Oryza Vol. 55 (Special Issue) 2018 (82-89)
DOI 10.5958/2249-5266.2018.00010.3

Paradigm shift of insect pests in rice ecosystem and their management strategy

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ABSTRACT

Insect population has changed both spatially and temporally over the period of time in a crop like rice. In the present study, data from the year 1965 to 2017 shows considerable increase of insect pests to 21 numbers. Their spread to large rice areas has been worked out which is a matter of concern, particularly Brown Planthopper (BPH), which has invaded all rice growing areas of the country. Present article focuses on more frequent occurrence of pests in different years related to the extent of damage incurred, which will be the principal concern of applied entomologists and farmers. Insects are classified as pests based not solely on numbers but on socioeconomic impact and on biological tolerance of the host to pest attack. In the present study, emphasis is placed upon host plant resistance to pests, proper monit oring and developing location-specific IPM packages for management of rice insect pests based on their initial populations and the processes by which they change to endemic form.

Key words: *Rice insect pest, host plant resistance, pest surveillance, IPM*

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for many people around the world especially in Asia where half of the global population exists. On the other side, world population is expected to be 9.2 billion in the middle of this century and in that situation it will be extremely challenging to provide enough food for all the people. To meet the global demand, rice production will have to be increased significantly by 2030 (Agronomag, 2017). In India, the yield increase in rice is the primary goal because it immensely contributes to food security of growing population. Biotic stresses act as a main hindrance in achieving such goal and among the biotic stresses; insect pests play a major role. Though the management of insect has been a primary issue since early eras of rice cultivation, but insect pests became more rampant with the development of high yielding and nitrogen responsive varieties which coincided the era of green revolution.

More attention has been given to manage these pests and it led to classify insect pests as per their time of occurrence, type of feeding and population size, etc. Management strategies have been formulated to cope up with different stages of crop plants vis-à-vis pest situations. The severity of major pests were being controlled with these formulated strategies, keeping the rice production in balance. But, during past years, upsurge of common as well as new pests has been experienced and so also the severity in different rice growing areas. In spite of application of high amount of pesticides, pests like BPH is devastating the rice crop causing heavy yield loss. But mostly, it was attributed to the failure of management options which were effective to the BPH.

Based on the above observations, some key questions arise in current scenario of rice pest management. Are the management strategies not properly laid ? Or has the pest situation changed and the present pest situation needs a complete modification of the management options? Unless the present pest situation is looked into with reference to the past history, it is not possible to draw any inference.

Therefore, the present study aims at the past and the current pest scenario in rice cultivation in India and to identify the paradigm shift, so that appropriate

management strategy can be formulated for crop protection in rice to minimize yield loss.

MATERIAL AND METHODS

Systematic survey and surveillance programmes and collection of information on rice pests are being conducted in the country by several Central Institutes, different State Agricultural Universities and State Agricultural Departments. Information drawn from different projects of National Rice Research Institute (NRRI), Cuttack and also from the pest incidence reports available from different States, Universities and from Production oriented survey of All India Co-ordinated Rice Improvement Project (AICRIP), Hyderabad have been analysed. Information of insect pests of a particular region/state over the years was assessed for revealing its endemic or sporadic nature. From the analysis, the emerging or outbreak of any insect pests in large area or in a particular time scale was discussed. The data on incidences of different insects pests in rice ecosystem were computed and study on paradigm shift of rice insect pests was analyzed by looking in to different aspects such as - (1) Number of economically damaging insect pests at definite year intervals. (2) The horizontal spread of insect pests in rice growing regions. (3) Increase in the severity of insect pest. (4) Shift of incidence period of insect pest and their effect on crop yield. Keeping in view of the pest scenario, management strategies were discussed.

