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Importance of intercropping for biodiversity conservation

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ABSTRACT

Traditional there are two strategies to handle pest problems in crop production, either dependence on non-chemical agricultural practices (such as cultural, mechanical, biological practices etc.) or reliance on existing natural pest control mechanisms. Intercropping is a cultural non-chemical agricultural practice where two or more crops are grown on the same field in a year with different cropping patterns. In this multiple cropping system, biodiversity and pest suppression are increased. Biodiversity can restore the natural elements of agro ecosystem because almost all favorable elements of natural enemies are available in diversified agro ecosystem. Energy intensive modern technology in agriculture is one of the vital causes for loss of biodiversity. In intercropping system biological pest control method can be ensured with higher level of crop diversity instead of energy intensive agriculture. Intercropping provides different benefits on pest management with two available hypotheses or mechanism. One of the hypotheses is the 'resource concentration hypothesis' and another is the 'natural enemies hypothesis'. Intercropping, directly and indirectly, influences to increase biodiversity which results in reduction of pest densities in crop fields. As a result, less expense for use of pesticide is required and finally higher yield also add some financial benefits. Intercropping system utilizes inherent ability of plant to protect pests. Therefore further knowledge about genotypic crop diversity, diversity of natural enemies, chemically-mediated mechanisms of Volatile Organic Compounds (VOCs) will be effective for further improvement of intercropping system for greater benefits.

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I. Introduction

Traditional farmers use different kinds of pest management strategies to handle pest problems in crop production systems where they do not want to use chemical pesticides. In broad aspects, there are two main strategies based on their uses. One is non-chemical pest control method that consists of cultural, mechanical, physical and biological practices those directly influence to pest population. Another is reliance on existing natural pest control mechanisms where biotic and structural diversity of complex

farming systems is involved. Biotic and structural diversification indirectly influences pest population. Different agronomical practices such as intercropping, overplanting or varying seeding rates, changing planting dates, crop rotation, timing of harvest, mixing crop varieties, selective weeding, use of resistant varieties, fertilizer management, water management, plowing and cultivation techniques are used in cultural pest management strategies of crop production (Altieri, 1993).

Biodiversity refers to the ecosystem of nature where all plant and animal species are available with all micro-organisms. Higher numbers of species indicate a higher level of biodiversity. In agriculture forestry and polyculture are common examples of crop diversity (Altieri, 1993). Different findings already showed that higher level of plant diversity can assist to improve pest management system in agriculture (Tooker and Frank, 2012). Biodiversity plays an important role in ecological services by restoring the natural elements of agro ecosystem (Altieri, 1993) because almost all favorable elements of natural enemies are available in diversified agro ecosystem (Perrin and Phillips, 1978). Higher natural vegetation of diversified crops assists to cover the soil surface and those are also helpful to prevent soil erosion, to maintain moisture and soil nutrient. Also, crop diversity maintains a check and balance between pest and natural enemies. But intensive agriculture disrupts natural balance through higher interruption that can make an imbalance condition in between pest and natural enemy's population (Altieri, 1993). Although In general polyculture enhances vegetation diversity but in few cases diversified plants negatively respond to natural enemies. For example provided food or resources by the plant sometimes favor the pests or can attract the members of fourth tropic level those are responsible to attack natural enemies of pests. Even though biodiversity has few negative points but most of cases biodiversity provides favorable environment for natural enemies in agroecosystem to suppress pests and sometimes helps to reduce crop damage (Gurr et al., 2003).

In polyculture system, pests and natural enemies of crops are available and they interact with each other naturally because general requirements of natural enemies are present in this system (Perrin and Phillips, 1978). There are different forms of polyculture cropping systems such as mixed cropping systems and intercropping systems. Although they are called with a different name but the mechanisms are more or less same because in both cropping systems more than one crop is cultivated together in a same land whereas the main difference in terms of crop. More than one main crops exist as main crop in mixed cropping system whereas in intercropping system one crop is grown as the main crop and other one assists the main crop in different aspects (Theunissen et al., 1995).

