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Role of potassium on insect pests and diseases of puddled transplanted rice cv. Lalat in Odisha

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ABSTRACT

Potassium (K) is one of the most important essential nutrients for rice crop. The role of K in enhancing rice productivity is well established. It also imparts resistance against diseases and insect-pests. A field study was conducted to evaluate the effect of different levels of K application on the disease and insect pest incidence of puddled transplanted rice during dry season (DS) 2013-14 and wet season (WS) 2014 involving 9 potash management options in 3 replications. The experimental soil was highly deficient in exchangeable K (25.85 mg/kg). Increase in K dose from recommended 40 kg/ha to 80 kg/ha significantly reduced all insect pest and disease incidence. Recommended dose of K 40 kg/ha along with one foliar spray of 1% KNO_3 at flowering was also effective than other treatments. Reducing fertiliser K to 50% and adding straw (3 t/ha) was not as effective as full dose of K, but had moderate effect on pest incidence. Both blast and brown spot incidence correlated negatively with K content in leaf at maximum tillering (MT) and panicle initiation (PI) stages with more correlation at MT stage (r= -0.59, -0.69) than PI stage (r= -0.48, -0.37) in dry season and PI stage (r=-0.51, -0.73) than MT stage (r= -0.48, -0.37) in wet season. Insect attack in both dry and wet seasons negatively correlated with K content in leaf at MT and PI stages with wet season having stronger correlation than dry season for all the major insects. From the study, it is also evident that not only the leaf K content, but K-N balance is also important for making the plant resistant to insect pest and disease attack. Thus, K nutrition is important for control of most common insect pests (stem borer, leaf folder, whorl maggot and Gundhi bug) and diseases (blast and brown spot) in rice.*

Key words: *Foliar application, insect pest incidence, potassium, straw, transplanted rice*

INTRODUCTION

Rice-rice is the predominant cropping system of Odisha contributing main food to the state. However, there is sign of productivity stagnation/decline and deterioration of soil fertility of the system because of a lack of potassium (K). Over recent years, increase in rice production has been achieved by the use of improved germplasm, associated with increased application of nitrogen (N) and phosphorus (P) fertilizers, but without a corresponding increase in the use of K fertilizers. This lack of K has been exacerbated by the practice of resource poor farmers who remove nutrients from their fields, especially K, in the form of straw for fuel and cattle feed (Wihardjaka et al., 1999). Requirement of K by rice is either equal to or more than that of N. But the dose recommended is only 50% of that of N and much less than the total removal by the plants. This has resulted in negative balance leading to depletion of soil K. Mitra (2015) reported negative balance of 37 kg K/ha/year with recommended dose of fertilizer (RDF; 80-40-40) to rice.

Out of all elements, potassium (K) is considered to be unique element due to its unique properties like activation of over 80 different enzymes and providing resistance to plant against diseases, insect pests, drought, cold etc. translocation of photosynthates to storage organs, increasing the quality of the products etc. (De Datta and Mikkelson, 1985; Tisdale et al., 1985; Pettigrew, 2008; Römheld and Kirkby, 2010). Incidence of insect pests and diseases are very common in rice causing severe damage to rice production. Crop loss due to insect pests amounts to 25% (Dhaliwal et al., 2007) and 12.2% due to diseases (Oerke, 2006). Brown spot has a worldwide distribution and has been reported in all rice growing countries, causing 20-90 per cent losses in grain yield (Vidhyasekaran and Ramadoss, 1973) and is known to occur in nutrient deficient soils (Ou, 1985). Incidence of brown spot in rice was also correlated with low available soil Si, Mn or K (Wang et al., 1980). Williams and Smith (2001) confirmed that the stem diseases of rice are more severe in K deficient soils and are less damaging when there was adequate K supply. Potassic fertilization has been experimentally proved to increase the resistance of the rice crop against diseases and insect pests by many researchers. Balanced fertilization of NPK can help rice plant to become more healthy for resistance to rice insect pests and diseases (Chau et al., 2003). Higher leaf K was associated with lower disease incidence. Sarwar (2012) suggested emphasizing on K application for high-yielding rice production which could reduce the input of fertilizers, and decrease the application of pesticides due to lower occurrence of pests, reduce losses of yield and finally increase farmers' income to sustainable development of rice protection and production.

