Optimization of Potassium (K) supply and plant nutrition through different K management practices under rice-rice system in Odisha

A

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Date: 23/07/15

CERTIFICATE-I

This is to certify that the thesis entitled "**Optimization of Potassium (K) supply and plant nutrition through different K management practices under rice-rice system in Odisha"** submitted in partial fulfilment of requirements for the award of the degree of Master of Science in Agriculture (Soil Science & Agricultural Chemistry) to the Orissa University of Agriculture and technology, Bhubaneswar, is a faithful record of bonafide and original research work carried out by **Suchismita Mohapatra**, Adm. No. 05 AC/13 under my guidance and supervision. No part of this thesis has been submitted for any other degree of diploma.

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

Chairman

Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled **"Optimization of Potassium (K) supply and plant nutrition through different K management practices under rice-rice system in Odisha"** submitted by **Suchismita Mohapatra** to Orissa University of Agriculture and Technology, Bhubaneswar, in partial fulfilment of the requirements for the degree of Masters of Science in Agriculture (Soil Science and Agricultural Chemistry) has been approved by the students' advisory committee and the external examiner.

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LIST OF TABLES

Sl. No.	Tables	Page No.
3.1	Initial soil Characteristics measured in December,2013	21
3.2	Treatment details of the field experiment	23
3.3	Calendar of operation followed in Rabi (2013-14) and Kharif (2014) season	24
3.4	Scale for brown spot infestation	36
3.5	Scale for blast infestation	38
4.1(a)	Effect of different K management practices on yield and yield attributing parameters in the Rabi season (2013-14)	40
4.1(b)	Effect of different K management practices on yield and yield attributing parameters in the Kharif season (2014)	41
4.2	Effect of different K management practices on K content (%) at different stages in Rabi (2013-14) and Kharif season (2014)	43
4.3	Effect of different K management practices on biomass accumulation (q ha^{-1}) at different stages in Rabi (2013-14) and Kharif season (2014)	45
4.4 (a)	Effect of different K management practices on K uptake (kg ha^{-1}) at different stages in Rabi (2013-14)	46
4.4 (b)	Effect of different K management practices on K uptake (kg ha^{-1}) at different stages in Kharif (2014).	46
4.5 (a)	Effect of different K management practices on Available K (kg ha^{-1}) in different layers at different stages in the Rabi season (2013-14)	47
4.5 (b)	Effect of different K management practices on Available K (kg ha^{-1}) in different layers at different stages in the Kharif season (2014)	48

4.6 (a)	Effect of different K management practices on Reserve K (kg ha^{-1}) in different layers at different stages in the Rabi season (2013-14)	50
4.6 (b)	Effect of different K management practices on Reserve K (kg ha^{-1}) in different layers at different seasons in the Kharif season (2014)	50
4.7 (a)	Effect of different K management practices on Non-exchangeable K ha^{-1}) in different layers in the Rabi season (2013-14)	51
4.7 (b)	Effect of different K management practices on Non-exchangeable K (kg ha^{-1}) in different layers in the Kharif season (2014)	52
4.8 (a)	Effect of different K management practices on soil organic Carbon, Available N and Available P in the Rabi season (2013-14)	53
4.8 (b)	Effect of different K management practices on soil organic Carbon, Available N and Available P in the Kharif season (2014)	54
4.9 (a)	Effect of different K management practices on soil pH in different layers at different stages in the Rabi season (2013-14)	55
4.9 (b)	Effect of different K management practices on soil pH in different layers at different stages in the Kharif season (2014)	56
4.10 (a)	Effect of different K management practices on Microbial respiration (mg CO_2/100g soil/day) in Rabi (2013-14) and Kharif season (2014)	57
4.10 (b)	Effect of different K management practices on Dehydrogenase activity (µg TPF/g/24hr) in Rabi (2013-14) and Kharif season (2014)	58
4.11 (a)	Effect of different K management practices on N and P uptake (kg ha^{-1}) at different stages in Rabi(2013-14) and Kharif (2014)	59
4.12 (a)	Effect of K management practices on K balance in Rabi season (2013-14)	60
4.12 (b)	Effect of K management practices on K balance in Kharif season (2014)	61
4.12 (c)	Effect of K management practices on K balance per annum (2013-14)	61

4.13 (a)	Effect of different K management practices on expression of Blast disease in the Rabi (2013-14) and Kharif (2014) season	63
4.13 (b)	Effect of different K management practices on expression of Brown spot disease in the Rabi (2013-14) and Kharif (2014) season	64
4.13 (c)	Effect of different K management practices on average expression of Brown spot and blast in the Rabi (2013-14) season	65
4.13 (d)	Effect of different K management practices on average expression of Brown spot and blast in the Kharif (2014) season	66
4.14 (a)	Effect of different K management practices on incidence of insect pest in the Rabi season (2013-14)	67
4.14 (b)	Effect of different K management practices on incidence of insect pest in the Kharif season (2014)	68
4.15 (a)	Effect of K management practices on Cost economics in Rabi season(2013-14)	70
4.15 (b)	Effect of K management practices on Cost economics in Kharif season(2014)	70
4.15 (c)	Effect of K management practices on Cost economics per year (2013-14)	71
5.1	Crop response (%) to different K management practices	73
5.2	Effect of different K management practices on K/N and K/P at different stages in Rabi(2013-14) and Kharif (2014)	74
5.3	Composition of straw and quantity of nutrient added through straw	86
5.4	Ranking of treatment on the basis of cost analysis	88
5.5	Evaluation of K management options	89

LIST OF FIGURES

Sl. No.	Figures	Page No.
3.1	Weather parameters measured during growth period of Rabi (2013-14) and Kharif (2014)	22
3.2	Lay out of the field experiment	25
3.3	At transplanting of the field during Rabi(2013-14) season	25
3.4	Fertilizer application during MT stage	26
3.5	Foliar spray during PI stage	26
3.6	Visit of scientists to field during grain filling	27
3.7	Treatment with straw for incorporation and crop cutting area	27
3.8	Analysis of soil for Reserve-K through boiling on hot plate	30
3.9	Analysis of soil pH by pH meter	30
3.10	Whorl maggot infestation	37
3.11	Blast infestation	37
3.12	Attack of leaf folder	37
3.13	Pesticide application	37
5.1	Partitioning of K to different stages as influenced by different treatment and seasons	77

5.2	Soil available K at different stages of crop growth as influenced by different types of K management practices	79
5.3	Soil reserve K at different stages of crop growth as influenced by different types of K management practices	81
5.4	Soil non-exchangeable K at different stages of crop growth as influenced by different types of K management practices	82
5.5	Potassium balance in different seasons as influenced by different K management practices	84
5.6	Correlation between different forms of K with total uptake	85

ABSTRACT

Under the IRRI-OUAT Collaborative Students' Research Programme, a field experiment was conducted with rice crop (cv: Lalat) grown on an acidic medium land located in the Central Research Farm of Orissa University of Agriculture and Technology, Bhubaneswar during two seasons, Rabi (2013-14) and Kharif (2014) in order to investigate the effect of different Potassium management practices on crop yield and Potassium availability in soil, potassium uptake and disease and insect incidence. The experiment was laid out in RBD with three replications and nine treatments consisting of T_1: 40 kg K_2O ha^{-1}, T_2: 60 kg K_2O ha^{-1}, T_3: 80 kg K_2O ha^{-1}, T_4: 20 kg K_2O ha^{-1}+ straw, T_5: 30 kg K_2O ha^{-1}+ straw, T_6:40 kg K_2O ha^{-1} +straw, T_7: straw,T_8: 40 kg K_2O ha^{-1}+ 1% KNO_3 foliar spray at Panicle initiation stage, T_9: control. Following IRRI protocol both plant and soil samples were collected at critical growth stages and analysis was done using standard methods.

Treatment with 40kg K_2O ha^{-1} applied through fertilizer along with a foliar spray(1% KNO_3) at Panicle initiation stage yielded highest in both Rabi (3.84 tha^{-1}) and Kharif (5.35 tha^{-1}) season. The yield was at par with those in 60kg K_2O ha^{-1} and 30kg K_2O ha^{-1}+straw in Rabi and 80kg K_2O ha^{-1} and 30kg K_2O ha^{-1}+straw in Kharif. In Rabi the crop responded up to 60kg K_2O ha^{-1} applied through fertilizer and 30kg K_2O ha^{-1} applied through fertilizer +straw. At 80kg K_2O or 40kgK_2O ha^{-1} + straw the yield declined.

Treatment that received K only through fertilizer with or without foliar spray showed negative balance where as application of K through straw alone or in combination with fertilizer showed positive balance of K in soil. When calculated on annual basis total K balance varied between -140 to 89.1 kg ha^{-1} $year^{-1}$ with the treatment that received 40 kg K_2O with foliar spray and produced highest yield in both Rabi and Kharif seasons causing highest negative balance and the treatment, 30 kg K_2O as fertilizer along with straw caused highest positive balance. Besides adding potassium, paddy straw incorporation also caused improvement of biological health and added all other nutrients to soil.

In both the seasons the treatment receiving higher dose of K showed the lower Percentage of Disease Incidence (PDI). Insect incidence was more in control or where only straw was applied, but less where more K was applied. Incidence of both disease and insects was moderate with combined application of both fertilizer K and straw. Considering, crop yield, K balance, effect on soil health and disease and insect incidence, application of 30 kg K_2O ha^{-1} through fertilizer along with straw incorporation is suggested as the best management option for rice-rice system.

INTRODUCTION

Rice is the staple food of more than half of the world population and is one of the main sources of income and existence for most of the developing countries in the world. Rice, grown under 35 % of the total food grain area, contributes 40% of the food grain production in India. The second green revolution is about to start in the eastern part of India and Odisha is going to play a vital role in this perspective as it contributes about 7 % to the total rice production in India (Department of Agriculture & cooperation, GOI,2013-14 & 2014-15). But as per the projections made by Kumar *et al*.(2000) basing on the estimates of population growth, there will be deficit of about 2.5 million tonnes if the present growth rate of supply continues till 2030 (CRRI Vision 2030).To fill up this deficit there is no other way except for increasing the production. The production cannot be raised by a single method rather integration of many methods may help us to manage this problem in the long run without hampering our precious natural resources.

Rice, as all other crops, requires the essential elements for its growth and). Out of all elements, Potassium (K) is considered to be unique element due to its unique properties like activation of over 80 different enzymes, luxury consumption by plants, providing resistance to plant against diseases, insect pests, drought, cold etc. translocation of photosynthates to storage organs, increasing the quality of the products etc. (Tisdale, 1985; DeDatta and Mikkelson, 1985; Pettigrew, 2008; Römheld and Kirkby, 2010).

Potassium (K) is considered next to Nitrogen (N) as regards its role in rice production and rice usually takes up more K than N. Before 60's its application was not felt necessary, as a general lack of response to applied K was reported in experiments conducted in India. With the introduction of high yielding varieties during late 60's there was heavy withdrawal of nutrients from the soil and during 70's there was response to the extent of only 2-5 % (Randhwa and Tandon, 1982). Despite large uptake some soils with low available (1N NH4OAC-extractable) K did not even respond to K application (Goswami and Banerjee, 1978). However with progress of cropping, the magnitude of response increased (Singh and Singh, 1978). In most of the cropping systems practiced in India, Potassium balance is negative (Mishra and

Mitra, 2001; Srinivasrao *et al*., 2011) and this negative balance is not reflected in the available K status over years of cropping.

In India, the common recommendation of potassic fertilizer in wetland rice (40-60 kg K_2O/ha) is only half of that of N (80-120 kg N/ha).Thus removal by the crop far exceeded the amount applied. During 70's there was no or negligible response to K application to rice because a major part of K requirement was met from soil source and Potassium was not a yield limiting factor as soil contained more of total K (more than 4000 kg/ha) that contributed significantly to K nutrition of rice. But gradually crop response to K application has become more pronounced.

Over the years however, continuous intensive cropping of rice thus has resulted in depletion of soil-K due to huge negative balance caused by more removal by the crops than applied and soil's K supply capacity has been decreased. Depletion has occurred not only from surface soil but also from bottom layers. K present in non-exchangeable sites and mineral forms has also come out for absorption by crops. This has happened due to proportionately more sink than supply. Question is how can we get rid of this problem, what are the other alternatives of K management practices that can abort K mining from soils? This experiment was thus planned in order to evaluate various management options with respect to K availability, K supply, K balance, K nutrition, crop yield and soil health. Hence, it is high time to check the negative balance of K and improve the K fertility of soil for optimization of K nutrition with more sustainability in crop production.

To combat the negative balance of K fertility application of K fertilizer is highly essential. In 2013-14, 22.80 lakh tonnes of MOP was consumed as compared to 306 lakh tonnes of Urea and 73.57 lakh tonnes of DAP. The N: P: K application ratio is very wide i.e. in 2012-13 it was 8.2:3.2:1 (Agricultural statistics at a glance, 2013). The Potassic fertilizer is not manufactured in India and the whole amount is imported from countries like Canada, Israel, Spain, etc. It's really pathetic that we depend 100% on imported Potassic fertilizers when 50% of our soils are deficient in K! So rather than depending totally on chemical fertilizers, we should go for integrated sources of K from chemical fertilizers, straw, foliar spray, etc.

Out of different K management practices straw incorporation is a very good way to return some amount of the K to the soil. Many researchers have found the

straw incorporation to improve the K status of the soil (Saha *et al*., 2009 and Perera *et al*, 2011).But straw incorporation has got some problems like increase in net immobilization in the field and release of harmful organic acids by rice straw decomposition. Hence there should be proper manner of incorporating straw in the field so that it may help to uplift the agriculture.

Foliar spray of K salts is another practice to supply the plants with K. Foliar nutrition when used as a supplement to the recommended soil fertilizer application is highly beneficial, as the crop gets benefitted from the foliar applied nutrients when the roots are unable to meet the nutrient requirement of the crop at its critical growth stage (Brar and Brar, 2004).

Potassium deficiency has become the most limiting nutrient for increasing rice yields (Dobermann *et al*. 1998; Wihardjaka *et al*. 1999).The problem of negative imbalance of K is like a cancer that has engulfed almost all the states of India. So it is the need of the hour to maintain the balance of Potassium by applying right dose of K and following alternative Potassium management practices to restore the soil health in this International Year of Soils. Further we also have to think of the projected demand for the future and this investigation may be considered as one of the many steps taken to suffice the gap. Keeping in view an experiment was carried out with the following objectives:

1. To monitor exchangeable and non-exchangeable forms of K in soil at key stages of growth under different K management practices
2. To monitor the uptake of K by rice during different periods of crop growth
3. To study the yield & yield attributing characters in relation to K availability in soil and K- nutrition at different stages of the crop
4. To study the impact K management options on insect and disease incidence

MATERIALS AND METHODS

In order to fulfill the objectives, a field experiment was conducted at the Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar under the *aegis* of CSISA Project of IRRI, Philippines. The experiment conducted for two seasons, Rabi (2013-14) and Kharif, 2014 with a rice-rice cropping system. The materials used and methods followed are described here under.

3.1 Materials

3.1.1 Location of the Experimental Field

The experimental field is a medium land located in the Central Research Station of Orissa University of Agriculture and Technology (OUAT), Bhubaneswar at a latitude of $20^0$15'N, and longitude of $81^0$52'E. The site comes under East and South Eastern Coastal Plain Agro-climatic zone of the state at an altitude of 25.5m above the mean sea level.

3.1.2 Climate

The climate is hot and humid with mean annual rainfall of 1467 mm. About 70% of total rainfall is received from July to September. The mean maximum and mean minimum temperatures are 33.2^0C and 21.4^0C respectively.

3.1.3 Soil Characteristics

The soil of the experimental site is acidic, low in organic carbon and available nitrogen, medium in available phosphorus and low in potassium and sandy loam in the surface layer (0-15cm). Lower layers contain more clay with reduced acidity. Taxonomically the soil belongs to *Inceptisols* and named as *Aeric Haplaquept*. The land remains ill drained during rainy season because of shallow water table whereas it is moderately well drained during summer season. The characteristics of the soil are given in Table–1.

Table-3.1 Initial soil Characteristics measured in 2013

Soil Characteristic	Value		
	0-15 cm	**15-30 cm**	**30-45 cm**
Textural class	Sandy loam (87% sand, 10.1% silt, 2.9% clay)	Clay loam	Clay
BD (g/cc)	1.47	1.3	1.42
$pH_{(W)}$	5.87	5.95	6.12
EC (dS/m)	0.2	0.134	0.194
Organic Carbon (%)	0.39	0.21	0.01
Available K (kg ha^{-1})	57.95	58.95	53.4
HNO_3 extractable K (kg ha^{-1})	181	192	244
Non-exchangeable K (kg ha^{-1})	123	133	191
Available N (kg ha^{-1})	170	-	-
Available P (kg ha^{-1})	21.0	-	-
Microbial Respiration (g CO_2 $(100g)^{-1}day^{-1}$)	5.86	-	-
Dehydrogenase activity (µg TPF/g soil/24 hr)	2.29	-	-

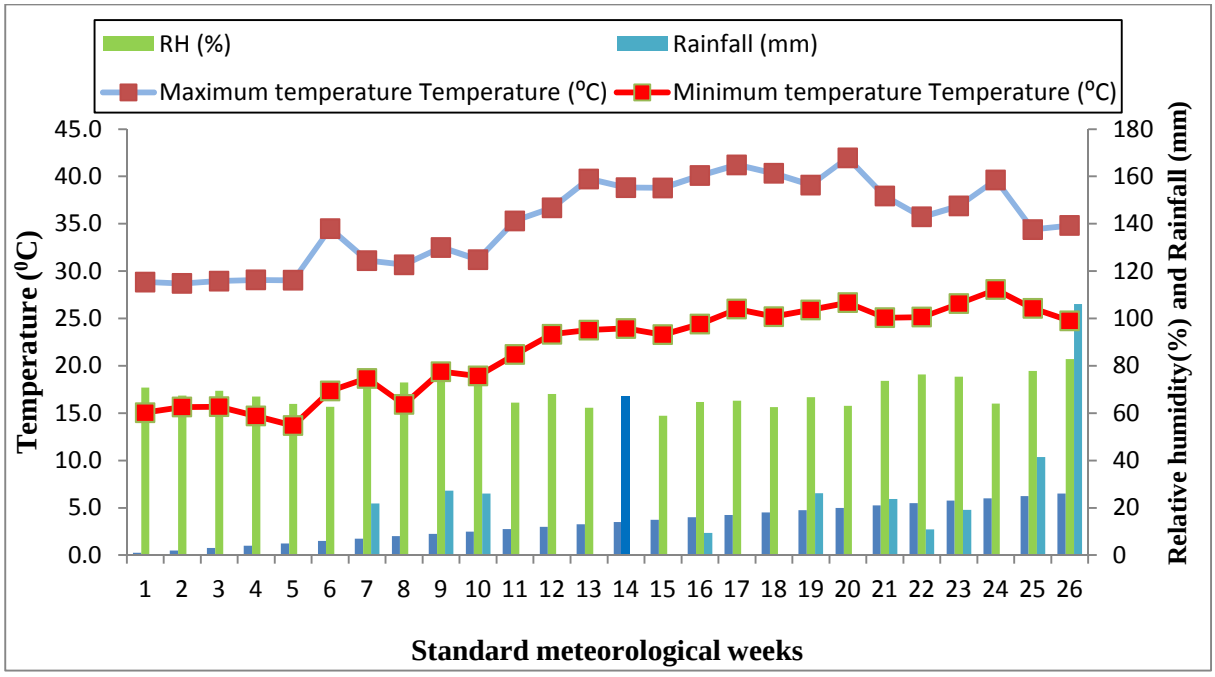

Fig 3.1(a) Rabi season (2013-14)

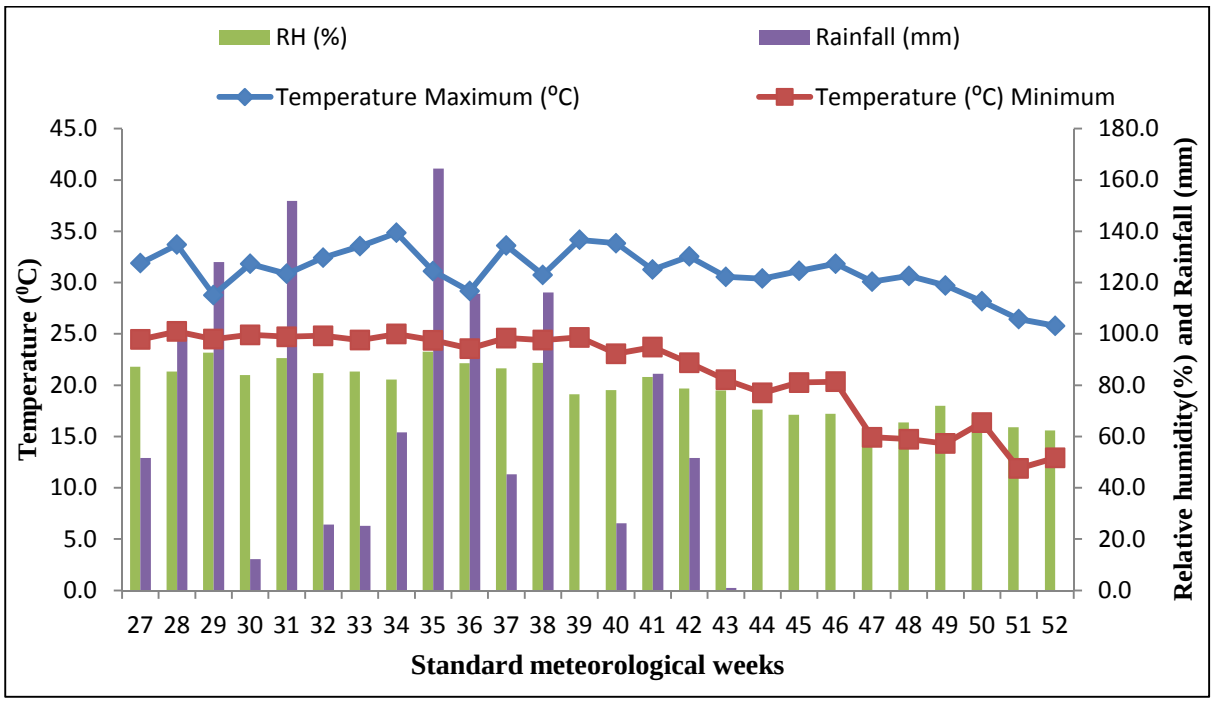

Fig 3.1(b) Kharif season (2014)

Fig 3.1 Weather parameters measured during growth period of Rabi (2013-14) and Kharif (2014) season

3.1.4 Experimental details

3.1.4.1 Treatment details

The experiment was laid out in randomised Block Design (RBD) with 9 treatments and 3 replications. The nine treatments are listed in Table 2.

