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REVIEW PAPER

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A review on advantages of cereals-legumes intercropping system: case of promiscuous soybeans varieties and maize

Josiah M. Kinama[1], Habineza M. Jean Pierre*[1,2]

[1]*Department of Plant Science and Crop Protection, University of Nairobi, Nairobi, Kenya*

[2]*University of Goma (UNIGOM), Goma, Democratic Republic of Congo (DRC)*

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Abstract

Intercropping is a practice mostly done by small-scale farmers. It's a cropping system which involves the growth of two or more plants in the same field during the same season to allow interactions between component crops. The importance of this cropping system implies insurance against total crop failure, yield improvement, weed control, pest and diseases control, biological nitrogen fixation, increased light interception, increased biomass formation, high incomes returns, yield advantages shown by land equivalent ratio. This study is a collection of reviewed reports recently done on intercropping and which have focused on cereal-legume intercropping. It assessed the advantages obtained from intercropping, especially in cereal-legume cropping system. However, reviewed reports showed useful information base for agricultural scientist with interest in the field of intercropping research with particular focus on cereal-legume intercropping system.

* **Corresponding Author:** M. Jean Pierre ✉ ir.jphaby@gmail.com

Introduction

Soybeans which nodulate effectively with diverse indigenous rhizobia are considered as promiscuous (Maphosa, 2015). Promiscuous in nodulation allows soybean to be introduced into a range of environments where lack of suitable inoculants would otherwise preclude growing the crop (Mpepereki *et al.*, 2000). Promiscuous soybeans are more important for small scale farmers because of their multiple benefits. Among those benefits include: increase of household nutrition from high protein and oil content, cash income from sales of the crop, biological nitrogen fixation which result in reduction of mineral fertiliser cost, and yield advantages derived from intercropping (Ijoyah, 2012). Intercropping, the practice done closely by small scale farmers is defined as the growth of two or more crops together, in the same field during the growing season to promote the interaction among component crops (Habineza *et al.*, 2017). Cereals –legumes cropping system is the most used by small scale farmers in Sub Saharan Africa because of their compatibility (Lithourgidis *et al.*, 2011). The reason of that combination is not only based of the high returns per unit area in intercropping than in sole crop, but also it offers the farmers insurance against crop failure, helps control erosion, weeds and insect infestation and brings about a more distribution of farm labour than sole crop. There are also some socio-economic, biological and ecological advantages in intercropping over mono-cropping (Mohammed *et al.*, 2008).

Many researchers worked on promiscuous and non promiscuous soybean intercropped with cereals such as Simpson, (1999); Mpepereki *et al.*, (2000); Osunde *et al.*, (2003); Sekamatte, *et al.*, (2003); Prasad & Brook, (2005); Muoneke *et al.*, (2007); Thole, (2007); Raji, (2007); Nekesa *et al.*, (2011); Kananji *et al.*, (2013); Sileshi, (2013); Zhang *et al.*, (2015); Tsujimoto *et al.*, (2015); Sebetha, (2015); Habineza *et al.*, (2018). The objective of this paper is to put together review of works carried out by researchers; especially on cereal-promiscuous soybean based intercropping, which could be useful for other agricultural scientists that would want to research in this field.

Intercropping system

General overview on intercropping system

Cropping system involves plants and plant-arrangements and the organization method utilized on a specific farm during a given period. That word isn't novel. It has been utilized more frequently in recent years, debating about sustainable agriculture. Growing two or more crops (i.e. intercrop or association) is necessary in agriculture in terms of better usage of resources, increasing light interception, increasing yields, productivity and raising soil fertility than sole cropping (Li *et al.*, 2013). Intercropping system comprises four technics which are: Mixed arrangement, where plants are grown simultaneously in association; row arrangement, where plants component are grown simultaneously in diverse rows; strip arrangement, where plants are grown simultaneously in diverse strips; and relay arrangement , where plant are grown in relay so that growth cycles overlap (Li *et al.*, 2013). Productivity and profitability are among the reason which allow preference of cereal- legume cropping system used to day by many farmers in order to achieve food and nutritional security and sustainability. Yield benefit, high use efficiency of light and water, and pest and disease reduction are major causes of intercropping preference. Legumes-cereals are intercropped aiming that, cereals will profit from the N fixed by legumes (Mohammed *et al.,* 2008). Plant legumes are also important in increasing production, as well as N and P nourishment of cereals. In intercropping, the level of reserve of nutrient, total yield and yield between intra and interspecific can be influenced by competition or the presence of ecosystem resources (Nwaogu and Muogbo, 2015). In addition, a lot of mechanisms explain how intercropping use water, light, nutrients proficiently than mono-cropping (Andersen, 2005). That situation can happen when the component crops are not competing for the same nutrients (Trenbath, 1993).

