}) resulted in gain of potassium during the first year of the experimentation. Whereas, during second year T_6 :(13.8 kg ha^{-1}) resulted in gain of potassium. Exhaustion of potassium in treatments was more, which resulted in a negative balance of K_2O in the soil, while rest of the treatments were showed negative balance during 2016. However, the negative balance of potassium was observed with all treatments during second year (2017) after harvest of second crop in Dry DSR-Mustard cropping sequence. The negative balance of K might be due to more uptake of potassium by Dry DSR-Mustard then the fertilizer added. (Tables 36 and 37). Jat *et al.* (2013) showed that highest yield of both rice and maize and also the highest system productivity were obtained with SSNM, further indicated that application of SSNM principles, aided by nutrient balance studies, can help improve nutrient management in rice-maize systems towards improving yield and profitability. Sharma and Jain (2014) reported negative balance of N and K in groundnut-wheat cropping system and also gain of K in clusterbean-wheat cropping system.

5.5.3 Influence of different nutrient management approaches on rice equivalent yield and economics of Dry DSR-Mustard cropping sequence

The higher Dry DSR equivalent yield (67.65 q ha^{-1}) were recorded in treatment receiving SSNM approach targeted yield of 55 q ha^{-1} followed by STCR approach targeted yield of 55 q ha^{-1} (63.67 q ha^{-1}) and were superior over absolute control, RDF, STL method, NE and farmers practice and Table 38. This might be due to balanced supply of nutrients to the crops throughout the crop growth period as FYM undergo decomposition during which series of nutrient transformation takes place and helps in their higher availability to the crops. Higher uptake of nutrients by the crops will result in higher yield. As there were build up of soil fertility status in terms of available N, P_2O_5, and K_2O in nutrient management approaches as compared to RDF, which might have

resulted in better uptake by the crops and responses well in terms of yield. This was ascribed to continuous supply of N, P and K throughout the crop growth period as the nutrient from inorganic sources were available to the crop in the early stages and in the later stages of the crop growth there was slow and continuous release of nutrients from the organic source made available. The results are in line with the findings of Rajesh (2016) succeeding sesamum sown after harvesting of DSR recorded higher rice equivalent yield, net returns and BC ratio under the genotype JKPH 3333 with 125 per cent recommended dose of nitrogen. Similarly Shreenivas (2016) reported higher maize-equivalent yield, sustainability yield index, gross returns, net returns and BC ratio were recorded with SSNM approach for targeted yield of 8.0 t ha^{-1} followed by STCR approach for targeted yield of 8.0 t ha^{-1} as compared to other treatments.

Economic analysis is one of the major criteria for evaluating efficient and economically available nutrient management practices. In the present study, Highest cost of cultivation (₹ 52,391 ha^{-1}) was observed with T_3: Farmer practice followed by application of T_8: SSNM approach targeted yield of 55 q ha^{-1} (₹ 45,561 ha^{-1}) and lowest cost of cultivation noticed in absolute control (₹ 30, 850 ha^{-1}). Among different treatments, the highest gross return and net returns (₹ 1,47,554 ha^{-1} and ₹ 1,01,993 ha^{-1}, respectively) was received from the application of T_8: SSNM approach targeted yield of 55 q ha^{-1} it was found on par with T_6: STCR approach targeted yield of 55 q ha^{-1} (₹ 1,38,904 ha^{-1} and ₹ 94,499 ha^{-1}, respectively) and T_7: SSNM approach targeted yield of 45 q ha^{-1} (₹ 1,31,029 ha^{-1} and ₹ 86,200 ha^{-1}, respectively) followed by T_3: Farmer practice (₹ 1,37,071 ha^{-1} and ₹ 84,680 ha^{-1}, respectively) and lowest gross and net returns (₹ 57,176 ha^{-1} and 26,326 ha^{-1}, respectively) were noticed in absolute control (Table 38 and Fig. 23). The improvement in Dry DSR-Mustard productivity might be the reason for higher returns under SSNM and STCR approaches. Yield increases under SSNM resulted in a vast improvement in the economic feasibility of food crop production.

The maximum benefit cost ratio (3.24) was obtained by the application of fertilizers through T_8: SSNM approach targeted yield of 55 q ha^{-1} followed by T_6: STCR approach targeted yield of 55 q ha^{-1} (3.13). This might be attributed to the higher grain/seed and straw/stover yield of Dry DSR and mustard crops in the respective treatment. The treatment absolute control obtained lowest benefit cost ratio (1.87). This was due to lesser yield obtained without application of chemical fertilizers and farm yard

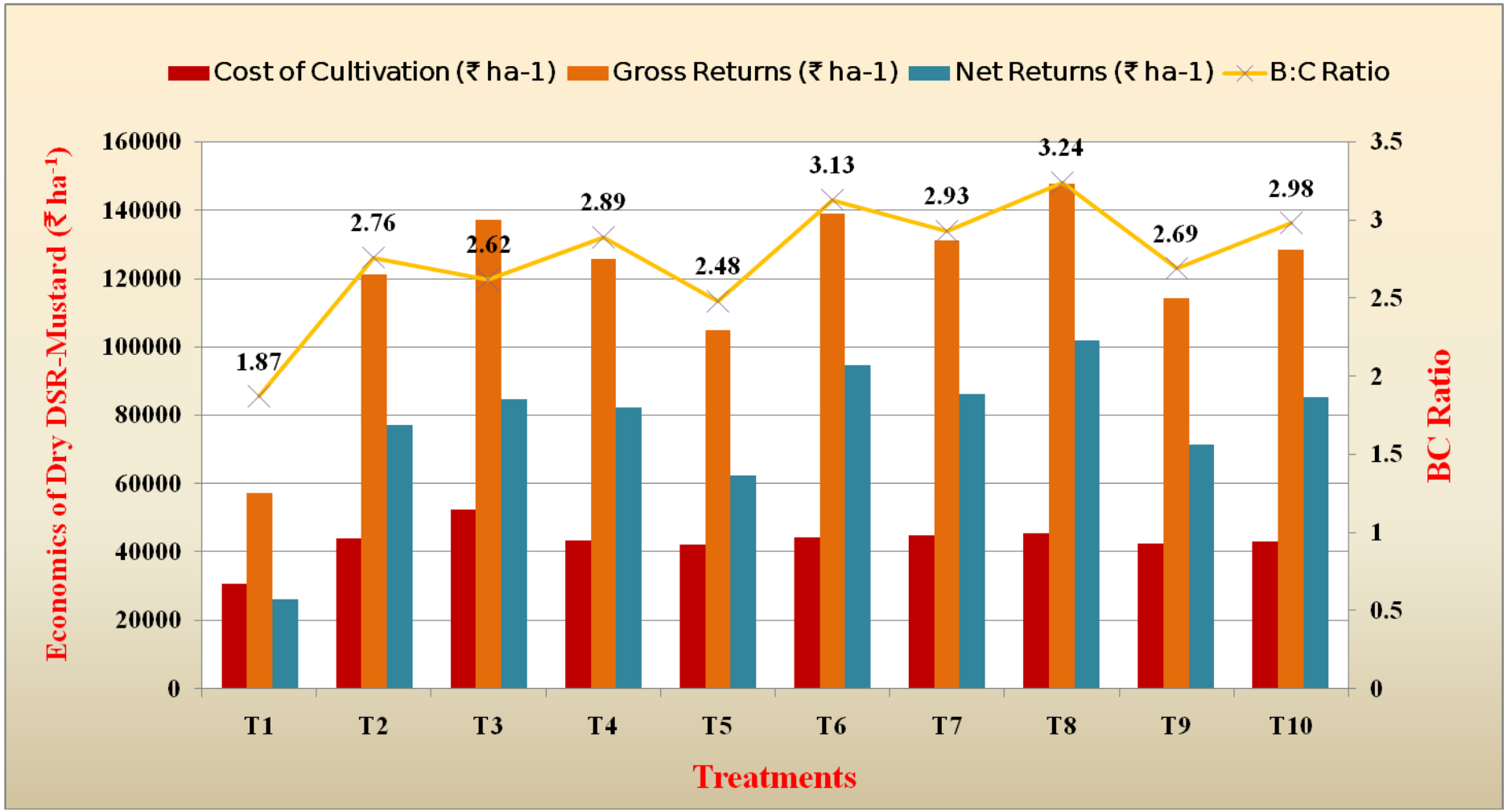


Fig. 23: Economics of Dry DSR-Mustard cropping sequence as influenced by different nutrient management approaches

manures. The results are in agreement with the several research workers. Dhillon *et al.* (2006) reported that the higher BC ratio of wheat (6.9), maize (5.12) and raya (6.19) and suggested that the target yield concept gave higher yield and hence better economic returns than farmers practice and general recommended dose. Khuong *et al* (2007) reported on economic efficiency, where SSNM helped to reduce fertilizer cost from 3.6 to 14.9 per cent, SSNM contributed to increase income and profit for rice growing farmers through the decrease of fertilizer cost and increase of profit and fertilizer cost ratio. Indeed, SSNM is a new and efficient fertilizer application. Karki and Ashok Kumar (2005) reported that the gross return over fertilizer cost was about 10 per cent greater with SSNM than farmers practice and the reason for higher economic returns may be due to increased grain yield for the targeted yield of at 40 q ha^{-1}.

The findings are in line with Yadhav and Hira Nand (2004) that SSNM practice increased net returns by 35 and 109 per cent in pigeonpea and pearlmillet over state recommendations. These findings are also in agreement with the findings of Rajashekara *et al.* (2010), Madhusudhan (2013), Umesh *et al.* (2014) and Shreenivas (2016). From the economic analysis, it is imperative that application of SSNM and STCR approach targeted yield of 55 q ha^{-1} for Dry DSR-Mustard cropping sequence would be advantageous in terms of cost effectiveness and higher returns per rupee investment.

Summary and Conclusions

VI. SUMMARY AND CONCLUSIONS

The summary and conclusions of the experiments entitled "Soil Test Based Nutrient Management Approaches in Dry DSR-Mustard cropping system" during *kharif* and *rabi* seasons of 2015-16 and 2016-17 in the farmer field of Vijayanagar camp, Tq: Raichur, Dist: Raichur are presented in this chapter. The experiments were conducted to identify the suitable nutrient management approaches for enhancing production potentials of Dry DSR-mustard cropping system, to monitor selected soil properties and nutrient status, uptake pattern and use efficiencies of different nutrients and profitability in Dry DSR-Mustard cropping sequence. The important findings of present study are summarized in this chapter.

6.1 Performance of Dry DSR for different nutrient management approaches

- The application of nutrients through SSNM approach for targeted yield of 55 q ha^{-1} produced significantly higher plant height, number of tillers, leaf area and total dry matter production (72.8 cm, 678.0, 1418 cm^2, and 62.25 g $plant^{-1}$, respectively) as compared to absolute control, RDF, STL and NE. However, it was on par with STCR approach targeted yield of 55 q ha^{-1}, farmer practice and SSNM approach targeted yield of 45 q ha^{-1}.

- Number of panicles m^{-2}, panicle length, number of grains $panicle^{-1}$, filled grains $panicle^{-1}$ and test weight were recorded significantly higher (438.1, 19.8 cm, 142.2, 134.1 and 13.98 g, respectively) with nutrients applied through SSNM approach for targeted yield of 55 q ha^{-1} as compared to absolute control, RDF, STL and NE. However, it was on par with STCR and NE approach targeted yield of 55 q ha^{-1}, farmer practice and SSNM approach targeted yield of 45 q ha^{-1}.

