

Review on: Inter-Cropping System and Its Advantages

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To cite this article:

Debela Bekele. Review on: Inter-Cropping System and Its Advantages. *Reports*. Vol. 1, No. 4, 2021, pp. 36-42.

doi: 10.11648/j.reports.20210104.12

Received: November 22, 2021; **Accepted:** December 16, 2021; **Published:** December 29, 2021

Abstract: The only way to increase agricultural production in the small or marginal units of farming is to increase the productivity per unit time and area. One method of increasing productivity is by using multiple cropping systems. It uses management practices where the total crop production from a single piece of land is achieved by growing single crops in close sequence, growing several crops simultaneously, or combining single and mixed crops in some sequence. Intercropping which is one of the multiple cropping systems is a growth of two crops in the same field, where the component crops are not necessarily sown at the same time nor harvested at the same time, but they are grown simultaneously for a portion of their growing periods. The objective of this paper is to revise intercropping systems and its advantages across the world. Some of the advantages of intercropping are increase productivity, greater stability of yield over different seasons, better use of growth resources, better control of weeds, pests and diseases, control erosion, fixation of nitrogen by the legume component and others. In Ethiopia, maize intercropped with common bean reduced the severity of Angular leaf spot (ALS) disease. When susceptible faba bean cultivar was grown with either barley, oat, triticale or wheat, on average there was 47.2% reduction of disease severity for intercrops compared to that of the faba bean monocrop and 29.6% less disease area under the disease progress curve (AUDPC) for intercrops compared to the faba bean monocrop. Disease spread was reduced in mixed cropping because physical barriers against aerial pathogens and their vectors, trapping effect, altering microclimate (shading and humidity) and by spacing effect. The prevalence of the legume-based intercropping systems improves soil fertility by biological N fixation. Biological N fixation (BNF) is a natural process in legume crops, where atmospheric nitrogen (N₂) is fixed into ammonia (NH₃) in plant root nodules by a symbiotic form of Rhizobia. At the end yield advantage occurs because component crops differ in their use of growth resources in such a way that when they are grown in combination they are able to 'complement' each other and so make better overall use of resources than when grown separately. For example Sorghum and common bean row intercropping gave the highest agronomic advantage (43%) at Babile and 40% at Alemaya over sole cropping of the component crops.

Keywords: Intercropping, Component Crops, Yield, Nitrogen Fixation, Land Equivalent Ratio

1. Introduction

Cropping system refers to the principles and practices of cropping as well as their interaction with farm resources, technology, aerial and edaphic environments to meet regional and global production strategies [40]. An important factor for adoption of a certain cropping system is the economic return or monetary gain per unit area and time while yield in general is the most important agronomic parameter for evaluating the importance of component crop in any type of cropping system [25].

Several factors affect the type of cropping systems used by small holders, including soil fertility, temperature, rainy

season length, and pressure on the land [62]. In general, the common approaches to design alternative cropping system are crop intensification, crop diversification and cultivar selection. These three approaches become inseparable and considered as a building block of a new system [63].

Agricultural success or failure may be determined by many factors but most importantly will be continue to be the adequacy, sustainability and quality of food supplies as the human population continues to grow [20]. In the small or marginal units of agriculture, the only way to increase production is to increase the productivity per unit time and area [15]. Various means can be used to achieve this goal, such as breeding more productive varieties or varieties that mature quicker with equal yields, or improving techniques of

culture, fertilizer use, irrigation, and weed and pest control.

Nevertheless, the limitations of these agricultural inputs and increasing pressure on the supply of arable land of the tropical regions may lead to more intensive multiple cropping [20], which includes the intensification of cropping in time and space dimensions [56]. A multiple cropping system is an intensification of cropping in time and space dimensions. This means, growing of two or more crops on the same field in one year. Multiple cropping systems allows growing more than one crop from a single piece of land. It is achieved by growing single crops in close sequence, growing several crops simultaneously, or combining single and mixed crops in some sequence [56]. It is the intensification of cropping both in space and time dimensions, as it includes sequential cropping, intercropping and mixed cropping [40].

