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Overview of entomology research under AICRIP –An experiential learning

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Introduction

In India, rice ecosystems are highly diverse and pose varied challenges to the rice farmers in terms of abiotic and biotic stresses limiting rice production in the country. In the context of ecosystem complexities, destabilizing pest problems as well as production requirements of different rices consumed, Indian Council of Agricultural Research (ICAR) had the foresight to come up with the concept of All India Coordinated Rice Improvement Project (AICRIP) way back in 1965. Since then, a nation-wide network of rice researchers actively supported by progressive rice farmers has been in vogue leading to development of high yielding varieties supported by suitable crop production and protection technologies for the rice farming community.

Entomology Programme

The Entomology programme under AICRIP was initiated during 1970s with major thrust on research areas related to host plant resistance (HPR) and Chemical control of insect pests of rice. A National Screening Nursery (NSN) trial was constituted to evaluate the breeding material for their reaction against major insect pests at multi-locations. The focus was on identification of donors and breeding lines for resistance to the key prevailing pests, gall midge and stem borer. Chemical control programme involved screening and evaluation of new chemicals/ insecticides for their efficacy against rice pests and compatibility of effective ones with other recommended pesticides for application in fields.

During 1980's, with the introduction of high yielding varieties and input intensive management practices, some of the insect pests like brown planthopper, cutworm and leaf folder which were hitherto considered to be of minor importance, assumed major pest status leading to the need based constitution of location specific trials on these pests. Efforts were also made to develop effective, economical and ecologically sound techniques of insecticide application. Explorative studies related to ecosystem approach were started through trials on pest management and ecology. HPR programme received global focus with the initiation of International collaborative trials such as International Rice Brown Planthopper Nursery (IRBPHN), International Rice Gall Midge Nursery (IRGMN), International Rice Stem Borer Nursery (IRSBN), and International White Backed Planthopper Nursery (IRWBPHN) across international locations to ensure utilising wider genetic base in identification of pest resistant germplasm lines. Installation of light traps in different locations also commenced to monitor changing pest scenario through assessment of trap catches throughout the year.

During the 1990s, the Entomology research programme under AICRIP continued with major focus on HPR followed by Chemical Control. The screening trials were continued for major insect pests of rice both under greenhouse conditions and at insect pests hotspot locations. Evolution and identification of field biotypes of gall midge led to initiation of gall midge biotype monitoring based on the pest reaction to a set of host plant differentials. Concerted research efforts were also initiated to investigate into quantification of natural biological control in in rice fields. A new multi-location field trial (Natural Biocontrol in Rice Ecosystem – NBRE) was designed to quantify the pest as well as natural enemy incidence in different rice ecosystems. Insecticide screening and pesticide compatibility trials were continued along with optimum pest control experiments highlighting the role of moderate pest resistant lines. On farm IPM trials were also carried out at various locations to develop and evaluate location specific IPM modules mainly consisting of HPR and Chemical control components.

In the 21st century, during the first decade (2000-2010), the focus shifted to evolving innovative eco-friendly pest management approaches like trap crop for stem borer management and use of semio-chemicals. Utility of sex pheromone for monitoring as well as mass trapping of yellow stem borer was evaluated and verified at different locations through field trials. Also, widespread incidence and importance of planthoppers in India and other Asian countries led to special studies on planthoppers for identification of genes and insecticide resistance. Investigations into Pest and Natural enemy compositions prevailing in different rice ecosystems of the country was another initiative launched during this period. Chemical control studies were continued with shift in attention to the role of biopesticides including botanicals. Changing rice cultivation practices with the introduction of newer methods of planting such as System of Rice intensification (SRI), aerobic rice and direct seeding resulted in change in insect pest scenario. Hence, studies were initiated to know the impact of these practices on pest incidence and damage potential. Efforts were also undertaken to quantify the yield losses due to key pests, particularly stem borer and leaf folder at different locations.