RESULTS AND DISCUSSION

Pest Scenario: Numerical accretion

Critical examination of rice insect pests during past 52 years (1965-2017) shows a gradual increase in number of pests. Only three insects, yellow stem borer (YSB), gall midge (GM) and green leaf hopper (GLH) were reported during 1965. Brown plant hopper (BPH) and white backed plant hoppers created havoc towards early 1975 and also continued afterwards. Case worm, Gundhi bug and Hispa appeared within another 5 years (1980). Termites became a problem of upland rice towards 1985 along with leaf folder in favorable lowland rice ecology. By 1990, thrips appeared at early stage of the crop whereas, leaf mite was observed at vegetative and late vegetative stage. Root weevil and black bug emerged as pest in certain rice pockets towards the year 2000. Pink stem borer became a damaging pest on late duration varieties of low land rice towards 2005 with panicle mites infesting at reproductive stage of rice crop. Infestation of blue beetle started and swarming caterpillar became more prominent towards 2010 whereas ear cutting caterpillar added its presence towards 2015. By 2017, Mealy bug and Grass hopper were also became prominent in rainfed favorable rice ecosystem. The overall observation shows that there is always addition of insect pests after each 5 or 10 years with the previous pest still remaining a matter of concern. Overall, analysis showed that three pests during 1965 in the country increased to 21 during 2017 (Table 1).

Ecology dependent pests & their dynamics

Ecosystems also play a major role in housing different pests. For example: Termites and grass hoppers infest upland rice. Since the ecology demands short duration varieties which flowers early, gundhi bug infests the crop at milky stage. Swarming caterpillar becomes a menace in hilly or forest crop areas which generally belongs to the category of upland ecology with bunded or non-bunded lands. The irrigated or favorable rainfed lowland rice is more prone to maximum number of pests due to its suitable crop condition, particularly the water. Insect pests like YSB, BPH, WBPH, Gall midge are of regular occurrence; in addition almost all insect pests occur at periodic intervals as sporadic pests (Table 2). Most of the research is being conducted for pest management in this ecology because the yield is highest with better scope for nutrient and pesticide management. The low land ecology is mostly unfavorable during rainy season. Sometimes, the water level increases to more than 30 cm and water stagnation is a major problem during rainy season. Yellow Stem borer and case worm are two major problems in this ecology. Though the ecology harbors fewer pests, the unfavorable conditions possess a challenge for management of insect pests.

Keeping the water scarcity into consideration, the alternate drying and wetting (ADW) rice system and aerobic rice was adapted in a big way. As the growing condition matches more with upland condition but with moist soil environment, they were also prone to these insect pest attacks. Mealy bugs are gaining a major pest status in these systems, so also in bunded upland. Root aphid and root weevil are showing their

Table 1. Status of rice insect pests over different years

Sl.No.	1965	1975	1980	1985	1990	2000	2005	2010	2015	2017
1	YSB	YSB	YSB	YSB	YSB	YSB	YSB	YSB	YSB	YSB
2	GM	GM	GM	GM	GM	GM	GM	GM	GM	GM
3	GLH	GLH	GLH	GLH	GLH	GLH	GLH	GLH	GLH	GLH
4		BPH	BPH	BPH	BPH	BPH	BPH	BPH	BPH	BPH
5		WBPH	WBPH	WBPH	WBPH	WBPH	WBPH	WBPH	WBPH	WBPH
6			CW	CW	CW	CW	CW	CW	CW	CW
7			GB	GB	GB	GB	GB	GB	GB	GB
8			Hispa	Hispa	Hispa	Hispa	Hispa	Hispa	Hispa	Hispa
9				LF	LF	LF	LF	LF	LF	LF
10				Termite	Termite	Termite	Termite	Termite	Termite	Termite
11					Thrips	Thrips	Thrips	Thrips	Thrips	Thrips
12					Mite	Mite	Mite	Mite	Mite	Mite
13						RW	RW	RW	RW	RW
14						BB	BB	BB	BB	BB
15							PSB	PSB	PSB	PSB
16							PM	PM	PM	PM
17								SC	SC	SC
18								BlB	BlB	BlB
19									ECC	ECC
20										MB
21										GH
Total	03	05	08	10	12	14	16	18	19	21

