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Intercropping Systems in Wheat (*Triticum sativum* L.) for Insect Pests and Disease Management – A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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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. In the current study, numerous instances were provided that show successful control of various insect pests when wheat was intercropped with mustard, Linseed, barley, mung bean, canola, and other crops. Wheat intercropping with other crops can be used as part of an integrated pest management strategy to reduce pest incidence while also increasing the number of beneficial organisms.

Keywords: Intercropping; pest management; Triticum sativum; wheat.

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1. 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 which gives numerous benefits and enhance resource use efficiency. Among various benefits, yield and growth enhancement, sustainability in production, environment safety to all flora and fauna in ecosystem are the highlights of it. In this cropping system, two or more agricultural crops are cultivated on the same piece of land at the same time, cohabiting for a long time during the crop cycle and interacting 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 emphasized with 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].

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 systems are responsible for large scale vegetation while using green methods and decreased risk of crop damage through insect pests and diseases. It involves the correct use the human workforce with a standard profit [7,8].

2. BENEFITS OF INTERCROPPING SYSTEM

Various benefits of intercropping are enhanced production, soil health, reduction 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.

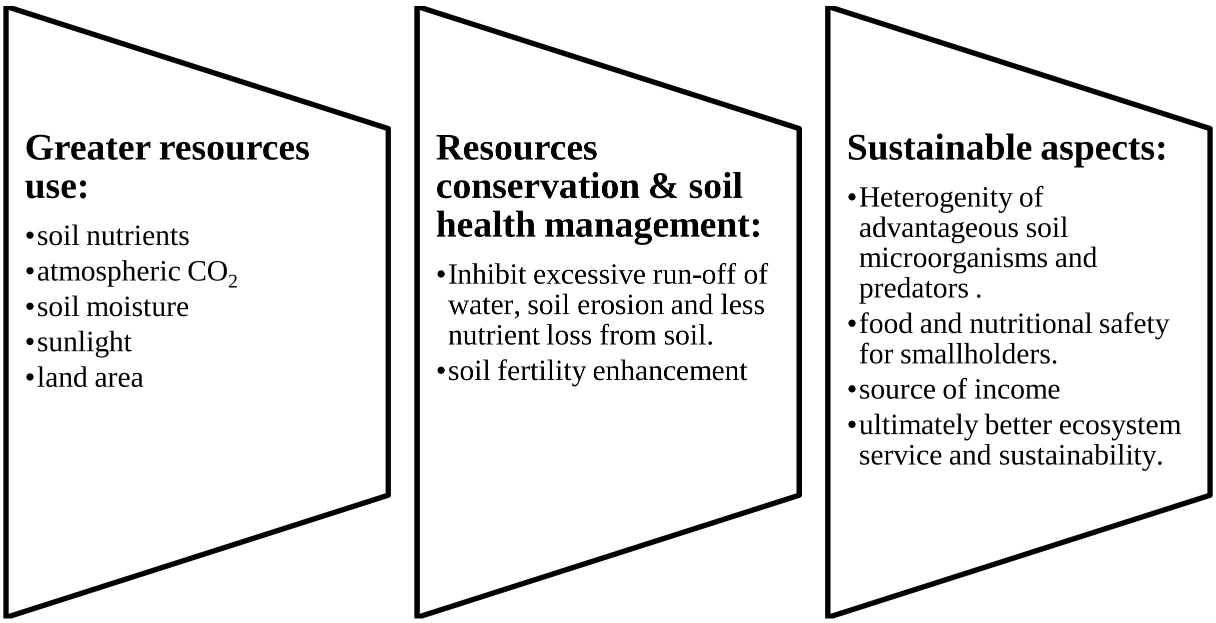

Fig. 1. Benefits of intercropping [9]

3. INTERCROPPING IN WHEAT

Cereal crop wheat, *Triticum sativum* 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. When cucumber was intercropped with soybean, wheat, and oats [16] it was found that wheat-cucumber intercropping significantly increased cucumber growth and wheat crop yield. Wheat and pea intercropping was found to be beneficial from an economic standpoint 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 in another study. In wheat, onion and garlic intercropping reduction in weed density was observed when it was performed in 4:2 rows strips [18]. Wheat - potato (*Solanum tuberosum*) relay intercropping system gave maximum advantage with slight change of crop geometry and maintaining intra-row spacing [19] on contrary to which Singh with his coworkers [20] reported mean decrease in the yield of wheat grain production with 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 1 which shows different effects of different wheat intercropping systems.

Intercropping has the potential to be a very promising cultural technique in terms of insect 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].