Small scale farmers of developing countries, especially from tropical regions, commonly use intercropping and mixed cropping whereas farmers of developed countries use capital and energy intensive technology like mono cropping systems. Energy intensive modern technology is one of the vital causes for loss of biodiversity because of large areas of agriculture under intensive cultivation (Cardinale et al., 2003) and this kind of agriculture is also a barrier for natural pest control system. Use of pesticides and fertilizers has a significant influence on flora and fauna which can be recovered by using different environment-friendly approaches like ICM (Integrated Crop Management). Intercropping is one of the tools of ICM where biological pest control method can be ensured with higher level of crop diversity instead of energy intensive agriculture.

II. Intercropping and biodiversity conservation

Nowadays biological pest control becomes a potentially important issue for ecosystem service of biodiversity although there is no guarantee of pest control by only increasing biodiversity because some plants do not provide favourable environment for natural enemies (Gurr et al., 2003). Therefore it is essential to understand the interaction of plant-pest-natural enemies to improve pest management system with favour of higher diversity (Gurr et al., 2003). There are two approaches; one is bottom up and another is top down approach in agro ecosystem. Vegetation diversification is an example of bottom up approach where diversified plants can directly influence the pest population through 'resource concentration hypothesis' effect. Trap cropping is also another potential mechanism where trap crop attracts pests away from nearby main crops. By this way trap crop can save the main crops from infestation of pests. On the other hand top-down approach where conservation biological control through increasing natural enemies are used to suppress pests through 'enemies hypothesis' effect

(Gurr et al., 2003). Natural pest management system can be improved by increasing the level of complexity of biodiversity. Different management of diversification can enhance natural pest management systems such as-

- Diversification within monoculture by changing one or few management practices that can enhance pest management such as harvesting time or harvesting process;
- Relax the monoculture by growing mix varieties or closely related species together;
- Allowing non crop vegetation within the monoculture to enhance the densities of natural enemies;
- Using the non-crop field margin in monoculture to provide food and shelter to natural enemies;
- Growing two or more crops together instead of monoculture
- Integrating agroforestry with cropping and livestock to increase arthropod densities;
- Changing the landscape level to enhance parasitism rate by providing food and shelter (Gurr et al., 2003)

Above mentioned strategies can be practiced in crop field and/or nearby non crop areas. Intercropping is one of the most important strategies that can be implemented in arable fields (Tooker and Frank, 2012).

Intercropping is a specific form of multiple cropping where two or more than two crops are grown on the same field in a year. In earlier stage of agriculture intercropping was practiced only in tropic region. But intercropping is also focused in temperate region after exploring the eco service of intercropping by researchers. In between 1970-1990 several researches have been conducted on intercropping to investigate economic importance of intercropping in temperate regions especially with a focus on vegetable crops (Theunissen et al., 1995). Nowadays some farmers of developed countries also follow this kind of crop production system for its beneficial ecosystem service instead of highly input based agriculture. Cabbage with clover, Carrots with onions, field beans with leak are examples of intercropping in developed countries where pest populations successfully suppressed. In the case of Cabbage with clover, clover cover between rows of cabbages and help to reduce pest populations (*Brevicoryne brassicae L., Artogeia rapae (L.) and Erioischia brassicae Bouché*) (Gurr et al., 2003).

Several forms of intercropping are practiced in different places based on farmers' needs. Intercropping is classified in different ways; based on spatial arrangement of crop there are three kinds of intercropping. Those are mixed intercropping, row intercropping and strip intercropping. In mixed intercropping no specific rows are created for main crop whereas in row inter-cropping crops are cultivated in specific rows. In strip cropping systems, strips of different crop types are intermingled. Sometimes non-crop plants are also introduced as a strip crop such as flower strips in cropped areas to provide food and shelter for natural enemies. Different crops, instead of non-crop plants, can also be grown in strips. The use of Lucerne strips within Australian cotton crops is an example where Lucerne acts as a trap for green crop mirid and also acts as a habitat for natural enemies (Gurr et al., 2003).

