Biotic stresses of agricultural crops in India: re-visiting national status and mitigation strategies

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Food crops in India suffer from many newly emerging and invading biotic stresses, i.e. insect pests/diseases/weeds. For sustainable food production, it will be worthwhile to switch into novel mitigation measures rather than protecting the crops by traditional methods of pest management which are now outdated and incompetent. Emphasis must be laid on the identification of novel mitigation measures based upon molecular markers, transgenes, gene-editing technologies, nanotechnology, etc.

In 2018–19, the food-grain and horticultural production touched 285 and 300 million MT respectively, in India[1,2]. This may be attributed to the green revolution technology that steered national food security, but at the same time caused redundant ecologies which favoured the build-up of biotic stresses in crops as many minor pests assumed the status of major pests and several new pests appeared. In addition, the flawed use of pesticides has led to problems of pesticide resistance, resurgence and contamination of the environment. In addition, climate change exerts a profound effect on the intensity of pest problems, that includes both the increase in severity as well as parasitic/virulent forms in both insects and microbes.

It is estimated that insect pests cause 15–20% yield loss in principal food and cash crops in India[3]. The scenario on key pests of crops has been changing rapidly owing to climate change, injudicious use of chemical pesticides and other human interventions. The pests emerged as their incidence on a particular crop increased considerably over a period of time, causing or likely to cause economic damage[4]. Sucking insect pests, mirid bug, mealybug, whitefly, aphids and plant hoppers on major crops; *Helicoverpa armigera* on vegetables and pulses; *Spodoptera litura* on vegetables, cotton and oilseeds; *Pieris brassicae* on crucifers; *Liriomyza trifolii* on vegetables; *Atherigona* spp. on spring maize; aphid complex like *Sitobion avenae*, *Rhopalosiphum maidis* and *Schizaphis graminum* on wheat, barley and oat; green mirid bug, *Creontiades biseratense* on cotton in Karnataka, Tamil Nadu, Maharashtra and Andhra Pradesh; eriophyiid and tetranychid mites on bean, brinjal, cotton, cucurbits, okra, apple, ber, citrus and mango in North India; *Maruca vitrata* on pigeon pea and cowpea in Andhra Pradesh, sugarcane pyrilla on wheat, oat, barley in Chhattisgarh have been reported to emerge in India[5–8]. The possible reasons for this emergence of pests are climate change provoking ecological impacts leading to change in herbivory, increased overwintering, increased number of generations, breakdown of host resistance as well as change of genotypes/impact of transgenics, injudicious use of pesticides, and modification of cultural practices/tillage. Invasive insect species are also an increasing threat to Indian agricultural commodities resulting in huge economic losses[9]. Since 1889, a total of 24 insect species have been reported to invade India[10]. The basic information on bioecology, genetic make-up, geographical distribution, resistant cultivars, augmentation of natural enemies, crop management practices, IPM and phytosanitary regulation of invasive insect species would be helpful to manage them. Changed patterns in climatic factors like temperature, precipitation, humidity and other meteorological parameters could impact on changes in biology and ecology, increased pest population and their damage potential by expanding distribution, enhanced survivability, allowing to develop adaptability, alteration in tritrophic interaction, outbreaks, migration, species extinction, change in host shift, emergence of new pests or biotypes, which in turn increase yield loss by a further 10–25% (ref. 11). The process of evolution of resistance in various pest species against pesticides is a major challenge for applied evolutionary biologists[12]. The resistance development in field populations is influenced by biological, genetic and operational factors[13]. An estimated 954 pest species have developed resistance against various types of pesticides[14]. Resistance detection helps in avoiding ineffective molecules and assists in making a proper recommendation of alternative molecules that are less resisted and can effectively control insect pests. This prevents wastage of pesticide applications that would have otherwise harmed the environment without actually having served the designated purpose of pest management[15]. Periodical monitoring and following insecticide resistance management suggested by the Insecticide Resistance Action Committee (IRAC) would be useful to manage the insecticide-resistant insect populations[1].

