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PUSH-PULL STRATEGIES IN INTEGRATED PEST MANAGEMENT

Veena P. Swami, Tabrez Ahmad, Vivek Kumar Dixit and Nootan Singh

PG Department of Zoology, BSNV PG College Lucknow, U.P INDIA , [ASIA]

Corresponding author Email:- dixit.vivek1991@gmail.com

ABSTRACT:-

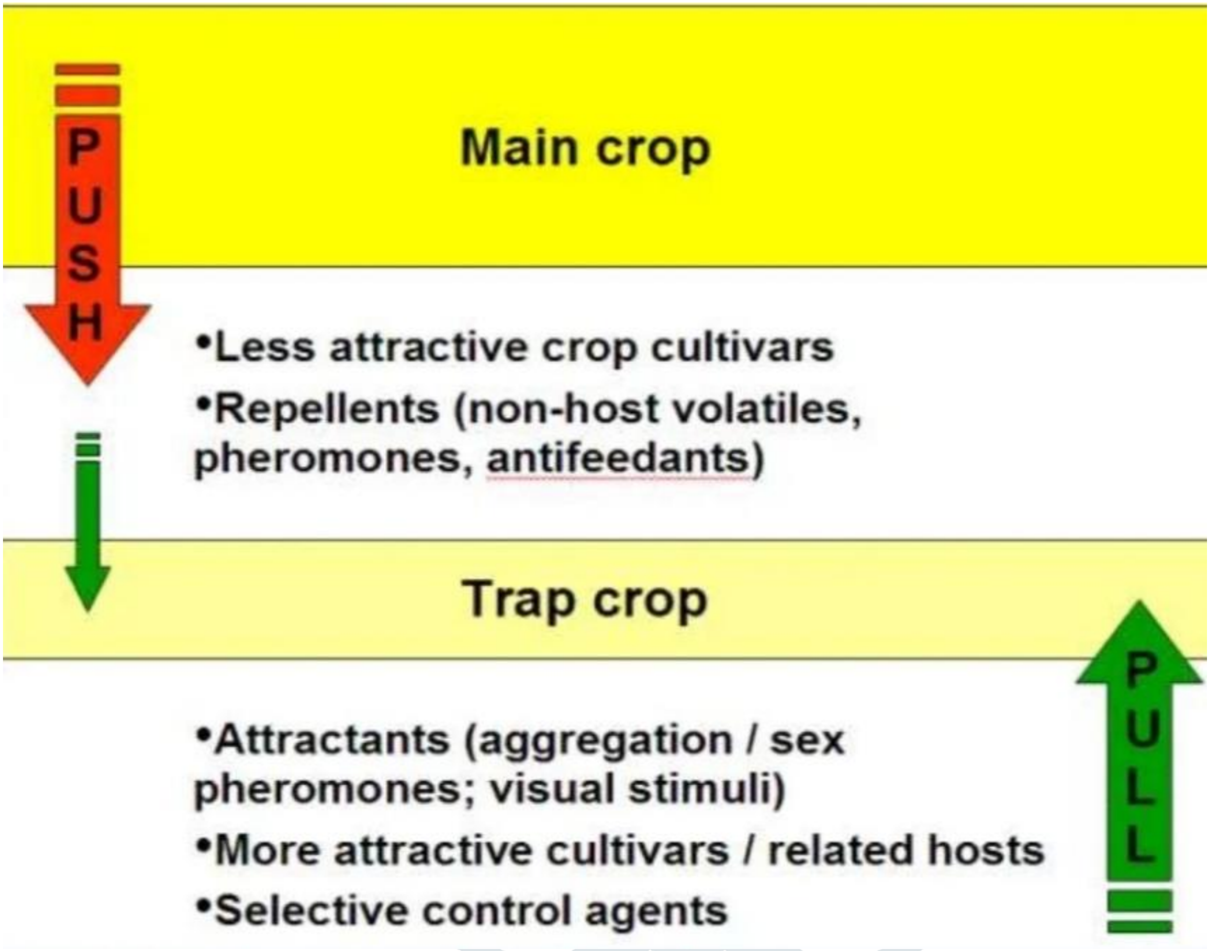
The push-pull strategy is a behavioural manipulation method that uses repellent/deterrent (push) and attractive/stimulant (pull) stimuli to direct the movement of pest or beneficial insects for pest management. Stimuli used for behavioural manipulation in push pull strategies include visual and semiochemical cues or signals that work by nontoxic mechanisms. Such strategies are therefore integrated with other population-reducing methods. Sustainable and environmentally sensitive components are favoured, and the use of insecticides can be reduced. The push-pull strategy undertakes a holistic approach in exploiting chemical ecology and agrobiodiversity.

Push-pull strategies targeted at pest insects are being developed in all major areas of pest management. However, their use is currently underexploited. Changing attitudes toward replacing broad-spectrum insecticides with new technologies, particularly semiochemical tools, to manipulate the behaviour of natural enemies for biological control will enable improved push-pull strategies to be developed and used more widely in the future. This paper summarizes the principles of the push pull strategy. Its potential components like semiochemicals, host-plant resistance, trap crops and selective pesticides or biological control agents and examples of practical applications of push pull strategies in integrated pest management.

Key words: Push, Pull, Semiochemicals, Habitat management, Trap crops.

I.INTRODUCTION:-

Pest management is the science of preventing, suppressing, or eradicating biological organisms that are causing a problem. The term "*Integrated Pest Management"* (IPM), implies integration of approaches and methods into a pest management system, which takes into consideration the ecology of the environment and all relevant interactions that pest management practices may have upon the environment in which one or more pest problems may exist. When IPM principles are applied to a given pest problem, it is generally assumed that environmental impact and economic risks have been minimized. Since IPM considers all applicable methods, it is also assumed that emphasis on chemical methods may be reduced when effective non-chemical alternative methods are available.



(Fig;1)

Push-Pull strategy in IPM is a behavioural manipulation strategy in which behaviour-modifying stimuli are integrated for reaching the sustainable pest management goal. The efficacy of using this strategy for the pest control is enhanced with a combination of attractants ("pull") and repellent ("push") Fig. 1.