Table-3.2 Treatment details

Treatment	Details of K Management Practices	Other Nutrients
T_1	40 kg K_2O ha^{-1} (Basal:second topdressing=20kg:20kg)	100% NP(80-40) + FYM @ 5 tha^{-1}
T_2	60kg K_2O ha^{-1} (Basal: second topdressing =30kg:30kg)	100% NP(80-40) + FYM @ 5 tha^{-1}
T_3	80kg K_2O ha^{-1} (Basal: second topdressing =40kg:40kg)	100% NP(80-40) + FYM @ 5 tha^{-1}
T_4	Straw incorporation @ 3 tha^{-1} +20 kg K_2O ha^{-1} (Basal: second topdressing =10kg:10kg)	100% NP(80-40) + FYM @ 5 tha^{-1}
T_5	Straw incorporation @ 3 tha^{-1} + 30 kg K_2O ha^{-1} (Basal: second topdressing =15kg:15kg)	100% NP(80-40) + FYM @ 5 tha^{-1}
T_6	Straw incorporation @ 3tha^{-1} +40 kg K_2O ha^{-1} (Basal: second topdressing =20kg:20kg)	100% NP(80-40) + FYM @ 5 tha^{-1}
T_7	Straw incorporation @ 3 tha^{-1}	100% NP(80-40) + FYM @ 5 tha^{-1}
T_8	40kg K_2O ha^{-1} (Basal application + foliar spray with KNO_3 @ 1.0% solution at PI stage with N-adjusted.	100% NP(80-40) + FYM @ 5 tha^{-1}
T_9	Control without K	100% NP(80-40) + FYM @ 5 tha^{-1}

All the treatment received recommended doses of N and P. (80 kg N and 40kg P_2O_5 per ha with N applied in 3 splits,25% basal,50% at first topdressing at MT stage and 25% at second top dressing at PI stage. In Kharif season Nitrogen dose was raised to 120kg ha^{-1} as per RCM (Rice Crop Manager) as during Rabi there was poor growth due to less N absorption and utilization.

3.1.4.2. Planting Details

- Cropping System: Rice-Rice
- Crop variety: Lalat in both seasons
- Plot Size: 5x6=30m^2
- Spacing: 20X10cm

The details of the field management practices with respective dates are given in the Table-3.

Table-3.3 Calendar of operation followed in Rabi (2013-14) and Kharif (2014) season

Sl. No.	Calendar of Operations	Rabi	Kharif
1	Ploughing and Straw incorporation	17.12.13	24.06.14
2	Seed bed sowing	22.12.13	29.06.14
3	Second ploughing	02.01.14	09.07.14
4	Puddling and land preparation	15.01.14	23.07.14
5	Transplanting	16.01.14	24.07.14
6	First top dressing at MT stage	05.02.14	13.08.14
7	Collection of soil and plant sample	15.02.14	23.08.14
8	Second top dressing and application of foliar spray	07.03.14	12.09.14
9	Soil and plant sampling at PI stage	17.03.14	22.09.14
10	Soil and plant sampling at harvest stage	16.04.14	22.10.14
11	Harvesting	24.04.14	31.10.14

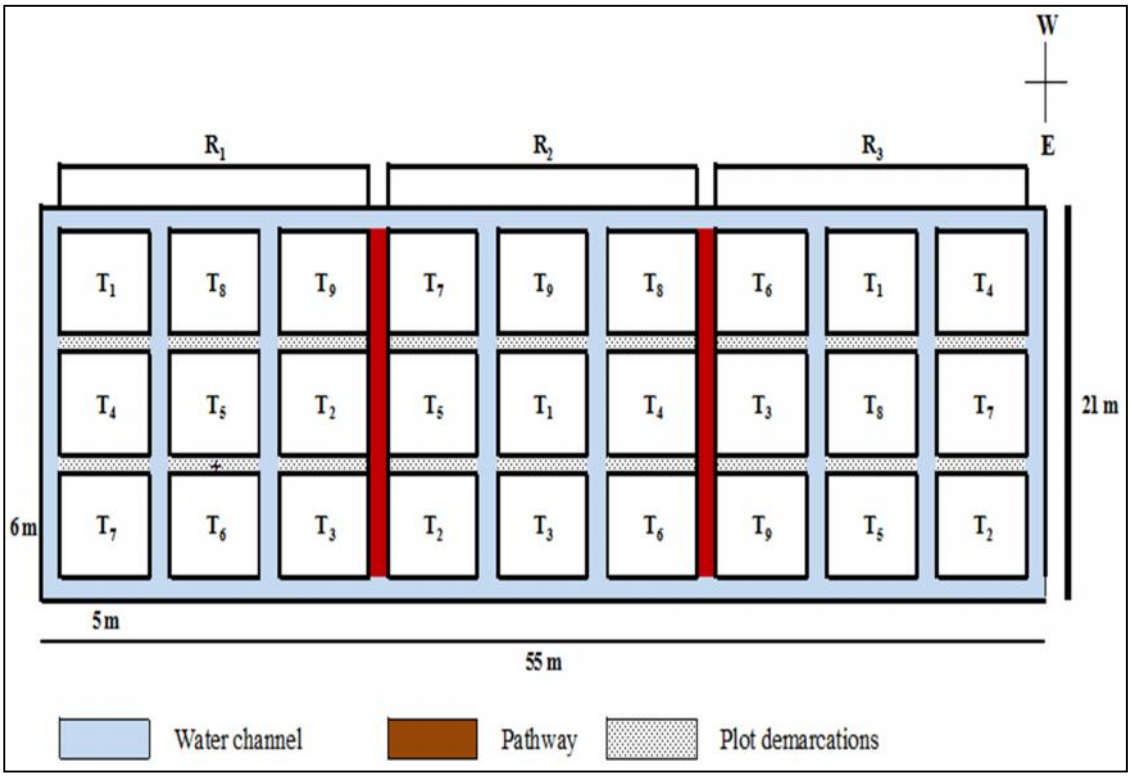

Figure-3.2 Layout of the experiment (2013-14)

Figure-3.3 At transplanting of the field during Rabi season (2013-14)

Figure-3.4 Fertilizer application during Maximum tillering stage

Figure-3.5 Foliar spray during Panicle initiation stage

Figure-3.6 Visit of scientists to the field during grain filling stage

Figure-3.7 Treatment with straw before incorporation

3.2 Methods

3.2.1 Soil Analysis

3.2.1.1 Sample Collection & Processing

Initial composite sample was collected before start of the experiment through screw type auger drawn from depths of 0-15cm, 15-30cm and 30-45cm. Mid season (Maximum tillering and Panicle initiation stage) and post harvest composite soil samples were collected from all the 27 plots through sampling tube and screw type auger from depths of 0-15 cm and 15-30 cm. These were then air dried under shade, crushed, sieved through 2mm sieve and stored in polyethylene packets with proper labelling with a permanent ink marker for analysis.

3.2.2 Laboratory Analysis

Soil samples were analysed for various physical, chemical and microbiological parameters following standard methods as given below.

3.2.2.1 Physical parameters

3.2.2.1.1 Bulk Density

It was determined by core method as described by Dastane, 1972.

3.2.2.1.2 Soil Texture

It was determined by Bouyoucos hydrometer method (Piper, 1950).

3.2.2.2 Chemical parameters

3.2.2.2.1 Soil pH

The pH of the soil-water suspension (1:2.5) was measured by means of a glass electrode pH meter (Jackson, 1973).

3.2.2.2.2 Electrical conductivity

The electrical conductivity (EC) of the soil-water suspension (1:2.5) was measured by a conductivity meter. The conductivity meter was standardized with 0.2 M KCl solution.

3.2.2.2.3 Organic Carbon

The organic carbon content in soil was determined by wet oxidation method of Walkley and Black as described by Piper (1950).

3.2.2.2.4 Available Nitrogen

It was determined by alkaline $KMnO_4$ method as outlined by Subbiah and Asija (1956). The distillation was carried out in the auto analyzer.

3.2.2.2.5 Available Phosphorus

The Olsen's available P was determined in soil following the method of Bray & Kurtz as described by Page *et al* (1982).

3.2.2.2.6 Available Potassium (K)

The available K was determined by extracting the soil with neutral normal ammonium acetate (NH_4OAc) solution and estimated by flame photometer as described by Hanway and Heidel, 1952.

3.2.2.2.7 Reserve Potassium (K)

The Nitric acid (HNO_3) extractable K was determined by boiling the soil sample with 1N HNO_3 solution and estimated by flame photometer as described by Wood and De Turk, 1940.

3.2.2.2.8 Non-exchangeable Potassium (K)

The non-exchangeable K was calculated by deducting the available K from the reserve or Nitric acid extracted K as described by Black (1965).

Figure-3.8 Analysis of soil for reserve K through boiling on a hot plate

Figure-3.9 Analysis of soil solution pH by pH meter

3.2.2.3 Microbial Parameters

3.2.2.3.1 Microbial Respiration (Anderson and Ingram, 1993)

One hundred gram of dry soil was moistened with little water to field capacity. Then the soil was placed in an air tight plastic bottle. 25 ml of 0.2 N NaOH solution was

taken in a beaker and the bottles were air tightened. The bottles were incubated at room temperature for 5 days without any disturbance. Then the beakers were taken out from the bottle after incubation and immediately 2 ml solution of $BaCl_2$ and 2 drops of phenolphthalein indicator were added. After adding $BaCl_2$ milky white precipitate appeared. Phenolphthalein indicator gives pinkish colour on the background of milky white precipitate. Then the solution was filtrated against standard HCl till the pinkish colour disappeared.

3.2.2.3.2 Dehydrogenase Activity

To a soil sample of 5g, 2.5 ml of distilled water and 1 ml of 3% TTC (2, 3, 5-Triphenyl terazolium chloride) were added and incubated at 37^0C for 24 hrs. The soil solution was filtered through a cotton plug and washed with methanol to remove the reddish colour from the plug and diluted to 100 ml. The red colour intensity was measured in spectrophotometer at 485 nm and compared with standard graph prepared with standard TPF (Triphenyl formazan) solution as described by Cassida *et al.*

3.2.2 Plant analysis

3.2.2.1 Collection of Plant Sample

To meet the requirement of the present investigation rice plant sample from individual treatment subplots were collected at maximum tillering (MT) stage (30 days after transplanting),panicle initiation (PI) stage (60 days after transplanting) and harvest stage for determination of nutrient content in the dry matter and measurement of biomass.

From each treatment subplot 24 plants were sampled with 12 plants from 2 opposite sites. Each site consisting of 2 adjacent rows with 6 hills in each row. The hills were cut at 2 cm above the ground level. The collected clumps were dried under sun and subsequently inside oven at $70^0 \pm 5^0$C.Dried plant materials were weighed and

chopped to small pieces with stainless steel scissors, ground by a willey mill and preserved for chemical analysis.

3.2.2.2 Laboratory Analysis Plant sample

The plant samples of the MT, PI and harvest stage were analysed for the Potassium content and the grain and straw sample collected during harvest were analysed for N, P and K content. The procedures are described below.

3.2.2.2.1 Nitrogen in Plant tissue

The N content of the plant sample was determined by three steps i.e. digestion, distillation and titration.

0.2 g of plant sample was taken for digestion by adding 10 ml concentrated H_2SO_4 and 2 g digestion mixture in digestion tube for 3-4 hours. That was allowed to cool for overnight. Then distillation of the digested samples was done by Kel-Plus auto analyzer by using a mixture of 2% boric acid and 3 drops of mixed indicator. The distillate was collected in a 250 ml conical flask after 10 minutes and was titrated against 0.05 N H_2SO_4 till pinkish colour appeared.

3.2.2.2.2 Phosphorus in plant sample

The Phosphorus present in the plant samples was extracted by a widely adapted method of wet oxidation. To 0.5 gm of straw sample taken in a conical flask 10 ml of concentrated HNO_3 was added and kept overnight and was pre-digested until the solution had nearly evaporated. Then 10 ml of di-acid was added and the sample was digested until the white fumes condensed inside the conical flask to give a white colour fluid. Distilled water was added and filtered through Whatman no.1 filter paper to a 100ml volumetric flask with repeated washings and the volume was made up with distilled water. 5ml of the aliquot was taken in a 25 ml volumetric flask and 5ml of Vanadomolybdate reagent was added to test the plant P by H_3PO_4-Vanadomolybdate yellow colour method. The absorbance reading was taken in a spectrophotometer at 470 nm wavelength.

3.2.2.2.3 Potassium in plant sample

The K content of the plant parts was also determined by wet oxidation method similar to phosphorous extraction and was measured by a flame photometer. The plant sample was digested using di-acid. The digest was filtered and diluted and the flame photometer reading was taken.

3.2.3 Agronomic observations

The agronomic parameters included observations on effective tillers per m^{-2}, number of grains per panicle, % filled grain, 1000 grain weight, harvest index and grain and straw yield for both the seasons. Grain and straw yield was measured basing on 4 m^2 yield.

3.2.4 Straw addition and management

In treatments where straw incorporation formed a component of manurial practices, harvesting was done by removing the panicle attached with 5cm straw. The field was then allowed to dry to field capacity moisture and field was ploughed by power tiller and straw was incorporated to a shallow depth. The second ploughing was done after 15 days for encouraging the decomposition. Other plots were also ploughed simultaneously.

3.2.5 Weed management

For managing the weeds Pretilachlor @ 500 ml a.i. per hectare was applied at the initial stage but for later stages manual weeding and bund cleaning was accomplished.

3.2.6 Disease and Insect management

The occurrence of diseases and insect pests were managed by recommended chemical practices like application of Furadan @ 10 kg per acre, Streptocycline @ 1.5 g per 10 litres and SAAF @ 2g per litre. All the three were applied as prophylactic measure and again during peak period of damage shown in figure 3.13.

3.2.6.1 Record of insect pests

Observations on the incidence of insect pests viz., stem borer, leaf folder, whorl maggot and gundhi bug were taken as per the standard procedure of sampling described as follows for the individual pest.

Pest incidence was recorded during both the seasons of the experiment. The data generated were compiled and statistically analysed after suitable transformation according to the standard procedure described by Panse and Sukhatme (1985).

3.2.6.1.1 Stem borer

Observation of stem borer incidence during vegetative stage was taken starting from 35 DAT to 60 DAT. 10 randomly selected plants were taken as sample size per treatment and the total tiller and dead hart count were noted down. The dead hart incidence during 45DAT was taken for calculation. The percentage of dead hart (DH) incidence was calculated as given below.

$$DH\ (\%) = \frac{\text{Total dead hart in 10 plants}}{\text{Total number of tillers in 10 plants}} \times 100$$

The stem borer incidence during panicle stage is expressed as white earhead (WEH). The WEH count was taken from 10 randomly selected plants and the total panicle bearing tiller (PBT) and the total number of WEH were recorded from the 10 randomly selected plants per square meter. The percentage of WEH was calculated as given below.

$$WEH\ (\%) = \frac{\text{Number of WEH in 10 randomly selected plants}}{\text{Total number of tillers in the 10 plants}} \times 100$$

3.2.6.1.2 Leaf folder

Leaf folder incidence as shown in figure 3.12 was recorded at 45 DAT from 5 numbers of randomly selected plants per treatment. The total number of leaves and total number of damaged leaves were recorded. The leaf folder

incidence was taken from the freshly damaged leaves having freshly laid excreta. The percentage of damage leaf (DL) was calculated as given below.

$$DL\ (\%) = \frac{\text{Total number of damaged leaves in 5 plants}}{\text{Total number of leaves in 5 plants}} \times 100$$

3.2.6.1.3 Whorl maggot

The whorl maggot appears in the field at early stage and nibbles the leaf from sides. These damaged leaves as shown in figure 3.10 were taken for observation and the percentage damaged leaves (DL) was found out as per the formula same as that of leaf folder given below.

$$DL\ (\%) = \frac{\text{Total number of damaged leaves in 5 plants}}{\text{Total number of leaves in 5 plants}} \times 100$$

3.2.6.1.4 Gundhi bug

The incidence of gundhi bug was noted during the milking stage of the crop since the pest come to suck the milk from the developing grains. The total number of live insects (nymphs and adults) were counted from one square meter demarcated area in the treatment plot and the gundhi bug population per square meter area at two places per treatment was calculated out.

3.2.6.2 Record of disease Incidence

The incidence of diseases such as brown spot and blast was observed during vegetative and reproductive stages of the rice-rice cropping system. Due to prophylactic measures taken the disease infestation was not severe. The scoring for disease incidence was done for two seasons of the experiment.

3.2.6.2.1 Brown spot

The incidence of brown spot was recorded during vegetative stage from 30 to 60 DAT and also during the harvest stages ranging from 80 DAT. 10 hills were selected

randomly from each plot and the leaves showing maximum disease intensity were scored as given in Table-3.4.

Table-3.4 Scale for brown spot

Description (Affected leaf area)	Score
No incidence	0
< 1%	1
1-3%	2
4-5%	3
6-10%	4
11-15%	5
16-25%	6
26-50%	7
51-75%	8
76-100%	9

3.2.6.2.2 Blast

The observation for blast (figure 3.11) was taken similarly as that for brown spot at both vegetative and harvest stages.10 hills were selected randomly from each plot and the leaves showing maximum disease intensity were scored as given in Table-3.5.

Figure-3.10 Whorl maggot infestation

Figure-3.11 Blast infestation

Figure-3.12 Attack of leaf folder

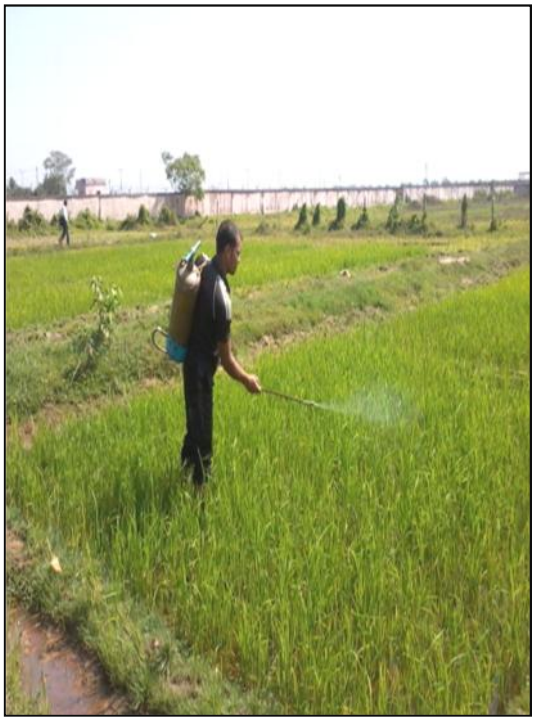

Figure-3.13 Pesticide application

Table-3.5 Scale for Blast

Characteristics	Score
No lesion	0
Small brown specks of pin head size without sporulation	1
Small round to slightly elongated necrotic gray spots, 1-2 mm in diameter with distinct brown margin and lesions, mostly found on the lower leaves	2
Lesion type same as in score 2, but significant number of lesions are on the upper leaves	3
Typical sporulating blast lesions, 3 mm or longer infecting less than 2 % area	4
Typical blast lesions with 2- 10 % leaf area	5
Typical blast lesions with 11- 25 % leaf area	6
Typical blast lesions with 26-50 % leaf area	7
Typical blast lesions with 51- 75 % leaf area	8
Typical blast lesions with >75 % leaf area	9

3.2.9 Cost economics

The gross and net returns as well as benefit to cost ratio of different K management in rice-rice cropping system were calculated taking the prevailing market price of different economics and by-products and cost of Input into consideration. Net return was calculated by deducting the cost of cultivation from gross return. Returns per rupee invested were computed by dividing the net returns with cost of cultivation.

3.2.10 Statistical analysis

Data in respect of yield, soil physical, chemical and microbiological characteristics and disease and pest incidence were subject to analysis of variance following statistical procedure (Panse and Sukhatme, 1985 and Gomez and Gomez, 1984). Relationship between different sets of variables was worked out by running correlation equations.

RESULTS

The relevant experimental results of the field experiment on effect of different potassium (K) management options on crop yield, K availability and pest incidence in both Rabi and Kharif rice and laboratory analysis of soil and plant samples carried out during the course of investigation are reported in this chapter. The results are given under the following headings.