Fungal diseases are another major threat to the most important crops and fungal pathogens causing large yield losses in different crops are well documented, which can be exemplified by the Bengal famine in India in 1943 due to the destruction of rice by *Helminthosporium oryzae*, and stem rust (*Puccinia graminis* f. sp. *tritici*) destruction of wheat in the pre-independence era. Blast (*Pyricularia oryzae*) of rice remains the most important fungal disease in India; however, sheath blight (*Rhizoctonia solani*) severity and spread has drastically increased in almost all rice-growing regions during the past few years[16], causing major yield losses as well as increased fungicidal sprays, as no effective resistant cultivars are available. Similarly, increased occurrence with high severity of false smut disease of rice has been observed in recent years. Among other cereals, large area under wheat is continuing to be vulnerable to stripe/yellow rust pathogen (*Puccinia striiformis*), which is evolving regularly rendering varieties susceptible. Leaf blight of wheat is another disease which is becoming serious and also spreading due to changing climatic conditions. Stalk rot, downy mildew and different leaf spots are the major constraints in maize crop in India, and sugarcane red rot with continuous emergence of variability in the pathogen is posing serious threat to sugarcane[17]. The emergence of virulent tropical race 4 (TR4) of *Fusarium* wilt has a devastating effect on banana cultivation in the world.

It has also been detected in India in recent past with high incidence and crop damage[18]. Climate change has posed a stiff challenge to sustainability of the series of *Sr* genes in wheat governing resistance against Ug99 race of *Puccinia graminis* f. sp. *tritici*[19]. Elevated temperature and CO_2 have also posed serious threat to potato to virulent isolates of late blight (*Phytophthora infestans*) and rice to blast and sheath blight[19]. Different economically important crops are now vulnerable to viruses which will be responsible for heavy crop loss in India. Due to the variability of strains, both viruses and their vectors, and also because of environmental factors, threatening plant virus diseases could not be managed successfully in several crops. There are also over 200 plant pathogenic bacterial species affecting plant health and those considered to be the most important belong to the genera of *Pseudomonas, Ralstonia, Agrobacterium, Xanthomonas, Erwinia, etc.* Although emerging bacteria and plant viruses observed in different crops exhibit limited incidence and effect on yield; in future they may cause heavy loss once they establish on alternate crops and weed hosts. Hence intensive research studies are required on the emerging bacterial and viral diseases of various crops. Plant parasitic nematodes, particularly the root-knot nematodes, *Meloidogyne* spp., cause severe yield loss to vegetable crops under intensive cultivation. They also became a major threat to protected cultivation of vegetables and ornamental crops. Rice root-knot nematode, *M. graminocola* has established in low-land rice cultivation. *Pratylenchus* spp. and *Rotylenchulus* spp. are noticed in very high frequencies in important pulse and oilseed crops of the country. Guava and pomegranate crops race severe threat from invasive nematode pest, i.e. *Meloidogyne enterolobii*[20]. The major weeds causing severe yield reduction in several crops include *Parthenium hysterophorus*, *Eupatorium adenophorum*, *Eupatorium odoratum*, *Mikania micrantha*, *Ageratum conyzoides* and *Galinsoga parviflora*. *Ageratum conyzoides* L. is an annual weed native to South America that has invaded and now naturalized several parts of southern Asia, including India[21]. Parasitic dodders (*Cuscuta* spp.) are becoming a serious problem in agro-ecosystems of South India and are being seen increasingly on many plants, including pulses and oilseeds throughout the country[22,23].

Conventional plant protection measures in vogue are suffering from loss of qualitative resistance of resistant cultivars due to the use of a limited number of genes (mostly major genes), paving the way for emergence of new strains with aggravated virulence, hazardous environmental risks of using chemical pesticides, farmers' distrust of biocontrol methods, emerging biotic stresses in the era of climate change and transboundary invasions, etc. Innovations in biotic stress management should include nanotechnology in pest management, fumigants, volatile and acoustic techniques for stored grains, post-harvest and vertebrate pest management, elaborated tritrophic pheromone/kairomone studies, identification of broad-spectrum resistance, utilizing wild species genepool, deployment of remote sensing technology for pest management, development of disease/pest prediction models, determination of factors leading to evolution of pests and pathogens, and development of technologies to minimize the adverse effect of climate change on biotic stresses of plants. Precision on pest survey/surveillance will be more if based upon artificial intelligence by establishing an automated detection system applying remote sensing, image processing, soft computing, etc.