YSB-Yellow stem borer, GM-Gall midge, GLH-Green leaf hopper, BPH-Brown plant hopper, WBPH-White backed plant hopper, CW-Case worm, GB-Gundhi bug, LF-Leaf folder, RW-Root Weevil, BB-Black bug, BlB-Blue beetle, PSB-Pink stem borer, PM-Panicle mite, SC-Swarming caterpillar, ECC- Ear cutting caterpillar, MB-Mealy bug, GH-Grass hopper.

presence in localized areas. Likewise, thrips, case worm, mealy bug, hispa, swarming caterpillar, gundhi bug gaining more importance in irrigated or shallow favorable lowland ecology. Case worm and leaf folder are regular pests followed by swarming caterpillar. Brown plant hopper, which is a major pest of favorable ecology, was seen to invade low land rice.

Pest expansion and severity

If we examine the pest status in rice during last 17 years (2001-2017) a gradual increase in the spread of insects to more rice growing areas was observed. Brown plant hopper which was restricted to certain south and eastern states of India during 1970's and was almost negligible during 1980's, again it assumed the major pest status by invading almost all rice growing regions of the country.

Table 2. Ecology-wise-insect pests

Sl. No.	Upland/Aerobic/ AWD	Irrigated/Shallow favorable lowland	Low land
1	Termites	YSB	YSB
2	Grass Hopper	BPH	Case worm
3	Gundhi Bug	WBPH	BPH
4	Swarming caterpillar	Gall midge	
5	Mealy bug	Thrips	
6	Root Aphid	Leaf folder	
7	Root weevil	Mealy bug	
8		Case worm	
9		Hispa	
10		Swarming caterpillar	
11		Gundhi bug	
12		Black bug	
13		Blue beetle	

The insects like leaf folder, yellow stem borer are occurring in severe form and more often they are difficult to control. The gall midge infestation was in a decreasing trend, it has been reported only from some parts of Jharkhand, Telengana, Chhattisgarh and Andhra Pradesh. But case worm spread was noticed in many states of southern and eastern states like Odisha, Jharkhand, Andhra Pradesh, Maharashtra, Kerala, Tamilnadu and Gujarat. Swarming caterpillar was also causing severe yield loss in Odisha and Assam. In addition, now swarming caterpillar also reported from Kerala and Karnataka. Insects like Gundhi Bug, WBPH, Hispa, Thrips were still showing their severity in small pockets. Recently, black bug and white grubs were also injurious to rice crop in small pockets. So overall, most of the insects over the years have increased their severity of occurrence.

In addition to the increase in pest species, there are also variations within the same insect of various species. Among stem borers, yellow stem borer (*Scirpophaga incertulus* Walk.) was the major dominant species in past and also it has the same status till today followed by striped borer (*Chilo suppressalis* W). Other four species, namely: White stem borer (*Scirpophaga innonata* W.), Pink stem borer (*Sesamia inferens* W), Dark headed borer (*Chilo polychrysus* M.) and Spotted borer (*Chilo partellus* S.) were existing in rice crop. But there was a gradual increase in their status in north-eastern regions during 2001-03, whereas pink and striped borers are increasing in coastal areas. Similarly gall midge, which was confined to 3 biotypes during (1970-83), formed another biotype (biotype 4) during 1986. Towards 2004, another 2 biotypes, *i.e.,* biotype 5 and 6 have been originated (Pasalu et al., 2004).

Current scenario of change in pest status and shift in infestation pattern

• Yellow stem borer (YSB) has continuously remained as the major pest of paddy till date. With expansion of rice cultivation, particularly the scented rice varieties to non-traditional belts like north western parts and hill regions of India, pink stem borer (PSB) and white stem borer (WSB) have assumed importance. Pink stem borer, *Sesamia inferens* was dominant particularly in the reproductive phase of the crop in north-western India. In southern state of Kerala and hills of Northern region, White stem borer, *Scirpophaga innotata* has become predominant.

• In the last three decades, rice gall midge, *Orseolia oryzae* Wood-Mason has evolved in response to selection by the introduction of resistant varieties in rice ecosystems across the country. The pest is now suppressed in eastern coastal region, but causing serious losses in new areas like Bihar and North-eastern state of Manipur in addition to traditional areas of Odisha, Andhra Pradesh, Madhya Pradesh and Kerala.