4.1 Yield and yield attributing parameters

4.1.1 Grain Yield

4.1.2 Straw Yield

4.1.3 Harvest Index

4.1.4 Effective tillers per square meter

4.1.5 Spikelets per panicle

4.1.6 Percent filled grain (fertility percent)

4.1.7 Test weight

4.2 Potassium uptake at different stages

4.2.1 Potassium content of plant

4.2.2 Plant biomass

4.2.3 Potassium uptake

4.3 Status of soil K at different stages

4.3.1 Available K

4.3.2 Nitric acid extractable K

4.3.3 Non-exchangeable K

4.3.4 Relationship of K availability with other parameters

4.4 Effect on Pest Incidence

4.4.1 Disease attack

7.1.2 Insect attack

4.6 Cost economics

4.1 Yield and yield attributing parameters

Results pertaining to yield parameters, grain and straw yield and harvest index are presented in Table 4.1 a and b.

Table-4.1(a) Effect of different K management practices on yield and yield attributing parameters in the Rabi season (2013-14)

Treatment		Effective tillers per square meter	No. of spikelet per panicle	Percent filled grains (%)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index
T_1	K_{40}	277	93	86.1	25.3	3.21	4.38	0.42
T_2	K_{60}	294	98	90.7	25.7	3.51	5.13	0.41
T_3	K_{80}	273	101	89.6	26.2	3.43	6.35	0.35
T_4	K_{20} + Straw	238	95	89.3	25.3	3.17	4.96	0.39
T_5	K_{30} + Straw	238	95	91.2	25.5	3.48	5.48	0.39
T_6	K_{40} + Straw	233	94	91.0	25.4	3.08	5.20	0.37
T_7	Straw	228	88	84.6	25.2	2.82	4.90	0.37
T_8	K_{40} + 1% KNO_3 spray	313	99	94.2	27.0	3.84	6.22	0.38
T_9	K_0	227	87	86.1	25.2	2.69	4.41	0.37
CV (%)		11.55	5.85	3.42	2.98	10.63	13.12	8.38
CD (0.05)		51.54	9.55	5.27	NS	0.60	1.19	NS

4.1.1 Grain Yield

A close perusal of the data in Table-1(a and b) revealed that the grain yield in Rabi varied from a lowest of 2.69 t ha^{-1} recorded in control without K application to a highest of 3.84 t ha^{-1} measured in the treatment with basal application of 40 kg K_2O ha^{-1} and foliar spray with 1% KNO_3 at panicle initiation stage. Other treatment such T_2 (60kg K_2O ha^{-1}), T_3 (80kg K_2O ha^{-1}) and T_5 (30kg K_2O ha^{-1} + straw) were at par and all other treatment produced significantly lower yield than T_8.

The grain yield in Kharif varied from a lowest of 4.21t ha^{-1} in the control plot to a highest of 5.35 t ha^{-1} recorded in the same treatment T_8 which also produced highest grain yield in Rabi. The treatment T_8 was at par with T_3 (80kg K_2Oha^{-1}). T_5

(30kg K_2O ha^{-1} + straw) and T_6 (40kgK_2O ha^{-1} +straw) and differed significantly from all others.

Table-4.1(b) Effect of different K management practices on yield and yield attributing parameters in the Kharif season (2014)

Treatment		Effective tillers per square meter	No. of spikelet per panicle	Percent filled grains (%)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index
T_1	K_{40}	406	103	82.0	25.0	4.34	4.84	0.47
T_2	K_{60}	440	99	87.5	25.9	4.72	6.35	0.43
T_3	K_{80}	436	110	85.5	26.4	4.87	6.69	0.43
T_4	K_{20} + Straw	408	99	86.8	25.2	4.39	4.26	0.51
T_5	K_{30} + Straw	440	104	86.6	26.8	5.17	5.89	0.47
T_6	K_{40} + Straw	460	104	86.9	27.0	4.94	5.37	0.48
T_7	Straw	375	101	84.6	26.3	4.55	4.99	0.48
T_8	K_{40} + 1% KNO_3 spray	444	102	85.1	26.9	5.35	5.88	0.48
T_9	K_0	400	98	84.1	25.8	4.21	4.35	0.49
CV (%)		11.34	7.41	3.36	4.08	7.55	14.61	8.68
CD (0.05)		NS	NS	NS	NS	0.62	1.37	NS

4.1.2 Straw Yield

Results on straw yield recorded in table-4.1 (a and b) showed that the straw yield varied from a lowest of 4.38 t ha^{-1} measured in T_1 that received 40 kg K_2O ha^{-1} to a highest of 6.35 t ha^{-1} measured in T_3 that received highest dose of K. The straw yield of Kharif season was more as compared to Rabi which ranged between a lowest of 4.26 tha^{-1} observed in the treatment with 20 kg K_2O ha^{-1} along with straw and 6.69 tha^{-1} in treatment receiving 80kg K_2O ha^{-1}.

4.1.3 Harvest Index

Result on harvest index presented in the Table-4.1(a and b) revealed that harvest index (HI) varied from 0.34 to 0.42 with no significant difference within the treatment. In Kharif the treatment which recorded highest yield i.e. T_8 also recorded the highest Harvest Index of 0.49 as compared to 0.43 in T_3. The Harvest Indices were higher in Kharif than Rabi and there was no significant difference among the treatment.

4.1.4 Effective tillers per square meter

Data recorded in the Table-4.1(a and b) showed that the number of effective tillers per square meter was much lower in Rabi than in Kharif. In Rabi the number varied between 227 and 313 as compared to 375 and 460 in Kharif. Significant variation within the treatment was measured only for the Rabi season.

4.1.5 Spikelets per panicle

Data pertaining to total number of spikelets in Table-4.1(a and b) per panicle showed that the number in Rabi varied significantly from the lowest of 87 observed in the control plot to a highest of 101 in the treatment with 80 kg K_2O ha^{-1} applied through fertilizer in two equal splits.

The number of grains per panicle in Kharif varied from 98 to 110 in the control plot and the treatment receiving 80 kg K_2O ha^{-1} respectively which was more than that found in Rabi but there was no significant difference within the treatment.

4.1.6 Percent filled grain (fertility percent)

The data Table-4.1(a and b) revealed that the percent filled grains in Rabi season varied from a lowest of 84.6 % in treatment with only straw incorporation to 94.2 % found in the treatments receiving 40 kg K_2O ha^{-1} at planting through fertilizer along with a foliar spray of 1% KNO_3 at PI stage respectively and the K management practices had significant effect.

The fertility percent in Kharif varied from the lowest 82% to a highest of 87.5% with no significant difference among the treatment. Application of 60 kg K_2O ha^{-1} through fertilizer in two splits at planting recorded highest fertility percent.

4.1.7 Test weight

The data pertaining to thousand grain weight at 14% moisture given in Table 4.1a-b showed that in Rabi it varied from a lowest of 25.2 g measured in the control plot to a highest of 27g in the treatment receiving 40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3. In Kharif the range of test weight remained same i.e. 25.2g to 27g. There was no significant effect of different K management practices on test weight of grains in both the seasons.

4.2 Potassium uptake at different stages

4.2.1 Potassium content of plant

The data presented in Table-4.2 depicted that the K content of the plants at MT stage of Rabi season varied between 1.12% and1.21% in the control and the treatment receiving 60 kg K_2O ha^{-1} respectively. In Kharif season the plant K content varied between 1.55% (40 kg K_2O ha^{-1}) and 1.72% (40 kg K_2O ha^{-1} and straw).

Table-4.2 Effect of different K management practices on K content (%) at different stages in Rabi (2013-14) and Kharif season (2014)

Treatment		Rabi			Kharif		
		Maximum tillering	Panicle Initiation	Harvest	Maximum tillering	Panicle Initiation	Harvest
T_1	K_{40}	1.13	1.19	2.07	1.55	1.62	1.68
T_2	K_{60}	1.21	1.48	2.04	1.67	1.91	2.05
T_3	K_{80}	1.18	1.24	2.11	1.72	1.92	2.07
T_4	K_{20} + Straw	1.14	1.37	1.58	1.56	1.68	1.70
T_5	K_{30} + Straw	1.10	1.24	1.98	1.62	1.92	2.05
T_6	K_{40} + Straw	1.18	1.34	1.87	1.74	1.85	1.85
T_7	Straw	1.10	1.24	2.02	1.63	1.81	1.75
T_8	K_{40} + 1% KNO_3 spray	1.16	1.24	1.95	1.62	1.90	2.10
T_9	K_0	1.12	1.09	1.49	1.57	1.74	1.71
CV (%)		4.55	13.4	8.06	9.87	7.36	11.76
CD (0.05)		NS	NS	0.27	NS	NS	0.38

The plant K content at PI stage varied from the lowest of 1.09% (control) to the highest of 1.48% (60 kg K_2O ha^{-1}) in the Rabi whereas in Kharif it varied from the lowest of 1.62% in the treatment receiving 40 kg K_2O ha^{-1} to a highest of 1.92% in two treatment, T_4 receiving 20 kg K_2O ha^{-1} along with straw and T_3 with 80 kg K_2O ha^{-1}.

The K content in the straw at the harvest stage in Rabi was lowest (1.49%) in control and highest (2.11%) in the treatment receiving 80 kg K_2O ha^{-1} whereas in the Kharif the lowest of 1.68% was observed in the treatment receiving 40 kg K_2O ha^{-1} and highest of 2.10% in the treatment receiving 40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3 at PI stage.

The K content of grain in the Rabi season was found to be lowest in the control and highest in the treatment receiving 40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3 at PI stage whereas in the Kharif it was lowest in the treatment receiving 40 kg K_2O ha^{-1} and highest in the treatment receiving 40 kg K_2O ha^{-1} along with straw (3t ha^{-1}**).**

4.2.2 Plant biomass

The data on plant biomass of different stage presented in Table-4.3 revealed that the biomass in Rabi at MT stage varied from a lowest of 12.1 q ha^{-1} to 16.5 q ha^{-1} in the treatment receiving only straw (3t ha^{-1}) and 40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3 at PI stage respectively. In Kharif season the treatments varied between 13.2 q ha^{-1} to 18.7 q ha^{-1} with lowest measured in treatment receiving 40 kg K_2O ha^{-1} along with straw and highest with 80 kg K_2O ha^{-1}.

In the PI stage of Rabi season the plant biomass varied significantly from the lowest (37.1 q ha^{-1}) in the K_{20} + straw to the highest (45.8 q ha^{-1}) in the treatment receiving 40 kg K_2O ha^{-1} along with straw. In the Kharif season the biomass varied between 38.2 q ha^{-1} and 44.8 q ha^{-1} with lowest in the treatment receiving 40 kg K_2O ha^{-1} and highest in 40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3.

The total biomass combining both straw and grain biomass at harvest stage in Rabi was highest 101 q ha^{-1} in the treatment T_8 receiving 40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3 and lowest 71q ha^{-1} in the control. But in the Kharif the

highest biomass was 116q ha^{-1} recorded in treatment T_3 receiving 80 kg K_2O ha^{-1} and lowest of 86 q ha^{-1} in the control.

Table-4.3: Effect of different K management practices on biomass accumulation (q ha^{-1}) at different stages in Rabi (2013-14) and Kharif season (2014)

Treatment		Rabi			Kharif		
		Maximum tillering	Panicle Initiation	Harvest	Maximum tillering	Panicle Initiation	Harvest
T_1	K_{40}	15.5	41.7	75.8	15.7	38.2	91.9
T_2	K_{60}	15.3	45.6	86.4	15.8	43.4	110.7
T_3	K_{80}	15.1	42.5	97.8	17.8	41.8	115.6
T_4	K_{20} + Straw	12.5	37.1	81.3	18.7	39.3	86.5
T_5	K_{30} + Straw	13.5	37.2	89.7	14.2	42.7	110.6
T_6	K_{40} + Straw	14.0	39.4	82.8	13.2	43.3	103.0
T_7	Straw	12.1	37.2	77.2	13.5	43.3	95.4
T_8	K_{40} + 1% KNO_3 spray	16.5	45.8	100.6	14.4	44.8	112.3
T_9	K_0	14.5	39.7	71.0	15.4	38.9	85.6
CV (%)		10.41	8.85	15.52	17.25	10.30	10.45
CD (0.05)		2.58	6.23	11.87	15.52	NS	18.32

4.2.3 Potassium uptake

The results given in Table-4.4(a and b) depicts that in Rabi the K uptake in the MT stage was low as compared to that in Kharif and it varied from lowest of 16.1 kg ha^{-1} measured in only straw to highest of 19.1 kg ha^{-1} measured in treatment receiving 40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3 at PI stage. In Kharif for the same stage the data varied from 21.9 kg ha^{-1} to 30.7 kg ha^{-1}in the treatments receiving only straw at 3t ha^{-1} and 80 kg K_2O ha^{-1} respectively.The uptake by the Panicle initiation stage was more in Kharif than in Rabi. In Rabi, highest uptake was found

for the treatment receiving 60 kg K_2O ha^{-1} (67.5 kg ha^{-1}) and the lowest for the control (43.4 kg ha^{-1}) whereas in Kharif the highest uptake was

Table-4.4(a) Effect of different K management practices on K uptake (kg ha^{-1}) at different stages in Rabi (2013-14)

Treatment		Maximum tillering	Panicle Initiation	Harvest		
				Straw	Grain	Total
T_1	K_{40}	17.40	49.73	90.52	10.59	100
T_2	K_{60}	18.46	67.53	104.62	12.29	117
T_3	K_{80}	17.86	52.68	133.75	13.34	147
T_4	K_{20} + Straw	14.35	49.21	78.35	13.31	92
T_5	K_{30} + Straw	14.79	46.11	108.87	14.62	123
T_6	K_{40} + Straw	16.57	53.02	97.28	10.47	107
T_7	Straw	13.38	46.15	99.03	12.13	112
T_8	K_{40} + 1% KNO_3 spray	19.08	56.74	121.25	17.66	139
T_9	K_0	16.12	43.37	65.68	7.29	74
CV (%)		11.18	11.46	17.53	18.15	15.64
CD (0.05)		3.18	10.24	30.4	3.98	30.42

Table-4.4(b) Effect of different K management practices on K uptake (kg ha^{-1}) at different stages in Kharif (2014).

Treatment		Maximum tillering	Panicle Initiation	Harvest		
				Straw	Grain	Total
T_1	K_{40}	24.66	62.04	83.47	13.49	97
T_2	K_{60}	26.41	83.51	130.49	17.42	148
T_3	K_{80}	30.65	80.42	138.67	16.89	156
T_4	K_{20} + Straw	29.18	66.30	72.90	14.24	87
T_5	K_{30} + Straw	22.88	82.17	120.93	16.79	138
T_6	K_{40} + Straw	22.84	79.52	99.46	18.72	118
T_7	Straw	21.93	77.35	88.62	14.62	103
T_8	K_{40} + 1% KNO_3 spray	23.38	85.67	124.18	18.00	142
T_9	K_0	24.58	67.93	73.56	13.23	87
CV (%)		20.7	11.2	18.63	14.1	16.97
CD (0.05)		NS	14.75	33.4	3.89	35.10

found for the treatment receiving 40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3 (85.7 kg ha^{-1}) and the lowest in the treatment receiving 40 kg K_2O ha^{-1} (62 kg ha^{-1}).

The K uptake by harvest stage for Rabi crop varied between 74 kg ha^{-1} (control) and 147 kg ha^{-1} (80 kg K_2O ha^{-1}) whereas in Kharif it varied between 87 kg ha^{-1} (control and 20 kg K_2O ha^{-1} along with straw of 3t ha^{-1}) and 156 kg ha^{-1} (80 kg K_2O ha^{-1}).

The maximum K uptake occurred between PI and harvest stage in Rabi season whereas in Kharif uptake was more within MT to PI stage.

4.3 Status of soil K at different stages

4.3.1 Available K

The data given in the Table-4.5(a and b) depicted that the available K in Rabi at MT stage varied from 68.4 kg ha^{-1} to 117.7 kg ha^{-1} in control plot and the treatment

Table-4.5(a) Effect of different K management practices on Available K (kg ha^{-1}) in different layers at different stages in the Rabi season (2013-14)

Treatment		Maximum tillering		Panicle Initiation		Harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	K_{40}	89.2	46.9	65.7	56.1	51.1	50.2
T_2	K_{60}	104.0	67.4	82.4	63.5	74.6	52.5
T_3	K_{80}	117.7	78.4	94.7	72.2	79.6	62.5
T_4	K_{20} + Straw	84.3	42.2	67.0	46.1	50.9	48.4
T_5	K_{30} + Straw	94.2	50.3	81.1	50.4	66.6	47.0
T_6	K_{40} + Straw	90.3	64.6	83.5	58.2	78.8	47.3
T_7	Straw	108.5	57.1	87.5	52.8	58.5	48.1
T_8	K_{40} + 1% KNO_3 spray	92.0	48.74	69.1	52.0	57.8	48.2
T_9	K_0	68.4	42.1	56.2	49.9	47.9	48.8
CV (%)		12.90	9.98	11.35	9.49	16.51	9.88
CD (0.05)		21.04	9.55	14.99	9.14	18.25	NS

receiving 80 kg K_2O ha^{-1} respectively which was higher than the initial 57.9 kg ha^{-1} but in Kharif season it varied from the lowest of 42.3 kg ha^{-1} (control) to 81.6 kg ha^{-1} (30 kg K_2O ha^{-1} along with straw of 3t ha^{-1}) which was lower in status than Rabi.

In subsoil the content varied from a 42 kg ha^{-1}(control) to 78.4 kg ha^{-1}(80 kg K_2O ha^{-1}) in the same manner as recorded in the surface layer Rabi and 33.1 kg ha^{-1} (control) to 55.3 kg ha^{-1}(40 kg K_2O ha^{-1} along with straw of 3t ha^{-1}) in Kharif.

Table-4.5(b) Effect of different K management practices on Available K (kg ha^{-1}) in different layers at different stages in the Kharif season (2014)

Treatment		Maximum tillering		Panicle Initiation		Harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	K_{40}	52.3	39.87	39.2	33.94	47.64	47.3
T_2	K_{60}	59.13	38.19	47.41	43.75	63.28	70.9
T_3	K_{80}	71.57	45.85	44.2	42.3	45.99	62.54
T_4	K_{20} + Straw	64.89	43.61	36.96	34.57	48.09	47.15
T_5	K_{30} + Straw	81.65	51.33	55.85	46.14	59.47	59.43
T_6	K_{40} + Straw	66.95	55.28	46.18	43.16	46.26	53.97
T_7	Straw	48.65	41.96	55.85	37.07	45.17	51.71
T_8	K_{40} + 1% KNO_3 spray	50.1	41.81	39.01	36.51	43.72	50.55
T_9	K_0	42.3	33.11	28.97	27.96	35.62	48.87
CV (%)		19.1	11.78	20.65	6.15	16.16	18.81
CD (0.05)		19.75	8.86	15.64	4.08	13.52	17.81

In PI stage the available K in the surface soil in the Rabi varied from 56kg ha^{-1} (control) to 94.7 kg ha^{-1} (80 kg K_2O ha^{-1}) but in Kharif it varied from 28.97 kg ha^{-1} to 55.85 kg ha^{-1} in control and both in treatment receiving 30 kg K_2O ha^{-1} along with straw of 3t $ha^{-1}$and only straw (3t ha^{-1}) respectively which was again low as compared to Rabi. In subsoil in Rabi it varied from 46 kg ha^{-1} (20 kg K_2O ha^{-1} along with straw of 3t ha^{-1}) to 72.2 kg ha^{-1} (80 kg K_2O ha^{-1}) and in Kharif it varied from 27.96 kg ha^{-1}

(control) to 46.14 kg ha^{-1} (30 kg K_2O ha^{-1} along with straw of 3t ha^{-1}).Both in Rabi and Kharif the sub-surface soils measured lower K than surface but the extent of difference was lower in Kharif.

At harvest stage in Rabi it varied from 47.9 kg ha^{-1}(control) to 79.6 kg ha^{-1}(80 kg K_2O ha^{-1}) in surface and 47 kg ha^{-1}(30 kg K_2O ha^{-1} along with straw of 3t ha^{-1}) to 62.5 kg ha^{-1} (80 kg K_2O ha^{-1}) in bottom layer. But in Kharif it varied from 35.6 kg ha^{-1}(control) to 63.2 kg ha^{-1} (60 kg K_2O ha^{-1}) in surface layer and 47.1 kg ha^{-1}(20 kg K_2O ha^{-1} along with straw of 3t ha^{-1}) to 70.9 kg ha^{-1}(60 kg K_2O ha^{-1}) in the sub-surface layer.

4.3.2 Nitric acid extractable K

Data in the Table-4.6 (a and b) showed that in Rabi season the Nitric acid extractable(Reserve) K at MT stage varied from 144 kg ha^{-1} to 215 kg ha^{-1} in surface soil and from 132 kg ha^{-1} to 215 kg ha^{-1} in sub soil.

But in Kharif it varied from 124 kg ha^{-1}(control) to 173 kg ha^{-1} (80kg K_2Oha^{-1}) in top layer whereas in bottom it varied from 101 kg ha^{-1}(control) to 186 kg ha^{-1}(80 kg K_2O ha^{-1}). In general the lower layer measured the lower value and Rabi season the reserve-K was more than the Kharif season.