Semiochemicals are natural products that, by acting as signals, regulate interactions between organisms e.g. plants and insects. Once the semiochemical interactions between a pest and its host plant have been elucidated, they can be exploited to regulate the pest population, providing an alternative control strategy to conventional toxicants. The choice of approach by which the semiochemicals are deployed relates to three options, i.e. from a natural plant source, from an extract or as a nature identical synthetic product. However, even where the most natural situations of mixed cropping are used, the scientific basis of the interaction must be established for robustness and sustainability of the approach. A complete understanding of the process allows a risk assessment to be made of any problems that might ensue when exploiting natural systems in different configurations from those encountered naturally.

A major approach to using semiochemical based pest control is to exploit ways of repelling pests from crop plants and attracting them towards trap plantations. Deploying semiochemicals generated naturally by plants is useful inorganic farming practice, where a range of mixed cropping techniques are employed already, which unconsciously utilize semiochemical effects. Thus, the acceptance and use of systems exploiting aspects of semiochemical deployment demonstrate an emerging role in organic farming practices. However, a comprehensive knowledge of the semiochemical interactions that underpin these techniques is vital if they are to be exploited fully.

Semiochemicals generated naturally by plants can be used to influence beneficial organisms as well as invertebrate pests. For example, plant defence chemicals, induced by pest or pathogen infestation, can affect the behaviour of pests and their natural enemies. Semiochemicals can be employed to maximize the impact of parasitic organisms that attack pest populations, for example, in the management of refugia for maintaining and increasing populations of these beneficial organisms. In addition, the approach can be applied against other organisms antagonistic to agriculture besides invertebrate pests. for example in weed control, where signals interfering with weed germination can be exploited.

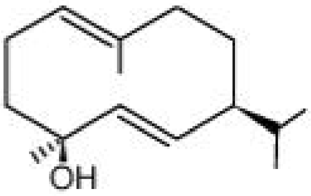
By understanding the composition and the mechanism of activity of semiochemicals, natural product extracts can be improved by selection of the best sources of natural materials and appropriate processes of extraction and formulation. Many natural products, particularly pheromones (semiochemicals acting between members of the same species), can be synthesized as nature-identical and the synthetic forms are often indistinguishable from the natural form. Synthesis can be expensive, but where possible, starting materials should be obtained from natural renewable resources. Nature-identical synthetic pheromones are used widely in parts of the world, either deployed in traps for monitoring, mass trapping and lure and kill strategies or for direct pest control approaches such as mating disruption. The synthetic and botanical pesticides basically effect on the beneficial insects ; and these pesticides also show the impact on heath of farmers and environmental damage.[32]

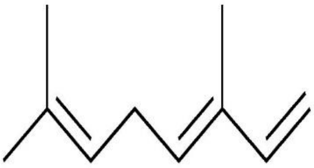
In addition, manipulation of beneficial species with pheromones is being investigated and synthetic food-related attractants and oviposition attractants have also been developed for pests where pheromones are not available. Already some nature identical synthetic semiochemicals have been accepted as compatible with organic farming practice. The registration of many sex and aggregation pheromones has been possible because they are nature-identical and are deployed away from the crop or on crop areas that are not consumed.

In most cases, semiochemicals, deployed alone, are not sufficiently robust to control pest populations directly. They are most effective when incorporated into strategies, such as the 'push-pull strategy, that are integrated with other forms of pest control, e.g. pathogens, parasitoids and predators, mechanical barriers and resistant plant varieties. The integration of semiochemical approaches with other methods of pest population reduction will help prevent the development of pest resistance to the overall strategy. Since the integrated strategy comprises a number of components that affect different aspects of pest behaviour and development each component can be relatively ineffective when compared to conventional pesticides. However, this has the advantage of not selecting efficiently for resistance to any component of the strategy and thus contributes to the sustainability of the approach.

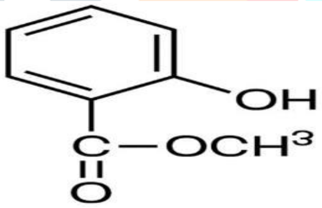
II. STRESS RELATED SEMIOCHEMICALS:-

Stress related compounds can also be active in increasing foraging by predators and parasitoids which attack the pests. The compounds involved come from a wide range of biosynthetic pathways, but prominent in these are the isoprenoid and lipoxygenase pathways. For example monoterpenes such as (*E*)-ocimene, and sesquiterpenes such as ( )-germacrene D. (Fig. 2) can be produced by plants and cause repellency to herbivores.





(E- Ocimene)



(Methyl Salicylate)

(Germacrene -D)

(Fig;2)

Recently, it was found that the heterologous expression of an *(E)*-B-farnesene synthase in *Arabidopsis thaliana* can be accomplished so that large amounts of *(E)*-B-farnesene are produced, which can affect aphids and their parasitoids.

Additionally, drought stress only minimally alters secondary metabolism in *Brachiaria mulato*, with emission of key volatile organic compounds necessary for stemborer host location such as (*Z*)-3-hexenyl acetate not significantly affected .[6]

III. ROLE IN TRANSGENIC CROPS:-

Methyl salicylate (Fig.2) has been identified as a stress-related plant semiochemical. This compound, as predicted, is associated with avoidance of cereal crops treated with a slow release formulation of this material. Thus, in field trials, methyl salicylate applied to wheat significantly reduced (by 30-40%) the overall number of aphids colonizing the crop. [35] Methyl salicylate is biosynthetically related to salicylic acid, a signal of systemic acquired resistance [29] which may indicate that the plant is upregulating defence pathways associated with hormonal activity of salicylate and could thereby present difficulties for colonisation by herbivores. Salicylic acid is produced in plants via the phenylalanine ammonia lyase pathway, a pathway known to produce many secondary metabolites, some of which are used for plant defence; plant defence. Clearly, there is a role for transgenic cereal crops that could release methyl salicylate as an inherent semiochemical defence in the leaves.

IV. DOSE-RESPONSE OF SEMIOCHEMICALS:-

However, the effect was not long-lived and the formulation needed to continue to release to provide ongoing field activity. In the field, methyl salicylate was used in slow release formulations over three seasons to cause aphids to disperse, consistently reducing the aphid population in a cereal crop by up to 50 percent. Although this level of control is highly reproducible, increasing the methyl salicylate dose does not increase the dispersal effect. This lack of dose response, once the chemical takes effect, is typical of semiochemicals and emphasises the need to use them as one component of an overall pest management strategy. However, incomplete control using one particular semiochemical has the advantage of impeding the development of resistant pest species.