Intercropping system profits

Intercropping system is known by many scientists as valuable to farmers in the for small-input/high-risk environment of the tropics.

Intercropping legumes-cereals is suitable small-scale farmers because of the capacity of cereals to reduce soil erosion and increasing of soil fertility by legumes. Flexibility, profit maximization, risk minimization are also causes of intercropping preference by small-scale farmers in addition increasing soil fertility, ecosystem conservation, weeds control and stable nutrition (Dwivedi *et al*., 2015). Cereals require the same space in sole crop as in intercrop to produce the same yield (Ijoyah, 2012). That is why intercropping is better for maximization of the land for production in this time where population is increasing exponentially while production is increasing arithmetically (Ijoyah, 2012). However, good intercropping achieve on best benefits due to positive interaction between the component crops (Lithourgidis *et al.,* 2011).

Weed control

Most scientists believe that, traditional intercrop systems are better in weeds control, than sole crop (Willey *et al.,*1983), but also that can depend on weed growth and its competition habits and the behavior of crop components during intercropping (Willey *et al.,*1983). It has been reported that cereals and cowpea intercrop decreased striga propagation on the high level (Khan *et al*., 2002). Mashingaidze (2004) also reported that maize-bean intercrop decrease weed biomass by 50-66% when the bean density is 222,000 plants ha^{-1} equivalent to 33% of the maize density (37,000 plants ha^{-1}).

Pest and diseases control

In terms of pests and diseases, the most recognized effect is that, one crop can offer protection to the spread of a pest or disease of the other crop (Willy *et al.,*1983). Sekamatte *et al*., (2003) also reported that termite which attack common bean can be controlled by soybean and groundnut intercropping. In addition, maize stalk borer infestation was higher in sole (70%) than in the intercrop of maize/soybean (Martin, 1990).

Soil erosion control

Plant cover in intercropping plays an important role in stopping energy from rainfall and prevent runoff which could cause soil erosion.

Its known that, cereals have the capacity to stop erosion and legumes can fertilize soil by fixing biological N and together they play complementary role (Thyamini, 2010). Kariaga (2004) showed that in maize-cowpea cropping system, cowpea acts as a good cover and decreases run off than maize-bean system. Rana and Rana (2011) found that taller crops act as wind barrier for short crops, in intercrops of taller cereals with short legume crops. However, sorghum-cowpea cropping system decreases erosion by 20-30% than sorghum mono crop by 45-55% compared to cowpea monocrop. However, Kinama *et al*., (2007), Kinama *et al*., (2011) found that, intercropping maize-senna and senna-cowpea reduced soil erosion compared to monocropped plots.

Biological Nitrogen Fixation (BNF) in cereal-legume intercropping system

BNF, which allows legumes to rely on atmospheric nitrogen (N), is better especially where fertilizer N is insufficient (Fujita *et al.,* 1992). That situation is more pronounced in Sub Saharan Africa (SSA) where annual N reduction was taken at all levels at rates of 22kg ha^{-1} (Smaling *et al.,* 1997) and mineral-N fertilizer is sometimes not accessible to growers (Jama *et al.,* 2000). Under different environment and soil situations, BNF for legumes contributes to N for growth and grain yield production for component crops. However, after disintegration of legume residues, the soil can restock N which can be used later by cereals. Legumes which can produce grain and green manure have a potential to fix 100 to 300kg N ha^{-1} from atmosphere (Table 2.1). Studies which quantify legumes which fix N are insufficient. However, the one available demonstrated technical problems in that situation (Jama *et al.,* 2000). For instance Fujita *et al.,* (1992) found that, 30-60kg N ha^{-1} year^{-1} are fixed by legumes in the soil.

Table 1. A summary of N_2 fixation potential from different categories of tropical legumes.

Legume system	% N derived from fixation	Amount fixed (kg N ha^{-1})	Time (days)
Grain	60-100	105-206	60-120
Green manure	50-90	110-280	45-200
Trees	56-89	162-1,063	180-820

Source: Fujita *et al.,* 1992.