At PI stage it varied from 142 kg ha^{-1} (control) to 211 kg ha^{-1}(80 kg K_2O ha^{-1}) in surface soil in Rabi and 148 kg ha^{-1} (straw) to 193 kg ha^{-1}(40 kg K_2O ha^{-1} along with foliar spray) in bottom layer. But in Kharif it varied from 109 kg ha^{-1}(60 kg K_2O ha^{-1}) to 128 kg ha^{-1} (control).In bottom layer it varied from 89 kg ha^{-1} (20 kg K_2O ha^{-1} along with straw) to 108 kg ha^{-1}(60 kg K_2O ha^{-1}) which measured lower value than surface soil.

Table-4.6(a) Effect of different K management practices on Reserve K (kg ha^{-1}) in different layers at different stages in the Rabi season (2013-14)

Treatment		Maximum tillering		Panicle Initiation		Harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	K_{40}	176	171	157	155	168	145
T_2	K_{60}	202	208	194	158	227	159
T_3	K_{80}	215	215	211	167	231	161
T_4	K_{20} + Straw	182	190	163	176	156	111
T_5	K_{30} + Straw	163	190	194	157	218	128
T_6	K_{40} + Straw	153	195	149	177	181	126
T_7	Straw	144	132	153	147	163	144
T_8	K_{40} + 1% KNO_3 spray	188	187	161	193	151	137
T_9	K_0	159	148	142	152	132	156
CV (%)		11.13	15.81	13.17	5.95	15.59	7.75
CD (0.05)		33.91	49.74	38.60	16.7	48.83	18.91

Table-4.6(b) Effect of different K management practices on Reserve K (kg ha^{-1}) in different layers at different seasons in the Kharif season (2014)

Treatment		Maximum tillering		Panicle Initiation		Harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	K_{40}	164	126	116	99	257	161
T_2	K_{60}	153	122	109	108	258	183
T_3	K_{80}	173	186	124	107	306	189
T_4	K_{20} + Straw	144	131	116	89	225	197
T_5	K_{30} + Straw	170	134	122	105	253	203
T_6	K_{40} + Straw	160	140	120	104	265	198
T_7	Straw	130	125	117	92	232	182
T_8	K_{40} + 1% KNO_3 spray	131	110	122	96	245	193
T_9	K_0	124	101	128	102	200	193
CV (%)		19.78	21.61	10.97	14.2	22.82	14.23
CD (0.05)		NS	48.86	NS	NS	NS	NS

During harvest stage of Rabi crop the top soil recorded 132 kg ha^{-1}(control) to 232 kg ha^{-1}(80 kg K_2O ha^{-1}) and bottom soil recorded a lower K that varied from 112 kg ha^{-1}(20 kg K_2O ha^{-1} + straw) of 3t ha^{-1}) to 161 kg ha^{-1}(80 kg K_2O ha^{-1}).In Kharif season the values were more which varied from 200 kg ha^{-1}(control) to 306 kg ha^{-1}(80 kg K_2O ha^{-1}) in top soil and in bottom layer varied from 161 kg ha^{-1}(40 kg K_2O ha^{-1}) to 203 kg ha^{-1}(30 kg K_2O ha^{-1} + straw of 3t ha^{-1}).

4.3.3 Non-exchangeable K

The data on Table-4.7 (a and b) on the non-exchangeable K revealed that at the MT stage of Rabi it varied from a lowest of 35.5 kg ha^{-1} in the treatment receiving only straw to a highest of 97.9 kg ha^{-1} in the treatment receiving 20 kg K_2O ha^{-1} + straw [1] in the surface .

Table-4.7(a) Effect of different K management practices on Non-exchangeable K (kg ha^{-1}) in different layers in the Rabi season (2013-14)

Treatment		Maximum tillering		Panicle Initiation		Harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	K_{40}	87.0	123.8	90.9	99.5	117.2	94.7
T_2	K_{60}	98.1	141.1	111.2	95.4	152.4	106.2
T_3	K_{80}	97.5	136.9	116.3	94.9	152.1	98.1
T_4	K_{20} + Straw	97.9	147.7	96.3	112.2	105.9	63.6
T_5	K_{30} + Straw	69.6	140.0	99.8	106.7	152.1	81.6
T_6	K_{40} + Straw	63.6	130.5	82.1	112.8	102.2	79.4
T_7	Straw	35.5	74.5	65.3	95.0	104.2	96.3
T_8	K_{40} + 1% KNO_3 spray	96.0	138.1	92.5	141.1	83.3	89.2
T_9	K_0	90.8	105.6	85.6	101.9	84.6	107.8
CV (%)		29.1	NS	31.5	23.0	51.2	20.1
CD (0.05)		20.6	23.0	19.5	12.5	25.3	12.8

But in the sub-surface it varied from lowest of 74.5 kg ha^{-1} in the treatment receiving only straw to a highest 147.7 kg ha^{-1} in the treatment receiving 20 kg K_2O ha^{-1} along with straw. In Kharif the non-exchangeable K varied from 78.8 kg ha^{-1} (20 kg K_2O ha^{-1} with straw of 3t ha^{-1}) to 111.2 kg ha^{-1} (40 kg K_2O ha^{-1}) in the surface and 68 kg ha^{-1} (control) to 140.5 kg ha^{-1} (80 kg K_2O ha^{-1}) in the sub-surface layer.

Table-4.7(b): Effect of different K management practices on Non-exchangeable K (kg ha^{-1}) in different layers in the Kharif season (2014)

Treatment		Maximum tillering		Panicle Initiation		Harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	K_{40}	111.2	86.4	76.6	64.6	209.5	113.8
T_2	K_{60}	94.1	83.4	61.7	63.8	195.0	111.7
T_3	K_{80}	101.8	140.5	79.5	64.6	226.2	126.9
T_4	K_{20} + Straw	78.8	87.9	79.2	54.7	177.1	149.5
T_5	K_{30} + Straw	88.0	82.8	66.5	58.4	193.7	143.2
T_6	K_{40} + Straw	93.5	84.7	73.3	60.5	218.8	143.6
T_7	Straw	81.4	83.3	60.9	55.2	186.7	130.6
T_8	K_{40} + 1% KNO_3 spray	80.4	68.1	82.8	60.0	201.5	142.5
T_9	K_0	81.6	68.0	98.6	73.9	164.7	143.8
CV (%)		NS	NS	NS	NS	NS	NS
CD (0.05)		24.9	32.5	18.9	21.4	26.6	21.4

The non-exchangeable in Rabi season at PI stage varied significantly between 65.3 kg ha^{-1} (straw of 3t ha^{-1}) and 116.3kg ha^{-1} (80 kg K_2O ha^{-1}) in surface soils and between 94.9 kg ha^{-1} (80 kg K_2O ha^{-1}) and 141.1 kg ha^{-1} (K_{40}+ foliar spray) in the sub-surface soils. In Kharif season at the PI stage there was no significant variation but the treatments varied from a lowest of 60.9 kg ha^{-1} (straw 3t ha^{-1}) to a highest of 98.6 kg ha^{-1} (control) in the surface and from 54.7 kg ha^{-1} (20 kg K_2O ha^{-1} with straw of 3t ha^{-1}) to 73.9 kg ha^{-1} (control) in the sub-surface layer.

At the harvest stage of Rabi the non-exchangeable K varied significantly from a lowest of 83.3 kg ha^{-1} in K_{40}+ foliar spray to highest of 152.4 kg ha^{-1} in the treatment receiving 60 kg K_2O ha^{-1} in the surface soil and 63.6 to 107.8 kg ha^{-1} in sub surface. In Kharif at harvest stage it varied from 164.7 kg ha^{-1} (control) to 226.2 kg ha^{-1} (80 kg K_2O ha^{-1}) in the surface and 111.7 kg ha^{-1} (60 kg K_2O ha^{-1}) to 149.5 kg ha^{-1} (20 kg K_2O ha^{-1} along with straw) in the sub-surface layer.

4.3.3 Relationship of K availability with other parameters

4.3.4.1 Available N and available P of soil

The data recorded in Table-4.8 (a and b) showed that in post harvest soil of Rabi, available N was lowest in the treatment receiving 40 kg K_2O ha^{-1}(132 kg ha^{-1}) and highest in the treatment receiving 30 kg K_2O ha^{-1} along with straw(166 kg ha^{-1}), whereas in post harvest soil of Kharif the available N varied from 106 kg ha^{-1} (control) to 167 kg ha^{-1} (80 kg K_2O ha^{-1}).

Table-4.8(a) Effect of different K management practices on soil organic Carbon, Available N and Available P in the Rabi season (2013-14)

Treatment		Organic Carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})
T_1	K_{40}	0.56	133	19.03
T_2	K_{60}	0.57	151	23.37
T_3	K_{80}	0.58	153	19.63
T_4	K_{20} + Straw	0.51	134	18.80
T_5	K_{30} + Straw	0.57	166	22.23
T_6	K_{40} + Straw	0.64	148	18.23
T_7	Straw	0.61	133	21.63
T_8	K_{40} + 1% KNO_3 spray	0.64	155	19.37
T_9	K_0	0.52	154	19.90
CV (%)		15.77	10.57	19.31
CD (0.05)		NS	NS	NS

Table-4.8(b) Effect of different K management practices on soil organic Carbon, Available N and Available P in the Kharif season (2014)

Treatment		Organic Carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})
T_1	K_{40}	0.51	155	19.2
T_2	K_{60}	0.49	163	24.0
T_3	K_{80}	0.43	167	20.8
T_4	K_{20} + Straw	0.40	139	19.7
T_5	K_{30} + Straw	0.49	155	21.8
T_6	K_{40} + Straw	0.40	134	22.3
T_7	Straw	0.42	125	21.2
T_8	K_{40} + 1% KNO_3 spray	0.52	142	20.2
T_9	K_0	0.37	106	20.0
CV (%)		17.98	22.09	15.49
CD (0.05)		0.37	NS	NS

The data in the same table revealed that the available P varied from 18.3kgha^{-1}(30 kg K_2O ha^{-1} + straw) to 23.4 kg ha^{-1} (60 kg K_2O ha^{-1}) in the Rabi season and in Kharif season it varied from 19.2 kg ha^{-1} to 24 kg ha^{-1} in the treatments receiving 40 kg K_2O ha^{-1} and 60 kg K_2O ha^{-1} respectively.

4.3.4.2 Soil Organic Carbon

The data given on the Table-4.8 (a and b) showed that after Rabi season the treatments did not have any significant effect on Soil organic carbon that varied between 5.2 and 6.4g kg^{-1} where as measurement made after Kharif 2014 showed significant difference among the treatment. A lower content (3.7-5.1g kg^{-1}) of organic carbon was measured in surface soil. Lowest was observed in control plot and highest in T_8 (Fertilizer K + foliar spray) that recorded highest yield.

4.3.4.3 Soil pH

The data on soil pH presented in the Table-4.9 (a and b) revealed that the K management treatment had no significant effect on soil pH at maximum tillering stage. In Rabi season it varied from 5.67 to 6.13 in surface soil and 6.07 to 6.59 in sub surface and in Kharif season, the surface soil pH was 5.66 - 6.08 and sub soil pH 5.73-6.08.

Table-4.9(a) Effect of different K management practices on soil pH in different layers at different stages in the Rabi season (2013-14)

Treatment		Maximum tillering		Panicle Initiation		Harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	K_{40}	6.11	6.24	5.72	5.95	5.83	5.67
T_2	K_{60}	6.13	6.59	5.78	6.27	5.36	5.87
T_3	K_{80}	6.11	6.20	5.68	6.07	5.17	5.84
T_4	K_{20} + Straw	5.98	6.07	5.71	6.04	5.32	5.94
T_5	K_{30} + Straw	6.3	6.45	5.92	6.12	5.18	5.84
T_6	K_{40} + Straw	6.13	6.12	5.72	6.0	5.22	5.88
T_7	Straw	5.9	6.5	5.61	6.26	5.18	6.17
T_8	K_{40} + 1% KNO_3 spray	5.8	6.3	5.46	5.83	5.09	5.88
T_9	K_0	5.98	6.32	5.52	6.33	5.37	6.32
CV (%)		3.55	4.22	2.99	3.28	3.3	7.12
CD (0.05)		NS	NS	NS	NS	NS	NS

At PI stage there was slight decrease in soil pH. In Rabi 2013-14, there was no significant difference among the treatment in both surface and sub surface. The surface soil pH varied between 5.46 and 5.92 and sub soil pH 5.83and 6,33. In Kharif season, the pH of the surface layer however, varied significantly within the treatment. It varied from a lowest of 4.73 (40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3) to a highest of 5.25(80 kg K_2O ha^{-1}) whereas in the subsurface layer the pH varied between 5.44 (40 kg K_2O ha^{-1} along with 3t ha^{-1} straw) and 6.16 (80 kg K_2O ha^{-1}) and there was

no significant difference. In Kharif season, pH was more acidic and lower layer always measured higher values.

Table-4.9(b) Effect of different K management practices on soil pH in different layers at different stages in the Kharif season (2014)

Treatment		Maximum tillering		Panicle Initiation		Harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	K_{40}	6.08	6.37	5.11	5.66	5.11	5.48
T_2	K_{60}	5.86	6.44	5.01	6.09	5.03	5.99
T_3	K_{80}	5.7	6.23	5.25	6.16	5.16	5.48
T_4	K_{20} + Straw	5.93	6.2	4.79	5.65	5.08	5.80
T_5	K_{30} + Straw	5.92	5.96	4.98	5.96	4.96	5.71
T_6	K_{40} + Straw	5.68	5.73	4.79	5.44	4.86	5.53
T_7	Straw	5.87	6.13	5.06	5.60	5.04	5.53
T_8	K_{40} + 1% KNO_3 spray	5.67	5.99	4.73	5.62	4.94	4.92
T_9	K_0	5.66	5.89	4.92	5.50	4.99	5.56
CV (%)		6.36	8.02	3.4	8.02	5.62	8.15
CD (0.05)		NS	NS	0.29	NS	0.49	NS

At harvest stage of Rabi-2013-14, the pH of surface soil varied from 5.09 to 5.89 without any significant variation among the treatment and in sub soil it varied between 5.67 and 6.32 without any significant difference among the treatment. In Kharif season pH varied from 4.86 (40 kg K_2O ha^{-1} along with 3t ha^{-1} straw) to 5.16 (80 kg K_2O ha^{-1}) in the surface and 4.92 (40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3) to 5.99 (60 kg K_2O ha^{-1}) in the subsurface soil.

4.4.4 Microbial activity in soil

As there was addition of different quantities of K and organic residue it was thought to be appropriate to study the effect on microbial activity which is a sensitive

indicator of soil fertility. Two parameters, microbial respiration and dehydrogenase activity were selected on the basis of laboratory ease and relevance.

4.4.5 Microbial respiration

The data presented in Table-4.10 a revealed that the microbial respiration measured in laboratory on processed soil collected in MT stage of the Rabi crop varied from a lowest of 5.04 $mgCO_2100gsoil^{-1}day^{-1}$ found in control plot to a highest of 5.69 $mgCO_2100gsoil^{-1}day^{-1}$ found in the treatment T_2 that received 60 kg K_2O ha^{-1}. It measured between 4.60 and 5.64 $mgCO_2100gsoil^{-1}day^{-1}$ at PI and 4.34 and 5.76 $mgCO_2100gsoil^{-1}day^{-1}$ at harvest. There was no significant difference within the treatment.

Table-4.10(a) Effect of different K management practices on Microbial respiration ($mgCO_2100gsoil^{-1}day^{-1}$) in Rabi (2013-14) and Kharif season (2014)

Treatment		Rabi			Kharif		
		Maximum tillering	Panicle Initiation	Harvest	Maximum tillering	Panicle Initiation	Harvest
T_1	K_{40}	5.57	4.92	4.79	6.37	10.83	9.3
T_2	K_{60}	5.69	4.81	4.89	6.78	11.48	9.37
T_3	K_{80}	5.56	4.62	4.29	6.91	11.49	9.35
T_4	K_{20} + Straw	5.34	5.3	5.76	6.39	10.94	8.95
T_5	K_{30} + Straw	5.1	5.37	4.74	6.78	10.94	9.22
T_6	K_{40} + Straw	5.2	5.53	4.34	6.73	11.21	9.6
T_7	Straw	5.5	5.64	4.98	6.83	11.27	9.72
T_8	K_{40} + 1% KNO_3 spray	5.29	4.87	5.08	6.72	11.06	9.53
T_9	K_0	5.04	4.60	5.67	6.00	10.82	9.07
CV (%)		13.88	11.51	30.51	4.95	4.32	4.11
CD (0.05)		NS	NS	NS	NS	NS	NS

In Kharif , at MT stage it varied from 4.45 $mgCO_2100gsoil^{-1}day^{-1}$(control) to a highest of 6.72 $mgCO_2100gsoil^{-1}day^{-1}$observed in treatment that received only straw but no Fertilizer. At PI stage the respiration measured higher values (10.82- 11.49 mg $CO_2100gsoil^{-1}day^{-1}$ which dropped at harvest (8.95-9.72 $mgCO_2100gsoil^{-1}day^{-1}$).

4.4.6 Dehydrogenase activity

The data presented in Table-4.10 b revealed that the dehydrogenase activity of surface soil collected at MT stage varied from a lowest of 5.77 µg TPF/g/24hr measured in control plot to a highest of 14.54 µg TPF/g/24hr in the treatment receiving 40 kg K_2O ha^{-1} along with a foliar spray of 1% KNO_3 respectively.

Table-4.10(b) Effect of different K management practices on Dehydrogenase activity (µg TPF/g/24hr) in Rabi (2013-14) and Kharif season (2014)

Treatment		Rabi			Kharif		
		Maximum tillering	Panicle Initiation	Harvest	Maximum tillering	Panicle Initiation	Harvest
T_1	K_{40}	11.4	9.5	4.55	13.61	9.55	22.7
T_2	K_{60}	10.88	12	4.86	17.43	13.49	14.59
T_3	K_{80}	11.87	18.3	6.08	24.14	17.16	16.62
T_4	K_{20} + Straw	8.54	7.65	4.26	18.65	11.92	12.68
T_5	K_{30} + Straw	10.87	13.82	5.55	18.07	17.12	13.16
T_6	K_{40} + Straw	10.11	14.68	5.84	24.02	21.48	17.08
T_7	Straw	5.77	8.17	3.21	25.73	20.35	24.14
T_8	K_{40} + 1% KNO_3 spray	14.54	12.3	5.85	17.97	15.69	14.22
T_9	K_0	14.21	6.54	3.18	14.31	7.23	4.66
CV (%)		56.73	20.75	16.95	25.2	12.99	46.41
CD (0.05)		NS	4.09	1.41	8.43	3.35	NS

In Kharif it varied from a lowest of 13.61 µg TPF/g/24hr to a highest of 25.73 µg TPF/g/24hr in the treatment receiving 40 kg K_2O ha^{-1} and the treatments receiving only straw of 3t ha^{-1}. The dehydrogenase activity in the PI stage varied from a lowest

of 6.54 µg TPF/g/24hr (control) to a highest of 18.3 µg TPF/g/24hr (80 kg K_2O ha^{-1}) in the Rabi season whereas in the Kharif season it varied from 7.23 µg TPF/g/24hr (control) to 20.35 µg TPF/g/24hr (only straw).At harvest stage of the Rabi crop the dehydrogenase activity varied between the lowest of 3.18µg TPF/g/24hr (control) to highest of 6.10 µg TPF/g/24hr (only straw) whereas in the Kharif season it varied between the lowest of 4.66 µg TPF/g/24hr (control) to the highest of 24.14 µg TPF/g/24hr (only straw).

4.5 Nitrogen and Phosphorus Absorption

4.5.1 N and P uptake by Plant

The data presented in Table-4.11 showed that the N uptake in the Rabi season was highest (37.85 kg ha^{-1}) in the treatment receiving 40 kg K_2O ha^{-1}alongwith a foliar spray of 1% KNO_3 at PI stage and lowest (25.65 kg ha^{-1}) in the treatment receiving only straw of 3 t ha^{-1}. In Kharif, the N uptake was highest (94.39 kg ha^{-1}) in the treatment receiving 40 kg K_2O ha^{-1}alongwith a foliar spray of 1% KNO_3 at PI stage and lowest (67.50 kg ha^{-1}).

Table-4.11 Effect of different K management practices on N and P uptake (kg ha^{-1}) at different stages in Rabi(2013-14) and Kharif (2014)

Treatment		Rabi		Kharif	
		N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})
T_1	K_{40}	57.04	13.28	70.23	23.77
T_2	K_{60}	63.18	14.01	82.55	32.87
T_3	K_{80}	68.74	17.66	90.79	32.94
T_4	K_{20} + Straw	57.17	14.93	71.79	21.49
T_5	K_{30} + Straw	64.05	16.08	87.80	31.03
T_6	K_{40} + Straw	57.02	13.75	80.61	28.30
T_7	Straw	54.22	11.83	78.58	25.68
T_8	K_{40} + 1% KNO_3 spray	75.52	17.93	94.39	30.57
T_9	K_0	50.03	10.07	67.50	21.49
CV (%)		12.32	13.64	10.49	13.67
CD (0.05)		12.95	3.40	14.61	6.52

The P uptake in the Rabi season varied significantly from a lowest of 10.07 kg ha^{-1} in the control to a highest of 17.93 kg ha^{-1} in the treatment receiving 40 kg K_2O ha^{-1}alongwith a foliar spray of 1% KNO_3 at PI stage. In Kharif season, the P uptake varied similarly with a lowest of 21.49 kg ha^{-1} in the control to a highest of 30.57 kg ha^{-1} in the treatment receiving 40 kg K_2O ha^{-1}alongwith a foliar spray of 1% KNO_3 at PI stage.