On the basis of time there are also three kinds of intercropping and those are full intercropping, relay intercropping and sequential intercropping. Both crops are grown simultaneously in the same time in full intercropping system. In relay inter-cropping 1st crop is grown singly then other crops are grown before harvesting of 1st crop. As a result they can overlap each other only a part of their life cycle (Perrin and Phillips, 1978). But it is not same in all the time in relay inter cropping, sometimes both crops are grown in same time but they are harvested in different time. As a result 1st crop can associate with 2nd crop throughout their lives, but 2nd crop can associate with 1st crop for only a short period of their lives (Andow, 1991). In sequential intercropping one crop is grown just after harvesting of another crop.

a) Implementation of intercropping system

To achieve maximum benefits from intercropping different crops related issues should be taken into account. Crop and/or species selection for intercropping is a vital point to get success from this strategy. As a compatible intercrop, Crop and/or species should have following characteristics -

- Selected species should have intercropping effects to suppress pest population
- Competition of intercrop with the main crop must be under a minimum level

- Intercrop has capability to suppress weed infestation in following year
- Compatible with the existing cropping pattern
- Seeds of intercrop should be available for general growers
- Selected crops/species must not be favorable for other pest and diseases
- Should have loss minimization capability of existing nutrient (Theunissen et al., 1995).

Intercropping is a cultural practice of crop production by which crop diversity can be improved and that can enhance natural pest management system. Different researches showed that in less diverse systems especially in monoculture herbivore can easily colonized and can reproduce higher number of population within less tenure time due to less interruption in host finding and better competition capability against natural enemies. On the other hand diversified cropping system like intercropping comprises with different natural elements of biological pest control that is also supported by ecological theory. Two different features of agro ecosystems contribute differently in herbivore dynamics that is also related with natural pest control system in agriculture. One of them is structural features of agro ecosystem that consist spatial and temporal crop arrangement. And other one is management features that represent crop diversity and input levels of agro ecosystems (Altieri, 1993). Few effective examples of intercropping are given below-

Benefits of intercropping were demonstrated in Northern China where cotton and wheat were grown as relay inter cropping. In this system attack of cotton aphid (*Aphis gossypii Glover*) were reduced and productivity of cotton was increased because winter wheat can serve as a reservoir to conserve arthropod predators and relay its predators to adjacent cotton fields. Natural enemies (ladybird beetles particularly *Coccinella septempunctata*) are more active due to presence of wheat where they can feed on prey and can provide support to cotton seedlings from the attack of aphid population. Cotton cultivation as mono crop without wheat showed a contrasting result where aphid populations increase rapidly in the emerging stage of cotton seedlings due to absence of natural enemies. Without wheat effective control of aphid is not possible due to late arrival of natural enemies into the cotton field (Landis et al., 2000).

Similarly intercropping maize with non-host molasses grass (*Melinis minutiflora*) also showed better pest suppression compared with maize monoculture in Africa. In maize-grass intercropping system, infestations of lepidopteran stem borers are reduced and parasitism rates by *Cotesia sesamiae* (Cameron) are increased. Grass accelerates "push-pull" mechanism where female stem borers are repelled and female parasitoids are attracted by volatiles of grass. In addition stem borer prefer to oviposit on the grass rather than maize and grass functions as a trap crop for stem borer. As a result in one hand higher number of parasitoids can contribute to suppress stem borer population by higher rate of parasitism and on the other hand grass inhibits the growth of the stem borer through making it incapable of developing (Khan et al., 1997).

Visitations of hymenopteran parasitoids are different in squash intercropped with maize and cowpea compare to mono cropped squash due to different cropping pattern. Hymenopteran parasitoids were also found consistently greater in tri-culture where squash, maize and cowpea were intercropped together. That result also referred that cropping pattern also influences higher number of hymenopteran parasitoid number in intercropped system. Higher parasitism rates of eggs and larvae of *Diaphania hyalinata* (L.) (Lepidoptera: Pyralidae) were the consequences of higher number of parasitoid in intercropped system. Presence of maize was the main cause of higher parasitoid in this tri-culture intercropped system (Letourneau, 1987).