- The application of nutrients through SSNM approach for targeted yield of 55 q ha^{-1} produced significantly higher grain and straw yield (54.73 and 68.38 q ha^{-1}, respectively) as compared to absolute control, RDF, STL and NE and it was on par with STCR approach targeted yield of 55 q ha^{-1} (51.79 and 64.70 q ha^{-1}) followed by farmer practice, NE approach targeted yield of 55 q ha^{-1} and SSNM approach targeted yield of 45 q ha^{-1}.

- Total nitrogen, phosphorus, potassium, sulphur, zinc and iron uptake were noticed significantly higher (117.72, 40.50, 151.93, 16.11 kg ha^{-1}, 342.4 and 3622.1 g ha^{-1}, respectively) with SSNM approach for targeted yield of 55 q ha^{-1} as compared to absolute control, RDF, STL and NE. However, it was on par with STCR approach targeted yield of 55 q ha^{-1}, farmer practice and SSNM approach targeted yield of 45 q ha^{-1}.

- Application of fertilizers as per SSNM approach targeted yield of 55 q ha^{-1} recorded higher nitrogen, phosphorus and potassium use efficiency of (54.88, 65.56 and 95.13 %, respectively). Similarly the higher agronomic efficiency of nitrogen, phosphorus and potassium (29.39, 77.50 and 30.74 kg grain kg^{-1} N applied, respectively) was found with treatment receiving SSNM approach targeted yield of 55 q ha^{-1}. Lower nitrogen, phosphorus and potassium use efficiency of (37.00, 16.87 and 84.38 %, respectively) was noticed with farmer practice and similarly lowest agronomic efficiency of nitrogen and phosphorus (11.53 and 17.46 kg grain kg^{-1} P_2O_5 applied, respectively) was found with farmer fertilizer practice.

- Application of nutrients as per SSNM approach targeted yield of 55 q ha^{-1} along with FYM @ 7 t ha^{-1} noted significantly higher bacterial (25.73.$\times 10^6$ cfu g^{-1} of soil), fungal (8.62×10^3 cfu g^{-1} of soil) and actinomycetes (10.14×10^4 cfu g^{-1} of soil) population in rhizosphere soil as compared to farmers practice and rest of the treatments. Similarly nutrient application as per SSNM approach for targeted yield of 55 q ha^{-1} were recorded significantly highest dehydrogenase (12.09 µg TPF formed g^{-1} of soil hr^{-1}) and phosphatase activities (14.91 µg PNP g^{-1} of soil hr^{-1}) as compared to farmers practice and rest of the treatments.

- The cost of cultivation of Dry DSR was higher (₹ 45,851 ha^{-1}) with farmer practice of fertilizer application. Significantly highest gross returns, net returns and BC ratio (₹ 1,20,668 ha^{-1}, ₹ 81,647 ha^{-1} and 3.10 respectively) was obtained from the application of fertilizers as per SSNM approach targeted yield of 55 q ha^{-1} as compared to farmers practice and other treatments. Whereas lower net returns and BC ratio were obtained from absolute control.

6.2 Residual effect of nutrients applied through different nutrient management approaches on the performance of mustard

- The residual effect of nutrients applied through either SSNM/STCR for targeted yield of 55 q ha^{-1} or farmer practice produced significantly higher plant height, number of branches and total dry matter production as compared to absolute control and other treatments.

- The number of silique $plant^{-1}$, number of seeds $silique^{-1}$, 1000 seed weight, seed yield and stover yield were recorded higher (314.5, 13.6, 4.35 g, 592 kg ha^{-1} and 1856 kg ha^{-1}, respectively) with residual nutrient effect of SSNM approach for targeted yield of 55 q ha^{-1} as compared to absolute control (180.5, 10.6, 3.88 g and 217 kg ha^{-1} and 660 kg ha^{-1}, respectively) and other treatments. No-significant difference in oil content were noticed among the treatments however, higher oil content were found with SSNM approach targeted yield of 55 q ha^{-1} (40.8 %). Higher oil yield (240.6 kg ha^{-1}) was obtained with SSNM approach targeted yield of 55 q ha^{-1} as compared to absolute control and other treatments..

- The significantly higher total uptake of nutrients were observed with the residual effect of nutrients applied through SSNM approach for targeted yield of 55 q ha^{-1} (26.07, 6.10 and 34.99 kg ha^{-1} N, P_2O_5 and K_2O, respectively) followed by farmer practice (25.66, 6.10, and 32.65 kg ha^{-1} N, P_2O_5 and K_2O, respectively) and STCR approach for targeted yield of 55 q ha^{-1} (21.91, 4.88, and 30.99 kg ha^{-1} N, P_2O_5 and K_2O, respectively) as compared to absolute control, RDF, STL and NE. Higher gross returns, net returns and BC ratio (₹ 26, 886 ha^{-1}, ₹ 20,346 ha^{-1} and 4.14, respectively) was obtained with the SSNM approach targeted yield of 55 q ha^{-1} as compared to absolute control, RDF, STL and NE. However, it was on par with residual nutrient effects of farmers practice and STCR approach for targeted yield of 55 q ha^{-1}.

6.3 Influence of different nutrient management approaches on soil fertility, balance, REY and economics of Dry DSR-Mustard cropping sequence

❖ The physico-chemical properties *viz.,* pH, electrical conductivity and organic carbon content were found to be non-significant with the adaptation different nutrient management approaches in Dry DSR-Mustard cropping sequence.

However, the available soil nutrient status found to be increased significantly with the adaptation of different nutrient management approaches. Higher availability of N, P_2O_5, K_2O, S, Zn and Fe (230.8, 82.6, 329.60 kg $ha^{-1}$and 17.55, 0.59 and 5.87 mg kg^{-1}, respectively) were observed with the nutrients applied through SSNM approach for targeted yield of 55 q ha^{-1} as compared to absolute control, RDF, STL and NE but slightly higher available N and P_2O_5 noticed in farmer practice as compared to SSNM approach for targeted yield of 55 q ha^{-1} after harvest of mustard crop in Dry DSR-Mustard cropping sequence and it was on par with SSNM or STCR approach for targeted yield of 45 or 55 q ha^{-1}. However, there was no definite trend were observed with available zinc.

- The minimum net loss of N (-7.15 and -19.32 kg ha^{-1}) & P_2O_5 (-7.9 and -8.1 kg ha^{-1}) and maximum gain of K_2O (27.9 and 17.8 kg ha^{-1}) were noticed with SSNM approach for targeted yield of 55 q ha^{-1} and maximum net loss of N (-117.58 and -124.5 kg ha^{-1}), P_2O_5 (-101.1 and -99.4 kg ha^{-1}) & K_2O (-21.7 and -17.9 kg ha^{-1}) were observed with the farmer practice fertilization during first (2015-16) and second (2016-17) year experimentation respectively.

- The cost of cultivation of Dry DSR-Mustard cropping sequence was higher (₹ 52,391 ha^{-1}) with fertilizer applied through farmer practice of fertilizer application. However, Significantly higher rice equivalent yield (67.65 q ha^{-1}), gross returns (₹ 1,47,554 ha^{-1}), net returns and BC ratio (₹ 1,01,993 ha^{-1} and 3.24, respectively) was received by the application of nutrients as per SSNM approach for the targeted yield of 55 q ha^{-1} as compared to farmers practice and other treatments. Whereas lower rice equivalent yield, gross returns, net returns and BC ratio were obtained with absolute control.

From the present investigation following conclusions have been made

The results obtained in the present investigation which was carried out for two consecutive years (2015-16 and 2016-17) by following different nutrient management approaches on performance of Dry DSR-Mustard cropping system. Based on the results following conclusions are made.

1. Applications of nutrients based on the soil test results in SSNM and STCR under field situation is more useful and profitable due to maximizing productivity and profitability as compared to farmers practice.

2. Application of nutrients through SSNM approach provides balanced nutrient supply to achieve the sustainable yield in Dry DSR-Mustard cropping sequence.

3. Site-specific nutrient management aims to reduce N fertilizer usage by 30 % and P fertilizer by 74 % as compared to farmers practice and it also reduce cost of fertilizers by 14.9 % and it could save plant nutrients.

4. Application of nutrients (150:43:115 kg N, P_2O_5 and K_2O ha^{-1}, respectively) along with FYM @ 7 t ha^{-1} plus deficient $ZnSO_4$ soil application @ 25 kg ha^{-1} and foliar spray of $FeSO_4$ @ 0.5 % as per SSNM approach targeted yield of 55 q ha^{-1} recorded higher productivity, nutrient uptake, NUE and nutrient availability in Dry DSR-Mustard cropping system.

5. The SSNM approach aims to obtain higher rice equivalent yield, gross returns, net returns and BC ratio (67.65 q ha^{-1}, ₹ 1, 47, 554 ha^{-1}, ₹ 1, 01, 993 ha^{-1} and 3.24, respectively) in Dry DSR-Mustard cropping sequence. SSNM approach is the best method of fertilizer application to obtain higher yield and profit. Hence, this method shall be addressed to the farmers as fertilizer practice in Dry DSR-Mustard cropping system.

Finally, the following conclusions area made, fertilizer recommendation in rice fields of TBP command area are presently too generalized does not match to the to the site-specific yield potential and local soil fertility status. On other side farmers are using imbalanced dose of nutrients, with higher tendency for N and P fertilizers. In our approaches, we made an effort to work out the nutrient requirement of crop to achieve the specified yield target by considering total nutrient uptake required by the crop to reach a specified yield target and nutrient supplying capacity of soil. Among them targeted yield approach *i.e* SSNM approach is unique and most realistic to achieve the targeted yield in Dry DSR. This approach offers the advantage to agronomists, extension workers, and farmers to achieve the specified yield target in Dry DSR and its residual effect on mustard to achieve a sustainable production and profit in Dry DSR-Mustard cropping sequence.

References

VII. REFERENCES

Abdulrahaman, S., Gines, H. C., Nagarajn, R., Satawathananont, S., Son, T. T., Tan, P. S. and Wang, G. H., 2002, Variation in the performance of site specific nutrient management among different environments with irrigated rice in Asia. *Better Crops Int.*, 16(20): 18-23.

Alagesan, A. and Babu, R. C., 2011, Impact of different nitrogen levels and time of application on grain yield and yield attributes of wet seeded rice. *Int. J. Food Agric. Vet. Sci*., 1(1): 1-5.

Anilkumar and Thakur, K. S., 2004, Effect of integrated nutrient management on promising composite maize (*Zea mays* L.) varieties under rainfed mid-hill conditions of Himachal Pradesh. *Indian J. Agric. Sci.*, 74 (1): 40-42.

Anonymous, 2006, *Proceedings of first national symposium on System of Rice Intensification (SRI) – Present status and future prospects*, 17-18 Nov, 2006, ANGRAU, Rajendranagar, Hyderabad (A.P): 1-2.

Anonymous, 2007, STCR: an approach for fertilizer recommendations based on targeted yield concept. *Tec. Bul.,* AICRP on STCR. Univ. Agric. Sci., Bangalore.

Anonymous, 2015, State wise area, production and yield of rice 2014-15. Directorate of Economics and statistics, Ministry of Agriculture, Govt. of India. p. 151-152.

Aon, M. A. and Colaneri, A. C., 2001, Temporal and spatial evolution of enzymatic activities and physico-chemical properties in an agricultural soil. *Appl. Soil Ecol*., 18: 255–270.

Apoorva, K. B., Prakash, S. S., Rajesh, N. L. and Nandini, B., 2010, STCR approach for optimizing integrated plant nutrient supply on growth, yield and economics of finger millet (*Eleusine coracana*). *European J. Biol. Sci*.,4(1): 19-27.

Attanandana, T., Vearasilp, T. and Soitong, K., 2002, Decision support system for fertilizer application in maize production: *Thai J. Soil Fert.,* 22: 174-186.