4.6 K Balance in soil

Calculation of K balance in soil with respect to K added from external source and K removed from field for both the seasons and the total balance for the year is presented in Table 4.12 (a-c).

Table-4.12(a) Effect of K management practices on K balance in Rabi season (2013-14)

Treatment	K added (kg ha^{-1})				K removed (kg ha^{-1})			Balance (kg ha^{-1})
	Fertilizer	FYM	Irrigation	Total	straw	grain	Total	
K_{40}	40.00	25	5.1	70.1	90.5	10.6	101.1	-31.0
K_{60}	60.00	25	5.1	90.1	104.6	12.3	116.9	-26.8
K_{80}	80.00	25	5.1	110.1	133.8	13.3	147.1	-37.0
K_{20} + Straw	20.00	25	5.1	50.1	7.9	13.3	21.2	28.9
K_{30} + Straw	30.00	25	5.1	60.1	9.9	14.6	24.5	35.6
K_{40} + Straw	40.00	25	5.1	70.1	9.4	10.5	19.9	50.2
Straw	-	25	5.1	30.1	10.1	12.1	22.2	7.9
K_{40} + 1% KNO_3 spray	42.25	25	5.1	72.35	121.3	17.7	138.9	-66.6
K_0	0.00	25	5.1	30.1	65.7	7.3	73.0	-42.9

From the data it is seen that in Rabi season K balance varied from –66.8 to 7.9.Treatment that received only fertilizer K or no K caused a negative balance with highest negative balance of -66.6 kg/ha seen in treatment T_8 that received 40kg K_2O ha^{-1} along with a foliar spray followed by T_3 that received 80kg K_2Oha^{-1}. Treatment that received both K fertilizer and straw showed positive balance that varied 7.9 to 50.2kg ha^{-1}.

Table-4.12(b) Effect of K management practices on K balance in Kharif season (2014)

Treatment	K added (kg ha^{-1})				K removed (kg ha^{-1})			Balance (kg ha^{-1})
	Fertilizer	FYM	Irrigation	Total	straw	grain	Total	
K_{40}	40.00	25	1.8	70.1	83.5	13.5	97.0	-26.9
K_{60}	60.00	25	1.8	90.1	130.5	17.4	147.9	-57.8
K_{80}	80.00	25	1.8	110.1	138.7	16.9	155.6	-45.5
K_{20} + Straw	20.00	25	1.8	50.1	8.5	14.2	22.7	27.4
K_{30} + Straw	30.00	25	1.8	60.1	10.3	16.8	27.0	33.1
K_{40} + Straw	40.00	25	1.8	70.1	9.3	18.7	28.0	42.1
Straw	-	25	1.8	30.1	8.8	14.6	23.4	6.7
K_{40} + 1% KNO_3 spray	42.25	25	1.8	72.35	124.2	18.0	142.2	-69.8
K_0	-	25	1.8	30.1	73.6	13.2	86.8	-56.7

Table-4.12(c) Effect of K management practices on K balance per annum(2013-14)

Treatment	K added (kg ha^{-1})			K removed (kg ha^{-1})			Balance (kg ha^{-1})
	Rabi	Kharif	Total	Rabi	Kharif	Total	
K_{40}	70.1	66.8	136.9	100.2	97.0	197.1	-60.2
K_{60}	90.1	86.8	176.9	116.6	147.9	264.6	-87.7
K_{80}	110.1	106.8	216.9	147.3	155.6	302.9	-86.0
K_{20} + Straw	50.1	46.8	96.9	21.2	22.7	43.9	53.0
K_{30} + Straw	60.1	56.8	116.9	24.5	27.0	51.6	65.3
K_{40} + Straw	70.1	66.8	136.9	19.8	28.0	47.8	89.1
Straw	30.1	26.8	56.9	22.2	23.4	45.6	11.3
K_{40} + 1% KNO_3 spray	72.35	68.8	141.15	139.1	142.2	281.3	-140.1
K_0	30.1	26.8	56.9	73.6	86.8	160.3	-103.4

In Kharif season it varied between -69.8 and 42.3kg ha^{-1}.The treatment only differed with respect to magnitude but the trend remained unchanged. Fertilizer treatment showed positive balance and the treatment that receive either straw alone or a combination of both fertilizer K and straw caused a positive balance.

When calculated on annual basis it is seen that the total K balance varied between -140 to 89.1 kg ha^{-1} $year^{-1}$ with highest negative balance observed in T_8 that produced highest yield and highest positive balance in T_5 that receives 30kg K_2O as fertilizer along with straw .

4.7 Incidence of disease and insect attack

4.7.1 Incidence of disease attack

4.7.1.1 Blast

The incidence of blast disease was recorded at vegetative and harvest stage of Rice crop var. Lalat both in Rabi and Kharif seasons and are presented in Table-4.13 and Figure-3.11. It was depicted from the table that in the vegetative stage of Rabi season the treatment receiving 80 kg K_2O ha^{-1} varied significantly with lowest Percent Disease Incidence (PDI) of 8.15% from the control plot with a PDI of 14.81%. In harvest stage also the treatments varied significantly with lowest PDI (5.93%) in treatment with 80 kg K_2O ha^{-1} and highest PDI (12.59%) in the control. The record and analysis of the blast disease in the Kharif season showed that the Percent Disease Incidence (PDI) was lowest (8.89 %) in the treatment receiving 80 kg K_2O ha^{-1} and highest (14.81) in the treatment receiving only straw of 3t ha^{-1}. In harvest stage also there was lowest PDI of 6.69% in treatment receiving 80 kg K_2O ha^{-1} and highest PDI of 13.33% in control plot. There were significant variations within the treatments both in vegetative and harvest stages of Kharif season.

The pooled analysis of incidence of blast over Rabi and Kharif seasons given in the Table-4.13 (c and d) showed that the disease expression was numerically high in Kharif as compared to Rabi. In both the seasons the treatment receiving 80 kg K_2O ha^{-1} showed the lowest PDI and the control showed the highest.

Table-13(a) Effect of different K management practices on expression of Blast disease in the Rabi (2013-14) and Kharif (2015) season

Treatment		Rabi		Kharif	
		Vegetative	Harvest	Vegetative	Harvest
T_1	K_{40}	10.37 (19.37)	8.15 (16.47)	11.11 (19.37)	9.63 (17.99)
T_2	K_{60}	9.63 (18.85)	7.41 (15.49)	9.36 (17.99)	8.15 (16.41)
T_3	K_{80}	8.15 (17.20)	5.93 (13.56)	8.89 (17.20)	6.67 (14.75)
T_4	K_{20} + Straw	10.37 (19.18)	8.15 (16.28)	11.11 (19.37)	10.37 (18.73)
T_5	K_{30} + Straw	10.37 (19.22)	8.15 (15.82)	10.37 (18.58)	8.89 (17.20)
T_6	K_{40} + Straw	11.11 (20.01)	8.89 (17.20)	11.85 (19.97)	9.63 (17.65)
T_7	Straw	13.33 (21.39)	11.85 (19.82)	14.85 (22.58)	12.59 (20.61)
T_8	K_{40} + 1% KNO_3 spray	9.63 (17.94)	7.41 (15.68)	9.63 (17.97)	8.15 (16.47)
T_9	K_0	14.81 (21.94)	12.59 (20.61)	14.07 (21.94)	13.33 (21.39)
SEM		0.87	1.19	0.93	0.98
CD (0.05)		2.62	3.56	2.77	2.94

4.7.1.2 Brown spot

The result of brown spot incidence of both vegetative and harvest stage of Rabi and Kharif season presented in Table-13 b. The data revealed that there was no significant difference among the treatments for incidence of brown spot in the vegetative stage of Rabi season. However the PDI varied between 17.78% and 22.22% in treatment receiving 80 kg K_2O ha^{-1} and the control. But in the harvest stage the treatments varied significantly between 10.37% PDI and 17.78%PDI in the treatments receiving 80 kg K_2O ha^{-1} and the control.

Table-13(b) Effect of different K management practices on expression of Brown spot disease in the Rabi (2013-14) and Kharif (2014)

Treatment		Rabi		Kharif	
		Vegetative	Harvest	Vegetative	Harvest
T_1	K_{40}	20.00 (27.03)	11.85 (19.97)	18.52 (25.29)	15.56 (23.07)
T_2	K_{60}	18.52 (25.39)	12.59 (20.61)	17.78 (24.71)	14.81 (22.34)
T_3	K_{80}	17.78 (25.44)	10.37 (18.64)	16.30 (23.42)	12.59 (21.18)
T_4	K_{20} + Straw	21.48 (27.53)	14.81 (22.51)	20.74 (26.96)	16.30 (23.72)
T_5	K_{30} + Straw	20.00 (27.03)	14.07 (21.34)	17.04 (24.08)	11.85 (19.97)
T_6	K_{40} + Straw	18.52 (25.39)	13.33 (21.39)	18.52 (25.39)	13.33 (21.39)
T_7	Straw	21.48 (27.60)	17.04 (24.28)	19.26 (25.85)	17.04 (24.08)
T_8	K_{40} + 1% KNO_3 spray	18.52 (25.39)	11.11 (19.18)	18.52 (25.29)	11.11 (19.18)
T_9	K_0	22.22 (28.06)	17.78 (25.44)	21.48 (27.45)	17.78 (24.71)
SEM		0.86	1.22	1.12	0.97
CD (0.05)		NS	3.65	NS	2.92

The incidence of brown spot in the vegetative stage in the Kharif season varied between 16.30% PDI and 21.48% PDI in the treatment receiving 80 kg K_2O ha^{-1} and the control. But there was no significant variation among the treatments. In harvest stage of the Kharif season there was significant variation between the treatments and the lowest PDI was found in the treatment receiving 20 kg K_2O ha^{-1} along with 3 t ha^{-1} straw (11.85%) and highest PDI in the control.

Table-13(c) Effect of different K management practices on average expression of Brown spot and blast in the Rabi (2013-14) season

Treatment		Blast PDI (%)	% decrease over control	Brown spot PDI (%)	% decrease over control	Yield (t ha^{-1})	% increase over control
T_1	K_{40}	9.26 (17.23)	32.4	15.93 (23.50)	20.4	3.21	19.33
T_2	K_{60}	8.52 (16.67)	37.8	15.56 (23.00)	22.2	3.51	30.48
T_3	K_{80}	7.04 (14.92)	48.6	14.07 (22.04)	29.6	3.43	27.51
T_4	K_{20} + Straw	9.26 (17.43)	32.4	18.15 (25.02)	9.3	3.17	17.84
T_5	K_{30} + Straw	9.26 (17.06)	32.4	17.04 (23.96)	14.8	3.48	29.37
T_6	K_{40} + Straw	10.00 (18.61)	27.0	15.93 (23.31)	20.4	3.08	14.5
T_7	Straw	12.59 (20.50)	8.1	19.26 (25.94)	3.7	2.82	4.83
T_8	K_{40} + 1% KNO_3 spray	8.52 (16.84)	37.8	14.81 (22.31)	25.9	3.84	42.75
T_9	K_0	13.70 (21.56)		20.00 (26.44)		2.69	
SEM		1.04		0.98			
CD (0.05)		3.13		2.95			

The data of the pooled analysis given in Table-13(c and d) of brown spot disease over the Rabi and Kharif seasons showed that numerically on an average the data of brown spot was more in Kharif as compared to Rabi. In Rabi the treatment receiving 80 kg K_2O ha^{-1} got the lowest PDI (7.04%) and control received the highest PDI (13.70%).

Table-13(d) Effect of different K management practices on average expression of Brown spot and blast in the Kharif (2014) season

Treatment		Blast PDI (%)	% decrease over control	Brown spot PDI (%)	% decrease over control	Yield (t ha^{-1})	% increase over control
T_1	K_{40}	10.37 (18.68)	22.20	17.04 (24.18)	13.2	4.34	3.08
T_2	K_{60}	8.89 (17.20)	33.32	16.30 (23.53)	17.0	4.72	12.11
T_3	K_{80}	7.78 (15.98)	41.65	14.44 (22.30)	26.4	4.87	15.67
T_4	K_{20} + Straw	10.74 (19.05)	19.42	18.52 (25.34)	5.7	4.39	4.28
T_5	K_{30} + Straw	9.63 (17.89)	27.76	14.44 (22.02)	26.4	5.17	22.8
T_6	K_{40} + Straw	10.74 (18.81)	19.42	15.93 (23.35)	18.9	4.94	17.34
T_7	Straw	13.33 (21.28)	-5.58	18.15 (25.00)	7.5	4.55	8.08
T_8	K_{40} + 1% KNO_3 spray	8.89 (17.20)	33.32	14.81 (22.29)	24.5	5.35	27.07
T_9	K_0	14.07 (21.96)		19.63 (26.12)		4.21	
SEM		0.77		1.27			
CD (0.05)		2.31		3.81			

4.7.2 **Incidence of Insect attack**

4.7.2.1 Stem borer

The data presented in Table-14 (a and b) showed that the stem borer incidence was in both vegetative and harvest stage as dead hart and white earhead respectively.

Table-14(a) Effect of different K management practices on incidence of insect pest in the Rabi season (2013-14)

Treatment		Stem Borer		Leaf folder (DL %)*	Whorl maggot (DL%)*	Gundhi Bug (no./sq. mt)
		Dead Hart (%)	White earhead (%)			
T_1	K_{40}	6.20 (2.57)	2.13 (1.39)	1.01 (0.98)	3.83 (1.94)	14.72 (3.78)
T_2	K_{60}	5.45 (2.28)	1.77 (1.27)	0.74 (0.84)	3.23 (1.75)	14.23 (3.65)
T_3	K_{80}	2.94 (1.69)	1.09 (0.97)	0.50 (0.71)	2.99 (1.73)	11.90 (3.41)
T_4	K_{20} + Straw	5.47 (2.32)	0.95 (0.89)	0.50 (0.71)	4.82 (2.17)	12.22 (3.47)
T_5	K_{30} + Straw	5.02 (2.3)	1.36 (1.11)	0.01 (0.99)	3.99 (1.97)	12.40 (3.40)
T_6	K_{40} + Straw	4.27 (2.01)	1.09 (0.93)	0.75 (0.84)	4.12 (2.01)	14.89 (3.79)
T_7	Straw	5.05 (2.24)	1.54 (1.15)	0.50 (0.71)	5.33 (2.25)	15.46 (3.86)
T_8	K_{40} + 1% KNO_3 spray	3.93 (1.97)	0.77 (0.79)	0.98 (0.93)	4.14 (1.99)	11.19 (3.34)
T_9	K_0	9.04 (2.32)	1.95 (1.39)	1.32 (1.11)	4.55 (2.08)	15.37 (3.90)
SEM		0.88	0.50	0.43	0.79	1.36
CD (0.05)		0.47	1.51	1.27	2.37	4.07

( ) indicate the square root values

*Indicate the damage leaf percent

In Rabi season the percent of dead hart incidence was highest (9.04%) in the control plot and lowest (2.94%) in the treatment receiving 80 kg K_2O ha^{-1} and in the Kharif season also the incidence was highest (11.52%) in the control plot and lowest (3.17%) in the treatment receiving 80 kg K_2O ha^{-1}.

In the harvest stage of the Rabi season the white earhead incidence was highest (2.13%) in the treatment receiving 40 kg K_2O ha^{-1} and lowest (0.77%) in the treatment receiving 40 kg K_2O ha^{-1} along `with 1% KNO_3 foliar spray at PI stage. In

the Kharif season the incidence was highest (7.93%) in the control plot and lowest (3.34%) in the treatment receiving 80 kg K_2O ha^{-1}.

Table-14(b) Effect of different K management practices on incidence of insect pest in the Kharif season (2014)

Treatment		Stem Borer		Leaf folder (DL %)*	Whorl maggot (DL%)*	Gundhi Bug (no./sq. mt)
		Dead Hart (%)	White earhead (%)			
T_1	K_{40}	7.58 (2.75)	6.02 (2.45)	0.96 (0.97)	4.43 (2.10)	9.60 (3.10)
T_2	K_{60}	6.81 (2.60)	4.70 (2.17)	0.82 (0.90)	3.63 (1.90)	7.50 (2.74)
T_3	K_{80}	3.17 (1.78)	3.34 (1.83)	0.60 (0.77)	1.78 (1.31)	7.38 (2.71)
T_4	K_{20} + Straw	7.91 (2.81)	5.29 (2.30)	1.35 (1.16)	4.87 (2.20)	7.17 (2.68)
T_5	K_{30} + Straw	6.72 (2.59)	4.42 (2.10)	1.50 (1.22)	4.27 (2.03)	7.90 (2.81)
T_6	K_{40} + Straw	6.05 (2.46)	4.96 (2.23)	0.94 (0.95)	2.09 (1.45)	8.14 (2.83)
T_7	Straw	7.54 (2.74)	6.57 (2.56)	1.75 (1.32)	5.30 (2.30)	9.33 (3.04)
T_8	K_{40} + 1% KNO_3 spray	4.04 (2.02)	5.27 (2.30)	0.73 (0.85)	3.64 (1.90)	7.40 (2.71)
T_9	K_0	11.52 (3.39)	7.93 (2.81)	1.63 (1.27)	5.60 (2.36)	13.00 (3.60)
SEM		0.1	0.06	0.06	0.13	0.11
CD (0.05)		0.29	0.17	0.19	0.39	0.62

( ) indicate the square root values

*Indicate the damage leaf percent

4.7.2.2 Whorl maggot

The data presented in Table-14 (a and b) revealed that the incidence of whorl maggot varied significantly from the lowest of 2.99% (80 kg K_2O ha^{-1}) to the highest of 5.33% (straw 3t ha^{-1}) in the Rabi season. In Kharif it varied significantly from the lowest of 1.78% to the highest of 5.60% in the treatments receiving 80 kg K_2O ha^{-1} and in the control respectively.

4.7.2.3 Leaf folder

The data presented in Table-14(a and b)revealed that in the Rabi season the leaf folder incidence was highest (1.32%) in the control and lowest (0.01%) in the treatment receiving 30 kg K_2O ha^{-1} along with straw 3t ha^{-1} . In the Kharif season the incidence was highest (1.75%) in the treatment receiving straw 3t ha^{-1} and lowest (0.60%) in the treatment receiving 80 kg K_2O ha^{-1}.

4.7.2.4 Gundhi bug

The data presented in Table-14(a and b) revealed that the number of of gundhi bug per square meter varied significantly from the lowest of 11.19 (40 kg K_2O ha^{-1} along with 1% KNO_3 foliar spray at PI stage) to the highest of 15.46 (straw 3t ha^{-1}) in the Rabi season. In Kharif it varied significantly from the lowest of 7.40 to the highest of 13 in the treatments receiving 40 kg K_2O ha^{-1} along with 1% KNO_3 foliar spray at PI stage and in the control respectively.

4.4 Studies on cost economics

Data on cost economics given in Table-15 (a-c) cost of cultivation, gross returns, net returns and return per rupee invest of both Rabi and Kharif season under different K management practices are presented in table-14(a and b). In both the seasons the cost of cultivation was highest in the treatment receiving 40 kg K_2O ha^{-1} with straw (3 t ha^{-1}) but the return per rupee invested was highest in the treatment receiving 40 kg K_2O ha^{-1} with 1% KNO_3 foliar spray with Rs.1.70 and Rs.2.29 due to highest net returns of Rs.24053.33 and Rs.44233.67 respectively in both Rabi and Kharif seasons respectively.

Table-15(a) Effect of K management practices on Cost economics in Rabi season (2013-14)

Treatment		Grain Yield (q/ha)	Straw Yield (q/ha)	Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	Return per rupee invested (Rs.)
T_1	K_{40}	32.08	43.75	32400.00	48008.33	15608.33	1.48
T_2	K_{60}	35.08	51.33	34140.00	52846.67	18706.67	1.55
T_3	K_{80}	34.25	63.50	34720.00	52930.00	18210.00	1.52
T_4	K_{20}+ Straw	31.67	49.58	35980.00	48025.00	12045.00	1.33
T_5	K_{30} + Straw	34.83	54.83	36270.00	52856.67	16586.67	1.46
T_6	K_{40} + Straw	30.75	52.00	36560.00	47020.00	10460.00	1.29
T_7	Straw	28.20	49.00	35400.00	43252.00	7852.00	1.22
T_8	K_{40} + 1% KNO_3 spray	38.42	62.17	34410.00	58463.33	24053.33	1.70
T_9	K_0	26.95	44.08	31240.00	41060.33	9820.33	1.31

Table-15(b) Effect of K management practices on Cost economics in Kharif season (2014)

Treatment		Grain Yield (q/ha)	Straw Yield (q/ha)	Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	Return per rupee invested (Rs.)
T_1	K_{40}	43.43	48.43	32400.00	63912.66	31512.66	1.97
T_2	K_{60}	47.23	63.49	34140.00	70586.36	36446.36	2.07
T_3	K_{80}	48.67	66.92	34720.00	72879.08	38159.08	2.10
T_4	K_{20} + Straw	43.90	42.57	35980.00	63960.78	27980.78	1.78
T_5	K_{30} + Straw	51.70	58.88	36270.00	76199.78	39929.78	2.10
T_6	K_{40} + Straw	49.37	53.66	36560.00	72504.33	35944.33	1.98
T_7	Straw	45.53	49.86	35400.00	66911.47	31511.47	1.89
T_8	K_{40} + 1% KNO_3 spray	53.50	58.84	34410.00	78643.67	44233.67	2.29
T_9	K_0	42.10	43.47	31240.00	61602.98	30362.98	1.97

It was followed by the treatment receiving 60 kg K_2O ha^{-1} in Rabi and 80 kg K_2O ha^{-1} in Kharif with net return per rupee invested of Rs.1.55 and Rs.2.10 respectively. Among the treatments receiving fertilizer as well as straw the highest return per rupee invested was in the treatment receiving 30 kg K_2O ha^{-1} and straw (3 t ha^{-1}) with Rs.1.46 in Rabi and Rs.2.10 in Kharif.