Population of leafhoppers especially nymph and adults were found less in weedy culture where weeds are grown as intercrop with one main crop. For example *Empoasca kraemeri* is the main pest of phaseolus bean in tropic region of Latin America. Significantly lower numbers of hopper pests were present in weedy plot where phaseolus beans were grown with weed as inter-cropping system. Generally Ground beetles (Carabidae), syrphids (Syrphidae) and lady beetles (Coccinellidae) are abundant in weed-diversified systems. In addition grassy weeds specifically Eleusine and Leptochloa have effective defense capability against adult leafhoppers due to have chemical repellent component compare with broad leaf weed in intercropping system (Perrin and Phillips, 1978).

Perrin and Phillips (1978) also explained population dynamics of pests that is influenced by intercropping. Inter-cropping has several potential advantages those can directly influence to the reduction of crop damage. Cow pea production in Northern Nigeria showed better yield in mixed or intercropping. In intercropping without pesticide cowpeas are capable to produce useful yields and sometimes better than monoculture with minimum pesticide whereas without insecticide in mono cropping is quite difficult (Perrin and Phillips, 1978).

Host seeking *M. persicae* were reduced by the role of chemically-mediated mechanisms of Volatile Organic Compounds (VOCs) in potato-onion intercropping. VOCs are released by herbivore damaged plant and also often released by undamaged plants. Actually plants use these volatiles as rapid defense signaling to repel herbivores and in the same time to attract natural enemies of herbivores. By this way plant can also influence the defense mechanism of neighboring plants. According to this mechanism migration of aphid pests into potato crops was significantly lower when onion was present as intercrop (Ninkovic et al., 2013).

In modern crop production 'Genotypic diversity', defined as genetic variation among varieties, can be improved by using different cultivars and/or species through intercropping system. Now it is well established that genetic plant diversity or intraspecific plant diversity can assist to reduce pest abundance and damage of crop production in agriculture. In addition genotypic diversity can improve plant fitness that can finally contribute to higher productivity. Intraspecific plant diversity works in both ways like bottom–up and top–down approach to control pest population in agriculture. General farmers can use this strategy with minimum changes in their existing production system and also with less financial investment. Day by day this strategy is becoming in more focus as a sustainable crop management tactic due to its yield stability and its favour of diversity (Tooker & Frank, 2012).

b) Benefits and cost of intercropping

Generalist parasitoids and predators are more abundant in intercropping as polyculture than monoculture because intercropping provides a higher range of food for a longer time during the growing season and enhance structural diversity leading more niches. Intercropping also provide moisture and shade to the soil surface thereby creating a microclimate that helps some predaceous carabid beetles to forage for a longer time, for example during the day as well as at night (Andow, 1991). Biodiversity is also increased in agroecosystem where legume cover crops are used as living mulches in relay intercropping systems (Gurr et al., 2003).

Intercropping as a polyculture provides different benefits on pest management with two available hypotheses or mechanism. One of the hypotheses is the 'resource concentration hypothesis' and another is the 'natural enemies hypothesis'. In resource concentration hypothesis explain how intercrop can be helpful for the main crop by using Visual and chemical stimuli towards herbivore. In natural enemies hypothesis explains about higher number of natural enemies in intercropping due to have higher range of food, shelter and microclimates in intercropping system. According to both hypothesis it is very clear that intercropping provides better natural pest management system in agriculture compared to monoculture (Altieri, 1993).

Intercropping system not only provides the ecological services such as pest suppression and better diversity but also provides financial benefits for crop growers. Clover with white cabbage is one of the best examples in this regard. In this system cabbage cv. Minicole was intercropped with *Trifolium repens* (white clover) and *Trifolium subterraneum* (subterranean clover) as compared to the mono crop of white cabbage. In this study different pests of white cabbage such as *Mamestra brassicae L.* (cabbage moth), *Brevicoryne brassicae L.* (cabbage aphid), *Delia brassicae L.* (cabbage root fly) were evaluated. In addition feeding injuries of caterpillar in cabbage plant were also evaluated according to economic threshold level. Harvested heads from intercropped cabbage were smaller than mono cropped cabbage but the compactness was high in case of heads of intercropped cabbages. In terms of gross financial result, intercropped cabbage gave better financial result compare to the cabbage from mono crop. Moreover intercrop also help to suppress of oviposition and larval pupations of observed pests. Finally we can say intercrop not only contributes in farming system by ecologically but also contributes by

economically. This system is also an acceptable form of sustainable horticulture that can be practiced by eco-friendly farmers (Theunissen et al., 1995).

