Intercropping Systems in Wheat (*Triticum aestivum* L.) for Pest and Disease Management – A Review

Abstract- Cereal crop wheat, Triticum sativum L.,is an important food and feed crop that is grown all over the world. There is a complementary relationship between legumes and cereals for nitrogen resources, it was found that intercropped legumes acquire a higher amount of atmospheric nitrogen in comparison to legumes grown as an individual crop Furthermore, both wheat and pulse intercropping give benefits in terms of minimizing pests and diseases.Intercropping not only restricts onset of pest species but also crop combinations conserves beneficial insects that can preserve the damaging pest population below the threshold level. Various examples have been provided in current study which shows effective control of various insect pests when wheat was intercropped with mustard, Linseed, barley, mung bean, canola etc. Intercrops of wheat with different crops can be part of an integrated pest management strategy to lower pest incidence while also to enhancing the population of other beneficial organisms.

Keywords- Intercropping, wheat, Triticumsativum, pest management

I. INTRODUCTION

Agricultural sustainability is a major goal for a country like India which is in need to provide abundant resources for continuously growing requirements. Intercropping is a sustainable process whichgives numerous benefits and enhance resource use efficiency. Among various benefits, yield and growth enhancement,sustainability in production, environment safety toall flora and fauna in ecosystem are the highlights of it.Two or more agricultural crops are grown on the same piece of land at the same time in this cropping system, so they cohabit for a long period during the crop cycle and interact with each other and with the agro-ecosystems. Intercropping is a cultural practice that involves extra diverse crop species or varieties to be grown together on the same piece of land [1].

Intercropping has been a well-adapted phenomenon since about 300 B.C in ancient Greece where evidences of it found with wheat, barley, and certain pulses often integrated with vines and olives[2].Intercropping which is also known as companion cropping not only popular in production of vegetables, cereals and pulses cropsbut are also observed equally emphasizedwith forage production in the temperate regions as fodder crops are in high demand[3,4].

New generation agriculture and green revolution technologies incorporates high energy and fossil-fuel-based inputs which has led to a significant increase in crop yields, but for the fulfilment of these requirements sustainability in agriculture disappeared [5,6].

The modern farming methods includes monoculture. It supersedes the biodiversity with a minimum number of cultivars in extensive areas. On the contrary, the conventional farmers of the growing nations maintain the biological diversity. In such nations, intercropping is widely observed. These systemsare responsible for large scale vegetationwhile using green methods and decreasedrisk of crop damagethrough pests and diseases. It involves thecorrect use the human workforce with a standard profit[7, 8].

II. BENEFITS OF INTERCROPPING SYSTEM

Various benefits of intercropping are enhanced production, soil health, Reduction in soil erosion, space utilization and system productivity etc. In addition, intercrops allow enhanced competition among different plant species specifically beneficial in weed control due to allelopathic influence of different crops on weeds. In South and Southeast Asia, the rice-wheat intercropping is the most common and widely practiced method. Rice-maize systems, as well as wheat- and barley-based farming systems, have the potential to be profitable in the future. Cereal-based farming systems have the disadvantage of being less sustainable, necessitating the incorporation of legumes into these systems.

