

## Insect Pest Challenges and Sustainable Management under Climate Resilient Regenerative Agricultural Production System

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Extreme climate variability resulted in ecological intensification and modification of insect pest population dynamics including enhanced overwintering survival, accelerated metabolic rates, disruptive trophic anomalies. Moreover, unpredictable climate variability have adverse effect on insecticide efficacy, promoting pest resistance, failure of forecasting models. Indiscriminate use of synthetic chemicals without due consideration on mode of action, efficacy, persistence, degradation in agro-ecology have make pest management protocols less effective under the backdrop of global climate crisis.

There should be a paradigm shift in planning for concerted, prudent, plant protection management protocols alleviating climate anomalies and fostering global agricultural research perspective for climate resilient, smart, sustainable agricultural production system for feeding the burgeoning population of the universe.

Agro-Ecosystem Analysis, regular survey and surveillance, scouting, insect pest monitoring and application of drone technology, Remote sensing, intervention of various traps like Light Traps, Malaise Traps, Adhesive Traps, Flight Interception Traps, Bowl Traps, Bucket Traps, Pitfall Traps, Soil Emergence Traps, Aquatic Arthropods Traps, Lindgreen Funnel Traps, Pheromone Traps, Camera Equipped Traps and development of predictive forecasting and management model protocols need to be strictly followed for sustainable management. The use of Nano-gelled pheromone resulted in effective, environmental friendly regulation of fruit flies *Bactrocera dorsalis*, the menacing pest affecting the crop productivity and quality of various fruit crops. Such technology need to be universally explored for management of the pest in various crops. Botanicals like Neem (*Azadiracta indica*), Pyrethrum, Nicotine, Rotenone, Sabadilla, Rytania etc. for their eco-friendly nature and bio-efficacy for suppressing insect pest population dynamics may offer an integral component for sustainable management.

Banker plant system offer an effective strategy for biological control in protected cultivation as well as normal crop fields. Banker plant system encourage the sustenance of population of natural enemy, facilitate the proliferation of beneficial organism and also facilitate the early introduction of natural enemies thus ensure less load of synthetic chemicals in agro-eco-system. Additionally Push and Pull system strategy through manipulation of behaviour of pest and natural enemies and also incorporating a repellent intercrop alongside attractive trap crops should be explored for successful management of insect pest.

Host plant resistance strategy involves the deliberate use of resistant crop varieties independently or in combination with other strategies to mitigate the effect of herbivore on crop yield and quality. Recent concept of Ecological Engineering as a framework for evaluating integrated pest management under the climate anomalies as resilient agricultural practice depending on utilizing crop cultural practices for influencing habitat modification and promoting biological control. Ecological Engineering supports the conservation of beneficial microbes and natural enemies that minimizes the carryover of pest population for ensuing crop season. Even Host Induced Plant Volatiles (HIPV) play a pivotal role in plant signalling to the natural predators of the insect herbivores, their neighbouring plants and various parts of affected plants and facilitate the interaction between plants and micro-organisms. The emission of a diverse range of HIPV in response to herbivore injury and their functional dynamics in plant communities usher in a new dimension of intricate relationships among various trophic levels. Moreover the HIPVs also act as deterrents to feeding and or oviposition by insect pests.

Nutrient enrichment amended with silicon through diatomaceous earth minerals with standardised graded doses will be a viable management protocol for Stem borer, a polyphagous pest for major crops.

Bio-agents through their multiple mechanisms like antibiosis, parasitism, competition, induction of host plant resistance need to be utilized for effective Integrated Pest and Disease Management practices. Agro-ecological and eco-physiological approaches through the activity of natural enemies particularly entomopathogenic nematodes like *Steinernema*, *Heterorhabditis* spp, NPV, Bt through their population dynamics and behavioural ecology need to be exploited judiciously for eco-friendly pest and disease management. Although entomopathogens, diverse group of insect pathogenic microorganism face challenges pertaining to environmental stability and field persistence, development of improved strain, novel formulation technology offer eco-friendly and sustainable pest management network reducing reliance on synthetic insecticides to reduce environmental and ecological hazards. Arbuscular Mycorrhizae and Myco viruses can be successfully utilized for integrated management strategies under climate resilient Regenerative Agriculture with great efficacy.

Although climate Resilient Regenerative Agriculture largely exclude chemical pesticides, need based application of new generation eco-friendly novel pesticide molecules through micro-irrigation system through Chemigation are highly effective against targeted pest and having reduced risk for environment and resistance development. The research on pesticide Chemistry should focus on development of chemicals having specific mode of action like chordotonal activity, juvenile hormone mimic, chitin synthesis inhibitor, blockage of sodium channel, inhibition of GABA based on the feeding habits and behavioural approach, growth developmental and multiplication pattern for targeted insect pest invading the crop plants for facilitating Integrated Resistance Management (IRM) under the realm of sustainable Management strategy.

Application of Nano-Technology with application of nano-emulsion, nano-suspension, nano-capsulation, nano-particles that exhibit specific physical, chemical and biological characteristics having slow degradation and controlled release of active ingredients should be effectively implemented for sustainable Insect Pest Management under climate crisis, a global burning issues in Agriculture, food safety and Ecology.

Weed management in conservation tillage, practices under other regenerative farming practices are difficult unless new novel non-chemical management strategies are developed. In developed countries research are being conducted for evolving non chemical strategies for sustainable weed management in arable crops. Integrated weed management encompassing physical, cultural, genetic, biological and eco-physical approach is a way forward for sustainable weed management under climate resilient Regenerative Agriculture. Allelopathy is one of the important potent tool for weed management. Although soil microbes have ability to reduce weed seed bank, due to lack of selectivity and inconsistency in field efficacy, there is significant barriers for development of suitable Myco-herbicides or bio-herbicides for successful weed management strategies. However deferred seeding of some crops having early vigour with enhanced weed competitiveness traits like black gram or other leguminous cover crops in cereal crop field as eco-physiological approach are promising for sustainable weed management strategy under climate smart Regenerative Agriculture. Recent advancement of some technology for post emergence weed control through integration of digital image analysis with automatic harrowing intensity adjustment can be effectively implemented for successful weed management under the backdrop of climate resilient Regenerative Agriculture.