In the second decade (2010-20), HPR continued being the core component of rice IPM, pest specific screening trials like Planthopper screening (PHS), Gall midge screening (GMS), gall midge special screening (GMSS) Leaf folder Screening Trial (LFST) and Stem Borer Screening Trial (SBST) were constituted to evaluate material derived from landraces and germplasm. Entries found promising were further screened in the Multiple Pest Resistance Screening Trial (MRST) to generate multiple pest resistant material. Evaluation of National Screening Nurseries (NSN1, NSN2, and NSNH & NHSN) continued across locations against major insect pests. This trial included promising entries from plant breeding trials *viz.*, Advance Variety Trial (AVT 2) material in NSN1, Initial Variety Trial (IVT) material in NSN2, entries bred for hill region in NSNH and experimental hybrids in NSNH. Besides, special complementary research network activities on evaluation of rice germplasm collection of National Bureau of Plant Genetic Resources (NBPGR) as well as material generated from rice biotechnology progressed with emphasis on rapid development of entries resistant to multiple biotic stresses including insect pests and diseases. Concomitantly, biodiversity and biological control studies were strengthened through initiation of studies on in situ conservation of biocontrol agents through ecological engineering for pest management (EEPM) and biointensive pest management (BIPM). A new initiative on fortnightly monitoring of pest incidence (Pest Survey Report – PSR) at different locations was also undertaken for development of year wise database on incidence of pests across rice ecosystems. Another new development involved formulation of an all-encompassing participatory multi location on farm IPM trial with a holistic approach of managing all the pests including insects, diseases and weeds, initiated involving multidisciplinary team of entomologists, agronomists and plant pathologists.

Salient findings and achievements

Changing pest scenario

Insect pest scenario in rice has changed drastically in the last five decades. During 1965, only three pests' i.e, gall midge, stem borer and green leafhopper were of serious concern. After the Green Revolution period fertilizer responsive high yielding varieties were introduced and subsequently there were substantial alterations in rice cultivation methods, input resource use and intercultural practices leading to remarkable shifts in insect pest scenario in terms of diversity and numbers. At present, about twenty insect species are categorised into pests of national and regional significance as well as emerging ones, resulting in significant yield loss. Short- and long-term assessment of pest populations through light trap catches under

AICRIP have revealed that among the pests of national significance, stem borers and planthoppers, followed by leaf folder continue to be the most widespread pests in terms of numbers and spread across the rice ecosystems. Among the pests of regional significance, swarming caterpillar (*Spodoptera mauritia*) along with other species, *Mythimna separata*, rice hispa and caseworm have been found increasingly prevalent.

Integrated Pest Management as the viable alternative

Integrated Pest Management with its holistic approach remains a sustainable and realistic option for rice farmers to manage the pests across different rice based cropping systems. IPM provides the ideal ecologically sound framework for managing pests under which crop management specialists can intelligently integrate available pest management components such as the use of pest resistant varieties, biological suppression or natural regulation, modification of agronomic practices and habitat manipulation or deploying, only as last resort, eco-friendly insecticides to tackle the pests in times of unexpected outbreaks or emergency situations. This long term strategy also has the potential to minimize the risks to the human health, environment as well as ensure economic and social gains for the farmers. IPM strategies have evolved over the years from reliance on single approach of chemical control to the present multi-faceted approach aided by the synergy of developments in scientific research and discoveries related to biotechnology and other fields. The newer technological innovations have offered novel opportunities for reducing dependency on chemical pesticides leading to the evolution of a holistic refinement of IPM for sustainable rice production. AICRIP has singularly provided an ideal research platform for the evolution and development of different components of IPM for adoption across rice systems, discussed briefly as under:

Pest surveillance

Pest surveillance forms the most vital cog of rice IPM strategy. Conventionally, farmers have been habituated to identify or diagnose pest problem only after pest appearance and still find it challenging to differentiate the damage symptoms arising out of an insect pest or disease attack or nutrient deficiency. Reliable and immediate identification of all the rice pests is now possible through the coordinated efforts of National Agricultural System organizations, Agricultural Universities under AICRIP and State Departments of Agriculture aided by farmers' active cooperation and response. Vast data sets on light trap catches of rice pests along with macro weather data collated by cooperating centres in the last fifty years has enabled the rice researchers to guide the farmers to monitor the onset and development of the pest population dynamics in the field. Advanced research on semio-chemicals has provided a valuable tool for accurately monitoring specific pest populations. Sex pheromones mediated traps are now popularly used by the farmers as monitoring tools to take timely actions for preventing yellow stem borer in rice. There is further scope for deployment of this technique in case of other species of stem borers like pink and white stem borers and pests such as leaf folder.