Babu, M., Nagarajan, R. and Ramanathan, S. P., 2000, Optimizing chlorophyll meter (SPAD) threshold value for different seasons and varieties in irrigated lowland

rice systems of the Cauvery Delta zone, Tamil Nadu, India. *Int. Rice Res. notes*. 25:27-28.

Balasubramanian, V. R., Rajendran, V., Ravi, N., Chellaiah, E., Castro, B. and Chandrasekaran, 2005, Integrated crop management for enhancing yield, factor productivity and profitability in Asian rice farms. *International Rice Commission News let*. FAO, Rome. 54: 63-65.

Baligar, V. C., Wright, R. J., Fageria, N. K. and Pitta, G. V. E., 1999, Enzyme activities in cerrado soils of Brazil. *Commun. Soil Sci. Plan Anal*., 30: 1551-1560.

Balota, E. L., Kanashiro, M., Colozzi, A., Andrade, D. S. and Dick, R. P., 2004, Soil enzyme activities under long-term tillage and crop rotation systems in subtropical agro ecosystems. *Brazil. J. Microbiol*., 35: 300–306.

Bandana S, C., Sandeep, S., Harvendra, S. and Vinay, S., 2014, Direct and residual effect of nutrient management in wheat-maize cropping sequence. *J. Indian Soc. Soil Sci.,* 62(2): 126-130.

Bandara, W. M. J., Kumagamge, D., Wickramasinghe, D.B. and Weerawarna, S. B. A., 2007, A site specific recommendation for rice grown in imperfect drained reddish brown earth soils low country dry zone of Sri Lanka, *Tropical Agric. Res*., 18:1-15.

Berra, R., Seal, A., Bhattacharyya, P., Das, T. H., Sarkar, D. and Kangjoo, K., 2006, Targeted yield concept and framework of fertilizer recommendation in irrigated rice domains of subtropical India. *J. Zhejiang Univ. Sci.,* 7 (12): 963-968.

Bharathi, C. and Poongothai, S., 2008, Direct and residual effect of sulphur on growth, nutrient uptake, yield and its use efficiency in maize and subsequent green gram. *Res. J. Agric. Bio. Sci.,* 4(5): 368-372.

Bhatti, A. U., Ali, R., Ullah, F. and Khan, M. J., 1998, Comparison of wheat yield under uniform and variable rates of fertilizer on spatially eroded land. *Com. Soil. Sci. Plant. Anal*., 29(19/20): 2855-2863.

Biradar, D. P. and Aladakatti, Y. R., 2007, Site specific nutrient management (SSNM) another green revolution in Northern Karnataka. *Better Crops*, 90(3).

Biradar, D. P., Aladakatti, Y. R., Rao, T. N. and Tiwari, K. N., 2006. Site specific nutrient management for maximization of crop yields in Northern Karnataka. *Better Crops,* 90 (3): 33-35.

Bolton, H., Elliott, L. F., Papendick, R. and Bezdicek, D. F., 1985, Soil microbial biomass and selected soil enzyme activities: Effect of fertilization and cropping systems. *Soil Bio*. *Biochem*., 17: 297-302.

Burton W.A., Pymer S.J., Salisbury P.A., Kirk J.T.O., Oram R.N., 1999 - Performance of Australian canola quality *Brassica juncea* breeding lines, pp.113-115. In: N., Wratten and P.A. Salisbury, (Eds.), 10th International Rapeseed Congress.

Cassida, L. E. Jr., Klein, D. A. and Santoro, T., 1964, Soil dehydrogenase activity. *Soil Sci*., 98: 371-376.

Cessay, M., Reid, W. S., Fermandis, E. C. M. and Uphoff, N., 2006, The effects of repeated soil wetting and drying on lowland rice yield with system of the rice intensification (SRI) methods. *Int. J. Agric. Sustainability,* 4(1): 5-14.

Chand, M., Benbi, D. K. and Benipal, D. S., 2006, Fertilizer recommendation based on soil test for yield targets of mustard and rapeseed and their validations under farmers' field conditions in Punjab. *J. Indian Soc. Soil Sci*., 54: 316-321.

Chandrapala, A. G., Yakadri, M., Mahender Kumar, R. and Bhupal Raj, G., 2010, Productivity and economics of rice (*Oryza sativa*) - maize (*Zea mays*) as influenced by methods of crop establishment, Zn and S application in rice. *Indian J. Agron*., 55(3): 171-176.

Chatterjee, A. K., Mandal, B. and Mandal, L. N., 1996, Interaction of nitrogen and potassium with zinc in submerged soil and low land rice. *J. Indian Soc. Soil Sci.,* 44(4): 792-794.

Chaudhary, R. K., Patel, T. D., Patel, J. B. and Patel, R. H., 1998, Response of chickpea cultivars to irrigation, nitrogen and phosphorus on sandy clay loam soil. *Int. Chickpea, Pigeonpea Newslett.,* 5: 24-26.

Chavan, A. P., Jain, N. K. and Mahadkar, U. V., 2014, Direct and residual effects of fertilizers and biofertilizers on yield, nutrient uptake and economics of groundnut (*Arachis hypogaea*)-rice (*Oryza sativa*) cropping system. *Indian J. Agron*., 59(1): 53-58.

Chu, V. H. and Tan, P. S., 2007, Study on site-specific nutrient management (SSNM) for high-yielding rice in the Mekong Delta. *Omonrice*, 15: 144-152.

Dahiya, S. S. and Bhatia, B. K., 1982, Effect of iron and nitrogen levels on dry matter yield and nutrients uptake by maize. *Haryana Agric. Univ. J. Res.*, 12(2): 254-258.

David, H. H., 2008, Effect of fertilizer salts on soil pH. *NCDA & CS Agronomic Division.*

Dev, G., Dhillon, N. S., Brar, J. S. and Vig, A. C., 1985, Soil test based yield targets for wheat production. *Fert. News*, 30(5): 50-52.

Devi, M. G., Sumathi, V., Reddy, S. T. and Aruna, P., 2012, Influence of levels and time of nitrogen application on yield, nutrient uptake and post-harvest nitrogen status of soil in aerobic rice. *Curr. Biol.*, 6(1): 98-102.

Dhaliwal, S. S., Walia, S. S., Wallia, M. K. and Manchanda, J. S., 2013, Buildup of micro, macro and secondary plant nutrients in site specific nutrient management experiment in rice-wheat system. *Int. J. Sci. Environ. Technol.*, 2(2): 236-244.

Dhillon, N. S., Bhajan Singh, Vig, A. C. and Braj, B. S., 1999, Experience of soil test based fertilizer recommendation in Punjab. *J. Res. Punjab Agric. Univ.*, 36: 14-16.

Dhillon, N. S., Brar, B. S., Benipal, D. S. and Mavi, M. S., 2006, Economics of various soil test based fertilization approaches for different crops. *Crop Res.*, 32(3): 377-381.

Dhillon, N. S., Sidhu, A. S., Brar, J. S. and Dev, G., 1987, Soil test based fertilizer requirements for varied targeted yields of cereals. *Indian J. Ecol.*, 14: 83-89.

Dhillon, N. S., Vig, A. C. and Brar, J. S., 2006, Soil test based target yield approach to formulating crop fertilization programme in Punjab. *J. Res. Punjab Agric. Univ.*, 34(4): 384-392.

Dhruvakumar, J., Sharma, G. D. and Mishra, R. R., 1992, Soil microbial population numbers and enzyme activities in relation to altitude and forest degradation. *Soil. Biol. Biochem.*, 24: 761-767.

Dick, R. P., Rasmussen, P. E. and Kerle, E. A., 1996, Influence of long-term residue management on soil enzyme activities in relation to soil chemical properties of a wheat-fallow system. *Biol. Fertil. Soils*, 6: 159-164.

Dingkuhn, M, Penning do Vries, F.W.T., De Datta, S.K., Van Laar, L., 1991, Concepts for a new plant type for direct seeded flooded tropical rice. In: Direct-seeded flooded rice in the tropics. Selected papers from the International Rice Research Conference, Seoul, Korea, p 17-38.

Doberman, A., Witt, C. and Dawe, D., 2002, Performance of site specific nutrient management in intensive rice cropping systems of Asia. *Better Crops Int.*, 16(1): 25-30.

Doberman, A., Witt, C., Dawe, D., Abdulrachman, S., Gines, H. C., Nagarajan, R., Satawathananont, S., Son, T. T., Tan, P. S., Wang, G. H., Chien, N. V., Thoa, V. W. K., Phung, C. V., Stalin, P., Muthukrishnan, P., Ravi, V., Babu, M., Chatuporn, S., Sookthongsa, J., Sun, Q., Eur, R., Simbahan, G. C. and Adviento, M. A. A., 2002, Site specific nutrient management for intensive rice cropping systems in Asia. *Field Crops Res.*, 74(1): 37-66.

Doberman, A., Witt, C., Robert, P. C. and Larson, W. E., 2000, SSNM concept for irrigated via system. *Proc. of 5th International Con. on Presis*, 25: 1-7.

Dubey, S. K. and Bisen, L. R., 1989, Nitrogen uptake by rice as influenced by different levels, sources and methods of nitrogen application. *Oryza*, 26(1): 37- 42.

Dudhat, M. S., Malavia, D. D., Mathukia, R. K. and Khanpara, V. D., 1997, Effect nutrient management through organic and inorganic sources of growth, yield, quality and nutrient uptake by wheat (*T. aestivum*), *Indian J. Agron.*, 42(93), 455-458.

Esfehani, M., Sadrzade, S.M., Kavoosi, M., Dabagh, M. N. A., 2005, Study on the effect of different levels of nitrogen and potassium fertilizers on growth, grain yield,

yield components of rice (*Oryza sativa*) cv. *Khazar*. *Iran Agron. J.*, 7(3): 226-241.

Evazi, Z. and Tabatabai, M. A., 1979, Phosphatase in soils. *Soil Biol. Biochem.*, 9: 167-172.

Ferguson, R. B., Hergert, G. W., Schepers, L. S., Gotway, C. A., Cahoon, J. E. and Peterson, T. A., 2002, Site specific nitrogen management of irrigated rice: yield and soil residual nitrate effects. *Soil Sci. Soc. America. J.*, 66: 544-553.

Fixen, P. E., 1998, Research needs for site-specific nutrient management to benefit agriculture. *Better Crops Int.*, 82(1): 16-18.

Gangwar, K. S., Gill, M. S., Tomar, O. K. and Pandey, D. K., 2008, Effect of crop establishment methods on growth, productivity and soil fertility of rice (*Oryza sativa*) based cropping systems. *Indian J. Agron*., 53(2): 102-106.

Gawai, P. P. and Pawar, V. S., 2005, Production, potential and economics of sorghum-chickpea cropping sequence under irrigated nutrient management system. *Crop Res*., 30(3): 345-348.

Gayathri, A., Vadivel, A., Santhi, R., Murugesa Bhoopathi, P. and Natesan, R., 2009, Soil test based fertilizer recommendation under integrated plant nutrition system for potato (*Solanum tuberosum* L.) in hilly tracts of nilgiris districts. *Indian J. Agric. Res.*, 43(1): 52-56.

Gayathry, G., 2006, Studies on dynamics of soil microbes in the rice rhizosphere with water saving irrigation and in-situ weed incorporation. *M.Sc. (Agri) thesis*, Tamil Nadu Agricultural University, Coimbatore, India.

Gheibi, M. N., Kholdebarin, B., Ghanati, F., Teimouri, S., Niroomand, N. and Samavati, M., 2009, Urease activity in maize (*Zea mays* Cv. 704) as affected by nickel and nitrogen sources. *Iranian J. Sci. Tech.*, 33(4): 299-307.