V. PRINCIPAL ELEMENTS OF BEHAVIOURAL MANIPULATION METHODS :-

The choice of a stimulus to be used for behavioural manipulation should depend on some desirable attributes: 1. Accessibility: The stimulus must be suitable for presentation in a form that the insect can perceive; 2. Definability: The more precisely the stimulus can be defined, the more precisely it can be reproduced artificially; 3. Controllability: The ability to control various parameters of a stimulus, including intensity and longevity, will give greater control in a behavioural manipulation; 4.. Specificity: The more specific a stimulus is to a particular behaviour of a pest, the more likely it can be used to manipulate that behaviour; 5. Practicability:

VI. USE OF SEMIOCHEMICALS IN PEST MANAGEMENT:-

SEX PHEROMONES:-

A combination of the sex pheromone which attracts males, and a food lure (a mixture of phenethyl propionate, eugenol and geraniol), which predominantly attracts females, has been used against the Japanese beetle, *Popillia japonica*. The combination trapped more males and females than the two attractants did when used separately .[25] Visual stimuli are also effective for this pest as the catch of beetles is greater in white traps than those of other colours.[26] Most work on the application of attractants to disrupt a finding behaviour has focused on mate location particularly of moths. Large amounts of synthetic females sex pheromone are applied as a slow release formulation to prevent males from finding females as a method of mating disruption .[4]

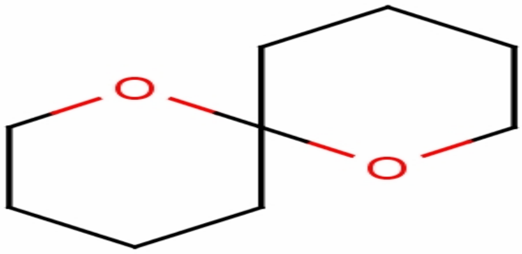
This method has been used successfully for control some pests as the cotton pink bollworm, *Pectinophora gossypiella* and the oriental fruit moth, *Grapholita molesta*, on stone fruits. The efficacy of mating disruption method is not satisfactory when the treated area is limited in size.

Ogawa *et. al.*,[33] stated that the area-wide use is the most important factor for success of mating disruption.

Cross *et*. *al*., [5] outlined a new method for the control of codling moth. *Cydia pomonella* and summer fruit tortix moth, *Adoxophyes orana* in apple orchard. The method entails luring the adult moth with semiochemicals to auto disseminators where the adults become contaminated with baculoviruses. Once adults are contaminated, the baculoviruses spread between individuals during mating and eggs together with the surrounding area can become contaminated during oviposition.

VII. AGGREGATION PHEROMONE:-

Interestingly, aggregation pheromones have been used successfully to trap insects of both sexes for controlling various Coleoptera, e.g. cotton boll weevil, *Anthonomus grandis* in the United States [17] and bark beetles in North America and Europe. [27] The olive fruit fly, *Dacus oleae*, a major pest of olives in the Mediterranean region, has been controlled effectively as with insecticides by an elaborate mass-trapping method.[16]

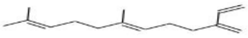


(**Fig; 3)** (1;7 – dioxaspiro undecane)

Females of this pest produce a blend of compounds that attract males over a distance. One of these compounds, 1,7-dioxaspiro undecane (Fig. 3) is also produced by males. The (R)-(-) enantiomer of this compound attracts only males and the (S)-(+) form of this compound elicits a response that appears to be aggregation by females. [15]. The method involves a combination of attractants and stimulants on an insecticide-treated wooden board.

VIII. ALARM PHERMONES:-

It is worth noting that alarm pheromones are also applied for increasing the efficiency of pest control means against aphids. Many species of aphids produce an alarm pheromone (E)-(B)-farensene (Fig. 4), which is normally released when aphids are attacked to increase their mobility and enhances chances of escape from natural enemies.

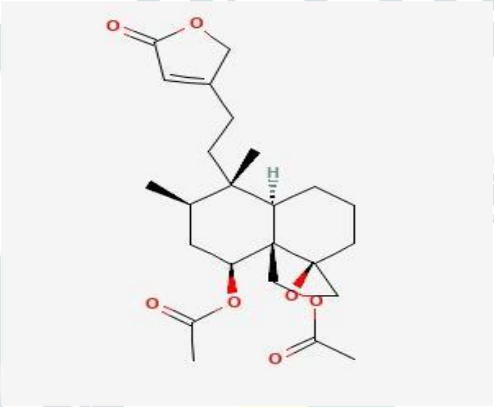


(Fig;4) (E)-(B)- farensene

This reaction to the alarm pheromone has been utilized to increase aphid contact with insecticides incorporated in synthetic pheromone formulation .[10] It is not surprising that the ingenious use of this strategy is also being applied successfully within the mosquito oviposition pheromone which has recently been used in Kenya to direct mosquitoes to lay eggs in specific pools where the emerging larvae could be destroyed by Juvenile hormone incorporated into the formulation or possibly with overcrowding factor.

IX. SIGNALLING CHANGES IN PLANT DEFENCE:-

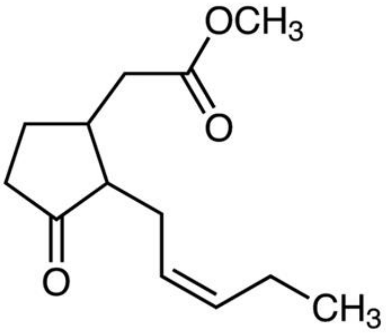
Ajugarin I (Fig. 5) is an antifeedant obtained naturally from the bugle plant *Ajuga remota* [9] It can be used in very low concentrations to deter feeding by Coleoptera such as the mustard beetle and also the major world pest, the Colorado potato Spraying the top parts of the plants with electrostatically charged droplets of a solution of ajugarin I deters the insect from feeding and forces them to the lower regions where their population is reduced with selective, insect growth regulating pesticides. Compared with conventional sprays, an electrostatic assisted spray is generally more efficient, because the droplets adhere to the plant, including the undersides of leaves, and less material is wasted needlessly spraying the soil.