In situations where it is not possible to prevent pest attacks, regular monitoring of pest populations becomes unavoidable and even essential to avert recurrences of pest outbreak particularly in view of unpredictable disruptions due to climate change scenario. Comprehending the shifts in pest profiles over time and space needs accurate and reliable tools of pest surveillance. Efforts are now in progress under AICRIP to generate relevant data related to changes in pest populations, soil profile, plant phenology and other phytofactors along with weather parameters over diverse ecosystems for a long period using Information Technology (IT) tools. Pest forewarning systems aided by Geographical information system (GIS) and weather data driven pest distribution maps are being developed to provide real time action advisories to farmers as part of decision support system.

Host plant Resistance (HPR)

Resistant varieties are the most efficient, economical and practical tools for encountering the pest problems and are ideally compatible with other components of IPM. However, it has been observed that the pest populations are quite capable of evolving adaptive biotypes or strains to overcome the effect of resistant varieties. Hence, concerted efforts have to be continuously in place to refine and develop varieties to withstand the newly evolving strains. Also, due to changing pest scenario and situations of altered pest profiles in different cropping systems with multiple biotic stresses occurring simultaneously in rice, developing multiple pest resistant varieties is always the need of the hour.

Enormous amount of genetic material has been screened under AICRIP leading to development of rich data base on sources of pest resistance in rice. Detailed findings on the resistant varieties/donors of pest resistance through concerted efforts till 2010, have been well documented by Bentur *et al* (2011). Research efforts undertaken in the last decade (2010-20) have further led to identification of more promising entries for utilization as resistant sources by the plant breeders.

Pest	Trial	Promising entries (source of resistance)
BPH & WBPH	PHS,GEMP, MRST, NSN, IRBPHN	5-B-3-B-4, NDR 9210, CRK 26-1-2-1, KAUM 95-1, RP 4510-75, IC Nos 346849, 347612, 343060, 311865, 346889, GRH 33, KAUM 166-2, KAUM 168-1, CR 3005-77-2, CR 3006-8-2, CR 3005-230-5, IR 65482-7-216-1-2-B, IC # 449784, 450029, IET# IET 22489, 22989, 21709, 22218, 21423, 22345, 23000, 23396, 22984, 22951, 21765, CR 3006-8-2, IR 65482-7-216-1-2-B, RP Bio 4919-501, CR 2711-149, KAUM 179-1, KAUM 179-2, KAUM 182-1, IET Nos 23118, 22486, 23073, 23110, 23083, 23101, 23132, 23130, IET Nos 23887, 23888, 23919, 23921, 23939, 23612, 23613, 23175, 23874, 23875, IET 24158, *KAUM 166-2, RP Bio 4918-236, RP Bio 4918-221 (S), RP Bio 4918-228(S),* IC Nos 463924, 578140, 578142, 578916, 578920 & Dhanrasi, CR 2711-149, KAUM 179-1, KAUM 179-2, KAUM 182-1, CR3006-8-2,RP 4918-228(S), JGL 19618, IET 23739(NSN1-51), IET 23081, IET 23052, IET 22055, IET 22302 and IET 22648, IET Nos 23150, 24452, 23918, 24485, 24490, 24493, 24503, 23906, 23929, 24424, 24537, 24367, 24393, 24629, 24714 and Swarna-dhan, BPT 2671, CB 05 022, CB 09 123, CB 12 701, CN 1231-11-7, CR 2711-149, IR 65482-7-216-1-2-B, CN 2072, CR 1898-32-69-CN 12-2, CR 2711-149*, KAUM 179-1, KNM 113, RP BIO 5478-166 M, RP BIO 5478-176 M, RP BIO 5478-196 M, CN 1231-11-7, IET24989, IET 25220 and IET 25419, IET 23906, 23934, 23053,23066, 24425, 24441, 24419, 24424, 24385, 24412, 25675, 25676, 25677, 24481(Repeat),CO 43(RP), Sabita(NC), Swarna (Recurrent Parent), IR 81896-B-B-195 (DP), BPT 2611, JGL 27371, MTU 1245, MTU 1247, IET 25835, IET 25846, Vivekdhan 62, IET No 25750, IET Nos 23934, 24426, 25086, 25053, CSR 23, 25512 and 25676
Gall midge	GMS, GMSS, MRST	JGL 18044, JGL 18080, JGL 19618, IC363753, CAUR-1, Madhuri 9, RCM-10, CORG 24, JGL 19618, CORG 15, KNM 113, KNM 563, SKL-3-22-19-31-55-11, NP 3113-7, KNM 134, KNM 489, KNM 539, KNM 557, KNM 637, IC 462402, IC 577036, CB-07-540, SB143, SB 319, DRR H2, RP Bio 4918-236, RP BIO 4918-221(S), PTB 33, IET No.s 23185, 23411, 23421,22764, 23459, 23464, 23383, 23913, 23972, 23525, 24159 & Lalat, IC# 462336, 463240, 353834, RP Patho-01, CB 07-540 IET # 22096, 21842, 21841, 22100, 22144, 22698, 22155, 22835, 22763, 23375, 23169, 23074, 23121, 23194, 23234, 23247, 23262, KNM 637, NP 3113-7, KNM 113, KNM 539, IC 578133, COGR-2, IET 22698, IET 23194 (NSN1-93), IET 24237, IET 24320, IET 24667 and IET 23536, KNM 1623, KNM 1625, KNM 1638, RDR 1181, RDR 1188, Vellaiilankalyan, RMSG7 (DRR 17B with *Gm4 + Gm8),* RP 5925-24, (B95-1 with *Gm8*), TH BR 69, TH BR 70 and TH BR 71(*Gm4* gene), KNM113 and KNM 339, IET 247441 and 25563, JGL 3828, JGL 21831, JGL 25998, JGL 27058, JGL 27075, KNM 1632, KNM1724, KNM 2275, KNM 1623, KNM 1638, WGL-825, WGL-1062, ASD 7,KAKAI (K 1417), PTB 12 and WGL 1145, KNM113, NP3113-7 Varalu, IET Nos 23610, 25051, 25519 and KNM 1638