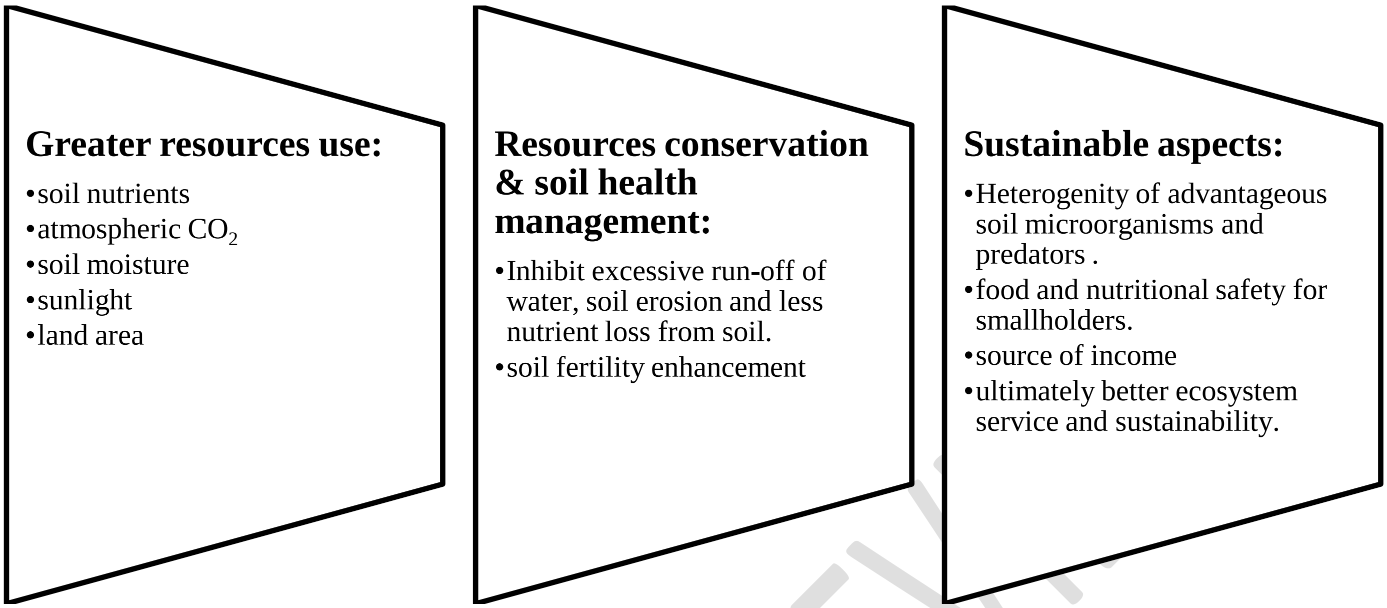

Figure 1. Benefits of intercropping [9]

III. INTERCROPPING IN WHEAT

Cereal crop wheat, *Triticumsativum* L., has its importance in the agricultural world for both food as well as feed[10]. There is a complementary relationship between legumes and cereals for nitrogen resources, it was found that intercropped legumes acquire a higher amount of atmospheric nitrogen in comparison to legumes grown as an individual crop[11].

According to facts, leguminous crops have ability to obtain atmospheric nitrogen with the help of symbiotic relationship with soil-dwelling bacteria[12], while cereals are dependent on soil and fertilizer nitrogen sources[13]. A plethora of data available that confirmed intercropping of cereals with legumes consistently increases nitrogen fixation in leguminous crops and also enhances uptake of soil nitrogen in cereal crops [13, 14]. Cereal crops, in general, grow quickly in the early season and compete for available nitrogen in the soil.It is found that nitrogen fertilization usually reduces the legume growth in the intercrop, as it favors acquisition of N in cereals and command of legume growth, hence Legume crop would remain more dependent over nitrogen fixation to meet their needs of nitrogen [14, 15].

Besides wheat legume intercropping, vegetable wheat intercropping is also been popular and profitable in some cases. Wang *et al*.[16] when intercropped cucumber with soybean, wheat and oats, it was found that wheat-cucumber intercropping gave significant enhancement of cucumber growth and yield of wheat crop. Subedi[17]found that wheat and pea intercropping was beneficial from economical perspective because the net grain yield was increased, and pea sowing rates of 30 to 45 kg/ha and wheat sowing rates of 120 kg/ha were recommended. Qayyum *et al*. [18]showed that wheat, onion and garlic intercropping decreased the weed density when it was performed in 4:2 rows strips. Wheat - potato (*Solanumtuberosum*) relay intercropping system gave maximum advantage with slight change of crop geometry and maintaining intra-row spacing [19]on contrary to which Singh *et al*. [20]reported mean decrease in the yield of wheat grain production almost 45%, when intercropped with potato crop. Also, intercropping has been evidenced to have effect on suppression of weeds [21]. Some examples are cited and presented in Table I which shows different effects of different wheat intercropping systems.

Intercropping has the potential to be a very promising cultural technique in terms of pest and disease incidence and infestation control[22]. In intercropping system additional crop with the main value-added crop may act as a barrier against different pests and diseases [23].