(Fig; 5) Ajagarin I

Another metabolite resulting from the phenylalanine ammonia lyase pathway is 1,2-dimethoxybenzene, which has been shown by electrophysiology to be a highly active compound pivotal in the interaction between another sucking insect, the brown planthopper, and its host, rice. Genetic manipulation of rice plants could allow disruption of the process by which plants produce 1,2-dimethoxybenzene, by preventing the biosynthesis of its precursor compound, catechol.

Jasmonic acid and its corresponding ester, methyl jasmonate, also have important roles as signals in plant defence. For example, methyl jasmonate (Fig. 6) induces the production of protinase inhibitors in certain plants.



(Fig;6) Methyl jasmonate

This has the effect of preventing insects from digesting their food, by inhibiting the necessary proteinase enzymes. When methyl jasmonate is allowed to permeate into the air above oilseed rape plants, for example, this induces the production of indolylglucosinolates, secondary metabolites involved in the defence of certain vegetables. This could have the net effect of deterring any unadapted herbivores from feeding on the plants and preventing any further progression of disease.

X. PUSHING AND PULLING:-

Nevertheless, it is rare for a single semiochemical to be very effective when used alone. Instead, the usual approach is a 'push-pull' strategy which involves 'pushing' the insects away from the harvestable, economic crops, and 'pulling' them onto a trap crop where their population is reduced by a biological control agent (such as a fungal pathogen) or highly specific but slow-acting pesticide. Thus, antifeedants, non-host volatiles, parasitoid attractants and compounds associated with plant defence can be used to achieve the 'push', while the sex pheromone and host volatiles can be used to 'pull' the insects onto the trap crop.

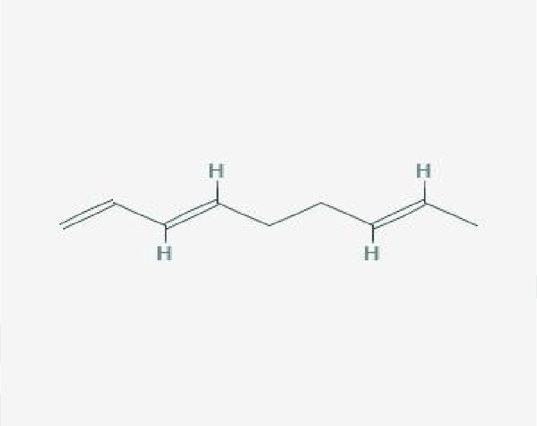
The benefits of a 'push-pull' strategy include a lower requirement for broad spectrum pesticides, saving these valuable materials for a 'fire fighting' role. In addition, there is less risk of producing populations of resistant insects. Because the components of a 'push-pull' strategy are not individually greatly effective, they do not select for resistance as strongly as conventional toxicant pesticides. Further, genetically modified plants that produce the key semiochemical like methyl salicylate could offer an environmentally cleaner solution for manufacture than conventional synthesis.

XI. TRAP CROPS IN PUSH PULL STRATEGY:-

MOLASSES GRASS*(Melinis minutiflora)*:-

In the field, although fewer stem borer larvae were found on maize where molasses grass was used as the intercrop, i.e. only the push component, and also in the full push-pull approach, there was increased parasitism as a consequence of increased foraging by the parasitoids. This could be explained by the release of (E)-ocimene and (E)-4,8-dimethyl-1,3,7-nonatriene by the molasses grass, which, as well as repelling adult stem borers, would also be expected to increase parasitoid foraging. These two compounds are well known to be produced by a range of plants, including maize [40] when damaged by larval feeding.

These compounds are released from grasses highly infested with stem borer larvae. Indeed, behavioural experiments showed that the (E)-4,8-dimethyl-1.3.7 nonatriene (Fig. 7), at a similar level to that released by the molasses grass, caused the same level of attraction as the molasses grass itself and the volatiles isolated by entrainment onto the porous polymer.[2]



(Fig ;7) (E) – 4,8 – dimethyl – 1,3,7,- nonatriene

Further studies, arising from attempts to understand why some wild grasses are more attractive than cultivated crop plants, have shown diurnal variation in the volatiles released by these plants.

XII. VETIVER GRASS (*Vetiveria zizanioides*):-

Vetiver grass technology is used globally as soil erosion management tool and in sustaining agricultural pproductivity. Vetiver grass technology, in its most common form, is the establishment of a narrow (less that I m wide) live stiff grass barrier, in the form of a hedge across the slope of the land .[14] Apart from its use as insect repellent and soil erosion management tool, vetiver grass has numerous traditional uses such as root paste for headaches and leaf paste for rheumatism and sprains . Commercial uses of vetiver grass mainly pertain to the extraction of vetiver oil through distillation of the roots. Vetiver oil has extensive applications in the soap and cosmetic industries and is also used as anti-microbial and anti-fungal agent in the pharmaceutical industry.[36]

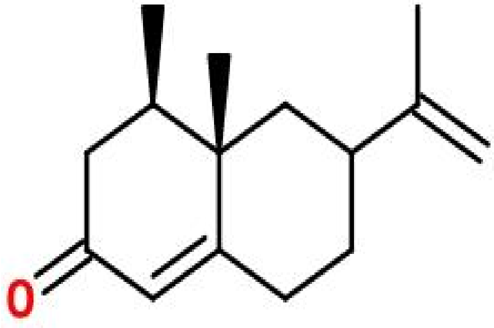
Stem borers (*Chilo partellus)* (Lepidoptera: Pyralidae) have been reported to infest culms and midribs of leaves of vetiver grass. An interesting observation was that although the levels of mortality amongst stem borer larvae were high and no pupae were ever found inside plants. In the worst case, the borer damaged approximately 39% of grass stems but no pupae were found [44] indicating that no larvae survived in the plants. An interesting observation made by ,[37] was that population densities of many of the herbivorous insects on vetiver was low and that they did not do any apparent damage to plants. Recent studies have demonstrated the beneficial effect of the combined use of *Brachiaria* and greenleaf *Desmodium* in the control of stemborers and striga, resulting in significantly increased grain yields.[23] Similarly *B. brizantha* also was found when ex-posed to *C. partellus* eggs to signal to the maize open pollinated varieties *Nyamula* and *Jowi* and the land race Cuba 91 causing these plants to release volatile attractants signals also for the parasitoid

Cotesia sesamia including the tetranorterpenes DMNT or TMTT.[30] If stem borer preference for vetiver grass is high, which seems to be suggested by these observations, the possibility exists that this plant could be used as a trap plant around crops on which stem borers are a problem. The strong attraction of vetiver grass for *C. partellus* moths makes this grass species an option as a trap crop in cropping systems where *C. partellus* is a pest.