Table-15(c) Effect of K management practices on Cost economics per year (2014)

Treatment		Grain Yield (q/ha)	Straw Yield (q/ha)	Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	Return per rupee invested (Rs.)
T_1	K_{40}	75.52	92.18	64800	111920.99	47120.99	1.73
T_2	K_{60}	82.32	114.82	68280	123433.03	55153.03	1.81
T_3	K_{80}	82.92	130.42	69440	125809.08	56369.08	1.81
T_4	K_{20} + Straw	75.57	92.15	71960	111985.78	40025.78	1.56
T_5	K_{30} + Straw	86.53	113.71	72540	129056.45	56516.45	1.78
T_6	K_{40} + Straw	80.12	105.66	73120	119524.33	46404.33	1.63
T_7	Straw	73.73	98.86	70800	110163.47	39363.47	1.56
T_8	K_{40} + 1% KNO_3 spray	91.92	121.00	68820	137107.00	68287.00	1.99
T_9	K_0	69.05	87.55	62480	102663.32	40183.32	1.64

After Kharif rice harvested, the average system economics presented in the Table-14(c) showing the highest return per rupee invested in the treatment receiving 40 kg K_2O ha^{-1} with 1% KNO_3 foliar spray (1.99) followed by both the treatment receiving 60 kg K_2O ha^{-1}(1.81) and 80 kg K_2O ha^{-1} (1.81) and the treatment receiving 30 kg K_2O ha^{-1} and 3 t ha^{-1} straw (1.78).

DISCUSSION

The discussions pertaining to the experimental findings are reported in this chapter under the following headings.

5.1 Effect on grain yield and crop response

5.2 Effect on potassium uptake

5.3 Changes in soil potassium

5.4 Effect on soil health

5.5 Effect on disease and insect pests

5.6 Cost analysis

5.7 Evaluation of K management options

5.1 Effect on grain yield and crop response

5.1.1 Grain yield

Perusal of results presented in the last chapter (Table 1 a and b) revealed that in Rabi, the crop yield that varied from 2.69 to 3.84 tha^{-1} was relatively low as compared to the yields (4.21 to 5.35 tha^{-1}) obtained in the following Kharif season. In Rabi the yield increased up to 60kg K_2O applied through fertilizer. But in Kharif, the crop responded beyond 60kg K_2O applied through fertilizer alone or a combination 40kg K_2O applied through fertilizer and straw. The high yielding treatments which were at par were in the order : 40kg K_2O applied through fertilizer and 1% KNO3 as foliar spray > 60kg K_2O as fertilizer > 30kg K_2O applied through fertilizer and straw in Rabi season and 40kg K_2O applied through fertilizer and 1% KNO3 as foliar spray > 30kg K_2O applied through fertilizer and straw > 80kg K_2O as fertilizer > 60kg K_2O as fertilizer in Kharif season. Treatment with only straw and the control are the low yielders.

In Kharif yield increased up to a highest dose of 80 kg ha^{-1} but in Rabi after 60kg level there was yield decline. Application of K beyond the optimum level leads to its luxury consumption with a reduction in Ca+Mg, as these are complementing

ions. In soils marginal in Ca and Mg supply, yield reduction occurs with increased K supply (Singh and Tomar,1994). In Rabi season this may be the situation.

5.1.2 Crop response

From the results on crop response calculated as per cent yield increase over control and presented in table 5.1 below. It is seen that highest crop response of 42.75 % in Rabi and 27.07% in Kharif were obtained in the treatment that received 40 kg K_2O through fertilizer and 1% KNO_3 through foliar spray. Second highest response of 30.48% was obtained with application of 60 kg K_2O as fertilizer in Rabi and 22.80 % by 30 kg K_2O as fertilizer and straw in Kharif. Third highest response of 29.37 % was obtained in treatment that received 30 kg K_2O through fertilizer and straw in Rabi whereas 17.34 % in 40 kg K_2O through fertilizer and straw in Kharif. Lowest response was obtained in treatment with straw only in Rabi and 40Kg K_2O ha^{-1} in Kharif.

Table-5.1 Crop response (%) to different K management practices

Treatment	K_{40}	K_{60}	K_{80}	K_{20}+ straw	K_{30}+ straw	K_{40}+ straw	Straw	K_{40}+ 1% KNO_3
Rabi	19.33	30.48	27.51	17.84	29.37	14.50	4.83	42.75
Kharif	3.08	12.11	15.67	4.28	22.80	17.34	8.08	27.07

5.1.3 Causes of low yield in Rabi season

Results depicted in table 4.1(a and b) revealed that yield obtained in Rabi crop is much less than the potential yield (6t ha^{-1}) of the rice variety Lalat and Kharif yield is optimum.

As compared to Kharif, the unexpected low yield in Rabi can largely be attributed to poor tillering and reduced number of spikelets per panicle when compared with those in Kharif crop. This might have happened due to inadequacy of N and P in the early part of growth .Low temperature prevailing during planting and tillering stage might be one of the reasons for less P diffusion and poor uptake and utilization of P. The applied N might have been lost through leaching due to more

leaching in Rabi season of irrigation water which was introduced more frequently after planting. Between Rabi and Kharif ,leaching is minimum in Kharif because of the land characteristic, where as it is more in Rabi with fall in water table resulting in faster downward movement of water and requirement of more frequent irrigation through which applied N might have been lost from the root zone through the process of leaching.

Table-5.2 Effect of different K management practices on K/N and K/P at different stages in Rabi(2013-14) and Kharif (2014)

Treatment		Rabi		Kharif	
		K/N	K/P	K/N	K/P
T_1	K_{40}	1.76	7.54	1.38	4.08
T_2	K_{60}	1.85	8.33	1.79	4.50
T_3	K_{80}	2.14	8.34	1.71	4.72
T_4	K_{20} + Straw	1.61	6.18	1.21	4.06
T_5	K_{30} + Straw	1.92	7.66	1.57	4.44
T_6	K_{40} + Straw	1.88	7.79	1.47	4.18
T_7	Straw	2.07	9.47	1.31	4.02
T_8	K_{40} + 1% KNO_3 spray	1.84	7.76	1.51	4.65
T_9	K_0	1.47	7.30	1.29	4.04

To substantiate the above cause, attempt was made to use nutrient ratio concept for identifying the sufficiency or deficiency of nutrients in plant. From the results on N and P absorption as compared to K it may be inferred that there is less absorption of N and P as compared to K. This is evidenced from the K/N and K/P ratio values (Table 5.2). The K/N ratio of plant sample in Rabi season varied between 2.87 and 3.76 as compared to 2.47 and 3.24 in Kharif. Similarly with respect to total

uptake, K/N ratio varied between 1.47 and 2.14 in Rabi and 1.21 to 1.79 in Kharif. Thus the value of the ratio is more in Rabi season than Kharif season both in terms of content and total uptake. From this it can be inferred that in Rabi season K and N are more imbalanced due to less absorption of nitrogen which may be a limiting factor.

Similarly K/P ratio with respect to content in plant was 10.47-15.27 as compared to 5.99-7.18 in Kharif and with respect to uptake it was 6.18-9.47 in Rabi and 4.02 -4.72 in Kharif. Taking the ratio of Kharif as optimum, the ratio in Rabi is almost double which may be due to lower value of P as K concentration and uptake by plant is within the normal range. Much higher values of K/N and K/P ratios at maturity in Rabi season in both content and total absorption than Kharif indicates less absorption of both of these two important primary nutrients N and P by the Rabi crop justifying why yield was low in Rabi crop.

5.2 Potassium Uptake

5.2.1 K-Content in Plant

Potassium content in plant (Table-4.2) showed an increasing trend with stage of growth. At maximum tillering and panicle initiation stage the content was more in Kharif than Rabi season where as at maturity it remained almost same. For both seasons, higher content of K in Kharif than Rabi has also been reported by Subbiah(1983) who assigned high temperature as the cause. In each season, however there was no significant difference among the treatments at MT and PI stage with respect to K content, whereas at maturity there was significant difference with respect to K content only in straw but not in grain. The treatment which received only fertilizer the content was more and with increased dose there was increase in the content in straw.

5.2.2 Biomass Accumulation

Results on biomass accumulation (Table- 4.3) revealed more biomass accumulation in Kharif than Rabi season. This goes against the fact that a crop of same variety accumulates more biomass in Rabi than Kharif season. At each stage of growth there was less accumulation of biomass resulting in much less yield in Rabi than the range, 4.25-5.35 t ha^{-1} obtained in Kharif.

5.2.3 Potassium partitioning to grain and straw

In Rabi, grains accumulated 10.47 to 34.10 kg K ha^{-1} as compared to 65.68-133.75 kg K. Thus 9.06-14.42% of the total K is partitioned to grain. In Kharif at maturity highest uptake (156kg ha^{-1}) was measured in treatment receiving 80 kg K_2O $ha^{-1}$and lowest (87 kg ha^{-1}) in control. At maturity grains accumulated 10.86 to 16.34% of the total K. Thus straw retained a major portion of K absorbed by the plant. Accumulation of K in grain in present finding was relatively low as compared to 25% reported by Kumbhar and Sonar (1979).

5.2.4 Partitioning of Potassium to different stages

Comparing the partitioning of K absorption to different periods of growth (Fig.5.1) it is observed that in Rabi the treatments that yielded more absorbed 12-13% of total K within maximum tillering, 23-27% during MT and PI and 59-64% within PI and maturity as compared 16-18%of total K within maximum tillering, 38-44% during MT and PI and 40-44% within PI and maturity in Kharif season. In a study Kumbhar and Sonar (1979) reported 24% within 37days, 41% during 38-58days which matched with the results of Kharif season. From the partitioning data it is clear that in the early vegetative growth period during Rabi season the crop absorbed less K than that in Kharif. Inadequate N and K supply might be the reason for this. Poor absorption of N, P and K might be the reason why number of panicles was less in Rabi as Potassium absorbed up to MT stage is used to increase number of panicles and number of grains per panicle (Panda, 1984).

In Rabi, the number of effective tillers was highest of 313 m^{-2} in treatment that received 40 kg K_2Oha^{-1} at planting and a foliar spray with 1% KNO_3 at PI stage and yielded highest grain. In contrast during Kharif the effective tillers were more in number. It varied from a lowest of 375m^{-2} (T_7, straw) to a highest of 460m^{-2} measured in treatment that received 40kg K_2O and straw.

5.3 Changes in Soil Potassium

5.3.1 Available K

On perusal of data (Table- 4.5 a and b) it is seen that 1N NH_4OAc extractable K is more in surface than in sub-surface soil in both the seasons at all stages of

Fig.5.1 Partitioning of K to different stages as influenced by different treatment and seasons

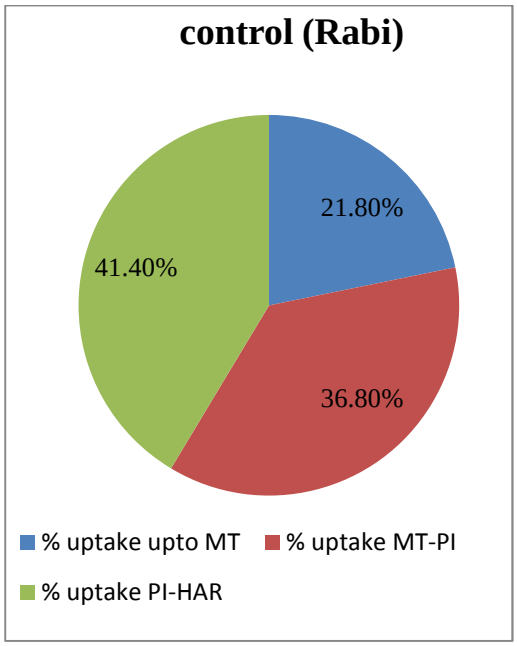

Fig.5.1(a)

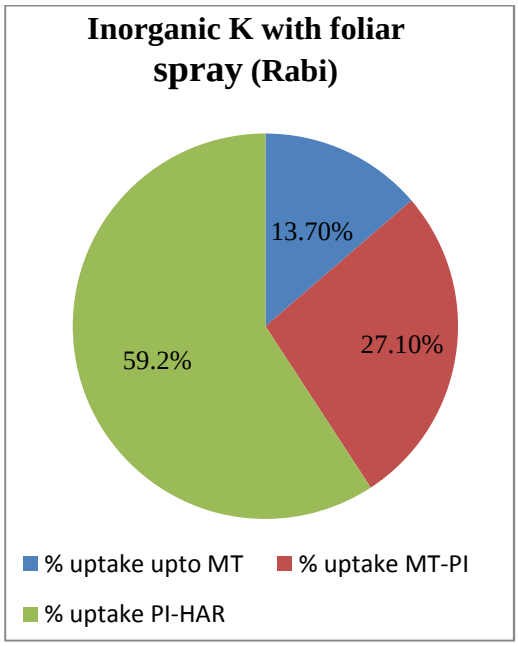

Fig.5.1(b)

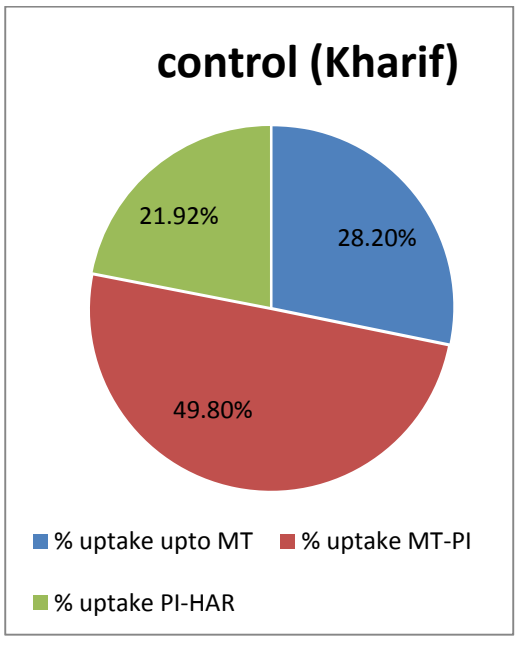

Fig.5.1(c)

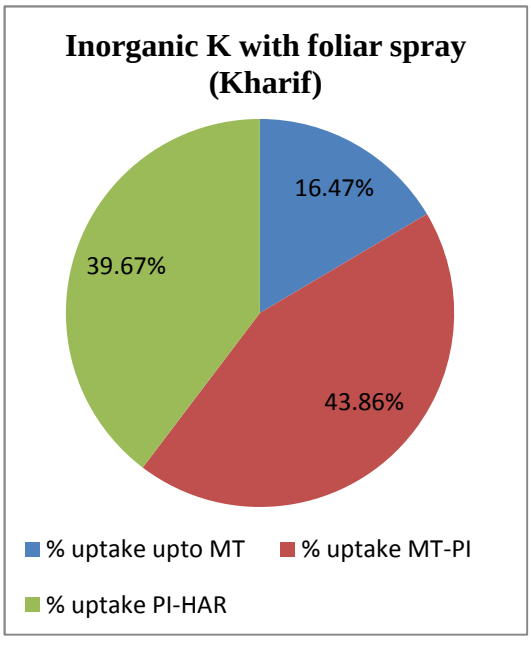

Fig.5.1(d)

growth. Available K was more in Rabi season than Kharif season. In surface soil there was decrease in available K by 21.93-36.05 kg ha^{-1} as compared to 14.14-18.97 $kgha^{-1}$ in subsoil. Among different treatments more decrease in surface soil might be due to plant uptake and leaching.

In both the seasons available K in surface layer decreased from MT to PI stage where as in bottom layer it is not conspicuous. In Rabi there was further decrease from PI to harvest stage where as in Kharif it increased.

With increase in the level of K available K increased in both the layers in both the seasons. Significant difference was only observed that received fertilizer K whereas the difference was not significant in treatment where both straw and fertilizer K were applied. In control lowest available K was found at all growth stages as compared to initial soil status but all the treatments measured higher values. The treatment where only straw was incorporated available K was almost equal to the treatments where both straw and fertilizer were applied. In both the seasons by grouping the treatments into 5 groups viz. fertilizer K, fertilizer K with straw, straw, fertilizer K with foliar spray, control, the groups can be ordered as fertilizer K > fertilizer K with straw> straw> fertilizer K with foliar spray and control.

5.3.2 Reserve K

Data on reserve K or 1N HNO_3 extracted K presented in table 4.6 a and b revealed that in surface layer the reserve K was more than that in sub-soil in both the seasons. The difference between the layers however was more in Kharif season. Within the stages the reserve K showed variation, there was a fall in reserve K from MT to PI stage and increase from PI to harvest stage. The fall during MT and PI stage might be due to release of non-exchangeable K and utilization of the available K by the crop. Increase in the content at harvest might be due to release of K from degenerated plant roots or drying of soil.

Like available K, application of fertilizer K also maintained high level of reserve K than combined application of fertilizer K and straw and with increase in K level there was increase in reserve K, it was more conspicuous with respect to fertilizer K alone. In treatment where only straw was applied reserve K measured lowest in both the seasons and in both the layers and in control plot also low values

Fig.5.2 Soil available K (kg ha^{-1}) at different stages of crop growth as influenced by different types of K management practices

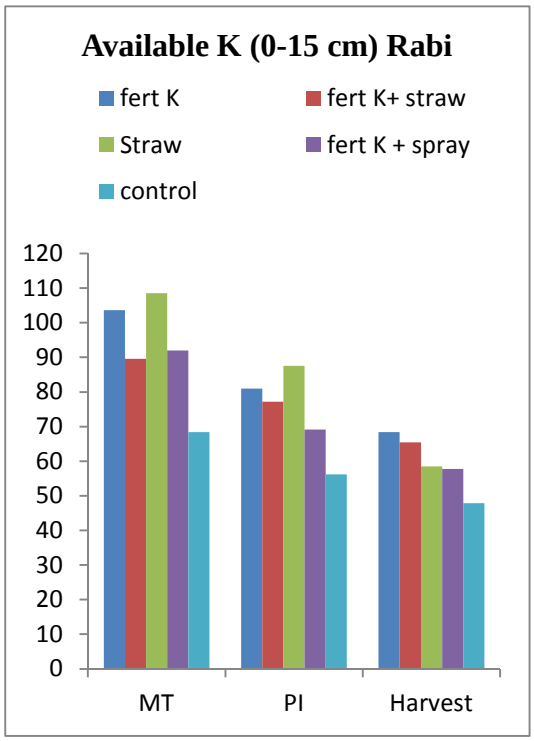

Fig.5.2(a)

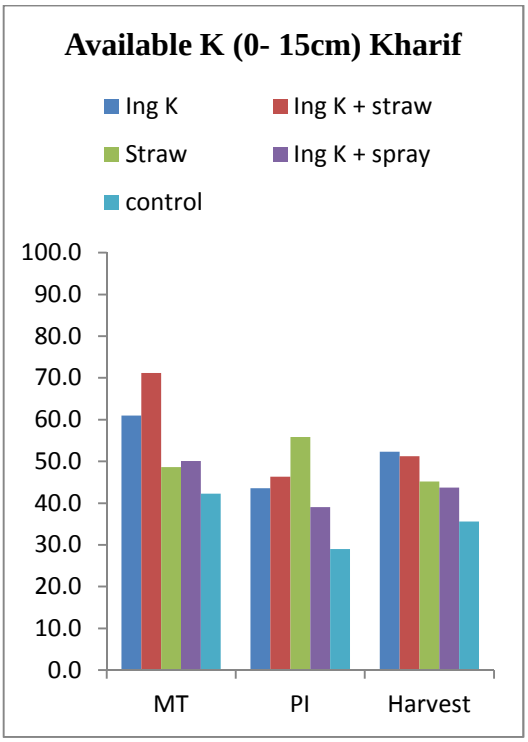

Fig.5.2(c)

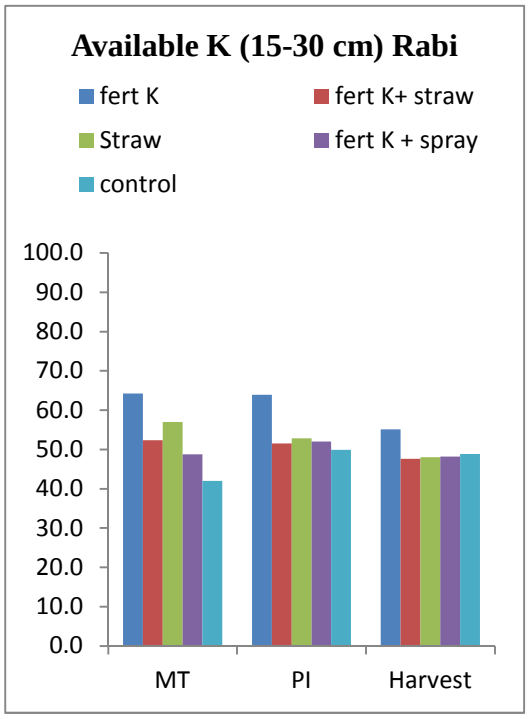

Fig.5.2(b)

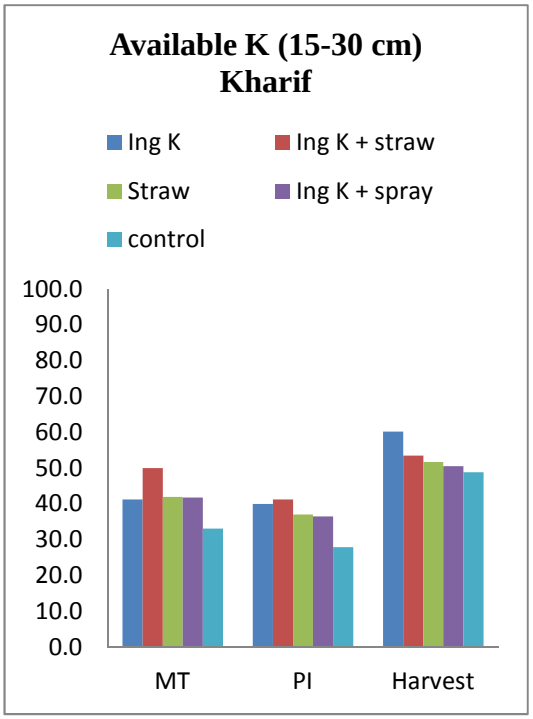

Fig.5.2(d)

were observed. In Rabi season the reserve K was more in Kharif season which might be due to more utilization by the Kharif crop.