Table I. Positive and negative impacts of differentintercropping systems of wheat.

Maincrop + intercrops	Out-comes	References

Wheat + Pea	Netincrease in crop yield.	24
Wheat + White Clover	Improved grain yield	25
Wheat + Mustard	Reduced grain yield	26
Wheat + Fabba bean	Net crop yield increase if applied in 1: 3 ratios.	27, 28
Wheat + Tori	negative effect on wheat yield	17
Wheat + Chickpea	Increase in main crop yield.	29
Wheat + Onion	Netincrease in crop yield.	18
Wheat + Cucumber	Improvement in cucumber quality and yield	30
Wheat + Potato	Significant reduction in wheat grain yield	20
Wheat + Sugarcane	Increase in inter-crop yield.	31
Wheat + Barley	Netincrease in crop yield.	32
Wheat + Maize	Netincrease in crop yield.	33
Wheat + Maize	Reduction in CO_2 emissions and enhances water use	34
Wheat + Fenugreek	Netincrease in crop yield.	35

IV. DISEASE MANAGEMENT WITHINTERCROPPING

Studies has been evidenced of reduction in diseases as a result of applications of intercropping in many cases [37, 38, 39]. Wheat and hop clover, *Madicagolupulina* intercropping results in less incidence of soil borne disease take all disease of wheat, *Gaeumanno mycesgraminis* [40]. Vilich-Meller [41] reported that leaf fungal diseases were less when winter rye was intercropped with winter wheat. Similarly, Pino et al., [42] reported that in comparison to tomato alone, maize-tomato intercropping showed a lower proportion of pest and disease occurrence. Bulson et al. [43] correlated reduction of pathogen borne diseases with increase in bean density when wheat and field bean were intercropped together. Hummel et al. [61] suggested that disease incidence in wheat- canola intercropping system reduces with the increase of canola ratio which indicates possible interference of canola on disease severity. According to Shiqin et al. [44] in intercropping systems of wheat with maize showed significant reduction of controlled wheat stripe and wheat powdery mildew rust by 16.7–45.7% and 14.7–27.0% respectively. However, if intercropping of wheat is done with potato or chili it does not have reduction in disease incidence significantly. Some examples are cited and presented in Table II which shows effects of different intercropping systems in disease reduction.

Table II. Decrease of disease by the applying intercropping system.

Crops	**Name of the controlled Disease**	**Inter-cropping Combination**	**References**
Wheat	Fusarium head blight (*Fusariumgraminearum*)	Wheat + mustard	39
Wheat	Alternaria blight (*Alternariatriticina*)	Wheat + mustard	37
Potato	Bacterial wilt (*Pseudomonas solanacearum*)	Maize + potato	36
Fabba bean	Chocolate spot (*Botrytis fabae*)	Maize + fabba bean and barley + fabba bean	38
Bean's	Angular leaf spot (*Phaeoisariopsisgriseola*)	Maize + bean	45
Pea	Ascochyta blight (*Mycosphaerellapinodes*)	Cereal + pea	46

V. INSECT PEST MANAGEMENT WITH INTERCROPPING

According to Trenbath[47] described benefits of intercropping methods in cropping systems as itgives better protection of crops from pest and diseases than sole crops. When compared to monocultures of the same species, numerous studies have indicated a considerable reduction in dangerous insects in mixed cropping systems [48, 49, 50, 51].

In marginal farming,this method of cropping is more acceptable due to the low occurrence of insect pests [52]. A study byDempster and Coaker [53] suggested that Clover was proven to suppress three common insect pests, *Brevicorne brassicae, Artogeia rapae, and Erioischia brassicae*, when cultivated as a cover crop with brassica crops.Ramert*et al*. [54] documented potential of strip cropping in increasing yield by reducing pests attack on crops. The webworm (*Antigostra sp*.) showed reduced infestation in sesamumwhen intercropped with sorghum [55]. Mixed cropping of beans with maize minimizes the population of *Empoasca krameria* @ 26% and *Spodoptera spp*@ 14% of beans intercropped with maize in comparison to alone maize cropping system [56].Similarly, cowpea with cotton also reduced population of sucking pests [57]. Stem borer (*Chilo zacconius*) and stink bug (*Nezara viridula*) evidenced to have reduction in population when checked in upland rice + groundnut cropping system [58].