XIII. VETIVER GRASS AS INSECT REPELLENT:-

Vetiver roots for example are used to repel cloth moths, head lice and bed bugs. Scientific reports do however exist of repellent compounds (261) present in vetiver oil extracted from roots of vetiver grass. Vetiver oil is a complex essential oil that consists of several hundreds of compounds of which six are reported to possess insect repellent properties. [18]

Zhu *et. al*.,[46] indicated that one of the components of vetiver roots, nootkatone (Fig. 8), was a strong repellent and toxicant to Formosan subterranean termites; *Coptotermes formosans* (Isoptera :Rhinotermitidae) and suggested planting of a barrier of plants that manufacturers a termite repellent could potentially provide repellence to this pest.



(Fig; 8) Nootkatone

Added-on benefits of vetiver grass technology is its use as insect repellent, its use in manufacture of building material, its slight use as animal feed and its possible use as a trap crop for *C. partellus*.

XIV. NAPIER GRASS (*Pennisetum purpureum)*:-

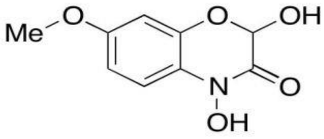
The added-on benefits of Napier grass, apart from its role as trap crop, are soil erosion management, large-scale use as forage and subsequent increased milk production as well as protection of crops against wind damage. Techniques of using wild grasses as trap crops for stem borers is used effectively in Africa in a push-pull strategy where Napier grass is used to concentrate oviposition away from maize crops and to reduce subsequent population development. [22] This principle of attractiveness for egg laying but low larval survival observed on certain grasses was exploited in the development of *habitat management systems* for stem borers in maize in Africa. The identification of alternative trap crops that could be used in cropping systems with maize, sorghum and rice, where stem borers are economically important pests, would be a significant contribution towards sustainable crop production. It has been reported that technologies such as vetiver grass or Napier grass as soil conservation measure will only be adopted significantly if there are added benefits to the technology other than a single benefit such as soil erosion protection. There are many similarities between the vetiver grass technologies as it is used for soil erosion management and Napier grass push-pull technology which is used for stem borer control. Vetiver grass has potential as trap crop component of an overall "push-pull" strategy to concentrate *C. partellus* oviposition away from the maize crop and reduce subsequent population development.

XV. BIOTECHNOLOGICAL EXPLOITATIONS IN PUSH-PULL APPROACH:-

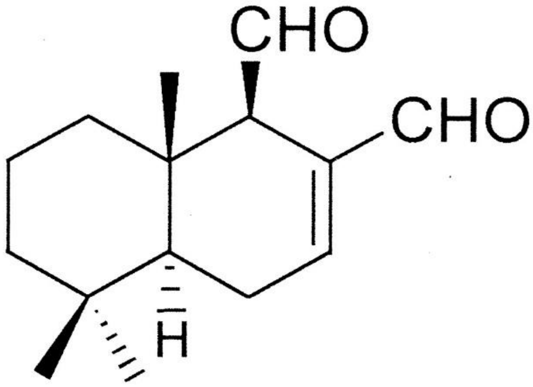
Two major developments are now set to revolutionize the use of semiochemicals First is the realization that semiochemicals cannot be used alone, but should be combined with population-reducing agents such as highly selective pesticides or biological control agents. Secondly, the use of biotechnology is essential, either for producing bulk semiochemicals that are already generated by higher plants as secondary metabolites, or for producing insect pheromones and their precursors by closely related metabolic pathways. Modifying higher plant genetics to produce semiochemicals within the crop plants themselves (for their own defence, or the defence of other crops and animals) is now in some cases a reality. Until it becomes feasible to transfer packets of 'metabolite yielding' genes from one plant to another, however, we must resort to other approaches, such as increasing the expression of key genes controlling metabolism.

Alternatively, we might transfer a single alien gene, preferably from another plant, so that a substrate already generated by the wild type plant is diverted into producing a metabolite that is useful in crop protection. Example illustrating the power of biotechnology approaches is provided by the cyclic hydroxamic acid Dimboa (2,4 dihydroxy-7-methoxy-1,4-benzoxazin-3-one) (Fig. 9), a secondary metabolite produced in maize. Dimboa confers resistance to the European corn borer pest by interfering with feeding behaviour, and to northern corn leaf blight and stalk rot. Researchers have recently identified and demonstrated the role of each of five genes responsible for biosynthesizing Dimboa - the immediate precursor of Dimboa in maize. It should therefore now be possible to transfer these genes, and subsequently confer the advantages of Dimboa synthesis, into other plant species.

(Fig;9) (Dimboa)



Another example is the dialdehydic isoprenoid polygodial (Fig. 10) from water pepper (*Polygonum hydropiper*) (Camps and Dargallo,),[3] which is effective in preventing the transmission of yellow dwarf virus in barley via the bird- cherry-out aphid (*Rhopalosiphum padi*).



(Fig;10) Polygodial

Drimenol is a precursor to polygodial and other dialdehydic drimane antifeedants, and is produced in higher plants by the action of a cyclase enzyme, such a cyclase enzyme is present not only in higher plants, but also in Basidiomycetes which like the related mushrooms, may be more amenable to exploitation by molecular genetics.

It may be considered that producing a maize variety capable of releasing (E) ocimene and (E)-4,8-dimethyl-1,3,7-nonatriene from the intact plants, as is the case with molasses grass, would be a way forward. Maize is already capable of producing both compounds, but only does so, at sufficient levels for crop protection, at high levels of infestation. The gene for (E)-ocimene synthesis in *Arabidopsis* and some other plants .[8]

Arimura *et. al.*, [1] is known, but not yet the gene for the synthesis of (E)-4,8-dimethyl-1,3,7- nonatriene.