Gholizadeh, A., Amin, M. S. M., Anuar, A. R. and Aimrun, W., 2009, Evaluation of SPAD chlorophyll meter in two different rice growth stages and its temporal variability**.** *European J. Scientific Res*., 37(4):591-598.

Gill, M. S., Kumar, A. and Kumar, P., 2006, Growth and yield of rice under various method and times of sowing. *Indian J. Agron*., 51: 123-127.

Gill, M.S., Shukla, A. K., Singh, M. P., Tomar, O. K., Rajkumar, K., Majumdar, and Tiwari, K. N., 2009, Evaluation of nutrient management options for corn yield, economics, and nutrient use efficiency, *Better Crops Int.*, 12-15.

Giri, A. A., Dahiphale, V. V., Gunjkar, M. V., Jadhav, A. S., 1999, Nutritional requirement of basmati rice under upland irrigated conditions on vertisols. *J. Maharashtra Agric. Univ.*, 24(3): 301-302.

Gomez, K. A. and Gomez, A. A., 1984, *Statistical Procedures for Agricultural Research,* 2nd Edition, A Wiley Inter Science Publications, New York, USA.

Gomez, K. A., 1972, Layout, sampling, sources of error technologies for field experiment with rice, *Int. Rice Res. Notes.,* Los Bonos, Philippines, pp. 37-39.

Greta, G. G. and Roland, J. B., 2009, Site-specific nutrient management (SSNM): Profitability to farmers, current level of adoption, and constraints to wider adoption in iloilo province, Philippines

Guanghuo Wang, Achim Dobermann, Christian Witt, Quingzhu Sun and Rongxing Fu., 2001, Performance of site-specific nutrient management for irrigated rice in Southeast china. *Agron. J.*,93: 869-878.

Halstead, R. L. and Sowden, F. J., 1986, Effect of long term addition of organic matter on crop yields and soil properties in clay and sandy soil. *Canadian. J. Soil Sci*., 48: 341-348.

Harrison, A. F., 1979, Seasonal variation of phosphate activity in woodland soils. *Soil Biol. Biochem.,* 11: 405-410.

Hongting Wang, Ji-Yun Jin and Bin Wang, 2005, Improvement of soil nutrient management via information technology. *Better Crops Int.,* 90: 12-13.

Hossain, B., Talukdernarayon, K. and Sulan Ahmed, 2001, Effect of zinc, boron and molybdenum application on yield and nutrient uptake. *J. Biol. Sci.,* 1(8): 19-25.

Iqbal, M. J., Zahida parveen, Jamil, A., Parveen, Z. and Amer jamil, 1998, Comparitive study of home. Physico-chemical characteristics and phosphate activity of corn and tobacco soils. *Sarhed J. Agril*., 14: 127-130.

Jackson, M. L., 1973, *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi, pp. 187.

Jansi, L. B. K., Murthy, K. V. R. and Naidu, M. V., 2013, Effect of graded levels and time of N-application nutrient uptake, yield and economics of semi dry rice. *J. Res. Angrau.*, 41(2): 21-25.

Jat, M. L., Satyanarayana, T., Kaushik, M., Parihar, C. M., Jat, S. L., Tetrawal, J. P. and Saharawat, Y. S., 2013. Fertilizer best management practices for maize systems. *Indian J. Fert.*, 9(4): 80-94.

Jemal Abdulahi, 2010, Response of maize (*Zea mays* L.) and chickpea (*Cicer arietinum* L.) to site specific nutrient management (SSNM) through targeted yield approach. *Ph.D. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore.

Jianmin, C., Ruifa, H. and Lifen, Z., 2007, Promote sustainable development for irrigated rice through SSNM technology in China. *Chinese J. Population Resources and Environ.*, 5(1): 53-57.

Kamaleshkukreja, M. M., Mishra, S. S., Dhankar, K. B., Kapur, and Gupta, A. D., 1991, Effect of long term manurial application on microbial biomass. *J. Indian Soc. Soil Sci.*, 39: 685-687.

Kandeler, E., Mosier, A., Morgan, J., Milchunas, D., King, J., Rudolph, S. and Tscherko, D., 2007, Response of soil microbial biomass and enzyme activities to the trescient elevation of carbon dioxide in a semi-arid grassland. *Soil Bio Biochem*., 38: 2448-2460.

Kanhaiya, L. R. and Singh, Y. V., 2014, Fertilizer recommendation based on soil testing for the targeted yield of rice in Eastern plain zone of Uttar Pradesh. *Bioscan Int. J. Life Sci.*, 9(2): 531-534.

Karki, T. B. and Ashok Kumar, 2005, Productivity, potential and economics of maize *(Zea mays* L.) as affected by various fertility levels. *Anna. Agril. Res.*, 26(2): 340-341.

Katkar, R. N., Sonune, B. A. and Kadu, P. R., 2011, Long-term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum

(*Sorghum bicolor* L.)-wheat (*Triticum aestivum* L.) system in Vertisol. *Indian J. Agric. Sci.*, 81(8): 734-739.

Keram, K.S., Puri, G. and Sawarkar, S. D., 2012, Assessment of soil test based fertilizer recommendation under rice-wheat cropping sequence and its impact on soil quality under agroclimatic condition of Kymore plateau zone of Madhya Pradesh, India. *JNKVV Res. J.*, 46(1): 62-68.

Khuong, T. Q., Tran, T. N. H., Pham, S. T. and Roland B., 2007, Effect of site specific nutrient management on grain yield, nutrient use efficiency and rice production profit in the Mekong Delta. *Omon Rice J., No.15*: 153-158.

Khurana, H. S., Steven, Phillips, B.S., Dobermann, Ajmer, S. A., Singh, Y. and Shaobing, P., 2007, Performance of site specific nutrient management for irrigated, transplanted rice in Northwest India. *Agron. J.*, 99: 1436–1447.

Khurana, H.S., Bijay, S., Dobermann, A., Phillips, S.B., Sidhu, A.S. and Yadvinder, S., 2008, Site specific nutrient management performance in a rice-wheat cropping system. *Better Crops India.* 92:26-28.

Kirchner, M. J., Woolum, A. G. and King, L. D., 1993, Soil microbial population and activities in reduced chemical input Agro ecosystems. *Soil Sci. Soc. American J.*, 57: 1289-1295.

Kiss, S., Dragon-Bularda, M. and Radubes, R., 1975, Biological significance of enzymes accumulated in soils. *Adv. Agron.*, 27: 25-87.

Kumar Ashok, 2008, Direct and residual effect of nutrient management in maize (*Zea mays* L.) - wheat (*Triticum aestivum*) cropping system. *Indian J. Agron.*, 53(1): 37-41.

Kumar, A., Majumdar, K., Jat, M. L., Pampolino, M., Kamboj, B. R., Bishnoi, D. K., Kumar, V. and Johnston, A. M., 2012, Evaluation of nutrient expert for wheat. *Better Crops Int.*, 27-29.

Kumar, S., Shivay, Y. S., Kumar, D. and Prasad, R., 2007, Effect of levels and source of nitrogen on NPK concentration, uptake and N use indices by a high yielding variety and hybrid rice. *Indian. J. Fert.*, 2(11): 53-56.

Limin, C. Pinghe, B., Mirasol, F., Pampolino, Johnston, A. M., Jiyunjin, Xinpeng, X., Shicheng, Z., Shaojunqiua and Weizhoua., 2013, Establishing a scientific basis for fertilizer recommendations for wheat in China. *Field Crops Res.,* 14: 1-8.

Lin, X. Q., Chen, H. X., Cheng, S. H. and Uphoff, N., 2009, Effect of plant density and nitrogen fertilizer rates on grain yield and nitrogen uptake of rice hybrid rice (*Oryza sativa* L.). *J. Agric. Biotech Sustainable Dev.,* 1: 44-53.

Lindsay, W. L. and Norvell, W. A., 1978, Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. American J.*, 42: 421-428.

Loganathan, S., Helkiah, J. and Thangavelu, S., 1995, Fertilizer application to groundnut based on soil test crop response equations. *Madras Agric. J*., 8(3): 1995-198.

Madhusudhan., 2013, Assessment of soil test based nutrient management approaches in maize (*Zea mays* L.). *M. Sc. (Agri.) Thesis,* Univ. Agric. Sci., Raichur.

Mahala, H. L, Shaktawat, M. S. and Shivran, R. K. 2006, Direct and residual effects of sources and levels of phosphorus and farmyard manure in maize (*Zea mays*) – mustard (*Brassicca juncea*) cropping sequence. *Indian J. Agron.,* 51(1): 10-13.

Maheswari, J., Maragatham, N. and James Martin, G., 2007, Relative simple irrigation scheduling and N application enhances the productivity of aerobic rice (*Oryza sativa* L.). *Am. J. Plant Physiol.,* 2(4): 261-268.

Majumdar, B., Venkatesh, M. S., Kailash Kumar and Patiram, 2002, Effect of nitrogen, sulphur and pig manure application on yields, nutrient uptake and quality parameters of maize-mustard crop rotation and residual nutrient build up in an acidic Alfisol of Meghalaya. *J. Hill Res*., 15(2): 63-70.

Mallarino, A. P., Webb, J. R. and Blackmer, A. M., 1991, Corn and soybean yields during 11 year of phosphorus and potassium fertilization on a high testing soil. *J. Prod. Agric*.,4 (3): 312-317.

Mamatha, G., Jayanthi, S., Bagyaraj, D. J. and Suresh, C. K., 2001, Microbial and enzymatic analysis from sandal root zone soil growing in red sandy loam. *Indian. J. Microbiol*., 41: 219-221.

Mandal, S.S. and Mahapatra, A.N.D., 1983, Studies on correlation between potassium and grain yield, yield attributes and growth characteristics of rice. *Indian Potash J.*, 8(1): 20-25.

Manna, M. C., Kundu, M., Singh, M. and Takkar, P. N., 2005, Influence of FYM on dynamics of microbial biomass and the turn over and activity of enzymes under soyabean wheat system on Typic Haplusterts. *J. Indian Soc. Soil. Sci*., 44: 409-412.

Manoj Kumar and Singh, M., 2003, Effect of nitrogen and phosphorus levels on yield and nutrient uptake in maize (*Zea mays* L.) under rainfed condition of Nagaland. *Crop Res.*, 25(1): 46-49.

Marinari, S., Mancinelli, R., Campiglia, E. and Grego, S., 2006, Chemical and biological indicators of soil quality in organic and conventional farming systems in Central Italy. *Ecol. Indic*., 6: 701-711.

Mauriya, A. K., Maurya, V. K., Tripathi, H. P., Verma, R. K. and Radhey, S. 2013, Effect of site-specific nutrient management on productivity and economics of rice (*Oryza sativa*)–wheat (*Tritucum aestivum*) system. *Indian J. Agron.,* 58 (3): 282-287.

Milapchand, D. K., Bendi and Azaad, A. S., 2004, Modifying soil test based fertilizer P recommendation for targeted yield of rice on a Typic Haplustaif. *J. Indian Soc. Soil Sci*., 52(3): 258-261.

Milapchand, Vig, A. C. and Sidhu, A. S., 1984, Evaluation of fertilizer recommendation based on soil test for targeted rice yield on cultivators. *J. Res. Punjab Agric. Univ*., 21 (1): 20-28.

Milp-Chand, Benbi , D. K. and Benipal, D. S., 2006, Fertilizer recommendations based on soil tests for yield targets of mustard and rapeseed and their validations under farmers field conditions in Punjab. *J. Indian Soc. Soil Sci*., 54(3): 316-321.