Main feature of intercropping system is to cultivate more than one crop in the same field with different cropping patterns that also lead to increase biodiversity. In the same time intercropped crops are added some economic value through their end products. Lucerne strip with cotton show a clear idea about economic benefit of intercrop. Hay made from Lucerne strip is a complementary production benefits after harvest of Lucerne. When agroforestry is included with other crops in intercrop then timber of agroforestry add some value in total production system. Intercropping directly and indirectly influences to increase biodiversity which results reduction of pest densities in crop field. As a result less expense for use of pesticide is required and finally higher yield also add economic benefits although it is sometimes difficult to determine the exact numerical figure (Gurr et al., 2003). Several evidences already showed that intercropping negatively influences insect pest management and positively influences crop yield with not only economic way but also with ecological sustainable way (Tooker and Frank, 2012).

IV. Discussion

Until today different forms of polyculture like intercropping, mixed cropping have received considerably more research attention than other forms of vegetation diversity. In addition researchers also did not give more focus on the mechanism of agroecosystem in agriculture (Andow, 1991). We have some information about specific mechanism of crops and arthropods in ecosystem. But they respond differently and show different mechanism according to different ecosystem. However we have lack of precise information on specific mechanisms of crops and natural enemies by which we can understand better about general effects of agroecosystem (Tooker and Frank, 2012).

Genotypic diversity is also less focused in previous days which can also contribute to improve phenotypic diversity. Increased phenotypic diversity with the combination of genotypic diversity can effectively enhance crops and arthropods species diversity. In addition combination of genotypic and phenotypic diversity helps to produce higher amount of above-ground biomass and also influence the abundance and behaviour of natural enemies (Tooker and Frank, 2012) In this regard it is essential to focus more on genotypic diversity in intercropping system for future sustainable pest management system.

Several researchers already reported about the diversity of crop but few researches have conducted research on diversity of natural enemies (Cardinale et al., 2003). However diversity of natural enemies is equally important in biological pest control. Moreover specialist natural enemies are more focused in commercial agriculture whereas generalized natural enemies are more abundant in poly culture according to the nature of ecosystem. The species richness of natural enemies in an agricultural ecosystem can influence the population size of a widespread insect pest. Multi-enemy impacts on crop pest species is the key issue for better understanding of the role of diversity richness of natural enemy in biological control, it is very essential to know. To get maximum benefits from natural enemies in intercropping system it is essential to know the behaviour of generalized natural enemies in intercropping system. We should also give more emphasis to know pros and cons of diversity and respond behaviour of natural enemies because may be some natural enemies don't have any direct role in pest suppression but they can facilitate other natural enemies to enhance pest suppression (Cardinale et al., 2003). VOCs are another opportunity for agriculture to manage pest population in crop production. More research on VOCs will give flexibility to the growers in their crop selection for intercropping. Researchers can use mechanism of VOCs to improve plant protection system. In the same way increase, the scientific understanding of communication between plants and its impact on other organisms can add value to diversification system (Ninkovic et al., 2013).

V. Conclusion

There are different agronomic purposes of intercropping practice and one of the most vital purposes is pest suppression (Altieri, 1993). Intercropping is a cultural practice of agriculture by which we can also

minimize our diversity problems. Different elements of natural pest management are available in intercropping system. In addition intercropping system conserve plant diversities that can help to maximize the action of natural enemies to control the vast majority of pests (Perrin and Phillips, 1978). We can use inherent ability of plant and nature to protect pest and to achieve better yield in intercropping system because biodiversity functions as renewal processes in agro ecosystems and provide ecological services to the society. Therefore, to understand the role of biodiversity in pest suppression is a fundamental issue to improve the efficiency of intercropping system (Altieri, 1993).

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