Pest	Trial	Promising entries (source of resistance)
Stem borer	GEMP, MRST, NSN	IC Nos 463445, 577293, 577566, 578116, 578672 , 463175, 466430, 578996, KAUM 166-2, RP Bio 4918-142, IET No.s 23004, 23009,23185, 23308, 22894, 22568, 23431, 23440, 22752, 22763, 22777, 22289, 23459, 23081, 23088, 23118, 23073, 23919, 23600, 23604, 23574, 23589, 23839,24007, 23961, 21936, 23923, 23935, 23003, 24083, 24114 & Jalmagna, W 1263, LF 293, Anjali, RP 4645-688, LF 270, TKM 6, SB 436, IC 114978 & CSR 23, IC Nos 462271, 578136, 578912, 578942, 578943 & 579029, IET No. 23604, 24062, 24071, 24114, NSN-H-03, NSN-H-05, NSN-H-06, NSN-H-08, NSN-H-43, NSN-H-47, RP 5587-B-B-B-258-1, RP 5588-B-B-B-B-32, RP 5588-B-B-B-B-63,IET 23642, IET 23053, IET 23596, IET 23413, IET 24601, IET 24673, IHRT 06, IHRT M-7 and HRT MS16 (IET 24894), JGL 23655, JGL 23824, JGL 23746, IIRR-BIO-SB-3, RP 5893-259-17-13-6-1-B-B-4, JGL 21836, RP 5588-B-215 and IIRR-BIO-SB-9, CR 1898-32-69-CN 12-2, RP 5588-B-B-B-B-63*, KNM 113, RP Bio 4918-142 S* and RP BIO 5478-166 M, IIRR-BIO-SB-8, RP 5588-B-B-B-B-38, RP 5588-B-B-B-B-159-2, JGL 23835, RP 5588-B-B-B-B-45, RP 5588-B-B-B-B-48, RP 5588-B-B-B-B-51, RP 5588-B-B-B-B-54, RP 5588, JGL 23848, JGL 23746, IIRR-BIO-SB-2, CN 2069, RP 5893-382-54-8-2-1-B-B, JGL 23848, JGL 23746 and RP 5893-382-54-8-2-1-B-B-5,
Leaf folder	LFST, GEMP, MRST, NSN	W 1263 (CBT), PTB 12, IC 449877, CR 2711-76, RP Patho-04, TNRH 206, IET # 22548, 21850, 22568, 22552, 21858, 22222, 22552, 22155, 22199, 22223, 22439, 22449, 22486, 22489, MTU 1162, RP Bio 4918-24k, IET 22222, IET 22155, JGL 21133, JGL 21828, MTU 1155, MTU 1160, IET 22155, RP 5588-B-B-B-B-76, RP5588-BBBB177-2 and RNT 42-1-1-1, IET 22489, JGL 21078, MTU 1153, MTU 1163, RP Bio 4918-236, RP Bio 4918-24K, RP Bio 4918-50-13, IR 65482-7-216-1-2-B and RP BIO 5478-196 M, IET24814, IET 25394, 23596 and 25041, MP 11, MP 209, NWGR-13108, Mahisagar
Multiple pests	GEMP	IC# 346207, 545441, 459646, 17065, 86004, 145397, 449784, 450029, 449994, 413645, IC 463924, 462407, 463445, 578116, 578148, 578406,
	MRST	RP 4680-1-2-23, RP 4681-16-2-569, RP 4684-35-1-732, RP 4686-48-1-937CR 2711-76, HR-DRR-02, RP 4918-212(S), RP 4918-228(S), RP Bio 4918-236, RP Bio 4918-228(S) & DRRH-2, CR3006-8-2, RP 4918-228(S) and JGL 19618, KNM 113, IR 65482-7-216-1-2-B, CR 2711-149, NP 3113-7, RP Bio 4918-142 S, CR 1898-32-69-CN 12-2 CN 2072, RP 5588-B-B-B-B-63, KNM 539 and RP BIO 5478-166 M, Co50, Bahadur, Varalu and KNM113
	NSN -1	IET # 22489, 22096, 22155, 22439, 22486, IET No.s 23185, 23118, 23073, 22989, 23081, 23440, 22752, 22486, 23009, 22565, 23083, 23132, 23078, 23004, Jalmagna (NC), Salivahana
	NSN-2	IET # 23000, 23148, 23033, 23040, IET No.s 23919, 23939, 23620
	NSN H	IET 22950, HPR 2143, IET No.s 22281, 22283, 22974, 23536, 23537, 23524, 23525, 23526
	NHSN	IET 22941 (IHRTMS11), IET No.s24111, 24159, 24131, 24149, 24151