Potassium balances in rainfed rice are particularly precarious because rainfed rice does not receive K in irrigation waters, which is an important part of the K balance in irrigated rice (Greenland, 1997). Red and laterite soils are inherently deficient in K (Sarangi et al., 2017). For sustainability of rice-rice production system in such soils K management is very important. Study is undertaken to optimise K nutrition of rice for higher productivity and sustainability without depleting soil K. In this paper, an emphasis has been laid to study the effect of different K management options on incidence of insect pest and disease occurrence in rice-rice cropping system of Odisha under a sub tropical climatic situation.

MATERIALS AND METHODS

Experimental site

The field experiment was carried out at the Central Research Station of Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, India (20°15'N, 81°52'E, 25.5m above MSL) during dry (December 2013-April 2014) and wet season (June 2014-October 2014). The experimental site comes under East and South Eastern Coastal Plain Agro-climatic zone of the state of Odisha. 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°C and 21.4°C, respectively. The soil of the experimental site is sandy loam with slightly acidic (5.87) pH, low in organic carbon (0.39%) and available nitrogen (170 kg/ha), medium (21 kg/ha) in available phosphorus and low (57.95 kg/ha) in potash in the surface layer (0-15 cm). Lower layers contain more clay with reduced acidity. Taxonomically the soil belongs to Inceptisols and grouped as *Vertic Haplaquept* and is a mixed hyperthermic. The land remains ill drained during rainy season because of shallow water table (1 m), whereas it is moderately drained during summer season.

Experimental design

The experiment was laid out in randomized block design with three replications and nine treatments consisting of T_1: 40 kg K_2O/ha (RDF), T_2: 60 kg K_2O/ha, T_3: 80 kg K_2O/ha, T_4: 20 kg K_2O/ha + straw, T_5: 30 kg K_2O/ha + straw, T_6: 40 kg K_2O/ha + straw, T_7: straw, T_8: 40 kg K_2O/ha + 1% KNO_3 foliar spray at panicle initiation (PI) stage and T_9: control. The individual plot size was 6 m × 5 m.

Crop management

The experiment was conducted on a typical rice-rice cropping system taking a medium land and medium duration (120-125 days) variety 'Lalat'. The seedlings transplanted at 25 days old and spacing of 20 × 10 cm was maintained. At the time of transplanting 30 kg N/ha as urea, 40 kg P/ha as diammonium phosphate and 25 kg Zn/ha as zinc sulphate were applied in all the plots. Another 80 kg N was applied in two splits at a ratio of 2:1 at 20 d and 50 d after transplanting (DAT). Potassium in form of muriate of potash was applied as per the treatment in split at a ratio of 50:50 at basal and at 50 DAT. Paddy straw left over in the field after removal of panicles was incorporated into soil after crop treatment for the next season crop. Foliar spray with 1% KNO_3 was done once at PI in T_8.

Disease and Insect management

The occurrence of diseases and insect pests were managed by recommended chemical practices like application of carbofuran 4% @ 10 kg per acre, Streptocycline @ 1.5 g per 10 litres and Carbendazim 12% and Mancozeb 63% WP combination @ 2 g per litre. All the three were applied as prophylactic measure and again during peak period of damage.

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).

Stem borer

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

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

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 was recorded from the 10 randomly selected plants per square meter. The percentage of WEH was calculated as given below.

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

Leaf folder

Leaf folder incidence was recorded at 45 DAT from 5 numbers of randomly selected plants per treatment (Fig. 1). 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.

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

Whorl maggot

The whorl maggot appears in the field at early stage and nibbles the leaf from sides. These damaged leaves as shown in Fig. 2 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.