XVI. PUSH-PULL STRATEGY IN WEED CONTROL:-

Perhaps the most pressing target is the control of weed striga, *Striga hermonthica* (Scrophulariaceae) by silver leaf grass, *Desmodium uncinatum*. This has been demonstrated to involve germination stimulation, comparable to that induced by host plants of striga, and a post germination inhibitory effect measured by inhibition of seed radicle development in the striga. Many legumes cause germination of striga seeds but, apparently, only the *Desmodium* genus produces highly effective inhibitory compounds. Characterization of these compounds demonstrates that they are unusual C-glycosylated flavonoids. Since legumes are rich in flavonoids, the specific enzymes affecting the C glycosylation would need to be introduced into edible bean legumes in the first instance. This process could be helped by the advanced genetics already being applied to *Medicago truncatula* [24] and *Lotus japonicas* [19] ,[21] and to other technologies now available for studying plants for which the full genomic sequence has not yet been determined, as with the *Desmodium* species.

If this type of approach to weed control continues to be successful and can be exploited using biotechnology, as proposed, then there are lessons for such approaches in industrialized agricultural cropping situations.

XVII. PUSH-PULL STRATEGY IN CONTROLLING LIVESTOCK PESTS AND DISEASE VECTORS:-

Combinations of repellent and attractant semiochemistry may also find use in push-pull tactics for controlling livestock pests and disease vectors. Several possibilities are currently being explored. The adults of the brown ear tick, *Rhipicephalus appendiculatus,* the vector of the cattle disease East Coast Fever (Theileria), have been shown to use push-pull semiochemistry to locate bovid ears [42]. Odour collected from the anal region repels the tick and that from ears will attract it. Interestingly, in a related species, *Rhipicephalus eversti*, which prefers to feed around the anal region, the two semiochemicals perform the opposite functions. Characterization of the attractant semiochemicals may allow the development of a push-pull tactic that combines the use of a source of a synthetic or botanical tick repellent at the ear and an attractant-baited trap treated with fungal pathogen or acaricide located on the back of the animal.

XVIII. MANAGEMENT OF STABLE FLY:-

The stable fly, *Stomoxys calcitrans*, has been considered as the most important insect pest of cattle in the United States. The negative impacts of biting result in significant weight loss and milk production, which attribute to huge economic losses in cattle industry. The control of this pest heavily depends on the application of insecticides, but only provides with marginal effectiveness, and this practice is often not practical for the organic cattle farming.

Stable flies use a wide variety of visual, olfactory, gustatory and physical stimuli in host location and selection. Of these, volatile semiochemicals play a major role in mediating host location, including oviposition. Several manure and rumen associated odorants have been identified with strong sensory responses of stable flies. Further studies suggest that bacterially derived volatile compounds also play a role as oviposition stimulants for gravid stable flies [28]. GC-MS analyses of odors collecting from *Citrobacter freundit* substrate (the most attractive medium for oviposition) show one or several volatile chemicals that may contribute to their oviposition attractiveness. Potentials of using these identified repellent and attractant candidates for use in the future stable fly integrated management is yet to be explored.

XIX. MANAGEMENT OF TSETSE FLY(*Glossina species*) :-

Tsetse flies, vectors of animal and human sleeping sickness show a gradation of feeding preference on different vertebrate animals and appear to use push pull semiochemistry actively to avoid some hosts and to locate those which are preferred.[11],[12] Identification of a series of kairomones for tsetse flies from preferred hosts [34] facilitated the development of baited traps and targets effective in large-scale suppression of these species [2]. Several synthetic and natural repellents, including a constituent of bovid odours, 2 methoxyphenol, have been evaluated but were found not to be sufficiently effective in protecting cattle in the field [41]. However, recent identification of a potent repellent blend from waterbuck, *Kobus defassa* [13] which is refractory to tsetse flies, may provide much better protection for cattle and effective push component in the push-pull approach for faster and more effective suppression of tsetse populations, particularly where cattle are the dominant source of a blood meal for the flies. The push-pull could be established by combining this approach with highly attractive individuals treated frequently with, for example, a bio-insecticide such as pyrethrum.

XX. MANAGEMENT OF MOSQUITOES:-

Push-pull may also find a useful application in controlling malaria vectors, particularly zoophilic species like *Anopheles arabiensis*. The use of animals to divert (pull) mosquitoes from feeding on and transmitting disease to human beings (zooprophylaxis) has been considered as a possible tool in reducing mosquito in Africa and Asia, livestock keeping has been associated with increased malaria prevalence, particularly where cattle sheds are close to human dwellings [38]. A major handicap is that no methodical scientific study has been undertaken on the effects of the relative proportion and spatial relation of the two hosts, and the extent of mixing of their competing odour plumes on the degree of diversion. A recent theoretical study suggests that effective zooprophylaxis is dependent on such factors [31]. In addition, incorporation of a push component in households, in the form of repellent fumigants from readily available local plants, could have a significant effect on malaria incidence members and levels of malaria [43].

XXI. BENEFITS OF PUSH-PULL STRATEGY :-

The principles of the push-pull strategy are to maximize control efficacy, efficiency, sustainability, and outputs, while minimizing negative environmental effects. Although each individual component of the strategy may not be as effective as a broad spectrum insecticide at reducing pest numbers, the efficacy is increased through tandem deployment of push and pull components. The push and pull components are generally nontoxic and, therefore, the strategies are usually integrated with biological control .

XXII. FUTURE PROSPECTS:-

Future research has to develop successful methods, modify and refine the methods to enhance the efficacy of pheromones in pest management Research should provide knowledge concerning how insects produce pheromones, how they trigger a response and the influences of that response. For example, researchers are beginning to uncover the hormones that trigger pheromones production as well as the binding proteins that bring the pheromones to their receptors. Investigators also are discovering the neurological pathways that pheromones stimulate in a responding insect and the enzymes the insect use to breakdown the pheromone so as to shut off its signaling. This basic research should lead to better ways for using pheromones or other compounds to manage behaviour of insect pests. Moreover, researchers are working to improve pheromone dispensers in the field so that chemicals are longer acting, less costly, more potent and easier to release.

Push-pull strategies involve the behavioural manipulation of insect pests and their natural enemies via the integration of stimuli that act to make the protected resource unattractive or unsuitable to the pests (push) while luring them toward an attractive source (pull) from where the pests are subsequently removed. The push and pull components are generally nontoxic. Therefore, the strategies are usually integrated with methods for population reduction, preferably biological control. Push-pull strategies maximize efficacy of behaviour-manipulating stimuli through the additive and synergistic effects of integrating their use. By orchestrating a predictable distribution of pests, efficiency of population-reducing components can also be increased. The strategy is a useful tool for integrated pest management programs reducing pesticide input. Basic science, and particularly understanding the chemical ecology of plant-insect interactions by combined analytical-chemical, neurophysiological and behavioural studies, can lead to practical developments to help resource-poor farmers. Although the experience to date has been restricted to cereal-based farming systems, however, the general approach is applicable to a much wider range of pest problems in a variety of crops, and thus can serve as a model for other researchers in their efforts to minimize pest-induced yield losses in an economically and environmentally sustainable manner.