Similar to available K the reserve K of the surface soil decreased from MT to PI stage and then increased to harvest stage. But in sub surface there was a continuous fall throughout all the stages. Reserve K was almost doubled of the available K indicating almost same amount of non-exchangeable K in soil.

5.3.3 Non- Exchangeable K

Perusal of data recorded in table 4.7 a and b revealed that bottom layer had more non-exchangeable K or fixed K at MT stage which decreased at PI indicating release of non-exchangeable K to meet the demand of crop. At harvest stage there was further decrease in the Rabi season whereas it increased in Kharif season. At MT and PI stage there was no clear cut difference between Kharif and Rabi season. But at harvest stage Kharif season recorded more non-exchangeable K.

In Rabi season there was significant difference among the treatments but in Kharif season difference was not significant. When the treatments were grouped in Rabi season surface layer contained non-exchangeable K were ordered: fertilizer K>fertilizer +straw> straw and in sub soil, fertilizer K+straw>fertilizer K> straw.

5.3.4 Correlation with Uptake

Correlation analysis of the data revealed that available K at MT stage of surface or sub surface or both surface+ sub layer did not correlate with uptake at MT (0.12, 0.346, 0.236) or at PI (0.397, 0.512, 0.473) but strongly correlated with total uptake (0.792**, 0.659*, 0.757*) . But reserve K at MT stage significantly correlated with uptake at MT and PI stages but not with total K uptake. But 0-30 cm non-exchangeable K significantly correlated with total uptake. Non-exchangeable K in both the seasons did not correlate with any stage K. During Kharif season neither of the K fractions in the MT stage correlated with K uptake at MT, PI or harvest stage. But at PI stage available K (0.680*) and reserve K (0.651*) of bottom layer strongly correlated with total uptake.

Correlation of different K fractions with yield showed that available K of 15-30 cm strongly correlated with Kharif yield (0.680*). Reserve K of surface layer

Fig.5.4 Soil Reserve K (kg ha^{-1}) at different stages of crop growth as influenced by different types of K management practices

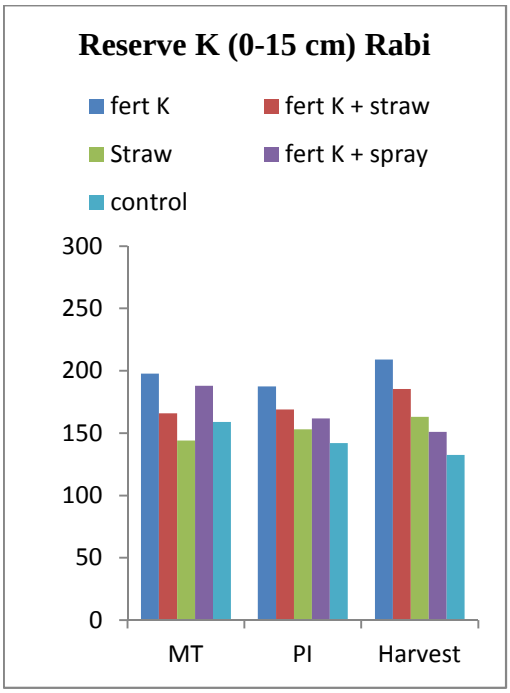

Fig.5.3(a)

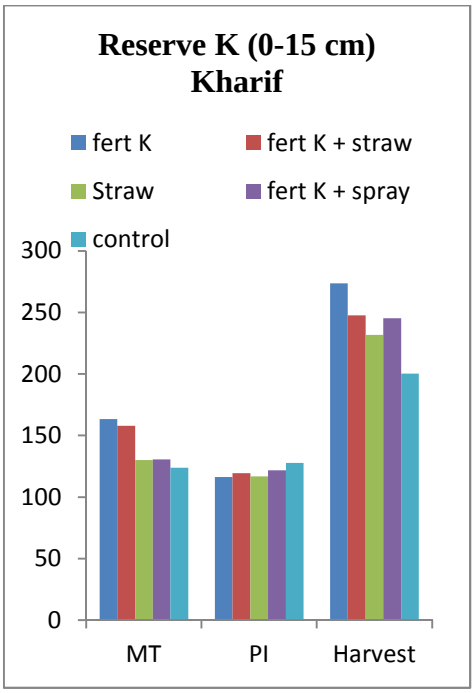

Fig.5.3(c)

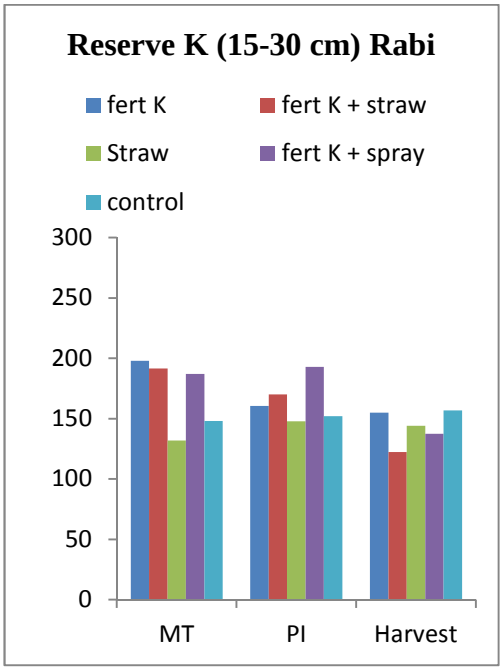

Fig.5.3(b)

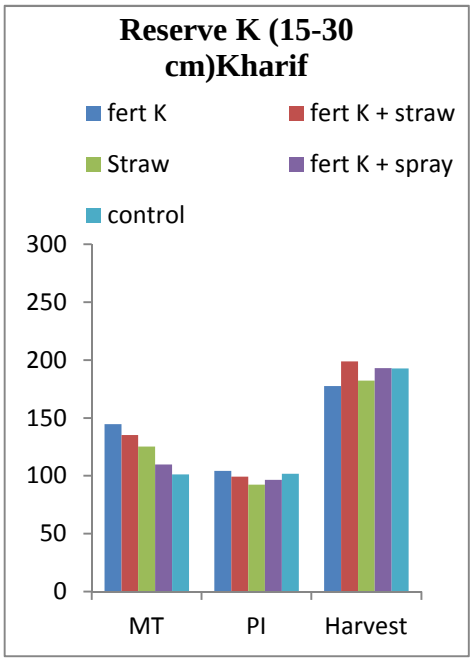

Fig. 5.3(d)

Fig.5.3 Soil Non-exchangeable K (kg ha^{-1}) at different stages of crop growth as influenced by different types of K management practices

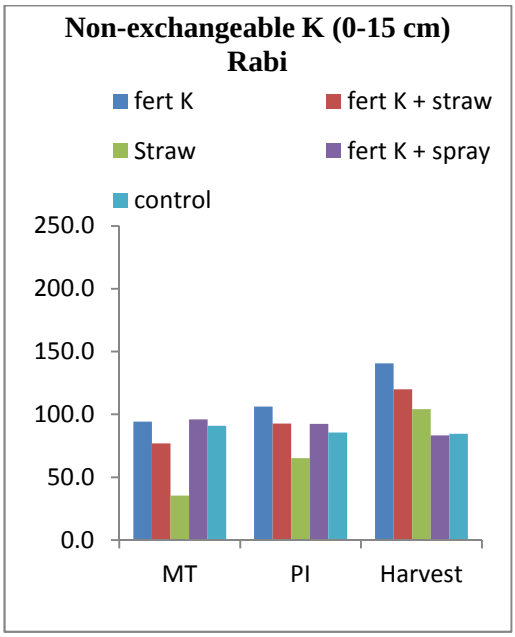

Fig.5.4(a)

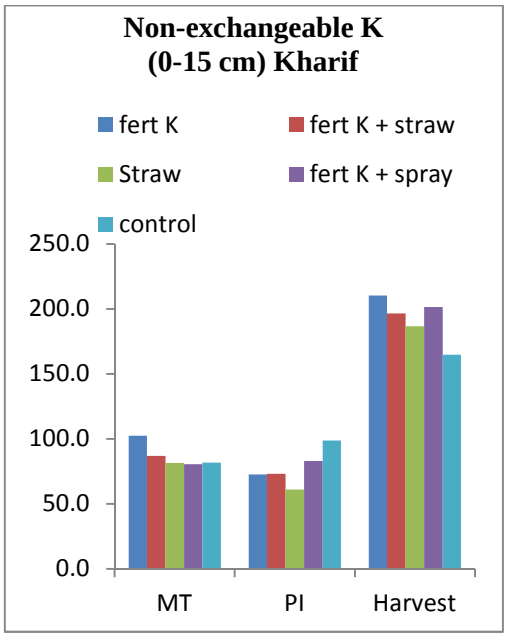

Fig.5.4(c)

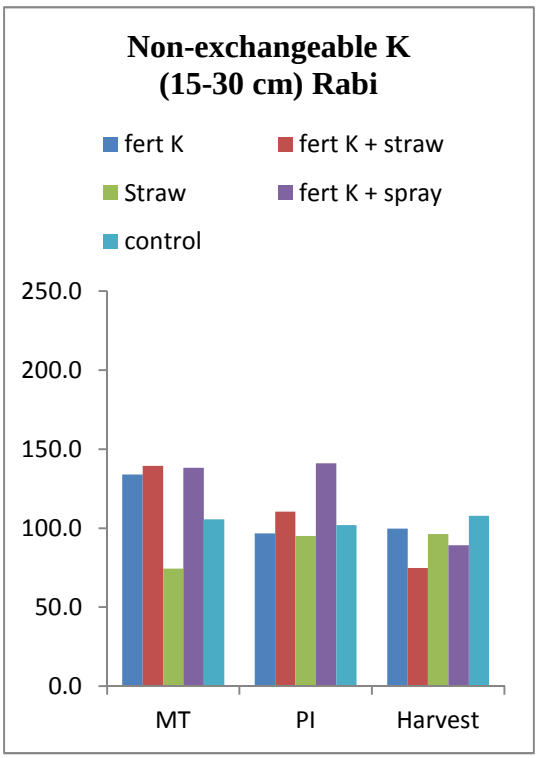

Fig.5.4(b)

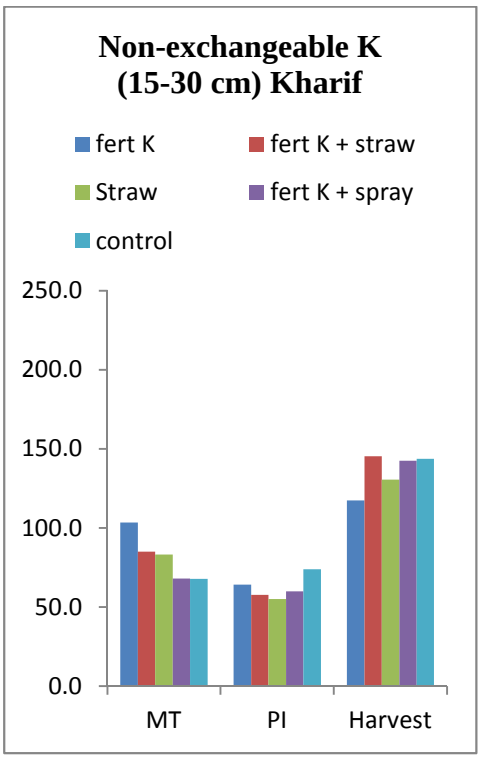

Fig.5.4(d)

(0.661*) or subsurface layer (0.713*) or total (0.735*) correlated with yield of Rabi season but not with the Kharif yield. Similarly reserve K measured at PI stage of entire depth (0-30 cm) correlated with the yield (0.854**) of Rabi season.

5.3.5 K balance in soil

Treatment that received K only through fertilizer with or without foliar spray showed negative balance where as application of K through straw alone or in combination with fertilizer showed positive balance of K in soil (Fig.5.6, Table-4.12 a-c). When calculated on annual basis total K balance varied between -140 to 89.1 kg ha^{-1} $year^{-1}$with the treatment that received 40kg K_2O with foliar spray and produced highest yield in both Rabi and Kharif seasons causing highest negative balance and the treatment, 30kg K_2O as fertilizer along with straw caused highest positive balance. It corroborated with the findings of Wihardjaka,1999.

5.4 Effect on Soil Health

Results on chemical and biological properties of soil measured after both Kharif and Rabi seasons revealed that treatment with integrated use of fertilizer and straw maintained a better biological health. But with respect to soil pH and available N and P, all the treatments were at par (table 4.8 a-b). This might have happened because of a short term study as the physical and chemical characters are less sensitive indicators of soil heath. But from actual calculation and past studies it can be inferred that in the long run integrated use of straw and fertilizer would add to soil fertility.

5.4.1 Nutrient addition through straw

Rice straw contains all the essential nutrients and through its incorporation it can add all these nutrients besides Potassium. Calculations made taking % of nutrients in straw and amount applied it is seen that one ton of straw adds 6kg N, 1.5kg P, 4.5 kg Ca, 2.0 kg Mg and 1kg S and Basing on the total straw incorporated. 18 kg N , 4.5 kg P , 45 kg K, 13.5 kg Ca, 6.0 kg Mg and 3 kg S are added every season to the soil. In a study Nagarajah (1980) reported similar result, 6.16 kg N, 0.83 kg P, 20.5 kg K, 4.16 kg Ca,2.33 kg Mg, 0.83 kg S to be added through 1t of paddy straw. Through 7 years experiment at IRRI ,Kundu and Ladha(1997) demonstrated that in situ incorporation of straw twice a year caused an average

Fig.5.5 Potassium balance in different seasons as influenced by different K management practices

Fig.5.5(a)

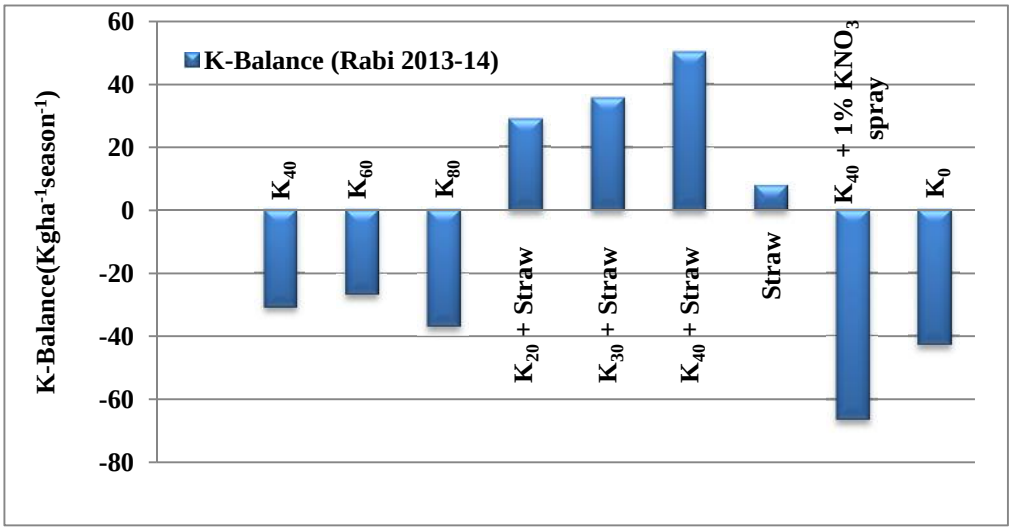

Fig.5.5(b)

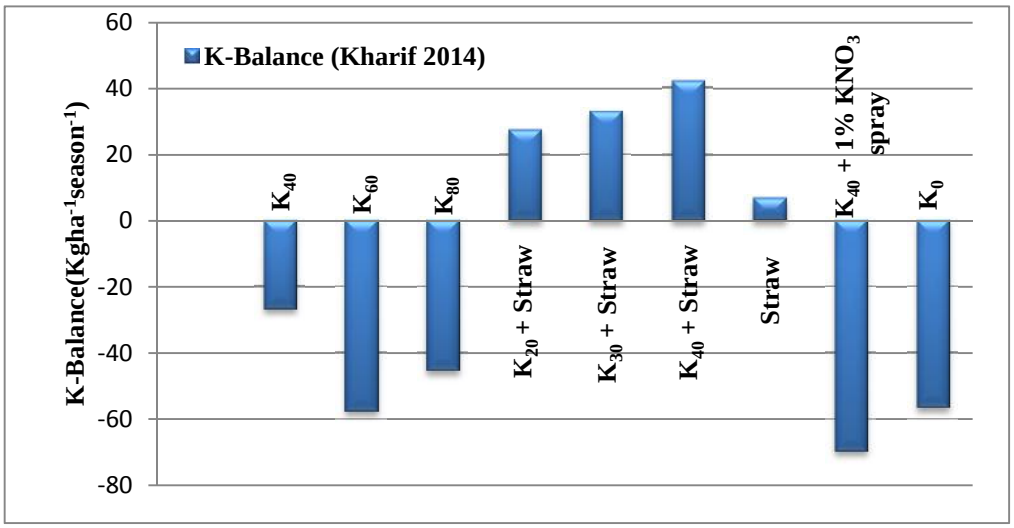

Fig.5.5(c)

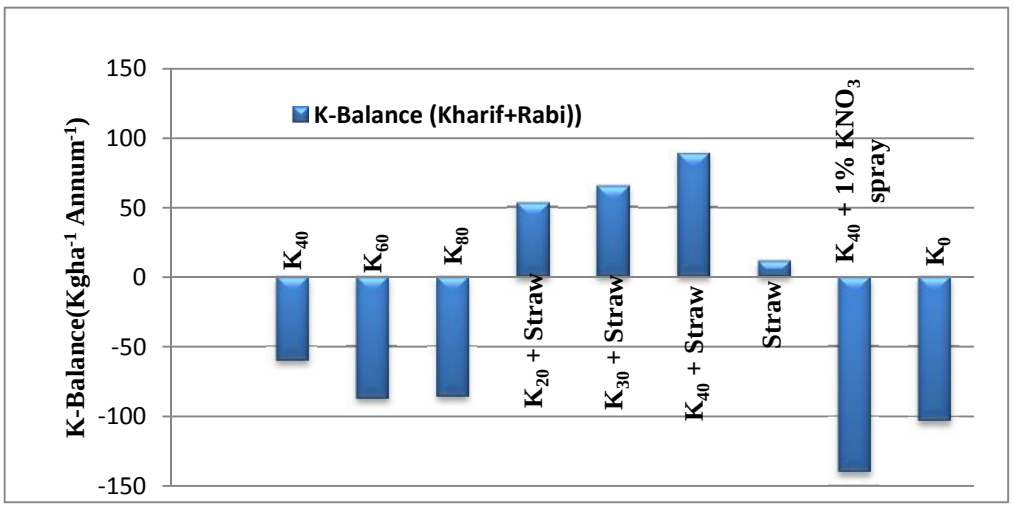

Figure 5.6 Correlation between different forms of K with total uptake

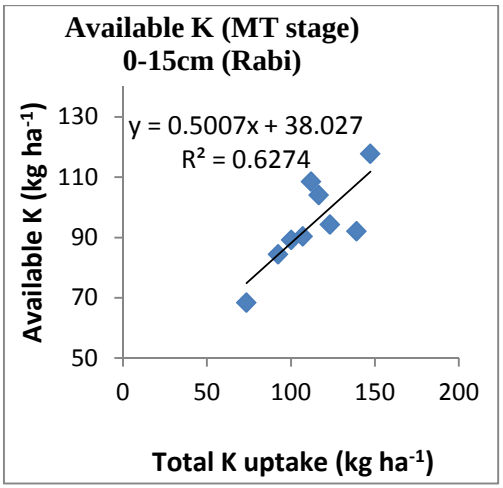

Fig. (a)

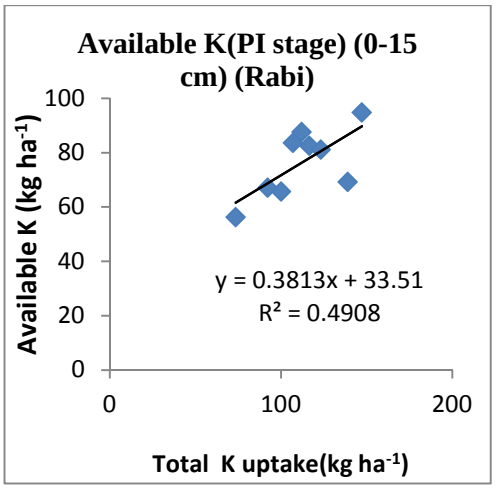

Fig.(b)