The multiple cropping systems represents an insurance system for subsistence farmers. It offers several biological and socio-economic benefits: improving food security, protecting soil, reducing pest and disease pressure, efficient use of water and nutrients, in a more sustainable way. Increased land use, better distribution of available workforce and income for the whole family. The multiple cropping systems consists of many types of cropping systems such as double cropping, inter cropping, strip cropping, etc.

Double-cropping is a production system that includes the growth of two separate crops at different times in the same growing season [66]. This system involves the harvesting of one species followed immediately by the planting of another. Compared with single cultivation, double-cultivation used climate, land, labor, and equipment resources more efficiently and produced more total grain [66]. It minimizes risk when a full season crop fails and increases land productivity [52].

Intercropping is one important of the multiple cropping systems. It is a growth of two crops in the same field, the component do not necessarily have to be sown at the same time nor harvested at the same time, but they are grown at the same time as part of the growth cycle [33]. Researches indicate that inter cropping is the best method of using land efficiently and improve soli fertility Therefore the aim of this review is to assess and summarize the effect of inter cropping on land use efficiently and soil improvement at different locations in the world and give at the end a brief recommendation.

2. Literature Review

Intercropping is also the growth of two crops in the same field, where the component crops are not necessarily sown at the same time nor harvested at the same time, but they are grown simultaneously for a portion of their growing periods [33]. This practice involves growing of two or more crops simultaneously on the same field. In intercropping systems, crop intensification could be in both time and space dimensions [41]. In an intercropping system, there is commonly one major crop and one or more added crops often sown later in the same season, with the main crop being of

primary importance for economic or food production reasons [33].

In an intercropping system there is intercrop competition during all or part of crop growth. Mixed intercropping, row intercropping, strip intercropping and relay intercropping are cropping practices categorized under intercropping system [41]. Intercropping is a dominant crop practice in the tropics [37]. Main objectives of intercropping are, intensification of cropping both in time and space dimensions and to raise production per unit area by increasing the plant population. It also entails better utilization of soil moisture, nutrients and solar radiation than sole cropping of the base crop. Legume crops and non-legume crops are generally intercropped with each other [40].

Some of the benefits of intercropping are increased productivity, improved yield stability in different seasons, better use of growth resources, better control of weeds, pests and diseases, control of erosion, fixation of nitrogen by the legume component and others [53, 18, 19, 33, 54, 15].

However, intercropping has some drawbacks. These are yield reduction of component crops due to unfavorable competition, and the difficulty of actual handling of mixed crops, especially when mechanization is required, different requirements for fertilizers, herbicides, and pesticides. These difficulties are typically associated with more developed agriculture; and subsistence farmers are well able to handle intercropping and have strong inherent preference for it [60].

There are many types of intercropping. Relay intercropping – the growing of two or more crops on the same field with the planting of the second crop after the first one, e.g. over seeding of a clover cover crop into cotton during defoliation, or planting of clover at lay by time of corn.

Row inter-cropping – the growing of two or more crops simultaneously on the same field with at least one crop planted in rows, e.g. planting corn in the rows and inter-seeding sorghum between the rows, harvesting all as silage or planting clover in between orchard tree rows. Strip intercropping – the growing of crops in alternate strips wide enough to permit separate crop production using machines, but close enough for crops to interact, e.g. planting alternating rows of corn and soybeans 6 rows each or alternating strips of corn and Sudan grass [56].

2.1. Relay Inter-cropping

Relay intercropping is cultivating of two or more crops on the same field with the planting of the first crop followed by the second crop, e.g. over seeding of a clover cover crop into cotton during defoliation, or planting of clover at lay by time of corn. Relay Intercropping of chickpeas on rice resulted in greater number of panicles per m², heavier grains (1000 grain weight) and increased above ground biomass yield especially when chickpea was relayed 2 to 4 weeks after sowing rice in Kenya [35].

In Ethiopia, rice / chickpea relay interculture in the fogella-vertisol region, performed using chickpea seed yield as a treatment, did not affect rice growth, yield, and yield components. And the chickpea relay intercropped between

rows of transplanted rice after twenty to thirty days from the planting time was completely dried and unable to give seed yield. Hence, under current crop management practice of rice at Fogera vertisol areas, chickpea cannot replace the grass pea in rice-grass pea relay intercropping system which is farmers practice [11].