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XXIV. REFERENCES:-

1. Arimura, G., Ozawa, R., Kugimiya, S., Takabayashi, J. & Bohlmann, J. (2004) Herbivore induced defense response in a model legume: two-spotted spider mites. *Tetranychus urticae*, induce emission of (E)-b-ocimene and transcript accumulation of (E)-b-ocimene synthase in *Lotus japonicus*. *Plant Physiol*. **135**.1976-1983.
2. Brightwell, R., Dransfield, R. D. and Kyorku, C. A. (1991). Development of a low-cost tsetse trap and odour baits for *Glossina pallidipes* and *G. longipennis* in Kenya. Med. Vet. Entomol. **5,** l3-164**.**
3. Camps, F., Coll, J. and Dargallo, (1984). *Neo*-clerodane diterpenoids from *Ajuga chamaepitys Phytochemistry*, **23**, 2577.
4. Carde, R.T. and Mink, A.K. (1995). Control of moth pests by mating disruption Successes and constraints. *Annual Review of Entomology*, **40**: 559-585.
5. Cross, J.V., Winstanley, D., Naish, N., Helton, S., Keane, G.,van Wezel, R. and Gakek, D. (2005). Semiochemical driven auto-dissemination of *Cydia pomonella* and *Adoxophyes* orana baculoviruses. IOBC Bulletin, **28**: 319-324.
6. Chidawanyika F (2015). Effects of drought on the production of ectrophysiologically active biogenic volatiles important for cereal pest management. *University of the Witwatersrand, South Africa* pp. **172** pp.
7. Cockburn J, Coetzee H, Van den Berg J, Conlong D. (2014). Large-scale sugarcane farmer’s knowledge and perceptions of Eldana saccharina Walker (Lepidoptera: Pyralidae), *push-pull and integrated pest managemen*t. Crop Protection. **56**:1-9.
8. Dudareva, N., Martin, D., Kish, C. M., Kolosova, N., Gorenstein, N., Faldt, J., Miller, B. and Bohlmann, J. (2003). (E)-b-Ocimene and myrcene synthase genes of florascent in snapdragon: function and expression of three terpene synthase genes of a new terpene synthase subfamily. *Plant Cell* **15**, 1227-1241.
9. Farmer, E. E. and Ryan, C.A. (1990). Interplant communication: airborne methyl jasmonate induces synthesis of protienase inhibitors in plant leaves *Proc. Natl. Acad. Sci. USA,* **87**, 7713.

10. Griffiths, D.C. and Pickett, J.A. (1987). Novel chemicals and their formulation for aphid control. Pages 1041-1046. In: Proceedings of the 14th *International Symposium on Controlled Release of Bioactive Materials*. The Controlled Release Society.
11. Gikonyo, N. K., Hassanali, A., Njagi, P. G. N. and Saini, R. K. (2003). Responses of *Glossina morsitans morsitans* to blends of electroantennographically active compounds in the odors of its preferred (buffalo and ox) and non-preferred (waterbuck) hosts. J. Chem. Ecol. **29**, 2331-2345.
12. Gikonyo, N. K., Hassanali, A., Njagi, P.G.N. & Saini, R.K. (2000). Behaviour of *Glossina morsitans morsitans* Westwood (Diptera: Glossindae) on waterbuck *Kobus defasa Ruppel* and feeding membranes smeared with waterbuck sebum indicates the presence of allomones. Acta Trop. **77**, 295-303.
13. Gikonyo, N.K., Hassanali, A., Njagi, P.G.N., Gitu, P.M. and Midiwo, J.O. (2002). Odour composition of preferred (buffalo and ox) and non-preferred (waterbuck) hosts of some savanna *tsetse* flies. J. Chem. Ecol. **28**, 961-973.
14. Grimshaw RG. (2003). The role of vetiver grass in sustaining agricultural productivity. (http://www.vet.org).
15. Haniotakis, G., Franke, W., Mori, K., Redlish, H. and Shurig. V. (1986). Sex specific activity of (R)-(-) and (S)-(+)-1,7-dioxaspiro[5.5] undecane, the major pheromone of *Dacus oleae*. *Journal of Chemical Ecology*, **12**: 1559-1586.
16. Haniotakis, G., Kozyrakis, M., Fitsakis, T., and Antonidaki, A. (1991). An effective mass trapping method for the control of *Dacus oleae*. *Journal of Economic Entomology*, **84**: 564-569) .
17. Hardee, D.D. (1982). Mass trapping and trap cropping of the boll weevil, *Anthonomus grandis*. In insect suppression with controlled release pheromone systems, eds. Kydonieus and Beroza, **2**: 65-71.
18. Jain S.C., Novicki S. Eisner T, and Meinwald, J. (1982). Insect repellents from vetiver oil: Zizanal and epizizanal. Tetrahedron Letters, **23**: 4639-4642.
19. Kato, T., Sato, S., Nakamura, Y., Kaneko, T., Asamizu, E. and Tabata, S. (2003). Structural analysis of a *Lotus japonicas* genome. V. Sequence features and mapping of sixty-four TAC clones which cover the 6.4 Mb regions of the genome. *DNA Res.* **10**, 277-285.
20. Khan, Z. R., Chiliswa, P., Ampong-Nyarko, K., Smart, L. E., Polaszek, A., Wandera, J. and Mulan, M. A. (1997). Utilization of wild gramineous plants for the management of cereal stemborers in Africa. *Insect Sci. Appl.* **17**, 143-150.
21. Kouchi, H., Shimomura, K., Hata, S., Hirota, A., Wu, G. Kumagai, H., Tajima, S.. Suganuma, N., Suzuki, A., Aoki, T., Hayashi, M., Yokoyama, T., Ohyama, T Erika, A., Kuwata, C., Shibata, D. and Tabata, S. (2004). Large-scale analysis of gene expression profiles during early stages of root nodule formation in a model legume. *Lotus japonicus*. *DNA Res.* **11**, 263-274
22. Khan, Z.R., Pickett, JA, and Van den Berg J. (2000). Exploiting chemical ecology and species diversity; stem borer and Striga control for maize and sorghum in Africa. Proceedings of the *Society of Chemical Industry* (*SCI*) Meeting. The economic and commercial impact of integrated crop management. *Society of Chemical Industry* (*SCI*) Meeting; *Uk*.