Source: AICRIP Progress Reports, Vol. 2 (Crop Protection)

As a futuristic strategy, the versatile tool of biotechnology has progressively provided novel and more powerful alternatives to cumbersome and time taking conventional resistance breeding. Work on transformation of plant systems with expression of multiple toxins in transgenic plant varieties through gene stacking and using genetic markers and DNA marker technology to tag and map several major resistance genes, has also been successful in conferring resistance to multiple pest problems. Disrupting gene function by the use of RNAi is another well-established technique in host plant resistance, while in the last few years, CRISPR/Cas9-based gene editing system has been another exciting means of exploiting genome intelligence for resistance breeding. Biotechnology research network projects involving the cooperating centres spread across the country have the potential to herald a new and more efficient strategy under AICRIP, in the coming years.

Cultural management

Appropriate manipulation of cultural practices offers the viable means for the resource deficient small and marginal farmers to indirectly suppress pest populations through resource use efficient techniques, particularly in rainfed rice. Simple practices like early and synchronous planting can help in either escaping damage or alleviating the effects of many pests and diseases. Similarly, water management and field sanitation measures can take care of biotic stresses through the removal of alternate hosts or creating conditions difficult for pest survival.

AICRIP studies have revealed that Integrated soil health and plant nutrient management strengthens plant system through induced resistance to withstand the insect populations preventing them from either reaching to 'pest' level status or enabling the plants to yield well despite stress impacts. Vigorous plant health also results in a substantial reduction of pesticide use ensuring cost optimization. Development of farmer friendly practices like application of Nitrogen in splits along with slow release fertilisers such as Neem coated urea help to meet the dual goal of higher yields and lower pest incidence. Novel practice of using leaf colour charts is recommended for optimized use of nitrogenous fertilizers. Site specific nutrient management is another practical means available to rice farmers to get direct benefits of pest suppression at no additional cost. Application of organic manures like FYM or vermicompost facilitates build-up of beneficial populations of detrivorous and plankton feeders as well as natural enemies or pest antagonists, both below and above the water.