In maize-bean relay cropping, there is more flexibility to increase bean production without affecting in maize yield. This may be due to the short duration the two crops being together in the field [8]. Despite the growing of crop production transformation in the world, multiple cropping systems have been historically important for common bean production in the tropical countries [65].

2.2. Advantage of Inter-cropping

2.2.1. Disease and Insect Pest Management in Intercropping

Different cultivation systems and production conditions can affect disease outbreaks, plant development and crop damage. The effects of diseases may depend on certain production conditions, locations and seasons [23]. Mixed cultures can reduce the spread of the disease, because of physical barriers to pathogens from air and its mediators, trapping effects, microclimate changes (shade and humidity), and distance effects. [4].

The severity of Angular leaf spot (ALS) in common beans can be reduced by mixed varieties and intercropping with cereals [5]. In Ethiopia, maize intercropped with common bean reduced the severity of Angular leaf spot (ALS) disease [6]. The incidence and severity of CBB and rust diseases reduced during intercropping [23]. This is because, maize acted as the physical barrier in different planting patterns to the free spread of the fungus propagules or reducing spore dissemination [37]. From the variety of factors involved in the facilitative production principle, the one most cited and documented is the reduction of pest attack frequently found in intercrops. All plant species inherently have some protection of defense against the invasion of pests [58]. Pest populations are lower in mixed crop as compared to monocrop systems. This is because: (1). patchy distribution and low concentration of food resources for pests (the “resource concentration hypothesis”), (2). adverse modification of crop microclimate (the “microclimate hypothesis”) and, (3). increased abundance and/or effectiveness of natural enemies (the “natural enemies hypothesis”).

Maize/bean intercropping significantly tended to be less subjected to attack by pod borer and bean fly compared to the sole beans and significantly reduced the incidence of stalk borers and comb worm on maize. This is because, maize prevents further infestation due to creating adverse conditions and uses as trap crop for African bollworm in which beans are vulnerable. Significantly, higher pest incidence occurred in simultaneously planted maize, where as in beans higher pest incidence was observed in relay-planted beans [37].

Mixed crop cultivation has recently been recognized as an agricultural system that will reduce the incidence of plant

diseases. It has been found that better disease control is possible if either host plants are mixed with non-host plants or if one crop changes the environment of the second crop so that the latter is less susceptible to disease infestation [36]. [29] showed that intercropping green gram with soybean or millet can significantly reduce the incidence of powdery mildew compared to when Green gram is grown as the sole crop. Intercropping legumes with cereals are known to improve disease control [13, 22, 21, 48]. Example chocolate spot reduction has been reported when faba bean was intercropped with cereals, but there are conflicting reports on the effect in intercrops with other legumes [17, 45].

2.2.2. Nitrogen Fixation by Legume Component

Nitrogen-fixing plant root activity benefits the roots of surrounding plants through the excretion of nitrogen from the nodules or through the microbial degradation of the nodules or the entire plant [50].

Differences in the distribution of rainfall and temperature during flowering could have influenced the development of roots which is important because large root systems could allow the development and support a large nodule mass [47]. Bean/corn intercropping is usually planted under conditions of low soil fertility and minimal technical input. This system allows to increase and diversify the yield per unit area and reduce the risk of total crop failure. In addition, the fixed nitrogen part of legumes can be used for companion crops, but these results are not conclusive [47].

The prevalence of the legume-based intercropping systems may be because some studies have shown that the non-legume components derive N from the legume components [7]. However, the extent to which this is true is still a subject of intense debate [38, 24, 59]. Others have concluded that in an intercropping system, nitrogen is not transferred directly from legumes to non-legume crops, but nitrogen can be used for subsequent crops [49, 64, 57].

Biological N₂ fixation (BNF) is a natural process in legume crops, where atmospheric nitrogen (N₂) is fixed into ammonia (NH₃) in plant root nodules by a symbiotic form of Rhizobia (*Rhizobium leguminosarum* bv. *viciae*) a gram-negative *Proteobacteria*. The plant assimilates this NH₃ into proteins, nucleic acids and other nitrogenous compounds [67].