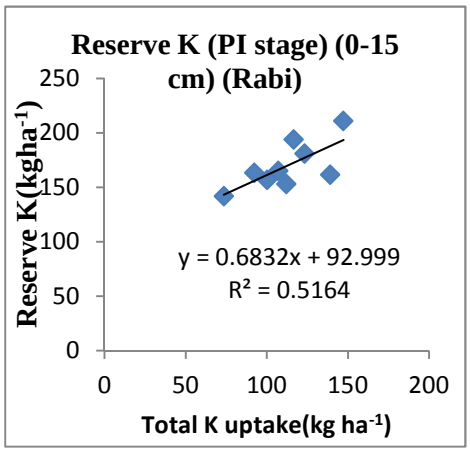

Fig (c)

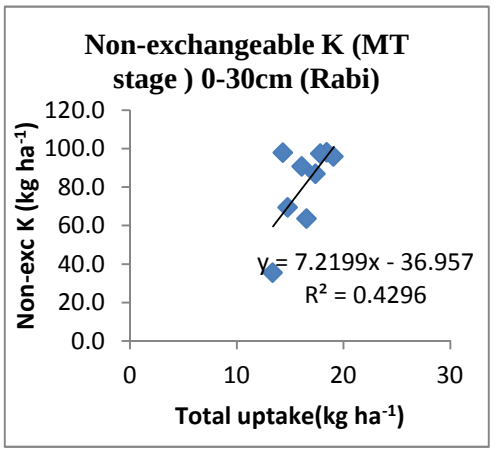

Fig (d)

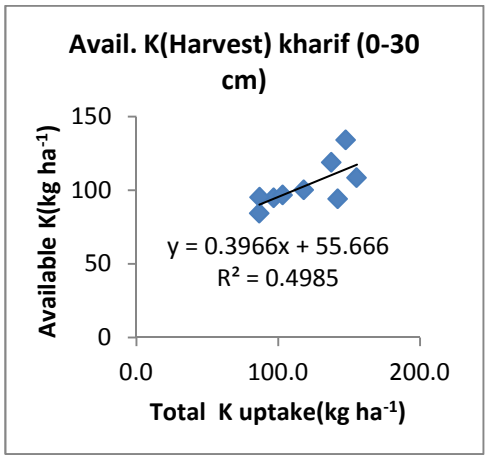

Fig (e)

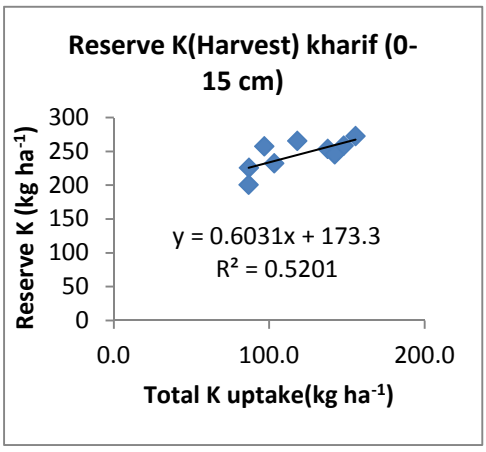

Fig (f)

increase of 48 kg N ha^{-1}. Besides it also added 1080 kg C ha^{-1} every season which helps maintaining the organic matter content of the soil.

Table-5.3 Composition of straw and quantity of nutrient added through straw

Nutrients	C	N	P	K	Ca	Mg	S
% in Straw	36	0.6	0.15	1.5	0.45	0.20	0.1
Addition through1t straw(kg ha^{-1})	3.60	6.0	1.5	15	4.5	2.0	1.0
Addition through 3t straw (kg ha^{-1})	1080	18.0	4.5	45	135	6.0	3.0

Under wetland condition there is also conservation of organic carbon and nitrogen. In a study a Roger and Ladha,1995 reported that anaerobic soil conditions compared with dry land soils not only preserve more straw N and guard against nitrification and subsequent leaching but also favour N conservation and biological N fixation.

5.4.2 Effect of straw incorporation on biological health

For sustainability of a cropping system, the soil should be biologically healthy. Soil dehydrogenase activity is considered as a very effective indicator of soil health and sustainability. Results presented in Table 4.10 b reveal that in both Rabi and Kharif seasons the dehydrogenase activity was more in straw or straw + inorganic fertilizer treatment than treatments that received purely inorganic fertilizer or control or inorganic fertilizer + foliar spray treatment. .Thus both biological health and sustainability is better the soils that receive either Inorganic fertilizer + Straw are biologically more healthy with more nutrients. Liu *et al.* (1990) reported that the use of organic fertilizers in addition to chemical fertilizers increased soil organic matter, total N, increased the effectiveness of P, increased population of soil organisms and enzyme activity particularly of urease.

5.5 Effect on Disease and Insect Pests

In both the seasons the treatment receiving higher dose of K showed the lower Percentage of Disease Incidence (PDI) and insect attack (Table 3.13 a-d, 3.14 at and b). Insect and disease incidence was more in control or where only straw was applied, but less where more K was applied. Incidence of both disease and insects was moderate with combined application of both fertilizer K and straw.

Lower pest damage on high dose K applied plants can arise from (1) pest's non preference due to high quality nutrients of plant; (2) higher pest mortality by high level K in plants and (3) plants chemical composition such as higher contents of defensive compounds that caused higher pest mortality.

Since tissue hardening and stomatal opening patterns are closely related to infestation intensity, N-balance with K is significant to disease susceptibility (Perrenaud, 1977). Examining the mechanism of induced resistance to insects pests in rice plant with enhanced K application and observed that rice plant receiving high amount of K accumulated more total phenols and orthodihydroxy phenols. Accumulation of polyphenols which are precursors of synthesis of several toxic compounds in plant system render the plant resistant to plant (Vaithilingam and Baskaran,1985) .

Role of potassium in imparting resistance is well documented , culm strength of rice plants was noted increased with improved K nutrition and increased stalk strength and decreased lodging are associated with proper K nutrition (DeDatta and Mikkelson, 1985). On the other hand , K deficiency in rice can make tissues vulnerable to pest attack by reducing grain yield. Vaithilingam and Baskaran (1985) examined the mechanism of induced resistance to insect pests in rice plant with enhanced K application. Increase in the application of K in the culture solution increased K, but decreased N, P, Mg, Si, Zn and soluble proteins in the rice plants.

Mondal and Mia (1985) studied the effect of K application on BLB inoculating rice plant with Xanthomonas Campestris at MT and Flag leaf stage. The results show that average lesion length was significantly lower in K treated soils than in soil to which K has not applied.

Mineral nutrients to provoke the creation of definite defense system by plant which is not in favor of the pest due to presence of mono-potassium phosphate (Reuveni and Reuveni, 1998) and K (Sarwar et al., 2011). Role of potassium in imparting resistance is well documented , culm strength of rice plants was noted increased with improved K nutrition and increased stalk strength and decreased lodging are associated with proper K nutrition (DeDatta and Mikkelson, 1985). On the other hand , K deficiency in rice can make tissues vulnerable to pest attack by reducing grain yield. Vaithilingam and Baskaran (1985) examined the mechanism of induced resistance to insect pests in rice plant with enhanced K application. Increase in the application of K in the culture solution increased K, but decreased N, P, Mg, Si, Zn and soluble proteins in the rice plants.

5.6 Cost Analysis

A particular management practice for adoption is judged on the basis of some criteria. For selecting a particular K management practice for recommendation, cost economics is one of such criteria. On the basis of cost of cultivation, gross return and net return benefit in rupees per rupee invested has been calculated as given in Table 4.15 a-c. The cost of cultivation is more where straw has been incorporated with or without fertilizer- K. Gross return depended upon yield. These parameters cannot be taken as direct economics of cultivation through different K-management options. But net return and Benefit cost ratio or return per rupee invested can be used as suitable indicator of cost economics. On the basis of return per rupee invested the best performing treatment are tabulated below. Taking the return per rupee invested in both the seasons into consideration the treatment can be ranked as 1.K_{40}+FS 2.K_{80} and K_{60} 3.K_{30}+straw and 4.K_{40}

Table-5.4 Ranking of treatment on the basis of cost analysis

Rank	Rabi	Kharif	Cropping Year
1	K_{40}+FS	K_{40}+FS	K_{40}+FS
2	K_{80} and K_{60}	K_{30}+straw, K_{80}	K_{80} and K_{60}
3	K_{40}	K_{60}	K_{30}+straw
4	K_{30}+straw	K_{40}+straw	K_{40}

5.7 Evaluation of Potassium management options

For evaluation of all the Potassium management options 5 criteria were selected which are given in Table 5.5.

Table 5.5 Evaluation of K management options

Treatment	Grain yield year^{-1} (qha^{-1})	Return per rupee invested year^{-1}	K balance year^{-1}	Impact on soil health	Effect of diseases and insect pests
K_{40}	75.52	1.73	-60.2	Moderate	Moderate
K_{60}	82.32	1.81	-87.7	Moderate	High
K_{80}	82.92	1.81	-86.0	Poor	High
K_{20} + Straw	75.57	1.56	53.0	Good	Moderate
K_{30} + Straw	86.53	1.78	65.3	Good	Moderate
K_{40} + Straw	80.12	1.63	89.1	Good	Moderate
Straw	73.73	1.56	11.3	Moderate	Low
K_{40} + 1% KNO_3 spray	91.92	1.99	-140.1	Poor	High
K_0	69.05	1.64	-103.4	Poor	Low

The total weightage of each treatment for all the 5 criteria was taken into consideration. Some criteria have absolute calculated values; some others like impact on soil and resistance to pests were qualitatively measured on the basis of results. The qualitative classification is somewhat arbitrary. A critical analysis of the table suggests that the treatment which receives 30 kg K_2O ha^{-1} and straw is the best treatment.

SUMMARY AND CONCLUSION

6.1 SUMMARY

6.1.1 Experimental Details

Under the IRRI-OUAT Collaborative Students' Research Programme, a field experiment was conducted with rice crop (cv: Lalat) grown on an acidic medium land located in the Central Research Farm of Orissa University of Agriculture and Technology, Bhubaneswar during two seasons, Rabi (2013-14) and Kharif (2015) in order to investigate the effect of different Potassium management practices on crop yield and Potassium availability in soil, potassium uptake and disease and insect incidence. The experiment was laid out in RBD with three replications and nine treatments consisting of T_1: 40 kg K_2O ha^{-1}, T_2: 60 kg K_2O ha^{-1}, T_3: 80 kg K_2O ha^{-1}, T_4: 20 kg K_2O ha^{-1} + straw, T_5: 30 kg K_2O ha^{-1} + straw, T_6: 40 kg K_2O ha^{-1} + straw, T_7: straw, T_8: 40 kg K_2O ha^{-1}+1% KNO_3 foliar spray at Panicle initiation stage, T_9: control. Following IRRI protocol both plant and soil samples were collected at critical growth stages and analysis was done using standard methods.

6.1.2 Grain Yield and Crop Response

Treatment with 40kg K_2O through Fertilizer along with a foliar spray(1% KNO_3) at PI stage yielded highest in both Rabi(3.84t ha^{-1}) and Kharif(5.35t ha^{-1}) season The yield was at par with those in K_{60} and K_{30}+straw in Rabi and K_{30}+straw, K_{60}+Straw and K_{80} in kharif. In Rabi the crop responded up to 60kgK_2O ha^{-1} applied through fertilizer and 30kg K_2O ha^{-1} +straw. At 80kg K_2O or 40kgK_2O ha^{-1} + straw the yield declined. But in Kharif the crop responded even up to the highest dose (K_{80}) applied through fertilizer alone or 40kg K_2O applied through Fertilizer + straw. The effect of either straw alone or in combination with fertilizer was better in Kharif season.

Much higher values of K/N and K/P ratios at maturity in Rabi season in both content and total absorption than Kharif indicates less absorption of both of these two important primary nutrients N and P by the Rabi crop justifying why yield was low in Rabi crop.

6.1.3 Potassium Uptake and K partitioning

Comparing the partitioning of K absorption to different periods of growth it is observed that in Rabi the treatments that yielded more absorbed 12-13% of total K within maximum tillering, 23-27% during MT and PI and 59-64% within PI and maturity as compared 16-18%of total K within maximum tillering, 38-44% during MT and PI and 40-44% within PI and maturity in Kharif season. This suggests that for producing more yield around 60% K needs to be absorbed after PI in Rabi and around 40% in each of the two stages MT to PI and PI to maturity in Kharif.

6.1.4 Changes in Soil Potassium Pools and K Balance

Treatment that received K through fertilizer with or without foliar spray showed negative balance where as application of K through straw alone or in combination with fertilizer showed positive balance of K in soil. When calculated on annual basis total K balance varied between -140 to 89.1 kg ha^{-1} $year^{-1}$with the treatment that received 40kg K_2O with foliar spray and produced highest yield in both Rabi and Kharif seasons causing highest –ve balance and the treatment, 30kg K_2O as fertilizer along with straw caused highest positive balance.

6.1.5 Effect on Soil Health

Treatment with integrated use of fertilizer and straw maintained a better biological health in terms of soil dehydrogenase activity which is considered as a potential biological indicator of total soil microbial activity. Through straw 18 kg N , 4.5 kg P , 45 kg K, 13.5 kg Ca, 6.0 kg Mg and 3 kg S are added every season to the soil which are not reflected in the two cropping seasons. However they contribute to total nutrient pool of the soil. From actual calculation and past studies it can be inferred that in the long run integrated use of straw and fertilizer would add to soil fertility.

6.1.6 Effect on Disease and Insect Incidence

The pooled analysis of incidence of blast and brown spot disease in rice showed that the disease expression was numerically high in Kharif as compared to Rabi. In both the seasons the treatment receiving higher dose of K (80 kg K_2O ha^{-1}) showed the lowest PDI and the control the highest. Insect incidence was more in control or where only straw was applied, but less where more K was applied

.Incidence of both disease and insects was moderate with combined application of both fertilizer K and straw.

6.1.7 Economics

On the basis of return per rupee invested the best performing treatment for both seasons are K_{40}+FS, K_{80} and K_{60} , K_{30}+straw and K_{40} .

6.2 Conclusion

- Basal application 40 kg K_2O ha^{-1} and foliar spray with 1 % KNO_3 (K_{40}+Foliar spray) at particle initiation produced highest grain yield in both Rabi and Kharif season. Application of 60 kg K_2O ha^{-1} through fertilizer (K_{60}) and application of 30 kg K_2O ha^{-1} with straw incorporation (K_{30}+ Straw) were at par with K_{40}+ foliar spray.
- Potassium absorption upto panicle initiation was 20 % more in Kharif than in Rabi season. In Rabi, around 60 % Potassium was absorbed during panicle initiation and maturity as compared to around 40 % in Kharif season.
- Reduced nitrogen, phosphorus and potassium absorption in the early vegetative period in Rabi season was responsible for reduced number of tillers and spikelets per panicle resulting in less yield. Low temperature and favourable soil condition were responsible for poor N and P availability in Rabi season.
- Application of potassium through chemical fertilizer maintained higher content of both 1 N NH_4OAc – extractable K (available K) and 1N HNO_3 – extractable K (Reserve K) in surface soil than combined application of reduced dose of fertilizer –K and straw or only straw in both Rabi and Kharif season.
- Change in non-exchangeable or fixed K was more conspicuous in Rabi than Kharif season. There was more release and use of non-exchangeable K from surface layer in treatment that received lower dose of fertilizer K + straw.
- Total crop uptake of K strongly correlated with available K of both surface and sub surface soil in Rabi season and available K and reserve K of sub surface soil in Kharif season.

- Total crop uptake of K strongly correlated with non-exchangeable K of 0-30 cm soil layer only in Rabi season, but not in Kharif season.
- Reserve K of surface or subsurface layer strongly correlated with the grain yield only of Rabi season but not of Kharif season.
- The treatment receiving only chemical fertilizer caused more negative balance and combined application of reduced dose of K and straw caused positive balance.
- The treatment, K_{40}+ foliar spray that produced highest yield, recorded highest negative balance in both seasons and the treatment that received 30 kg K_2O ha^{-1}+ straw recorded highest positive balance.
- Combined application of moderate dose of Potassium and straw maintained better soil health than the treatment that received only fertilizer.
- Disease and insect pest incidence decreased with increase in the level of potassium. Combined application of fertilizer K and straw had moderate effect on pest incidence.
- Treatment that received potassium only through fertilizer with or without foliar spray of KNO_3 were more remunerative than combined application of both chemical fertilizers and straw.
- Considering yield, effect on soil health, K balance, pest incidence and economics, combined application of fertilizer-K (30 kg ha^{-1}) applied in two equal splits and straw incorporation is suggested for the recommendation as it maintains better soil health without any negative K balance, produces high yield and reduces pest attack with more profit.

However, for more conformation of these results and generation of more information the study may be continued on long term basis in a number of locations under different climatic conditions.

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APPENDICES

Cost of cultivation

Sl. No.	Components of cost	Unit/Man days (MD)	Cost (Rupees)
A. Labour			
1	Tractor ploughing and puddling	10 hrs	6000
2	Tractor for carrying and threshing	4 hrs	2400
3	Cleaning field and bunds	4 MD	512
4	Application of manure and basal fertilizer	5 MD	640
5	Seed treatment, sowing and nursery management	5 MD	640
6	Uprooting and transplanting	15 MD	1920
7	Hand weeding	10 MD	1280
8	Application of plant protection chemicals	3 MD	384
9	Irrigation (need based)	2 MD	256
10	Application of fertilizers	2 MD	256
11	Cutting, bundling, loading and unloading of straw	10 MD	1280
12	Threshing, winnowing, bagging and storing	10 MD	1280
		Sub-total	16848
B. Inputs			
1	Seeds	60 kg	1200
2	Seed treating chemicals	180 g	201.6
3	Manure	5 t	5000
4	Fertilizers		
	Urea (N)	80 kg	960
	Diammonium phosphate(DAP) (P_2O_5 and N)	40 kg	1880
	Muriate of Potash(MOP) (K)	40 kg	1160
5	Micronutrient(Zinc)	25 kg	1250
6	Plant protection chemicals	-	3000
7	Weedicide	-	900
		Sub total	15551
		Total	32400

Price of grain = 1360 (Rupees per quintal)

Price of straw = 100 (Rupees per quintal)

Gross income (Rupees) = Price of grain + Price of straw

Net income (Rupees) = Gross income - cost of cultivation

Return per rupee invested = (Gross return)/ (Cost of cultivation)

Weather data

Standard meteorological weeks	Starting date of the weeks	Mean Minimum temperature (^{0}C)	Mean Maximum temperature (^{0}C)	Mean Relative humidity (%)	Cumulative Rainfall (mm)
1	01-01-14	15.1	28.9	71	0
2	08-01-14	15.6	28.7	67	0
3	15-01-14	15.7	29.0	69	0
4	22-01-14	14.7	29.1	67	0
5	29-01-14	13.7	29.0	64	0
6	05-02-14	17.3	34.5	63	0
7	12-02-14	18.7	31.1	72	21.8
8	19-02-14	15.9	30.7	73	0
9	26-02-14	19.4	32.5	78	27.2
10	05-03-14	18.9	31.2	80	26
11	12-03-14	21.2	35.3	65	0
12	19-03-14	23.3	36.7	68	0
13	26-03-14	23.8	39.7	62	0
14	02-04-14	23.9	38.8	67	0
15	09-04-14	23.3	38.8	59	0
16	16-04-14	24.4	40.1	65	9.4
17	23-04-14	26.0	41.2	65	0
18	30-04-14	25.2	40.3	63	0
19	07-05-14	25.9	39.1	67	26.2
20	14-05-14	26.7	42.0	63	0
21	21-05-14	25.1	37.9	74	23.8
22	28-05-14	25.1	35.7	76	10.9
23	04-06-14	26.6	36.9	75	19.1
24	11-06-14	28.1	39.6	64	0
25	18-06-14	26.1	34.4	78	41.5
26	25-06-14	24.7	34.8	83	106.1
27	02-07-14	24.5	31.9	87	51.6
28	09-07-14	25.2	33.7	85	100.1
29	16-07-14	24.5	28.8	93	128

30	23-07-14	24.9	31.8	84	12.2
31	30-07-14	24.7	30.9	91	151.8
32	06-08-14	24.8	32.4	85	25.7
33	13-08-14	24.4	33.5	85	25.2
34	20-08-14	25.0	34.8	82	61.6
35	27-08-14	24.4	31.1	93	164.4
36	03-09-14	23.6	29.2	89	115.6
37	10-09-14	24.6	33.6	87	45.2
38	17-09-14	24.4	30.7	89	116.1
39	24-09-14	24.7	34.2	77	0
40	01-10-14	23.1	33.8	78	26.1
41	08-10-14	23.7	31.3	83	84.4
42	15-10-14	22.2	32.5	79	51.6
43	22-10-14	20.5	30.6	78	1
44	29-10-14	19.2	30.4	70	0
45	05-11-14	20.3	31.1	68	0
46	12-11-14	20.3	31.8	69	0
47	19-11-14	14.9	30.1	63	0
48	26-11-14	14.7	30.6	65	0
49	03-12-14	14.3	29.7	72	0
50	10-12-14	16.4	28.2	69	0
51	17-12-14	11.9	26.4	64	0
52	24-12-14	12.9	25.8	62	0