Precision farming based on intensive grid-sampled information obtained by GIS and global positioning system (GPS) is the futuristic dimension initiative under AICRIP towards development of efficient soil and plant health management systems in rice.

Conservation and utilization of bio control agents

AICRIP studies have led to a comprehensive understanding of rich and diverse wealth of beneficial biological control agents and their natural *in situ* interactions in rice ecosystems, for optimum use as key components of IPM. Augmentative releases of natural enemies can further be made to supplement the efforts for their natural conservation. Release of egg parasitoids, *Trichogramma japonicum* adults against yellow stem borer and *T. chilonis* against leaf folder are recommended to supplement the already existing natural populations of these parasitoids and thus increase the per cent parasitism in rice fields (Gururaj Katti *et al*, 2007).

In the last decade, Biointensive pest management strategies (BIPM) have been developed to strengthen the natural regulatory mechanisms for *in situ* management of pest populations with least disturbance to the balance of nature. BIPM focusses more on measures to restructure the agricultural ecosystem towards conservation of natural enemies to the disadvantage of a pest. Habitat manipulation through naturally innovative strategies such as use of trap crop and ecological engineering, are few of the attempts designed to protect rice crop with minimum damage to the environment. Modifying rice habitat by growing aromatic rice, preferably Pusa Basmati 1 as a trap crop can effectively help in the management of yellow stem borer as this pest prefers scented rice as host over the non-scented varieties. The technique was systematically evaluated through multi-locational testing under AICRIP and is recommended for stem borer endemic areas. It is particularly useful in rice-rice cropping system of the peninsular region (Padma Kumari *et al* 2017).

Similarly, Ecological engineering for natural enemy impact / conservation biological control has also been found successful for the management of planthoppers (Chitra Shanker *et al*, 2016). Growing flowering plants such as marigold, pulses like cowpea soybean *etc.* on bunds surrounding paddy fields can effectively help in reducing planthopper pests in paddy fields in an eco-friendly way. These crops serve as reservoirs of natural enemies by acting as pollen and nectar sources to attract natural enemies of planthoppers.

Behaviouristic manipulations using sex pheromones

Pheromones are the chemicals produced by one species that affect the behaviour of other members of the same species. They are usually very specific to the species that produce them. Pheromones have no adverse effects on the biota or the environment, are unaffected by rain fall and hence would be fully compatible with an integrated pest management (IPM) approach to control rice pests.

Sex pheromones have been found promising for the management of yellow stem borer (YSB), in monitoring as well as direct control through male annihilation by mass trapping. The rationale of pheromone mediated mass trapping technique is to place enough traps to concentrate pest insects into a restricted space (catch enough males) and leave the females of the species without mates. Extensive multi location trials have revealed that mass trapping technique offers great promise against monophagous pests like yellow stem borer, particularly in areas where the crop is cultivated extensively and contiguously (Krishnaiah *et al* 2004).

Chemical management

Pest management using chemicals with its curative effects and ease of application continues to be an important choice of the farmers for managing insect pest populations in rice. Regular screening and evaluation of newer insecticide molecules for their efficacy against rice pests under AICRIP has helped in the identification of suitable chemical options in different cropping system regimes depending on pest prevalence (Krishnaiah *et al* 2008). In the last decade, Chemical control studies have shown that newer chemicals and botanicals with novel modes of action and effectiveness at very low doses are compatible with other pesticides and have the potential to fit well into rice IPM programmes.

Newer Insecticide	Target pest
i. Fipronil @ 50 g a.i./ha, ii. Sulfoxaflor 24% SC w/v (21.8% w/w) @ 75 & 90 g a.i./ha, iii. Imidacloprid plus ethiprole (Glamore 80 SG) @ 100 g a.i./ha, iv. Triflumezopyrim (DPX-RAB 55 106 SC)., @ 25 g a.i./ha, v. Dinotefuran (Token 20 SC) @ 40 g a.i./ha	Planthoppers
i. Coragen 20% SC (Rynaxypyr) at 30 g a.i./ha, ii. Acephate 95% SG (Acephate) @ 500 g a.i./ha iii. Spinetoram 6% w/v (5.66% w/w) + Methoxyfenozide 30% w/v (28.3% w/w) SC @ 135 & 144 g a.i./ha	Stem borer. leaf folder and other lepidopteran pests
i. Buprofezin 20% + Acephate 50% WP (RIL- 049/F1) @ 1000 g/ha ii. Flubendiamide 4% plus buprofezin 20% SC(RIL-IS-109) @ 1000 g a.i./ha iii. Flubendiamide 240% g/L plus Thiacloprid 240% % g/L (Belt Expert 480 SC-g/L) @ 120 g a.i./ha	Stem borer and planthoppers