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

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 numbers of live insects (nymphs and adults) were counted from one square meter demarcated area in the treatment

Fig. 1. Whorl maggot infestation

Fig. 2. Attack of leaf folder

plot and the gundhi bug population per square meter area at two places per treatment was calculated out.

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.

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. Ten hills were selected randomly from each plot and the leaves showing maximum disease intensity were scored as given in Table 1.

Blast

The observation for blast 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 1.

Statistical analysis

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

RESULTS AND DISCUSSION

Grain yield

There was significant effect of different K management practice on grain and straw yield during both seasons. However, the grain yield (t/ha) in dry season (DS) varied from 2.69 recorded in control to 3.84 measured in T_8. Other treatment such as T_2, T_3 and T_5 were at par and all other treatment produced significantly lower yield than T_8. The grain yield (t/ha) in wet season (WS) varied between 4.21 in T_9 and 5.35 in T_8 which also produced highest grain yield in DS. The treatment T_8 was at par with T_3, T_5 and T_6 and differed significantly from all others. The high yielding treatments which were at par were in the order: T_8>T_2 >T_5 in DS and T_8>T_5>T_3>T_2 in WS. Treatment with only straw and the control are

Table1. Scale for brown spot and blast

Description (Affected leaf area) brown spot	Score	(Characteristics of leaf) Blast	Score
No lesion	0	No incidence	0
< 1%	1	Small brown specks of pin head size without sporulation	1
1-3%	2	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
4-5%	3	Lesion type same as in score 2, but significant number of lesions are on the upper leaves	3
6-10%	4	Typical sporulating blast lesions, 3 mm or longer infecting less than 2 % area	4
11-15%	5	Typical blast lesions with 2- 10 % leaf area	5
16-25%	6	Typical blast lesions with 11- 25 % leaf area	6
26-50%	7	Typical blast lesions with 26 -50 % leaf area	7
51-75%	8	Typical blast lesions with 51 - 75 % leaf area	8
76-100%	9	Typical blast lesions with > 75 % leaf area	9

the low yielders.

Similar trend was observed with straw yield in which during both the season grain yield varied significantly. T_8 was statistically superior straw yield than T_1, T_4, T_7 and T_9, respectively during DS and only T_4 and T_9 in WS. However, the remaining treatments produced similar straw yield during both seasons. The harvest indices were higher in WS than DS and there was no significant difference among the treatment.

Plant K content and uptake

The potassium concentration in plant did not vary significantly at maximum tillering (MT) stage and panicle initiation (PI) stage during both the season. However, at the time of harvest during both the season K content in plant was higher in only T_8 as compared to other treatments. During DS it was 1.95 ppm and WS 2.10 ppm.

The K uptake in DS was less than WS in all the stages. The maximum K uptake occurred between PI and harvest stage in DS, whereas in wet uptake was more within MT to PI stage.

In DS at MT the K uptake (kg/ha) varied from 16.1 (T_7) to 19.1 (T_8). In wet season at maximum tillering stage the data varied from 21.9 kg/ha (T_7) to 30.7 kg/ha (T_3). At PI in DS, highest uptake (kg/ha) was found for T_2 (67.5) and the lowest for the control (43.4), whereas in WS the highest uptake (kg/ha) was found for T_8 (85.7) and the lowest in T_1 (62). The K uptake (kg/ha) at harvest stage for dry crop varied between 74 (control) and 147 (T_3), whereas in WS it varied between 87 (T_9 and T_4) and 156 (T_3).

Incidence of disease attack (blast and brown spot)

The incidence of blast disease was recorded at vegetative and harvest stage of rice crop var. Lalat both in dry and wet season. A pooled analysis of both stages presented in Table 2 indicated that during DS the T_3 with lowest percent disease incidence (PDI) of 7.04% varied significantly from the control plot with a PDI of 13.70%. However, other treatments were statistically similar except T_7 with straw alone. Percent decrease over control was the highest in T_3 (48.6%) followed by T_8 (37.8%) and minimum 8.1% decrease over control was recorded with straw alone. Where as in case of brown spot disease, T_3 had minimum PDI (14.08%) which was significantly lower than that found in T_4, T_5, T_7 and T_9. Similarly, reduction in PDI over control was the highest with T_3 (29.6%) followed by T_8 (25.9%). Those treatments received reduced dose of recommended K along with straw had less than 20%

Table 2. Effect of different potassium management practices on average expression of brown spot and blast in the dry 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			

Values in brackett indicates the transferred angular values

Table 3. Effect of different potassium management practices on average expression of brown spot and blast in the wet 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			

Values in bracket indicates the transferred angular values

PDI over control.