Mirasol, F., Witt, C., Pasuquin, J. M., Johnston, A. and Fisher, M. J., 2012, Development approach and evaluation of the nutrient expert software for nutrient management in cereal crops. *Comput. Electron. Agric*., 88: 103-110.

Mishra, A., Singh, J., Das, P. And Paikaray, R. K, 2003, Site specific nutrient management for maximization of productivity in hybrid rice. *Better crops Int.,* 11(2): 88-92.

Mishra, B., Shekhar, K.S., Bharadwaj, A.K., Witt, C. Buresh, R.J., 2006, Development of site-specific nutrient management for irrigated rice-wheat in North India, *Int. Symp. Balanced Fert.,* (1) 193-217.

Moeskops, B, Sukristiyonubowob, David Buchana, Steven Sleutela, Lenita Herawatyb, Edi Husenb, Rasti Saraswatib, Diah Setyorinib, and Stefaan De Neve, 2010, Soil microbial communities and activities under intensive organic and conventional vegetable farming in West Java, Indonesia. *Applied Soil Ecol.,* 45: 112-120.

Mollah, M. R. A., Khalequzzaman, K. M., Hossain, M. M. and Rahman, S. M. L., 2008, cropping pattern based fertilizers recommendation for mustard-Boro-T. Aman Rice cropping pattern under AEZ-25 Nandigram, Bogra. *J. Soil Nature*, 2(2): 31-34.

Mukopadhaya, D. and Majumdar, K., 2010, Response of rain fed rice to soil test based nutrient based application in terrai alluvial soils. *Better Crops India*, 92: 13-15.

Murugappan, U., 1985, Soil test crop response studies on sugarcane for efficient fertilizer use. *Ph.D. thesis.* TNAU, Coimbatore.

Nagarajan, R., Dobermann, A., Witt, C., Abdulrachman, S. and Muthukrishnan P., 2003, Estimating indigenous nutrient supplies for site-specific nutrient management in irrigated rice. *Agron. J.* 95:924-935.

Navin, K. J and Anil K. Dahama, 2006, Phosphorus and zinc requirements of wheat under wheat (*Triticum aestivum*)-pearl millet (*Pennisetum glaucum*) cropping system. *Archives of Agron. Soil Sci.,* 52(6): 645-653.

Package of practices for crop improvement, 2015, *Univ. Agric. Sci., Raichur.* p: 499.

Pal, S., Ghosh, S. K. and Mukhopadhyay, A. K., 2000, Split application of potassium on rice (*Oryza sativa*) in coastal zone of West Bengal. *Indian J. Agron.,* 45(3): 575-579.

Pampolinoa, M. F., Manguiata, I. J., Ramanathanb, S., Ginesc, H. C., Tand, P. S., Chid, T. T. N., Rajendrane, R. and Buresh, R. J., 2007, Environmental impact and economic benefits of site specific nutrient management (SSNM) in irrigated rice systems. *Agri. Systems.*, 93(1-3): 1-24.

Pankaj Kumar, Nintu Mandal, Singh, R.P. and Nirmal De., 2013, Nutrient management in direct seeded rice and its residual effect on uptake, translocation and recovery of nutrients in rainfed lentil. *An Asian J. Soil Sci.,* 8 (2):226-230.

Pankaj, K. P., Nintu, M., Singh, R.P. and Nirmal, D., 2013, Nutrient management in direct seeded rice and its residual effect on uptake, translocation and recovery of nutrients in rainfed lentil, *An Asian J. Soil Sci.,* (8) 2:226-230.

Paradkar, V.K., Tiwari, D.K., Ghanshyam, D., Mishra M. K. and Alawa, S.L., 2016, Site specific nutrients management and conservational tillage practices in maize-mustard relay cropping under rainfed conditions. *Eco. Environ. Cons.,* 22(3); 1409-1412.

Patel, K. S., Nayak, G. S. and Dwivedi, A. K., 2001, Balanced use of fertilizers in urid and pigeon pea on vertisol of Jabalpur. *J. Soils Crops,* 11(2): 173-177.

Peng S., Roland, J., Buresh, Jianliang, H., Xuhua, Z., Yingbin, Z., Jianchang, Y., Guanghuo, W. and Dobermann., 2010, Improving nitrogen fertilization in rice by site-specific N management. *Agron. Sustain. Dev.* 30:649–656.

Piper, C. S., 1966, *Soil and Plant Analysis.* Academic Press, New York, pp. 367.

Police Patil, A. S., 2011, Yield maximization in aerobic rice through site specific nutrient management approach. *Ph. D. Thesis*, Univ. Agric. Sci., Bangalore.

Prabhuraj, D. K., Thimmareddy, H., Mahadevappa, L. and Bongale, U. D., 2006, Soil test based fertilizer requirement for specific yield target of mulberry in alfisol under irrigated conditions. *Mysore J. Agric. Sci.*, 40(4): 464-470.

Prakash, S. S., Narasimha reddy, P. N., Basavaraja, P. K., Nethradhani Raj, C.N., Veerabhadraiah, A. M., Muralidharudu, Y. and Subbarao, A., 2007, *Technical bulletin* on STCR - an approach for fertilizer recommendations based on yield target.

Pramer, D. and Schmidt, E. L., 1964, *Experimental soil microbiology.* Burgers Publishing. Minneapolis, Minnesota, USA.

Prasad, B. and Prasad, J., 1994, Balanced and efficient fertilization of rice for its specific yield through soil testing and integrated nutrient management in calcareous soil. *Ann. Agric. Res.,* 15(3): 291-296.

Prasad, B., Prasad, J., Prasad, R. and Sharma, V. K., 1998, fertilizer prescription for *rabi* wheat based on targeted concept under varying soil fertility calcareous soils. *Ann. Agric. Res.* 9(2): 154 – 158.

Raghu, A. N., 2013, Assessment of soil test based fertilizer levels in paddy (*Oryza sativa* L.). *M.Sc Thesis.* Univ. Agric. Sci., Raichur.

Rajashekara, R., Wani, S. P., Sahrawat, K. L. and Pardhasaradhi, 2010, Integrated nutrient management to enhance on-farm productivity of rainfed maize in India. *Int. J. Soil Sci.,* 5(4): 216-224.

Rajesh, 2015, Performance of rice (*oryza sativa* l.) genotypes as influenced by different levels of nitrogen under transplanting and direct seeding methods and their residual effects on succeeding sesame (*Sesamum indicum* L.) *Ph.D. Thesis*. Univ. Agric. Sci., Raichur.

Ram, A. J., Dungrani, R. A., Arvadia, M. K. and Kanwar, L., Sahrawat, 2011, Diversification of rice (*Oryza sativa* L.) based cropping systems for higher productivity, resource-use efficiency and economic returns in South Gujarat of India. *Archives Agron. Soil Sci.,* 58(6):561-572.

Ramachandrappa, B. K., Sathish, A., Dhanapal, G. N. and Srikanth Babu, P. N., 2014, Nutrient management strategies for enhancing productivity of dryland crops in Alfisols. *Indian J. Dryland Agric. Res. & Dev.*, 29(2): 49-55.

Ramamoorthy, B., Narasimhan, R. L. and Dinesh, R. S., 1985, Fertilizer application for specific yield targets of Sonara 64 (wheat). *Indian Farming*, 17(5): 43-48.

Ramesh, S. and Chandrasekaran, B., 2007, Effect of establishment techniques and nitrogen management on LNC, flowering, nitrogen use efficiency and quality of rice hybrid. *Indian J. Agron.,* 2 (1): 38-45.

Rana, D.S., Giri, G. and Pachauri, D.K. 2007. Direct and cumulative residual effect of phosphorus and sulphur on yield trend, system productivity, economics and balance sheet of Indian mustard (*Brassica juncea*) – sunflower (*Helianthus annuus*) – urdbean (*Vigna mungo*) cropping system. *Indian J. Agric. Sci.*, 77(7): 408-414.

Rao, D. L. N., 2005, Soil microbial diversity in chemical and organic farming. Paper presented at ‘‘*National seminar on organic farming-Current Scenario and future thrust*’’ at Agric. Univ., Hyderabad, pp 61-64.

Rao, K. T., Rao, C. H. P., Subbaiah, G. and Rao, M.S., 1998, Effect of nitrogen management on yield and nutrient uptake in direct seeded and transplanted rice. *Andhra Agric. J.*, 45(3/4): 222-224.

Ravi, K. and Rao, K. R., 1992, Studies on levels and times of application of potassium for *kharif* rice (*Oryza sativa* L.). *The Andhra Agric. J.*, 39 (2): 74-76.

Ray, P. K., Jana, A. K., Maitra, D. N., Saha, M. N., Chaudhury, J., Saha, S. and Saha, A.R., 2000, Fertilizer prescriptions on soil test basis for jute, rice and wheat in a Typic Ustochrept. *J. Indian Soc. Soil Sci.,* 48: 79-84.

Reddy, B. G. and Reddy, M. S., 1999, Available macronutrient status in soil as influenced by integrated nutrient management in maize-soybean cropping system. *J. Res., Angrau.,* 27(4): 404-407.

Rekhi, R. S., Benbi, D. K. and Bhajan Singh., 2000, Effect of fertilizers and organic manures on crop yields and soil properties in rice-wheat cropping system. *Rice-Wheat Consortium Paper Series.* 6. Pp. 1-6.

Riazuddin Ahmed, S., Chandrasekhar Reddy, K. and Shaik M., 1999, Soil test yield goal approach as an aid to balanced fertilization to rice in intensive cropping system. *Oryza,* 36(3): 223-227.

Rutkowska, A., Pikuła, D. and Stepien, W., 2014, Nitrogen use efficiency of maize and spring barley under potassium fertilization in long-term field experiment. *Plant Soil Environ.,* 60(12): 550-554.

Sagar, G. K. and Reddy, G. R., 1995, Uptake of phosphorus and potassium as influenced by different forms of urea, levels of nitrogen and times of application of nitrogen in rice. *Andhra Agril. J.*, 42(1-4): 92-93.

Salinas-Garcia, J. R., Velazquez-Garcia, J. D., Gallardo-Valdez, A., Diaz-Mederos, P., Caballero-Hernandez, F., Tapia-Vargas, L. M. and Rosales-Robles, E., 2002, Tillage effects on microbial biomass and nutrient distribution in soils under *rainfed* corn production in central-western Mexico. *Soil Tillage Res.,* 66: 143-152.

Sanjay, M. T., Prabhakara Setty, T. K. and Nanjappa, H. V., 2006, Evaluation of soil test crop response approach for rice under different methods of crop establishment. *Mysore J. Agric. Sci.,* 40(3): 300-305.

Santhi, R. and Selvakumari, G., 1999, Yield targeting and integrated plant nutrition system for soil fertility maintenance in a rice based cropping sequence. *Madras Agric. J*., 86 (1-3): 138-139.

Sapkota, B.,Majumdar, K., Jat, M. L., Kumar, A., Dalip, K. Bishnoia, A. J. Mirasol, P., 2014, Precision nutrient management in conservation agriculture based wheat production of North West India: Profitability, nutrient use efficiency and environmental footprint. *Field Crops Res.,* 155(14): 233-244.

Saraswathy, R. and Bama, K. S., 2004, Phosphotase enzyme activities and phosphorus content in rice rhizosphere soil. *J. Ecol.*, 16(6): 413-417.

Satyanarayana, T., majumdar, K. and Biradar, D. P., 2011, New approaches and tools for site-specific nutrient management with reference to potassium. *Karnataka J. Agric. Sci.*, 24 (1): 86-90.

Satyanarayana, T., Majumdar, K., Pampolino, M., Johnston, A. M., Jat, M. L., Kuchanur, Sreelatha, D., Kumar, Y., Biradar, D. P. and Patil, S. G., 2013, Nutrient expert: A tool to optimize nutrient use and improve productivity of maize. *Better Crops India*, 97: 21-24.