Source: AICRIP Progress Reports, Vol. 2 (Crop Protection)

However, use of pesticides is recommended only in situations of pest outbreaks or resurgences or only as a last resort when alternate options do not yield results. Also, farmers are advised to use only the Government approved insecticides as per the recommended list available on the website of Directorate of Plant Protection, Quarantine & Storage, Faridabad, under the Ministry Of Agriculture & Cooperation (major use of pesticides as on 30.11.2021.pdf ppqs.gov.in). For effective chemical use, the correct choice of active ingredient, suitable formulation, time of application and application techniques need to be made based on pest biology and crop phenology. Ongoing research on the uses of unmanned aircraft (drones) for various agricultural activities, including surveying fields; crop health and watering; application of pesticides and fertilizers provides the scope of using chemicals in more effective and environment friendly manner.

Use of biopesticides and botanical pesticides though advocated as environment friendly component of IPM, is another potential area in need of a fresh relook in the light of new developments in advanced chemistry and formulation technology. Newer analytical standardization tools can improve and refine their performance as effective, cheap and widely available alternative products for ready use by farmers.

IPM evaluation and verification

IPM is the most appropriate approach to overcome biotic stresses and obtain sustainable rice yield with least damage to the environment. Earlier workers verified and demonstrated the efficiency as well as cost effectiveness of location specific IPM technology on farmers' fields compared to conventional farmers' practices. However, in order to make IPM more adaptive, there is need to develop more than one IPM modules at every location thereby addressing to the plant protection needs of diverse farmers' situations within and across the rice ecosystems. AICRIP has provided an ideal mechanism to evaluate and demonstrate location specific IPM modules for superior performance and cost effectiveness at each location in different rice ecosystems of the country. Multi-disciplinary team of scientists have contributed towards more efficient and practical IPM modules differing in their package of optimized pest management components to address the requirements of farmers across the rice ecosystems (Gururaj Katti *et al*, 2022; AICRIP Progress Reports 2015-2020). The IPM modules have shown clear superiority to the farmers' practices in terms of higher benefit cost ratios.

Conclusion – A personal Note

AICRIP is a unique and broad based programme with a well thought out set of objective criteria to evaluate rich rice breeding material of the country involving local landraces, diverse germplasm, advanced breeding material across multi locations representing the different rice ecosystems of the country. The ultimate aim is to develop high yielding and nutritionally fortified rice varieties along with suitable production and protection technologies to ensure economic and social benefits to the rice farmers and meet the rice consumption needs of general public in the country. The uniqueness of AICRIP lies in the holistic teamwork of multi-disciplinary rice research workers belonging to ICAR, Central and State Agricultural Universities, Private Sector agencies and State Departments of Agriculture in tandem with progressive farmers contributing to the strength and authenticity of the programme in producing realistic outputs. In AICRIP, all the cooperating centres are provided with adequate opportunities to contribute and test breeding material along with research infrastructure support across multi disciplines to efficiently carry out the programme. AICRIP's framework of multi location and multi-disciplinary generation and evaluation of research material through a healthy spirit of competition and exchange of scientific information across multiple stakeholders, has been instrumental in rapid progress of rice research over time and space in India. Recently, Government of India (GOI) has endorsed the need to develop an efficient Natural Farming based sustainable programme to tackle ill effects of modern intensive agriculture. AICRIP offers an efficient and holistic mechanism to evaluate and assess the potential of this chemical-free alias traditional farming method's role in the future rice production roadmap of the country.

On a personal note, AICRIP has profoundly enriched my experiential learning through exposure to very diverse range of rice ecosystems and constant interaction with vastly talented, experienced and committed rice research workers across the country. AICRIP is very well equipped and ever ready to embrace the fast paced advances in cutting edge technologies in rice research heralding a potentially promising future.

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