23. Khan ZR, Midega CAO, Hooper AM, Pickett JA (2016). *PushPull*: *Chemical Ecology-Based Integrated Pest Management Technology*. *Journal of Chemical Ecology*.**42**:689-697.
24. Lamblin, A. F. J. Crow, J.A. Johnson, J.E, Silverstein, K.A.T., Tomothy, M.K., Alan, K., Benz, D., Stromvik, M.. Gabriella, E., VandenBoschl, K.A., Cook, D.R. Young. N.D. and Retzel, EF. (2003). MtDB, a database for personalized data mining of the model legume Medicago truncatula transcriptome. *Nucleic Acids Res.* **31**, 196-201.
25. Ladd, TL, Klein, M.G and Tumlinson, J.H. (1981). Phenethylpropionate + eugenol + geraniol (3:7-3) and Japonilure: a highly effective joint lure for Japanese beetles *Journal of Economic Entomology*, **74**: 665-667.
26. Ladd, T.L. and Klein, M.G. (1986). Japanese beetle response to colour traps baited with phenethyl propionate Ceugenol Cgeraniol (3:7:3) and Japonilure. *Journal of Economic Entomology*, **79**: 84-86 .
27. Lanier, G.N. (1990). Principles of attraction annihilation: mass trapping and other means. Behaviour-modifying chemicals for insect management. New York: Dekker: **25**-45.
28. Logan, J.G and Birkett, M.A. (2007). Semiochemicals for biting fly control: their identification and exploitation. *Pest Management Science*, **63**: 647-657.
29. Lucas, J.A. (1999). Plant immunization: from myth to *SAR*. Pesticide Science **55**, 193 -196 .
30. Magara HJO, Midega CAO, Otieno AA, Ogol CKPO, Bruce TJA, Pickett JA, Khan ZR (2015). Signal grass (*Brachiaria brizantha*) oviposited by stemborer (*Chilo partellus*) emits herbivoreinduced plant vola-tiles that induce neighbouring local maize (Zea mays) varieties to recruit cereal stemborer larval parasitoid *Cotesia sesamiae*. *Int J Sci Basic Appl Res*. **19**:341–375.
31. Nedorezov, L. V., Hassanali, A. and Sadykov, A. M. (2005). Individual-based model of mosquito choices up odour plumes to alternative hosts. In Proc. Fifth Eur. *Conf.On Ecological Modelling (*ed. A. S. Komarov), pp. **136**-137.
32. Ndakidemi B, Mtei K, Ndakidemi P.A. (2016). Impacts of Synthetic and Botanical Pesticides on Beneficial Insects. *Agricultural Sciences*: **7**:364-372.
33. Ogawa, K., Kobayashi, T. and Hego, T. (2005). The systemic and efficient use of mating disruption. *IOBC Bulletin*, **25** (7): 480.
34. Owaga, M. L. A., Hassanali, A. and McDowell, P.G. (1988). The role of 4-cresol and 3-n propylphenol in the attraction of tsetse to buffalo urine. *Insect Sci. Appl.* 9, 95 100
35. Pettersson, J., Pickett, J.A., Pye, BJ, Quiroz, A., Smart, LE, Wadhams, LJ; and Woodcock, CM. (1994). Winter host component reduces colonization by bird cherry-out aphid, *Rhopalosiphum padi (*L) (Homoptera. Aphididae), and other aphids in cereal fields. *Journal of Chemical Ecology* **20**, 2565-2574.
36. Rao RR, and Suseela, M.R. (2000). *Vetiveria zizanioides* (Linn.) Nash-a multipurpose eco-friendly grass of India. Proceedings of the Second *International Conference on Vetiver*. Office of the Royal Development Projects Board, Bangkok. **444**-448 .
37. Shangwen C. (1999). Insects on vetiver hedges. *Vetiver Newsletter*, Number **23**: 17-18

38. Seyoum, A., Balcha, M., Balkew, A. A. and Gebre-Michael. T. (2002). Impact of cattle keeping on human biting rate of Anopheline mosquitoes and malaria transmission around Ziway, Ethiopia. *East Afr. Med. J.* **79**, 485-490.
39. Saha T, Chandran N. (2017). Chemical ecology and pest management: *A review International Journal of Chemical Studies.* **5**(6):618-621.
40. Turlings, T. C. J., Tumlinson, J. H. and Lewis, W. J. (1990), Exploitation of herbivore induced plant odors by hostseeking parasitic wasps. *Science.* **250**, 1251-1253.
41. Torr, S. J., Mangwiro, T. N. C. and Hall, D.R. (1996). Responses of *Glossina pallidipes* (Diptera: Glossinidae) to synthetic repellents in the field. *Bull. Entomol. Res.* **86**, 609-616.
42. Wanzala, W., Sika, N. F. K., Gule, S. and Hassanali, A. (2004). Attractive and repellent host odours guide ticks to their respective feeding sites. *Chemoecology* **14**, 229 -232.
43. WHO (1982). Manual on environmental management for mosquito control with special emphasis on malaria vectors. Geneva, Switzerland: *World Health Organisation.*
44. Xinbao Z. (1992). Vetiver grass in P.R. China. *Vetiver Newsletter*, Number **8**:134-138.
45. Yacoubou, A.-M., Wallis, N.Z., Menkir, A., Zinsou, V.A., Onzo, A., Garcia-Oliveira, A.L., Meseka, S., Paterne, A., (2021). Breeding maize (Zea mays) for Striga resistance: Past, current and prospects in sub- saharan africa. *Plant Breed.* **00**, 1–16.
46. Zhu B.C.R., Henderson G., Chen, F., Maistrello, L., Laine, R.A. (2001). Nootkatone is a repellent for Formosan subterranean termite (*Coptotermes formosanus*). *Journal of Chemical Ecology*, **27**: 523-531.