Satyanarayana, V. and Prasad, V. V., 2002, Influence of integrated use of farmyard manure and inorganic fertilizers on yield and components of irrigated lowland rice. *J. Plant Nutrition*, 25(10): 2081-2090.

Selvakumari, G., 1998, Yield targeting and integrated plant nutrition system for soil fertility maintenance in a rice based cropping sequence. *Madras Agric. J.*, 86 (1-3): 138-139.

Shaobing, P., Roland, J., Buresh., Jianliang, H., Xuhua, Z., Yingbin, Z., Jianchang, Y., 2010, Improving nitrogen fertilization in rice by site-specific N management. *Agron. Sustain. Dev.* 30:649–656.

Sharma, A. R. and Mittra, B. N., 1989, Effect of N and P on rice and their residual effect on succeeding wheat/gram crop. *Indian J. Agron.,* 34(1): 40-43.

Sharma, J. C., Karwasra, S. P. S., Sharma, A. P. and Panwar, B. S., 1989, Soil test fertilizer recommendation for increased economic yield of rice, *Int. Rice Res. Newslett.*,**14**: 32-33.

Sharma, R. P., Pathak, S. K., Haque, M. and Manser Lal, 2008, Productivity, profitability and nutrient balance as influenced by diversification of rice (*Oryza sativa*) - wheat (*Triticum aestivum*) cropping system. *Indian J. Agron.*, 53(2): 97-101.

Sharma, R.K., Shrivasatva, U.K., Tomar, S.S., Tiwari, P.N. and Yadav, R.P. 1999. Nutrient management in soybean (*Glycine max*) – mustard (*Brassica juncea*) crop sequence. *Indian J. Agron.,* 44(3): 493-498.

Sharma, S. K. and Jain, N. K., 2014, Nutrient management in wheat (*Triticum aestivum*)-based cropping systems in sub-humid southern zone of Rajasthan. *Indian J. Agron.*, 59(1): 26-33.

Sharma, V.K. and Singhal, S.K., 2014, Validation of soil test based fertilizer prescriptions for targeted yield of pearl millet, rice, wheat and mustard at farmers' field. *Ann. Plant Soil Res.*, 16(4): 367-371.

Sharma, V.K., Pandey, R.N. and Sharm, B.M., 2015, Studies on long-term impact of STCR based integrated fertilizer use on pearl millet-wheat cropping system in semi arid condition of India. *J. Environ. Biol.,* 36: 241-247.

Shedzhen, N. K., Aleshin, E. P. and Doseeva, O. A., 1991, Variation in enzyme activity of rice field soil under the effect of trace element fertilizers. *Soviet Agric. Sci.*, 8: 15–16.

Shreenivas, B. V., 2016, Sustainable nutrient management approaches for maximizing productivity and profitability of maize-chickpea cropping system in vertisol of upper krishna project (UKP) command area. *Ph.D. Thesis.* Univ. Agric. Sci., Raichur.

Singaram, C. P. and Kamalakumari, K., 1995, Long-term effect of FYM and fertilizers on enzyme dynamics of soil. *J. Indian Soc. Soil Sci.,* 43: 378-381.

Singh, A. K., Bhatti, B. P., Sundaram, P. K., Santosh Kumar, Bahrati, R. C., Naresh, C. and Mathura Rai., 2012, Study of site specific nutrient management of cowpea seed production and their effect on soil nutrient status. *J. Indian. Agril. Sci.,* 4(10): 191-198.

Singh, A. K., Gautama, U. S., Singh, J., Singh, A. and Shrivastava, P., 2015, Impact of nutrient management technologies in transplanted rice under irrigated domains of Central India. *African J.Agric. Res.,* 10(5), 345-350.

Singh, K.N., Khan, G.M. and Bali, A.S. 2001, Response of brown sarson (*Brassica campestris* subsp. *oleifera* var. brown *sarson*) to residual effect of organic manure, nitrogen and transplanting dates of rice (*Oryza sativa*). *Indian J. Agron.,* 46(3): 395-399.

Singh, V.K., Tiwari, K.N., Gill, M.S., Sharma, S.K., Dwivedi, B.S., Shukla, A.K. and Mishra, P.P. 2008, Economic viability of site-specific nutrient management in rice-wheat cropping system. *Better Crops Int.,* 92 (3):29-30.

Singh, Y. and Singh, Y. K., 2000, Fertilizer application for specific yield targets. *J. Indian Soc. Soil Sci.,* 6: 169-173.

Singh, Y. V., Sharma, P. K. and Meena, R., 2014, Effect of soil test crop response technology on productivity and economics of rice crop of Varanasi district of Uttar Pradesh. *J. Rural & Agric. Res.,* 14(1): 77-80.

Sneh, G., Chandes, K., Mundra, M. C. and Kapoor, K. K., 1999, Influence of inorganic fertilizers and organic amendments on soil organic matter and soil microbial properties under tropical conditions. *Biol. Fertil Soils,* 29: 196-200.

Sonar, K. R., Dhage, A. S., Bagul, K. M., Kadam, J. R., Patil, N. D., Mahajan, S.V. and Bapaka, D. G., 1984, Fertilizer requirement for targeting of *kharif* sorghum yield

in Vertisols of Maharashtra. In: *Souvenir, 12th Workshop of All India Co-ordinated Project for Investigations on Soil Test Crop Response Correlation*, 26-28 September 1984, pp. 47-49.

Sourov and Sanyal, 2007, Site-specific potassium management for rice grown in selected alluvial soils of West Bengal. *Better Crops India.* (1):22-24.

Subba Rao, A. and Sanjay Srivastava, 2000, Soil test based fertilizer use-a must for sustainable agriculture. *Fert. News,* 45(2): 25-38.

Subba Rao, A., Sanjay Srivastava, Samanta, Maji, A. K., Singh, K. N., and Raju, N. S., 2005, Prescribing optimum doses of nutrients for targeted yield through soil fertility maps in Andhra Pradesh, *J. Indian. Soc. Agril. Stat*, 59(2): 131-140.

Subbiah, B. V. and Asija, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Cur. Sci.,* 25: 259-260.

Subhendumandal and Swamy, S. N., 2003, Effect of time of nitrogen application on yield and yield attributes of rice (*Oryza sativa* L.) cultivars. *Env. Ecol.,* 21(2): 411-413.

Subramoney, N. and Padmanabhan Nambiar, E., 1969, Soil test crop response correlation studies in Kerala. *J. Indian Soc. Soil Sci*., 17: 179-182.

Sunjingjing, Zhu, M., Yangiaoqia, Zhang, C. and Yaojun, 2015, Microbial, urease activities and organic matter responses to nitrogen rate in cultivated soil. *Open Biotech. J*., 9: 14-20.

Surendra Singh and Sarkar, A. K., 2001, Balanced use of major nutrients for sustaining higher productivity of maize-wheat cropping system in acidic soils of Jharkhand. *Indian J. Agron.,* 46(4): 605-610.

Suri V. K. and Verma T. S., 1999, Targeted yield concept for efficient and economic fertilizer use in a maize-wheat cropping system and build up of native fertility in a *Typic Haiplustalf. J. Indian Soc. Soil Sci.,* 47(1): 67-72.

Tamboli, B. D., Patil, Y. M., Somawanshi, R. B. and Sonar, K. R., 1996, Soil test based fertilizer recommendation for targeted yields of *kharif* groundnut in Vertisols of Maharashtra. *J. Maharashtra* Agri. Uni., 21(3): 321-324.

Tandon, H. L. S, 1976, Fertilizer demonstration based on the targeted yield approach. *Fert. News,* 35(3):27-30.

Tetarwal, J. P., Baldev Ram and Meena, D. S, 2011, Effect of integrated nutrient management on productivity, profitability, nutrient uptake and soil fertility in rainfed maize (*Zea mays* L.). *Indian J. Agron.,* 56(4): 373-376.

Thakur, A. K., Uphoff, N. and Anthony, E., 2009, Assessment of physiological effects of system of rice intensification (SRI) practices compared with recommended rice cultivation practices in India. *Exptl. Agric*., pp. 1-22.

Thakur, D. R., Prakash, B. M., Kharwar, P. C. and Bhalla, S. K., 1998, Effect of nitrogen and plant spacing on yield, nitrogen uptake and economics in baby corn (*Zea mays*). *Indian J. Agron.,* 43(4): 668-671.

Thakur, R.N., Arya, P.S. and Thakur, S.K. 1999. Response of french bean (*Phaseolus vulgaris*) varieties to fertilizer levels, rhizobium inoculation and their residual effect on onion (*Allium cepa*) in mid-hills of north-western Himalayas. *Indian J. Agron.,* 69(6): 416-418.

Tolanur, S. I. and Badanur, V. P., 2003, Changes in organic carbon, available N, P and K under integrated use of organic manure, green manure and fertilizer on sustaining productivity of pearl millet-pigeon pea system and fertility of an Inceptisol. *J. Indian Soc. Soil Sci.,* 5(1): 37-41.

Trinh Q. K., Tran, T. N., Huan, S. T. and Roland. B., 2007, Effect of site specific nutrient management on grain yield, nutrient use efficiency and rice production profit in the Mekong Delta. *Omonrice,* 15:153-158.

Trivedi, S.K. and Singh, V. 1999. Response of blackgram (*Phaseolus mungo*) – Indian mustard (*Brassica juncea*) cropping sequence to fertilizer application. *Indian J. Agric. Sci.,* 69(2): 86-89.

Troug, E., 1960, Fifty years of soil testing Trans. 7th*Int. Congr. Soil Sci*., 4: 46-52.

Umesh, M. R., 2008, Investigation on balanced fertilization for maize–pigeonpea cropping sequence in *Alfisols* of Karnataka. *Ph.D. Thesis.* Univ. Agric. Sci., Bangalore.

Umesh, M. R., Manjunatha, N., Shankar, M. A. and Jagadeesha, N., 2014, Influence of nutrient supply levels on yield, nutrient uptake, grain quality and economics of corn (*Zea mays* L.) in *Alfisols* of Karnataka. *Indian J. Dryland Agric. Res. & Dev*., 29(1): 73-78.

Upendra, A. R., Dakshina Murthy, K. M., Sridhar, T.V., Tejeswara Rao, K. and Rajendra Prasad T .V. P., 2013, Effect of site-specific nutrient management on productivity, profitability and soil N, P and K balance in rice-rice-cropping system. *Prog. Agric.*, 13(1): 1-6.

Uphoff, N., 2006, Thoughts on the history, principles and practices of SRI and on its importance for the present scenario. *National Symposium on System of Rice Intensification – Present status and future prospects*. 17-18 November, p. 3- 10.

Velayutham, A., Velayudham, K. and Balasubramanian, R., 1992, Effect of split application of potassium to low land rice on NPK uptake and yield. *Orissa J. Agric. Res.*, 5(3-4): 162-165.

Venkateswarlu and Singh, M., 1980, Response of rice varieties to different spacings and fertility levels on yield attributes and yield. *Indian J. Agron.*, 25(2): 263-272.

Verma, T. S., Singh, V. K. and Paul, J., 2002, Prescription based fertilizer recommendations for rice, maize and wheat in different agro-climatic zones of Himachal Pradesh. *J. Indian Soc. Soil Sci.*, 50(3): 272-277.

Verma, T., Suri, V. K. Sandal, S. K. and Paul, J., 2005, Validation of soil test-based fertilizer adjustment equations on targeted yield in wet temperate zone of Himachal Pradesh. *Indian J. Agric. Sci.*, 75(10): 654-657.