• Gall midge which was also a pest of dry season rice during 1968, gradually shifted to *kharif* season (Prakasa Rao et al., 1968). Infestation has decreased considerably due to its late occurrence and also cultivation of resistant varieties.

• Brown plant hopper (BPH) which was having major pest status during early 1970s to mid-1980s, remained inconspicuous upto late 1990s and again is assuming the major status in most of the rice growing tracts of India and abroad from 1998 onwards. But very often, instead of vegetative stage of the crop, it is infesting rice at panicle initiation to milky stage, causing heavy yield loss as occurred in Odisha during 2014 and 2017.

• Earlier, White backed plant hopper (WBPH) infesting early growth stage of kharif rice also now infesting at late growth stage and rabi rice. In most of the cases, it was occurring as a mixed population with BPH.

• Whorl maggot and thrips, which were not recorded in Odissa upto early 1970s, are presently occurring almost regularly in most part of the state in early growth stage of the crop.

• Other insect pests which have changed their status from minor to the major pest of concern were leaf folder - *Cnaphalocrocis medinalis*, rice hispa- *Dicladispa armigera* and rice case worm- *Nymphula depunctalis* during 2005.

• Outbreak of swarming caterpillar/ear cutting caterpillars experienced more often during 2006 and onwards. Though sporadic, it caused severe damage to rice crop in Odisha and Assam.

• A Gelechid leaf folder species, *Brachmia arotreae* was of regular occurrence since mid 1990s .The surti caterpillar, Nisaga complex (Euteroplidae) has appeared as a serious pest of paddy in medium land of Odissa (Senapati, 2004).

• Leaf folder has now assumed major pest status in the entire country particularly in areas of high fertilizer input use. Its resurgence due to indiscriminate use of granular pesticides like carbofuran and phorate in farmers fields has further compounded the problem (Prasad et al., 2010).

• White grub has become major pest in the hilly regions of Uttaranchal state.

• Mealy bug (*Brevennia rehi*) has been recently observed as an important pest of upland rice in Assam, West Bengal and Odisha.

• In years of delayed monsoon or low rainfall during June-July, severe outbreaks of rice thrips (*Stenchetothrips biformis*) has been reported.

• Black bug (*Scotinophara* spp.) in Tamil Nadu, Blue beetle (*Leptispa pygmaea*) in Kerala and leaf /panicle mites in Odisha and AP are gaining prominence.

Weather factors affecting the insect pest incidence

Weather factors such as temperature, humidity, rainfall, sun shine hours, wind velocity and overall, natural calamities like cyclone, flood, drought, tornado etc. also affect the pest status of insects. Insects are cold blooded organisms, *i.e.,* their body temperature is approximately the same as that of environment. So, temperature is considered to be the single most important environmental factor which mostly influences the insect behaviour, distribution, development, survival and reproduction (Bale et al., 2002). Researchers have estimated that, with a 2^0C temperature increase, insects might experience one to five additional life cycles per season (Yamamura and Kiritani, 1998). It alone can become a key factor for insect emergence and predominance in dry season rice. But in wet season, all the weather parameters like temperature, rainfall, humidity, sun shine hours and wind velocity work together for rise or fall of the insect population and damage.

The stem borer brood emergence during dry season was very much temperature sensitive whereas it was sensitive to rain falls in wet season. Increase in minimum temperature and maximum temperature remaining within 28-30^{0}C, insect like YSB can infest the dry season rice crop for a longer period necessitating better management strategies. But in *Kharif* (Wet season), prolonged rain fall upto 2nd-3rd week of October shifted the pest to long duration varieties. Delayed monsoon with more number of heavy rain fall days had pushed gall midge occurrence to last week of September or October without much harm to the crop. The same situation of delayed monsoon has also resulted in delayed transplanting in farmers field inviting more of case worm, leaf folder, thrips and hispa at the initial stage of plant growth. Swarming caterpillar becomes a menace after heavy rainfall and flood.