Transgenic crops, though proven to be safe with benefits, are still debated for emergence of superweed species and breach of valuable genetic diversity of crop plants available at their source areas. Future research should target novel and innovative methods developed after deciphering the molecular mechanism of host–pathogen/insect interactions. The next generation of transgenic products in the field of crop protection should focus more on the use of antimicrobial peptides, recombinant antibodies, gene silencing, CRISPR/CAS 9, etc. Host-induced gene silencing and spray-induced gene silencing by applying miRNA and sRNA offer best alternatives to using ecologically hostile chemotherapeutants for the management of biotic stresses in agricultural crops.

1. http://nhb.gov.in/Statistics.aspx?enc (accessed on 15 May 2020).
2. https://economictimes.indiatimes.com/news/economy/agriculture/final-production-estimate-2018-19-india-clocks-record-foodgrain-production/printarticle/74102786.cms (accessed on 15 May 2020).
3. Rathee, M. and Dalal, P., *Indian J. Entomol*., 2018, **80**, 267–281.
4. Sharma, H. C., Pathania, M., War, M. A., Pavani, T. and Vashishth, S., In Proceedings of a National Conference on Pulses, ICAR-Indian Institute of Pulses Research, Kanpur, 2016, pp. 124–137.
5. Udikeri, S. S., Kranthi, K. R., Patil, S. B. and Khadi, B. M., *Karnataka J. Agric. Sci*., 2012, **23**, 153–156.
6. Halder, J. and Srinivasan, S., *Ann. Plant Prot. Sci*., 2012, **20**, 205–269.
7. Murali Baskaran, R. K. *et al.*, *National Status of Biotic Stresses of Crops*, ICAR-National Institute of Biotic Stress Management, Raipur, Chhattisgarh, India, 2018, p. 174, ISBN: 978-81-942788-1-8.
8. Mallikarjuna, J., Yele, Y. and Jain, S. K., *Indian J. Entomol*., 2019, **81**, 516–517.
9. Sharma, K. R., Jaiswal, D. K., Babul, S. R. and Saraoj, A. K., *Indian J. Agric. Allied Sci*., 2018, **4**, 19–25.
10. Gupta, N., Verma, S. C., Sharma, P. L., Thakur, M., Sharma, P. and Devi, D., *J. Entomol. Zool. Stud.*, 2019, **7**, 482–489.
11. Shrestha, S., *Acta Sci. Agric*., 2019, **3**, 74–80.
12. Gould, F., Brown, Z. S. and Kuzma, J., *Science*, 2018, **360**, 728–732.
13. Sarwar, M. and Salman, M., *Int. J. Bioinformat. Biomed. Eng.*, 2015, **1**, 344–351.
14. Kole, R. K., Roy, K., Panja, B. N. and Sankarganesh, E., *Indian J. Anim. Health*, 2019, **58**, 53–70.
15. Kranthi, K. R., Indian Society for Cotton Improvement, Mumbai, 2012, pp. 1–70.
16. Laha, G. S. *et al.*, Technical Bulletin No. 91, ICAR-Indian Institute of Rice Research, Hyderabad, 2017, p. 95.
17. Chhabra, M. L., Parameswari, B. and Viswanathan, R., *Vegetos*, 2016, **29**, 1–4.
18. Thangavelu, R., Mostert, D., Gopi, M., Devi, G. P., Padmanaban, B., Molina, A. B. and Viljoen, A., *Eur. J. Plant Pathol.*, 2019, **154**, 777–786.
19. Gautam, H. R., Bhardwaj, M. L. and Kumar, R., *Curr. Sci.*, 2013, **105**, 1686–1691.
20. Walia, R. K. and Chakrabarti, P. K. (eds), *Nematode Problems of Crops in India*, ICAR-All India Coordinated Research Project on Nematodes in Agriculture, 2018, p. 400.
21. Pimentel, D., Lach, L., Zuniga, R. and Morrison, D., *BioScience*, 2000, **50**, 53–65.
22. Mishra, J. S., Moorthy, B. T. S., Bhan, M. and Yadurajy, N. T., *Crop Prot.*, 2007, **26**, 625–629.
23. Mishra, J. S., *Indian J. Weed Sci.*, 2009, **41**, 1–11.

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