Walkley, A. J. and Black, C. A., 1934, Estimation of soil organic carbon by the chromic and titration method. *Soil Sci*., 37: 29-38.

Wang, G., Zhang, Q.C., Witt, C., Buresh, R.J., 2007, Opportunities for yield increases and environmental benefits through site-specific nutrient management in rice systems of Zhejiang province, China. *Agric. Systems*, (94): 801–806.

Wang, H. 2001, Variation in the performance of site specific nutrient management among different environments with irrigated rice in Asia. *Better Crops Int.*, 16(20): 18-23.

Website:*http:// www.ipni.net* 2010.

Wijebandara, I. D., 2007, Studies on distribution and transformation of soil zinc and response of rice to nutrients in traditional and system of rice intensification (SRI) method of cultivation. *Ph.D. Thesis.* Univ. Agric. Sci., Dharwad. p: 235.

Witt, C., Pasuquin, J. M. and Dobermann, A., 2006, Towards a site-specific nutrient management approach for maize in Asia. *Better Crops,* 90(2): 28-31.

Xinpeng Xu, Ping, H., Mirasol, F. P., Johnston, A. M., Limin, C. and Weizhou, 2014, Fertilizer recommendation for maize in China based on yield response and agronomic efficiency. *Field Crops Res*., 157: 27-34.

Yadav, D. S and Alok Kumar, 2009, Long-term effect of nutrient management on soil health and productivity of rice (*Oryza sativa*) - wheat (*Triticum aestivum*) system, *Indian J. Agron*., 54(1): 15-23.

Yadhav, K. S. and Hira Nand, 2004, Site specific nutrient management for optimal food grain production in Haryana. *Better Crops Int.,* 88(2): 21-22.

Appendices

APPENDIX – I

Nitrogen and phosphorous concentration in dry direct seeded rice after harvest during 2015 and 2016

Treat-ments	Nitrogen (%)									Phosphorous (%)								
	Grain			Straw			Total			Grain			Straw			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	1.26	1.18	1.22	0.33	0.34	0.34	1.59	1.52	1.55	0.47	0.48	0.48	0.06	0.05	0.055	0.53	0.53	0.53
T_2	1.21	1.24	1.23	0.42	0.44	0.43	1.63	1.67	1.65	0.55	0.57	0.56	0.12	0.14	0.129	0.67	0.71	0.69
T_3	1.37	1.39	1.38	0.62	0.64	0.63	1.99	2.02	2.01	0.60	0.62	0.61	0.14	0.16	0.150	0.74	0.78	0.76
T_4	1.29	1.31	1.30	0.49	0.54	0.52	1.78	1.83	1.80	0.50	0.47	0.49	0.07	0.11	0.089	0.57	0.58	0.57
T_5	1.14	1.19	1.17	0.39	0.42	0.41	1.53	1.60	1.56	0.40	0.44	0.42	0.08	0.10	0.085	0.48	0.54	0.51
T_6	1.30	1.31	1.31	0.59	0.60	0.60	1.89	1.91	1.90	0.49	0.50	0.50	0.12	0.14	0.125	0.61	0.64	0.62
T_7	1.36	1.35	1.36	0.57	0.59	0.58	1.93	1.93	1.93	0.52	0.53	0.53	0.11	0.13	0.118	0.63	0.66	0.64
T_8	1.36	1.38	1.37	0.62	0.63	0.63	1.98	2.01	1.99	0.56	0.57	0.57	0.13	0.15	0.140	0.69	0.72	0.71
T_9	1.20	1.24	1.22	0.42	0.46	0.44	1.62	1.68	1.65	0.46	0.49	0.48	0.09	0.11	0.098	0.55	0.60	0.57
T_{10}	1.34	1.35	1.35	0.53	0.55	0.54	1.87	1.89	1.88	0.48	0.50	0.49	0.11	0.12	0.115	0.59	0.62	0.61

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

APPENDIX – II

Potassium and sulphur concentration in dry direct seeded rice after harvest during 2015 and 2016

Treat-ments	Potassium (%)									Sulphur (%)								
	Grain			Straw			Total			Grain			Straw			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	0.39	0.41	0.40	1.11	1.14	1.13	1.50	1.54	1.52	0.080	0.070	0.075	0.090	0.110	0.100	0.17	0.18	0.18
T_2	0.42	0.43	0.43	1.32	1.35	1.34	1.74	1.77	1.75	0.083	0.103	0.093	0.101	0.121	0.111	0.18	0.22	0.20
T_3	0.44	0.46	0.45	1.25	1.29	1.27	1.69	1.73	1.71	0.092	0.113	0.103	0.128	0.146	0.137	0.22	0.26	0.24
T_4	0.40	0.38	0.39	1.10	1.01	1.06	1.50	1.44	1.47	0.085	0.096	0.090	0.096	0.106	0.101	0.18	0.20	0.19
T_5	0.47	0.52	0.50	1.48	1.55	1.52	1.95	2.04	1.99	0.080	0.100	0.090	0.095	0.110	0.102	0.17	0.21	0.19
T_6	0.52	0.54	0.53	1.60	1.62	1.61	2.12	2.15	2.14	0.104	0.120	0.112	0.128	0.146	0.137	0.23	0.27	0.25
T_7	0.51	0.53	0.52	1.61	1.63	1.62	2.12	2.15	2.14	0.100	0.110	0.105	0.130	0.157	0.144	0.23	0.27	0.25
T_8	0.53	0.55	0.54	1.75	1.84	1.80	2.28	2.35	2.31	0.110	0.130	0.120	0.135	0.152	0.144	0.25	0.28	0.26
T_9	0.42	0.43	0.43	1.12	1.16	1.14	1.54	1.57	1.56	0.082	0.090	0.086	0.096	0.113	0.105	0.18	0.20	0.19
T_{10}	0.43	0.44	0.44	1.34	1.36	1.35	1.77	1.79	1.78	0.090	0.100	0.095	0.104	0.124	0.114	0.19	0.22	0.21

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

APPENDIX – III

Zinc and iron concentration in dry direct seeded rice after harvest during 2015 and 2016

Treat-ments	Zinc (ppm)									Iron (ppm)								
	Grain			Straw			Total			Grain			Straw			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	16.08	15.57	15.82	23.01	22.84	22.93	39.09	38.41	38.75	128.37	125.87	127.12	151.20	148.24	149.72	279.57	274.11	276.84
T_2	14.17	16.48	15.33	24.32	27.42	25.87	38.49	43.9	41.20	146.74	151.24	148.99	186.53	197.03	191.78	333.27	348.27	340.77
T_3	19.77	21.08	20.43	31.70	34.80	33.25	51.47	55.88	53.68	251.42	255.77	253.60	298.05	308.55	303.30	549.47	564.32	556.90
T_4	15.29	17.60	16.45	28.75	31.85	30.30	44.04	49.45	46.75	178.22	182.72	180.47	218.53	228.95	223.74	396.75	411.67	404.21
T_5	15.85	18.16	17.00	22.71	25.81	24.26	38.56	43.97	41.27	134.20	130.42	132.31	170.46	180.96	175.71	304.66	311.38	308.02
T_6	20.89	22.80	21.85	32.88	35.98	34.43	53.77	58.78	56.28	254.42	259.50	256.96	318.00	320.23	319.12	572.42	579.73	576.08
T_7	19.16	21.47	20.31	31.10	34.20	32.65	50.26	55.67	52.97	247.12	250.40	248.76	289.90	305.45	297.68	537.02	555.85	546.44
T_8	20.50	22.81	21.65	32.10	35.20	33.65	52.6	58.01	55.31	255.32	261.37	258.35	320.20	330.42	325.31	575.52	591.79	583.66
T_9	14.41	16.72	15.57	27.50	30.60	29.05	41.91	47.32	44.62	145.40	146.56	145.98	201.25	211.73	206.49	346.65	358.29	352.47
T_{10}	18.66	19.97	19.32	30.79	33.89	32.34	49.45	53.86	51.66	192.62	196.28	194.45	221.43	231.93	226.68	414.05	428.21	421.13

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

APPENDIX – IV

Nitrogen and phosphorous concentration in mustard after harvest during 2016 and 2017

Treatments	Nitrogen (%)									Phosphorous (%)								
	Grain			Straw			Total			Grain			Straw			Total		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	2.13	1.71	1.92	0.54	0.42	0.48	2.67	2.19	2.43	0.50	0.40	0.45	0.090	0.085	0.088	0.59	0.49	0.54
T_2	2.35	2.13	2.24	0.61	0.48	0.54	2.96	2.67	2.81	0.54	0.43	0.49	0.120	0.110	0.115	0.66	0.55	0.60
T_3	2.63	2.41	2.52	0.70	0.59	0.64	3.33	3.05	3.19	0.61	0.58	0.60	0.159	0.139	0.149	0.77	0.73	0.75
T_4	2.42	2.09	2.26	0.63	0.50	0.56	3.05	2.65	2.85	0.53	0.46	0.50	0.120	0.110	0.115	0.65	0.58	0.61
T_5	2.20	1.80	2.00	0.60	0.48	0.54	2.80	2.34	2.57	0.51	0.40	0.46	0.100	0.090	0.095	0.61	0.50	0.55
T_6	2.37	2.01	2.19	0.64	0.52	0.58	3.01	2.59	2.80	0.52	0.49	0.51	0.124	0.125	0.125	0.64	0.61	0.63
T_7	2.32	2.10	2.21	0.63	0.52	0.57	2.95	2.67	2.81	0.53	0.48	0.51	0.129	0.126	0.128	0.66	0.61	0.63
T_8	2.54	2.29	2.42	0.69	0.55	0.62	3.23	2.91	3.07	0.55	0.54	0.55	0.135	0.132	0.134	0.69	0.67	0.68
T_9	2.25	1.83	2.04	0.60	0.47	0.53	2.85	2.36	2.60	0.52	0.42	0.47	0.120	0.112	0.116	0.64	0.53	0.58
T_{10}	2.39	1.95	2.17	0.63	0.51	0.57	3.02	2.52	2.77	0.53	0.42	0.48	0.117	0.116	0.117	0.65	0.54	0.59

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

APPENDIX – V

Potassium concentration in mustard after harvest during 2016 and 2017

Treat-ments	Potassium (%)								
	Grain			Straw			Total		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	0.56	0.54	0.55	1.58	1.54	1.56	2.14	2.10	2.12
T_2	0.60	0.61	0.61	1.63	1.59	1.61	2.23	2.22	2.23
T_3	0.61	0.59	0.60	1.63	1.60	1.62	2.24	2.21	2.22
T_4	0.59	0.58	0.59	1.61	1.58	1.60	2.20	2.18	2.19
T_5	0.60	0.58	0.59	1.62	1.58	1.60	2.22	2.18	2.20
T_6	0.62	0.60	0.61	1.64	1.60	1.62	2.26	2.22	2.24
T_7	0.63	0.62	0.63	1.65	1.62	1.64	2.28	2.26	2.27
T_8	0.65	0.67	0.66	1.68	1.67	1.68	2.33	2.35	2.34
T_9	0.58	0.57	0.58	1.59	1.57	1.58	2.17	2.15	2.16
T_{10}	0.60	0.61	0.61	1.62	1.61	1.62	2.22	2.23	2.22

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control (No NPK & FYM)
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (Targeted yield 45 q ha^{-1})
T_6: STCR approach (Targeted yield 55 q ha^{-1})
T_7: SSNM approach (Targeted yield 45 q ha^{-1})
T_8: SSNM approach (Targeted yield 55 q ha^{-1})
T_9: Nutrient expert approach (Targeted yield 45 q ha^{-1})
T_{10}: Nutrient expert approach (Targeted yield 55 q ha^{-1})