BPH and WBPH were observed within a temperature range of 30 ± 3^{0}C with a humidity range of 80-90% (Rout and Jena, 2012). The factors which influences BPH outbreak along with conducive temperature were low atmospheric humidity but with adequate irrigation water. Close spacing enhances BPH, WBPH and gall midge population. This was due to the increase in more foliage per unit area. Due to close canopy formation, a higher RH of 94-98% was maintained in the basal portion of the rice plants which are the actual zones of activity of hatched nymphs of BPH and WBPH and maggots of GM (CRRI Annual Reports, 1974 and 1976). The causes of out break of various rice pests differ with more numbers rainy days. Hot and high humid conditions during July, August, September with low sunshine hours support hispa and case worm population. Swarming caterpillar becomes a menace after heavy rainfall and flood. The leaf folder, *Cnaphalocrocis medinalis* needs temperature of 25-32^{0}C and high RH of 83-90% for its better development. In lower temperature of 15^{0}C and below, eggs of rice gundhi bug stops hatching, while 25^{0}C was the congenial temperature for normal hatching with high humidity of about 95% .

On the whole, there are rice insect pests which can increase their incidence with the scarcity of rain and on low humidity are *Brevennia rehi* (Homoptera), *Nephottetix virescenes*, *Stenochaetothrips biformis* (Thysanura), *Odontotermis obesus*, *Microtermis obesi*, *Cyclotermis obesus* (Odonata), *Marasmia patnalis*, *M.exigua* (Lepidoptera), *B. arotrea* and *Atherigona oryzae* (Diptera). The other group of insects which need high rainfall, flooded soil and high humidity are *Scirpophaga incertulus*, *Nymphula depunctalis*, *Cnaphalocrocis medinalis*, *C. Polychrysus* of Lepidoptera; *Nilaparvata lugens*, *Sogatella furcifera* of Homoptera; *Orceolia oryzae*, *Hydrellia gresiola*, *H. Philippina*, *Chironomid* spp. of Diptera and *Dicladispa armigera* of Coleoptera (Senapati, 2004).

Expected pest menace in future with changed climate

(i) Changed climate, particularly increase in temperature can potentially affect the insect survival, development, geographic range and population size. (Biotype development)

(ii) Insects may moderate their life cycle accordingly to the changed climate. Some may go to diapause in unfavourable weather and develop more rapidly during suitable period. This acceleration of development may take place resulting more generations per year (e.g., BPH and YSB)

(iii) Migration of insects may become early or late or overwintering may be expanded.

(iv) Changed weather may affect the natural enemy and host- insect response differently. Parasitism may be reduced if host population emerge and pass through vulnerable life stages before parasitoids emerge.

(v) Host may pass through vulnerable life stages more quickly at high temperature reducing the opportunity for paracitism.

(vi) Gender ratios of insects may be changed in some pest species such as thrips, potentially affecting reproduction rate.

(vii) Insect that spends important stage of their life cycle in the soil may be less affected by temperature changes than those that are above ground as soil provides a type of insulation which can buffer temperature changes more than air. On the otherhand, warmer winter temperature may be important in lowering winter mortality of insects thereby increasing their population.

(viii) More insect species may attack more hosts in temperate climate. Based on evidence for the record, it was reported that the diversity of insects and the intensity of their feeding have increased historically with increasing temperate climate.

(ix) However, increased temperature also may reduce incidence of some insects when not supported by adequate rain or humidity. Insects may become less responsive to insect-alarm-pheromone released under attack by predators and parasitoids, resulting chance for more predation. (Awmack et al., 1997)

On the whole, the major factors responsible for the change in insect pest scenario are the change in weather parameters to suit the insects most for their multiplication and feeding, extensive cultivation of high yielding varieties without pest resistance, intensive rice cultivation throughout the year, imbalanced use of fertilizers and indiscriminate use of pesticides.

Management Strategy

Though the occurrence and severity status of insects are showing considerable change/shift over years, much change in management strategies has not been in operation at present. The components which can contribute to successful pest management were -

1. Host plant resistance: To combat the present pest situation, research on host plant resistance should be taken to the forefront. Development of pest

resistant varieties should be the top most priority as well as an important component of IPM.