On the perusal of experimental data given in Table 3, during wet season, a similar consistent trend was observed with disease attack in which PDI % of blast was significantly lower in highest amount of K fertilizer received T_3 (80 kg K_2O/ha) than control (T_9), straw alone (T_7) and with 20 (T_4) and 30 (T_5) kg K_2O/ha fertilizer along with straw and recommended dose (T_1, 40 kg of K_2O/ha). However, T_2 and T_8 were statistically similar to all the treatments except control and straw alone. Percent decrease in blast incidence

Table 4. Effect of different potassium management practices on incidence of insect pest in the dry season

Treatment		Stem borer		Leaf folder	Whorl maggot	Gundhi Bug	Yield(t/h)
		Dead heart (%)	Whiteear head (%)	(DL%)*	(DL%)*	(no. / sq. mt)	
T_1	K_{40}	6.20 (2.57)	2.13 (1.39)	1.01 (0.98)	3.83 (1.94)	14.72 (3.78)	3.21
T_2	K_{60}	5.45 (2.28)	1.77 (1.27)	0.74 (0.84)	3.23 (1.75)	14.23 (3.65)	3.51
T_3	K_{80}	2.94 (1.69)	1.09 (0.97)	0.50 (0.71)	2.99 (1.73)	11.90 (3.41)	3.42
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)	3.17
T_5	K_{30} + Straw	5.02 (2.3)	1.36 (1.11)	1.01 (0.99)	3.99 (1.97)	12.40 (3.40)	3.48
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)	3.08
T_7	Straw	5.05 (2.24)	1.54 (1.15)	0.50 (0.71)	5.33 (2.25)	15.46 (3.86)	2.82
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)	3.84
T_9	K_0	9.04 (2.32)	1.95 (1.39)	1.32 (1.11)	4.55 (2.08)	15.37 (3.90)	2.7
SEM		0.88	0.50	0.43	0.79	1.36	-
CD(0.05)		0.47	1.51	1.27	2.37	4.07	0.60

Values in bracket indicate the square root values, *Indicate the damage leaf percent

Table 5. Effect of different potassium management practices on incidence of insect pest in the wet season

Treatment		Stem borer Dead heart (%)	Whiteearhead (%)	Leaf folder (DL%)*	Whorl maggot (DL%)*	Gundhi Bug (no. / sq. mt)	Yield (t/h)
T_1	K_{40}	7.58 (2.75)	6.02 (2.45)	0.96 (0.97)	4.43 (2.10)	9.60 (3.10)	4.34
T_2	K_{60}	6.81 (2.60)	4.70 (2.17)	0.82 (0.90)	3.63 (1.90)	7.50 (2.74)	4.72
T_3	K_{80}	3.17 (1.78)	3.34 (1.83)	0.60 (0.77)	1.78 (1.31)	7.38 (2.71)	4.87
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)	4.39
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)	5.17
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)	4.94
T_7	Straw	7.54 (2.74)	6.57 (2.56)	1.75 (1.32)	5.30 (2.30)	9.33 (3.04)	4.55
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)	5.35
T_9	K_0	11.52 (3.39)	7.93 (2.81)	1.63(1.27)	5.60 (2.36)	13.00(3.60)	4.21
SEM		0.1	0.06	0.06	0.13	0.11	-
CD (0.05)		0.29	0.17	0.19	0.39	0.62	0.62

Values in bracket indicate the square root values, *Indicate the damage leaf percent

over control was 41.65% in T_3 followed by T_2 (33.3 %) and T_8 (33.3 %). Similar to blast disease, PDI (%) of brown spot was found minimum in T_3, which significantly lower than T_9, T_7 and T_4 26.4 % and 24.5 % decreased disease incidence over control was recorded with T_4, T_5 and T_8, respectively.