APPENDIX – VI

Details of cost of cultivation of dry direct seeded rice in different treatments (₹ ha^{-1}) during *kharif* 2015

Sl No.	Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
1.	**Land preparation**										
	a) Ploughing (2) (₹ 1000 Plough^{-1})	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	b) Harrowing (2) (₹ 1000 Harrow^{-1})	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	c) Reverse blade (1) (₹ 500 Reverse blade^{-1})	500	500	500	500	500	500	500	500	500	500
	c) Seed rate 30 kg @ ₹ 30 kg^{-1}	900	900	900	900	900	900	900	900	900	900
	d) Sowing (₹ 450 hr^{-1}seed drill)	1350	1350	1350	1350	1350	1350	1350	1350	1350	1350
	e) Manual weeding (18 women days x ₹ 120 day^{-1})	2160	2160	2160	2160	2160	2160	2160	2160	2160	2160
	g) Irrigation labour cost (2 man days x ₹ 250 day^{-1})	500	500	500	500	500	500	500	500	500	500
2.	**Manure/ Fertilizer cost**										
	a) Urea (₹ 7 kg^{-1})	0	1224	2755	1489	1507	1888	1663	2027	1373	1629
	b) DAP (₹ 23.67 kg^{-1})	0	2573	8542	1930	0	1441	1801	2213	1286	1441
	c) MOP (₹ 17 kg-^{1})	0	1417	1700	1063	1643	2210	2686	3258	1048	1275
	d) $ZnSO_4$(₹ 40 kg^{-1})	0	1000	1000	1000	1000	1000	1000	1000	1000	1000
	e) $FeSO_4$ (0.5%)(₹ 240 kg^{-1})	0	1200	1200	1200	1200	1200	1200	1200	1200	1200
	d) FYM (₹ 650 t^{-1})	0	4550	4550	4550	4550	4550	4550	4550	4550	4550
	e) Application cost (50 ₹/ bag fertilizer) (FYM application ₹1000)	0	1367	1901	1356	1312	1458	1471	1480	1312	1346

APPENDIX – VI. Contd...

Sl. No.	Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
3.	**Cost of chemicals** **a) Herbicides**										
	Pendimethalin @1750 ml ha^{-1}	1347	1347	1347	1347	1347	1347	1347	1347	1347	1347
	Nominee gold @250 ml ha^{-1}	1818	1818	1818	1818	1818	1818	1818	1818	1818	1818
	b) Plant protection measures										
	Chloropyriphos @ 1000 ml ha^{-1}	500	500	500	500	500	500	500	500	500	500
	Tricyclazole @ 250 g ha^{-1}	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040
	Coragen @250 ml ha^{-1}	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150
	b) Spraying cost (2 man days x ₹ 300 day^{-1})	500	500	500	500	500	500	500	500	500	500
4.	**Harvesting, threshing and bagging (20 man days x ₹ 250 day^{-1})**	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
5.	**Marketing cost (₹ 50 per 75 kg bag)**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
6.	**Miscellaneous cost**	500	500	500	500	500	500	500	500	500	500
7.	**Total cost of cultivation**	23265	36596	44913	35853	34477	37012	37636	38993	35034	35706
8.	**Gross Returns (₹ 2100 q^{-1} grain) (₹ 1000 t^{-1} straw)**	51331	97627	109384	102041	83440	113545	106692	120798	92741	105223
9.	**Net Returns (₹ ha^{-1})**	28066	61031	64471	66188	48963	76533	69056	81805	57707	69517
10.	**BC Ratio**	2.21	2.67	2.44	2.85	2.42	3.07	2.83	3.10	2.65	2.95

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

APPENDIX -VII

Details of cost of cultivation of dry direct seeded rice in different treatments (₹ ha^{-1}) during *kharif* 2016

Sl. No.	Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
1.	**Land preparation**										
	a) Ploughing (2) (₹ 1000 Plough^{-1})	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	b) Harrowing (2) (₹ 1000 Harrow^{-1})	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	c) Reverse blade (1) (₹ 500 Reverse blade^{-1})	500	500	500	500	500	500	500	500	500	500
	c) Seed rate 30 kg @ ₹ 40 kg^{-1}	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
	d) Sowing (₹ 500 hr^{-1}seed drill)	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
	e) Manual weeding (18 women days x ₹ 150 day^{-1})	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700
	g) Irrigation labour cost (2 man days x ₹300 day^{-1})	600	600	600	600	600	600	600	600	600	600
2.	**Manure/ Fertilizer cost**										
	a) Urea (₹ 6.0 kg^{-1})	0	1049	2361	1276	1181	1577	1426	1737	1177	1396
	b) DAP (₹ 25 kg^{-1})	0	2717	9022	2038	978	1815	1902	2337	1359	1522
	c) MOP (₹11 kg^{-1})	0	917	1100	688	1137	1467	1738	2108	678	825
	d) $ZnSO_4$(₹ 40 kg^{-1})	0	1000	1000	1000	1000	1000	1000	-	1000	1000
	e) $FeSO_4$ (0.5%)(₹ 240 kg^{-1})	0	1200	1200	1200	1200	1200	1200	1200	1200	1200
	e) FYM (₹ 650 t^{-1})	0	4550	4550	4550	4550	4550	4550	4550	4550	4550
	e) Application cost (50 ₹/ bag fertilizer) (FYM application ₹1100)	0	1467	2001	1456	1438	1554	1571	1562	1412	1446

APPENDIX- VII Contd...

Sl. No.	Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
3.	**Cost of chemicals** **a) Herbicides**										
	Pendimethalin @1750 ml ha^{-1}	1347	1347	1347	1347	1347	1347	1347	1347	1347	1347
	Nominee gold @250 ml ha^{-1}	1818	1818	1818	1818	1818	1818	1818	1818	1818	1818
	b) Plant protection measures										
	Chloropyriphos @ 1000 ml ha^{-1}	500	500	500	500	500	500	500	500	500	500
	Tricyclazole @ 250 g ha^{-1}	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040
	Coragen @250 ml ha^{-1}	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150
	Spraying cost (2 man days x₹ 300 day^{-1})	600	600	600	600	600	600	600	600	600	600
4.	**Harvesting, threshing and bagging (18 man days x ₹ 300 day^{-1})**	5200	5200	5400	5400	5400	5400	5400	5400	5400	5400
5.	**Marketing cost (₹ 50 per 75 kg bag)**	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
6.	**Miscellaneous cost**	700	700	700	700	700	700	700	700	700	700
7.	**Total cost of cultivation (₹)**	25355	38255	46789	37763	37039	38718	38942	39049	36931	37494
8.	**Gross Returns (₹ 2060 q^{-1} grain) (₹1000 t^{-1} straw)**	43293	97854	112760	104894	88530	114791	107079	120537	94232	105614
9.	**Net Returns (₹ ha^{-1})**	17938	59599	65971	67131	51491	76073	68137	81488	57301	68120
10.	**BC Ratio**	1.71	2.56	2.41	2.78	2.39	2.96	2.75	3.09	2.55	2.82

Note: FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray $FeSO_4$ @ 0.5 per cent were applied for all treatments except absolute control

T_1: Absolute control
T_2: Recommended dose fertilizer
T_3: Farmers practice
T_4: STL method
T_5: STCR approach (45 q ha^{-1} yield targeted)
T_6: STCR approach (55 q ha^{-1} yield targeted)
T_7: SSNM approach (45 q ha^{-1} yield targeted)
T_8: SSNM approach (55 q ha^{-1} yield targeted)
T_9: Nutrient expert approach (45 q ha^{-1} yield targeted)
T_{10}: Nutrient expert approach (55 q ha^{-1} yield targeted)

APPENDIX – VIII

Details of cost of cultivation of mustard (₹ ha^{-1}) during *rabi* 2015-16

Sl No.	Operations/ inputs used	Quantity (kg/ No./hrs)	Rate (₹ kg^{-1}unit^{-1})	Cost (₹ ha^{-1})
1.	Land preparation	0	0	0
2.	Seed	4 kg	120	480
3.	Labour cost for sowing	10 women days	120	1200
4.	Manual weeding	5 women days	120	600
5.	Irrigation	1 men days	300	300
6.	Manure/ Fertilizer cost	0	0	0
	Insecticide			
7.	Monocrotophos	1000 ml	450	450
8.	Labour cost for spraying	1 men and 1 women days	300 &120	420
9.	Labour cost for harvesting	10 women days	120	1200
10.	Labour cost for threshing & drying	5 women days	120	600
11.	Miscellaneous cost	-	-	800
12.	**Total cost of cultivation (₹ ha^{-1})**			**6,050**
	Outputs generated			Selling price (₹ q^{-1})
13.	Seed yield of mustard			4,300.00
14.	Stover of mustard			50.00

APPENDIX – IX

Details of cost of cultivation of mustard (₹ ha^{-1}) during during *rabi* 2016-17

Sl No.	Operations/ inputs used	Quantity (kg/ No./hrs)	Rate (₹ kg^{-1}unit^{-1})	Cost (₹ ha^{-1})
1.	Land preparation	0	0	0
2.	Seed	4 kg	120	480
3.	Labour cost for sowing	10 women days	150	1500
4.	Manual weeding	4 women days	150	600
5.	Irrigation	1 men days	300	300
6.	Manure/ Fertilizer cost	0	0	0
	Insecticide			
7.	Monocrotophos	1000 ml	450	450
8.	Labour cost for spraying	1 men and 1 women days	300 &150	450
9.	Labour cost for harvesting	10 women days	150	1500
10.	Labour cost for threshing & drying	5 women days	150	750
11.	Miscellaneous cost	-	-	1000
12.	**Total cost of cultivation (₹ ha^{-1})**			**7,030**
	Outputs generated			Selling price (₹ q^{-1})
13.	Seed yield of mustard			4,500.00
14.	Stover of mustard			50.00

STUDIES ON SOIL TEST BASED NUTRIENT MANAGEMENT APPROACHES IN DRY DIRECT SEEDED RICE-MUSTARD CROPPING SYSTEM

RAGHAVENDRA **2017** **Dr. K. NARAYANA RAO**
Major advisor

ABSTRACT

Field experiments were conducted in the farmer field of Vijayanagar camp, Tq/Dist: Raichur during *kharif* and *rabi* seasons of 2015-16 and 2016-17 on soil test based nutrient management approaches in dry direct seeded rice-mustard cropping system. The experiment was laid out in RCBD with ten treatments and three replications. Application of nutrients as per SSNM approach for targeted yield of 55 q ha^{-1} for Dry DSR and its residual effect on mustard was registered significantly higher growth, yield and yield attributes. Application of nutrients as per SSNM approach for targeted yield of 55 q ha^{-1} for Dry DSR registered significantly higher grain and straw yield (54.73 and 68.38 q ha^{-1}, respectively) and residual mustard seed yield and stover yield (592 kg ha^{-1} and 1856 kg ha^{-1}, respectively) over farmers practice and other soil test methods. Total uptake of major and micronutrients as well as higher use efficiency of N-54.88 %, P-65.56 % and K-95.13 % were observed in Dry DSR with nutrient application through SSNM approach targeted yield of 55 q ha^{-1} as compared to farmers practice and other soil test methods. Further, farmer practice recorded highest (₹ 52,391 ha^{-1}) cost of cultivation in dry direct seeded rice-mustard cropping sequence. Whereas, Significantly higher gross returns (₹ 1,47,554 ha^{-1}), net returns (₹ 1,01,993 ha^{-1}) and BC ratio (3.24) was obtained with SSNM approach for the targeted yield of 55 q ha^{-1} as compared to farmers practice and other treatments in dry direct seeded rice-mustard cropping system. SSNM approach is unique and most realistic to achieve the targeted yield in dry direct seeded rice-mustard cropping system.