In wheat cropping system, Ma *et al*.[58] observed and concluded about the biological control of wheat aphid (*Macrosiphum avenae*) was enhanced in case of strip cropping of wheat and Alfalfa with the increase of predatory mite (*Allothrombium ovatum*) population than in wheat monoculture. English grain aphid, *Sitobion avenae* population significantly decreased when oil seed rape and garlic were intercropped in winter wheat [16] than in sole crop. In addition, significant increase of aphid parasitoids were also observed with wheat-oilseed rape intercropping treatments. Moreover, the results of wheat-mung bean intercropping on its natural enemies showed that this intercropping cuts down aphids population greatly and the ratio 12:4 of wheat: Mung bean accordingly produced the greatest results. It has also been evaluated that parasitoides and predators population density was higher in intercropped field in comparison to wheat alone fields [60]. Hummel et al [61] suggested that canola and wheat might be used in an integrated pest management strategyas it shows significant reduction in damage obtained by *Delia spp*in comparison to their monocrop pattern.However is has also been reported by Hummel et al [62]canola and wheat intercrops increase the population of some carabid species (ground beetles), potentially increasing the load on some canola insect pests. Some examples are cited and presented in Table III which shows effects of different intercropping systems in insect pest reduction.Negligence at part of agriculturists, adaptations of harmful non-ecofriendly practices and lack of proper knowledge have resulted into reduction in our beneficial flora and fauna [63]. Beneficial organisms not only maintain balance in ecosystem, they also provide numerous benefits in crop pollination and genetic variability of crops. Intercropping or enhancement of multiple flora would help those beneficial organisms to grow and flourish in the crop ecosystem [64, 65]. This would create a safe environment for honey bees, natural enemies, and/or wild pollinators to visit their crops, as well as improve pest control [66, 67].

Table III. Insect Pest controlled in intercropping.

Main crop	**Pest controlled**	**References**
Wheat + mustard	Wheat Aphid (*Diuraphis noxia*)	68
Wheat+Linseed(Linumusitatissimum L.)	Termites	49
Wheat + barley	Aphid *(Diuraphis noxia)*	48
Wheat + mung bean	Aphid and enhances Ladybird	60
Wheat + canola	Ground beetle (*Carabidae)*	62
Groundnut+ cowpea	Leaf folder (*Cnaphalocrocis medinalis)*	51
Mustard+ cabbage	Cabbage head borer (*Hellula undalis)*	50
Tomato+ cabbage	Diamondback moth*(Plutella xylostella*)	68

CONCLUSION

Intercropping promotes better yield production as the competition among variety of crop family for available recourses is different and adjustable due to variable requirement of those (different rooting depths, nutrient requirement, growth stage) and in this manner all mixed crops facilitates the growth of each other. Farmers practice intercropping for a variety of reasons, including plant health and the most efficient use of limited land resources. Winter cover cropping, for example, is a farming strategy that promotes species diversity. Through various studies, it has been discovered that diversified farming systems promote much improved biodiversity, soil quality, carbon sequestration, water-holding capacity in surface soils, energy-use efficiency, and climate change resistance and resilience when compared to traditional farming systems. Intercropping has been suggested as a way to increase biodiversity and production on a broad scale. Intercropping has been in traditional use for hundreds of centuries. However, its agronomical perspective is still unclear. Intercropping systems can also be more difficult to manage than pure stands, particularly during harvest. More studies need to be conducted for understanding the functional aspect of intercrops and to develop intercropping systems which go well with today's farming systems. Intercropping is possible in traditional agricultural systems to achieve equivalent yield levels if the compatible combinations of plant species are selected. Intercropping can also help in enhancing the arthropod diversity. Therefore, we recommend that intercropping must be employed in the conventional agricultural practices for widening and diversifying the horizons of cropping systems. The use of intercropping in conjunction with other farming systems can improve the quality of agricultural systems and boost biodiversity while maintaining comparable yields.

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