Incidence of insect attack

Stem borer, leaf folder, whorl maggot and Gundhi bug were the major insect pests that attacked the crop during both the DS and WS (Table 4 and 5). During DS, among the treatments T_3 had significantly lower (2.94%) Dead heart (DH) % as compared to other treatments. However, T_8 (3.93%) had also significantly lower DH % than other treatments. The different treatment combination did not show any effect on white ear head incidence.

Damaged leaf % due to leaf folder was also minimum in T_3 followed by T_8. Both the treatments had significantly lower leaf folder attack than treatments that received RDF (T_1), lower K doses along with straw (T_4 and T_5), straw alone (T_7) and control (T_9). With respect to damaged leaf % caused by whorl maggot, there was no significant difference among the treatments. In respect of Gundhi bug population on plants, T_8 had significantly lower population in comparison to T_7 and T_9. However, all other treatments had almost a similar population.

Table 6. Effect of potassium management options on leaf content of K and K/N ratio in both dry and wet season

Treat-ment No.	Treatment	Dry Season Leaf K% at MT stage	Dry Season Leaf K% at PI stage	Dry Season K/N ratio of leaf at harvest	Wet Season Leaf K% at MT stage	Wet Season Leaf K% at PI stage	Wet Season K/N ratio of leaf at harvest
T_1	K_{40}	1.13	1.19	1.76	1.55	1.62	1.38
T_2	K_{60}	1.21	1.48	1.85	1.67	1.91	1.79
T_3	K_{80}	1.18	1.24	2.14	1.72	1.92	1.71
T_4	K_{20} + Straw	1.14	1.37	1.61	1.56	1.68	1.21
T_5	K_{30} + Straw	1.1	1.24	1.92	1.62	1.92	1.57
T_6	K_{40} + Straw	1.18	1.34	1.88	1.74	1.85	1.47
T_7	Straw	1.1	1.24	2.07	1.63	1.81	1.31
T_8	K_{40} + 1% KNO_3 spray	1.16	1.24	1.84	1.62	1.9	1.51
T_9	K_0	1.12	1.09	1.47	1.57	1.74	1.29

Table 7. Correlation between insect pest and disease incidence and leaf K content and K/N ratio at various stages in both dry and wet season

Pest Incidence	Correlation Coefficient values (r)					
	Dry Season			Wet Season		
	Leaf K% at MT stage	Leaf K% at PI Stage	K/N ratio of leaf at harvest	Leaf K% at MT stage	Leaf K% at PI Stage	K/N ratio of leaf at harvest
Blast (PDI%)	-0.59	-0.48	-0.43	-0.43	-0.51	-0.76
Brownspot (PDI%)	-0.69	-0.37	-0.47	-0.58	-0.73	-0.75
Dead Hart (%)	-0.40	-0.42	-	-0.62	-0.61	-
White Ear Head (%)			-0.29	-	-	-0.64
Leaf Folder (DL%)*	-0.19	-0.35	-0.57	-0.49	-0.33	-0.66
Whorl maggot (DL%)*	-0.69	-0.26	-0.31	-0.85	-0.56	-0.67
Gundhi Bug no./sq. m)	-0.18	-0.15	-0.20	-0.42	-0.45	-0.47

During both seasons, a consistently similar trend was observed. T_3 had significantly lower % dead hart (3.17) than remaining other treatments. Though T_8 was significantly higher than T_3 but it also had significantly reduced % dead heart than T_1, T_2, T_4, T_5, T_6, T_7 and T_9, respectively. Almost similar trend recorded in white ear head in which T_3 had significantly lower than other treatments. Similar trend was observed with % damaged leaf due to leaf folder and whorl maggot.