According to [68] BNF from legume crops contributes 2.95 Tg N to agriculture globally. BNF has a high potential for low-input systems, as in large regions of Africa, where more N is removed from the soil than is replenished, which results in depletion of soil nutrients and land degradation [69].

Atmospheric nitrogen (N) fixation in crop and pasture legumes also plays a key role in providing human and livestock protein and for maintaining soil fertility in agro-ecosystems [70]. Improving N fertilizer efficiency and exploitation of biologically fixed N (BNF) are thus of great importance for long-term sustainability of crop production in agro-ecosystems [71]. The global high price for N fertilizer and the overall environmental impact of excessive fertilizer use [72, 73] warrant a growing interest in legume BNF,

especially for smallholder farmers in the tropics.

For instance the principal agronomic advantage of faba bean in inter cropping is its ability to fix nitrogen by symbiosis with *Rhizobium* bacteria, and thereby substantially contribute to the supply of protein for human food and animal feed and greatly reduce dependence on energy consuming mineral N fertilizers [31].

2.2.3. Land Use Efficiency

Yield advantage occurs because component crops differ in their use of growth resources in such a way that when they are grown in combination they are able to 'complement' each other and so make better overall use of resources than when grown separately. Probably the main way that complementarity can occur when the growth patterns of the component crop differ in time so that the crops make their major demand on resources at different times or temporal complementarity [54, 60]. The major growth resources may be more efficiently utilized by intercropping include light, nutrients and water, in combinations that include both a legume and non-legume [43].

Land Equivalent Ratio (LER)

LER is the most commonly used type of cropping index. Its inherent use is that different crops whatever their type or levels of yield, are put on a relative and directly comparable basis. To avoid bias because of differences in yield proportions, it can be calculated based on monetary values [60].

$$LER = La + Lb = Ya/Sa + Yb/Sb$$

where La and Lb = the LERs for individual crops in the mixture and

Ya and Yb = the individual crop yields in an intercropping situations,

Sa and Sb = the yield of species a and b as sole crops.

For the purpose of comparing genotypes combination, it may be sensible to use the same standardizing factors for each combination, which leads to Sa and Sb being defined as the maximum or the average sole crop yields. But, each intercrop compared with its respective sole crop only at its optimum populations and spacing [34]. While monetary advantage (ma) was calculated as, yield of combined intercrop yield * (LER-1)/LER [60].

Tamado Tana and Eshetu Mulatu [51] Conducted field experiments at Alemaya and Babile in 1996 and 1997 to evaluate the agronomic performance and productivity of sorghum, maize, and common bean grown in row intercropping, mix cropping and sole cropping. Sorghum and common bean row intercropping gave the highest agronomic advantage (43%) at Babile and 40% at Alemaya over sole cropping of the component crops as shown by their LER values. However, sole maize gave the highest gross monetary value at Alemaya (8054 ETB ha⁻¹). [52] Affirmed that, in Ethiopia, LER was usually selected as a criterion to assess the agronomic advantage of intercropping systems as it already mentioned by other authors [34]. The yield advantage of any intercrop is attributed to below and above ground plant interactions. The interactions may be competitive, neutral, or

complementary [51]. However, the interactions are likely to vary depending up on the temporal and spatial differences in resource use by component crops [2].

Intercropping did indeed show a much improved stability over any sole crop systems though it should be appreciated that if stability is assessed in this way, a reduced incidence of crop failure can occur partly because of a higher intercropping yield as well as a genuine reduction in the variability of the yield [44]. The economic return or monetary gain per unit area and time is one of the major considerations for adoptions of a certain cropping system and yield is the foremost agronomic parameter to compare the importance of component crop in any type of cropping system [25].

In the tropics, cereal/legume intercropping is a common practice aimed at minimizing risks associated with monoculture. Intercropping may provide a balanced diet, reduce labor peaks, minimize crop failure due to adverse effects of biotic and abiotic factors, protect soil against erosion, improve the use of limited resources, increase stability of yield and provide higher returns [9, 3, 16, 48].

Productivity advantages of intercropping may arise from complementary use of growth resources such as N and water in either space or time [3, 38, 10]. Moreover, productivity of mixtures could exceed those of sole crops, as the mixing of the two crops may favor more significant yield components in either crop [32].