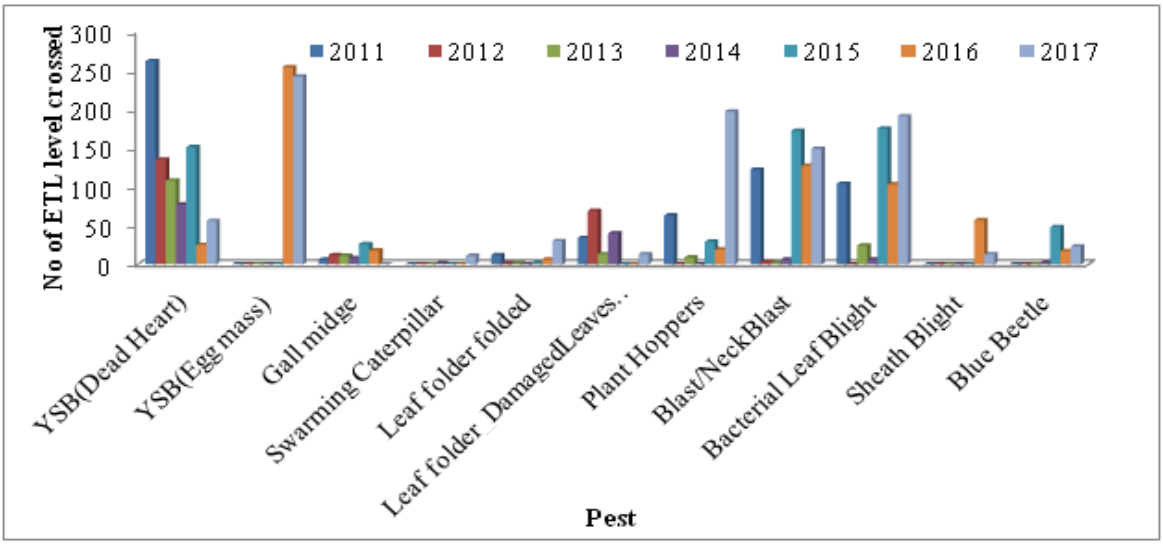

Fig. 1. Rice pest scenario in Maharashtra over the years and role of surveillance