Studies on cost economics

Data on cost economics given in Table 8 which includes cost of cultivation, gross returns, net returns and return per rupee invest of both *Rabi* and *Kharif* season under different K management practices. After *Kharif* rice harvested, the average system economics shows that the highest return per rupee invested in the treatment receiving 40 kg K_2O/ha with 1% KNO_3 foliar spray (1.99) followed by both the treatment receiving 60 kg K_2O/ha (1.81) and 80 kg K_2O/ha (1.81) and the treatment receiving 30 kg K_2O/ha and 3 t/ha straw (1.78).

In both the seasons the treatment receiving higher dose of K showed the lower PDI and insect attack (Table 2, 3, 4 and 5). Insect pest 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. Higher incidence in case of straw application even with higher dose of K might be due to the 1st year of straw incorporation in highly K deficient soil and moreover slow decomposition of K during DS. Similarly, Surekha et al. (2006) reported that straw incorporation starts showing positive effect on rice crop after the two year of incorporation.

Both blast and brown spot incidence correlated negatively with K content in leaf at MT and PI stages (Table 6 and 7) with more correlation at MT stage (r= -0.59, -0.69) than PI stage (r= -0.48, -0.37) in dry season and PI stage (r= -0.51, -0.73*) than MT stage (r= -0.48, -0.37) in wet season. Incidence of both the diseases significantly correlated with the K/N ratio leaf (-0.76*, -0.75*) only in wet season. This shows that it is not only the K content, but N-K balance is an important criterion for blast and brown spot occurrence in wet season rice. Since tissue hardening and stomatal opening patterns are closely related to infestation intensity, N-balance with K is significant to disease susceptibility (Perrenaud, 1990). 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.

Insect attack in both dry and wet seasons correlated negatively with K content in leaf at MT and PI stages with wet season having stronger correlation than dry season for all the major insects (Table 7). With respect to stem borer attack dead heart % significantly correlated with K/N ratio of leaf at harvest with stronger correlation in dry season (r=-0.81**) than wet season (r=0.62*). This suggests that it is not only the K content but K-N balance is also important for making the plant resistant to stem borer attack. With more N and less K in leaf the stem borer attack is more.

Similar observation was also made with respect

Table 8. Effect of potassium management practices on cost economics per year

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	111921	47121	1.73
T_2	K_{60}	82.32	114.82	68280	123433	55153	1.81
T_3	K_{80}	82.92	130.42	69440	125809	56369	1.81
T_4	K_{20} + Straw	75.57	92.15	71960	111986	40026	1.56
T_5	K_{30} + Straw	86.53	113.71	72540	129056	56516	1.78
T_6	K_{40} + Straw	80.12	105.66	73120	119524	46404	1.63
T_7	Straw	73.73	98.86	70800	110163	39363	1.56
T_8	K_{40} + 1% KNO_3 spray	91.92	121.00	68820	137107	68287	1.99
T_9	K_0	69.05	87.55	62480	102663	40183	1.64

to leaf folder attack. But whorl maggot attack measured in terms of damaged leaf % more correlated with the K content of MT stage than the PI stage. With respect to Gundhi bug incidence, however, there existed insignificant negative correlation with K content and K/N ratio.

Examining the mechanism of induced resistance to insects pests in rice plant with enhanced K application, Vaithilingam and Baskaran (1985) 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 insect pests. It was reported that plant damage by insect is comparatively less in K applied plants due to reduced carbohydrate accumulation, elimination of amino acids (Baskaran et al., 1985), higher silica content and increase in the sclerenchymous layer (Dale, 1988).

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.

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 5. 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.

CONCLUSION

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 was more remunerative than combined application of both chemical fertilizers and straw. Insect attack in both dry and wet seasons also correlated negatively with K content in leaf at MT and PI stages with wet season having stronger correlation than dry season for all the major insects. Further, it was obvious that the treatments that were less affected by diseases and insect pests showed comparatively better yield. It is evident that K fertilizer is important for managing most common insect pests (stem borer, leaf folder, whorl maggot and Gundhi bug) and diseases (blast and brown spot) in rice.

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