In the same manner and elsewhere, the beneficial effects of intercropping of wheat with legumes was ascribed to the more efficient use of environmental resources by the intercrops than by pure stands [7, 14, 27]. Measurements such as the total yield, total revenue, land equivalent ratio, crowding coefficient, aggressivity value and system productivity index have been used to quantify the efficiency of intercropping systems relative to sole cropping [28, 1]. However, the land equivalent ratio is the most used convention for intercrop vs. sole crop comparisons. This may stem from the fact that increasing land-use efficiency is the most important reason for producing crops in intercrop.

In Ethiopia, food production for a rapidly growing population from a continually shrinking farm size is a prime developmental challenge. Researches indicate that intercropping is a good way of using land efficiently. The most important intercropping mixtures used by farmers can be grouped into three broad categories: cereal-cereal, cereal-legume, and tree-annual [30]. The cereal- legume intercropping is the most common [6]. In many parts of tropical Africa and South America, common bean and other legumes are traditionally grown as intercrops with maize of varying growth stages [39]. In common bean, simultaneous planting and relay crops are the two types of intercrop [65].

In 2001 and 2003, mixed intercropping of wheat and faba bean at Holetta Agricultural Research Center, in the central highlands of Ethiopia was compared with sole cultivation of each crop. Mixed intercropping increased land equivalent ratio by +3% to +22% over sole cropping. By increasing the faba bean seed rate in the mixture from 12.5 to 62.5%, wheat grain yield decreased from 3601 kg ha⁻¹ to 3039 kg ha⁻¹ while faba

bean grain yield increased from 141 kg ha⁻¹ to 667 kg ha⁻¹. Nonetheless, the highest total grain yield, gross monetary value, system productivity index, and crowding coefficient were

achieved when wheat at its full seed rate intercropped with faba bean at a rate of 37.5% with a yield of 4031 kg/ ha [26].

Table 1. Effects of intercropping on component grain yield, land equivalent ratio and gross monetary advantage of wheat and faba bean, 2002–2003.

Intercropping	wheat	faba bean	LER	Gross monetary value (US \$ ha ⁻¹)
Sole wheat	3801a	-	1.00b	760b
Sole faba bean	-	1819a	1.00b	418c
Wheat /faba bean (100:12.5)	3601ab	141e	1.03b	753b
Wheat /faba bean (100:25)	3394bc	352d	1.08b	760b
Wheat /faba bean (100:37.5)	3482b	548c	1.22a	823a
Wheat /faba bean (100:50)	3198dc	574bc	1.16ab	772ab
Wheat /faba bean (100:62.5)	3039d	667b	1.17ab	761b
Significance level	***	***	**	***
LSD 0.05	264.1	121.4	0.1	50.7

Source Getachew *et al.*, 2008. Agronomy for Sustainable Development

2.3. Planting Date

In most double-cropping systems, planting crops at the optimum time is a major problem [46]. In double-cropped late-planted soybean, delayed planting reduces number of days to maturity reduces the number of days to flowering, and decreases the length of vegetative and reproductive periods of development, decreases plant height and others. These reductions are due to a shorter photoperiod encountered by soybean plants [12].

In regions where growing season's precipitation is commonly insufficient to meet crop requirements, the magnitude of the soil water reserve at planting is often related to crop yield [42]. Unless the use of earlier maturing cultivars is adopted, or those suited to late plantings are developed, risk of plantings and instability of returns from double cropping is expected [74].

3. Conclusion and Recommendation

Inter cropping is a best cropping system to gain highest economic return per unit area. This system increases economic return by increasing total yield per unit area. It reduces cost of agricultural inputs costs like fertilizer and pesticides. It is also an insurance cropping system especially when one crop is failed by any disaster farmers can have a harvest of one crop. During inter cropping the first thing to be considered is selection of component crops. Legume-cereal based intercropping is an important technique to improve soil fertility. Therefore in inter cropping system we have to use crops of different resource requirement. The best example for this is faba bean/maize inter cropping. In disease control inter cropping, crops resistant to different diseases should be inter cropped e.g. wheat can be grown in faba bean to control chocolate spot.

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