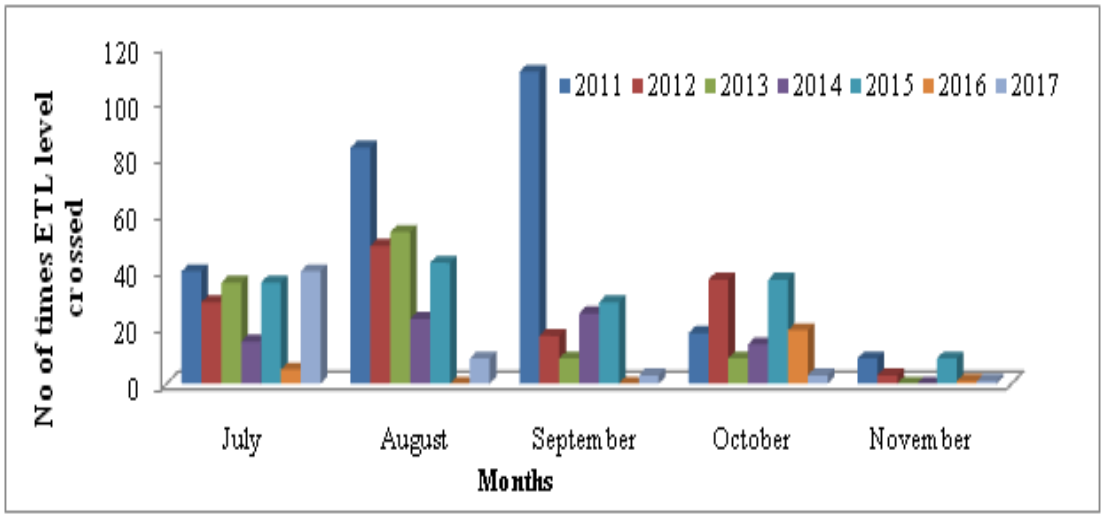

Fig. 2. Occurrence of YSB in different months of the years its gradual decrease

2. Proper Surveillance: Pest surveillance is another major aspect of IPM which decides the proper management strategy. A robust and continuous surveillance system in the state of Maharashtra from the year 2011 to 2017 could detect insect pests at proper time and brought down the incidence rate of major pests like YSB, plant hoppers, gall midge etc. by application of protection measures at economic threshold level. It also indicated the increase of any pest within a particular period of the crop season so that proper control strategy can be applied. For example, plant hopper population was maximum in 2017 and YSB decreased over the years in wet season rice . However, Maximum infestation of YSB was in August and September (Fig. 1 and 2) which was addressed at the early incidence period (Jena and Adak, 2017).

Similarly, Proper surveillance helped in identifying pest at its initial stage of occurrence in on-farm IPM trial laid by ICAR-NRRI, Cuttack in participatory seed production villages. The number of pests decreased from 2012 to 2017 and even if more pests were observed during years like 2013, 2015 and 2016, their intensity decreased as protection measures were taken at the stage of initial incidence. Accordingly, amount of pesticide use was also decreased. There was an overall gain of yield as well as low protection cost (Fig. 3) for the farmers (Jena et al., 2017).

3. Development of models for predicting insect pest scenario: Changing biotic stress scenario has highlighted the need for future studies on models which can predict the severity of important insect pests of rice in real-field conditions. Simultaneously, insect pest management strategies should be reoriented in changing conditions with amalgamation of new strategies for sustainable crop protection.

4. Pesticide research: Pesticides still play a major role in pest management of rice. At present, recommended pesticides from Central Insecticide board, India are to be thoroughly evaluated against each insect pest for their lethal dose and persistant toxicity so that effective insecticides can be identified/validated in relation to their dose, time and type of application.

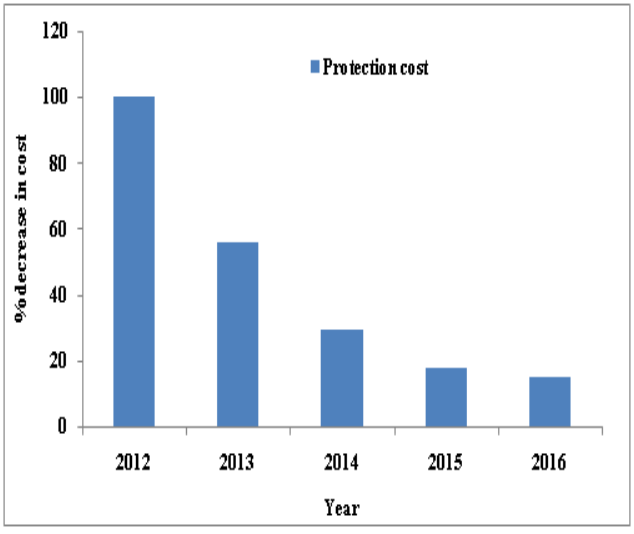

Fig. 3. Decrease of protection cost in onfarm IPM practice at Mahanga, Cuttack

5. Inclusion of IPM strategy: Location specific integrated pest management (IPM) packages are to be developed and demonstrated in farmers' field for better yield and adoption strategy.

CONCLUSION

There is a shift in occurrence, incidence level and spread of insect pests in rice growing areas of the country which warrants immediate action to address it. Proper management of rice insect pest is essential for ensuring good harvest. The use of economic thresholds of insect pest can facilitate need-based application of insecticides thereby avoiding unwanted pesticide use, and reducing environmental pollution. Marker-assisted selection is coming forward to help in developing resistant varieties within less time target. Simultenously, with the refined insecticide use method and holistic approach of IPM emphasizing pest surveillance can successfully reduce pest menace in rice inspite of its changing scenario, ensuring high yield.

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