4. DISEASE MANAGEMENT WITH INTERCROPPING

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, *Madicago lupulina* intercropping results in less incidence of soil borne disease like, take-all disease of wheat, caused by *Gaeumannomyces graminis* [40]. In case of winter rye and winter wheat intercropping, reduction in leaf fungal diseases was observed [41]. Similarly, Pino and coworkers [42] reported that in comparison to tomato alone, maize-tomato intercropping showed a lower proportion of pest and disease occurrence. A correlated reduction of pathogen borne diseases was noticed with increase in bean density when wheat and field bean were intercropped together [43]. Hummel and his coworkers [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 one study [44] the 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 2 which shows effects of different intercropping systems in disease reduction.

5. INSECT PEST MANAGEMENT WITH INTERCROPPING

According to Trenbath [47], the benefits of intercropping methods in cropping systems include better insect pest and disease protection for crops than single crops. Numerous studies have found a significant reduction in dangerous insects in mixed cropping systems when compared to monocultures of the same species [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 [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. In another documentation [54] potential of strip cropping in increasing yield by reducing pests attack on crops was discussed. 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 *Spodopteraspp@* 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 (*Chilozacconius*) and stink bug (*Nezara viridula*) evidenced to have reduction in population when checked in upland rice + groundnut cropping system [58].

Table 1. Positive and negative impacts of different intercropping systems of wheat

Main crop + intercrops	Out-comes	References
Wheat + Pea	Net increase 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	Net increase 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	Net increase in crop yield.	[32]
Wheat + Maize	Net increase in crop yield.	[33]
Wheat + Maize	Reduction in CO_2 emissions and enhances water use	[34]
Wheat + Fenugreek	Net increase in crop yield.	[35]

Table 2. Decrease of disease by the application of intercropping system

Crops	Name of the controlled Disease	Inter-cropping Combination	References
Wheat	Fusarium head blight (*Fusarium graminearum*)	Wheat + mustard	[39]
Wheat	Alternaria blight *(Alternaria triticina*)	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 (*Phaeoisariopsis griseola*)	Maize + bean	[45]
Pea	Ascochyta blight (*Mycosphaerella pinodes*)	Cereal + pea	[46]

Table 3. Reduction of insect pests in different intercropping systems.

Main crop	Pest controlled	References
Wheat + mustard	Wheat aphid (*Sitobion avenae)*	[68]
Wheat+Linseed (*Linum usitatissimum* L.)	Termites (*Odontotermes obesus*)	[49]
Wheat + barley	Aphid *(Diuraphisnoxia)*	[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]

The biological control of the wheat aphid (*Macrosiphum avenae*) was observed and concluded to be enhanced in the case of strip cropping wheat and Alfalfa with an increase in predatory mite (*Allothrombium ovatum*) population than in wheat monoculture [58]. 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 parasitoids and predators population density was higher in intercropped field in comparison to wheat alone fields [60]. In their another study [61], they 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 this has also been reported by Hummel and team [62] that canola and wheat intercrops increase the population of some carabid species (ground beetles), and found potentially increasing the load on some canola insect pests. In addition to these some more examples are cited and presented in Table 3 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].

6. DISADVANTAGES OF INTERCROPPING

Intercropping systems, on the other hand, have some disadvantages. Because intercropped plants compete for light, soil nutrients, and water, the main crop in an intercropping system rarely achieves the same yield as a monoculture. Reduced major crop yields, lower productivity during droughts, and high labour inputs in places where labour is scarce and expensive are some of the examples of drawbacks [69]. This yield loss could be economically significant if the main crop has a greater market price than the intercropped plants. The Land Equivalent Ratio was commonly used to estimate productivity in intercropping systems. In most mixtures, wheat's partial LER was less than 0.5, whereas pea's partial LER was greater than 0.5, showing that pea had an advantage over wheat in these intercropping systems [70]. Also, when early and late maturing crops are planted in intercropping systems, late maturing crops tend to experience from growth panelties, while early maturing crops benefit [71].

7. 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. Some findings imply that intercropping can be helpful in both stressful (rainfed) and non-stressful (irrigated) moisture supply situations [72]. Therefore, farmers in rainfed locations can also utilise them because they are the most profitable methods. The majority of Indian agriculture is rainfed [73]. 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. There is a wealth of evidence showing intercropping cereals with legumes boosts nitrogen fixing in leguminous crops while also increasing nitrogen uptake in cereal crops.Wheat intercropping with pulses and oilseeds not only fetches higher prices, but it also reduces the risk of crop failure.Theuse of intercropping of wheat with oilseedsand other leguminous cropscan improve the quality of agricultural systems and boost biodiversity while maintaining comparable yields.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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