Osunde *et al.* (2004) has shown that, 40 % of N can be fixed by legumes biologically without nitrogen fertilizer in intercropping system of soybean with cereals and 30% in the monocrop. Sanginga *et al.* (1996) found that Mucuna amassed in 12 weeks about 160kg N ha^{-1} when intercropped with maize. Eaglesham *et al.* (1981) recorded that cowpea fixed about 41kg N ha^{-1}, in intercropping with maize. According to Ofori and Stern (1987) the quantity of N fixed by legume in cereal- legume intercrop, depends on numerous factors, like plant species , plant morphology, density of crops component, technics aspect, and growth habit of the component crops. Fujita *et al.* (1992) found that, zero use of N-fertilizer and shading didn't affect N_2-fixation by the component groundnut crop. However, when 50kg N ha^{-1} was used, BNF was reduced to 55%. This means that, heavy use of combined N reduces BNF, which was verified by Ofori and Stern (1987) who assessed the N economy of a maize-cowpea in intercrop. Furthermore, according to Fujita *et al.* (1992) plant population contributes to amount of N resulting from dinitrogen fixation. Even if the annual potential fixation rates of N can be 300kg N ha^{-1}, the quantity measured on field of the small-scale farmers is still very little (6kg N ha^{-1} to 80kg N ha^{-1}), excluding soybean whose range of fixation comprises 100 and 260kg N ha^{-1} in a period which cannot exceed three months (Li *et al.,* 2004). In addition, some scientists have shown that grains obtained from the component plants are the main contributors of N loss from the intercropping system and can range from 50 to 150kg N ha^{-1}. Denitrification, leaching and volatilization are the mechanism in which nitrogen can be lost or the material harvested, especially in the grains (Stern, 1993). Osunde *et al.* (2003) and Habineza *et al.* (2018b) reported that, BNF by promiscuous varieties of soybeans in cereal-legume intercropping offers a potential for reducing the speculation made by scale farmers on nitrogen fertilizers.

Transfer of nitrogen in cereal intercropped with legume

Previous studies have reported that intercropping non-legumes and legumes supply nitrogen to non-legumes through nitrogen from legumes (Fujita *et al.,* 1992). Eaglesham, *et al.,* (1981), reported that in SSA nitrogen fixed by the leguminous plants component in current growing season are available to the associated cereal. Eaglesham *et al.,* (1981) revealed that during association of maize and cowpea, maize crops had used 24.9% of fixed nitrogen by cowpea. Fujita *et al.* (1992), reported that, the benefits of associating crops with legumes could be affected by crop densities and legume growth stages. Nitrogen is found by succeeding crops due to nodule senescence, root and fallen leaves (Giller and Mapfumo, 2006). However, Habineza *et al.* (2018b), found that, variety TGX1990-5F could be recomended to small-scale farmers for intercropping with maize because it produced higher nodules and fixed higher N, hence reducing the cost for N fertilizers

Residual effects of cereal-legume cropping system

Legumes in intercropping accumulate N in the soil and that N can be available for feeding the next plant which can be in rotation, sole crop or in intercropping during next season (Ofori and Stern, 1987). However, Yusuf *et al.* (2009) reported maize productivity was 46% greater when grown after soybean than when grown after other maize. Wortmann *et al.*, (1994) found that Tephrosia (*Tephrosia vogelii*), velvet bean (*Mucuna pruriens*), sunhemp (*Crotalaria juncea*), organic matter increased maize production from 3-6 T ha^{-1} without mineral N fertilizer.

In addition, Whitbread and Pengelly, (2004) reported that production of maize was improved by 25% and 88% after intercropping of mucuna-maize and cowpea-maize respectively. Phiri *et al.* (1999) reported that maize production was enhanced 24.4% after Sesbania sesban -maize cropping system. Kureh *et al.* (2006) obtained that, production of maize was 28% greater one year after soybean application and 21% greater one year after cowpea application than successive maize planting. However, they found also that, maize production was 85% greater two years after soybean and 62% greater two years after cowpea than planting maize successively. Nevertheless, Recous *et al.* (2008) reported maize improved productivity of 34.0% after 4 successive intercropping of maize and gliricidia than sole maize.

Franzluebbers *et al.* (2016) found that 30% efficient productivity of millet was increased in millet-cowpea cropping system than sole millet planting. Akinnifesi *et al.*, (2007) reported that maximizing the input of legume N to the next plant, is essential to exploit total quantity of N in legume plant, the amount of N given from N_2 fixation, the quantity of legume N mineralized and the effectiveness of use of this mineral N. Nevertheless, it is not always easy to improve these aspects. However, recent studies on nodulation of promiscuous soybean varieties and non promiscuous soybean showed that, non-promiscuous soybean varieties produced high amount of nodules after inoculation with *Bradyrhizobium japonicum* and fertilizer application than promiscuous soybean varieties non innoculated (Njeru *et al.*, 2013; Klogo *et al.*, 2016). This might improve the amount of nitrogen fixation for non-promiscuous soybean compared to promiscuous soybean varieties (Njeru *et al.*, 2013; Klogo *et al.*, 2016). Thus, selection and breeding for promiscuous varieties which could produce high amount of nodules and enhance biological nitrogen fixation gains in smallholder systems are needed.

Maturity of the crops

When component crops for intercropping have different growing times for each stage, competition can be reduced because each plant would need nutrients in its specific time which can be different for another component plant, so, fertility in the soil cannot be finished and production advantage can be greater than in the sole crop (Ofori and Stern, 1987). Thus, plants which can present their maturity in different times are very important because they can equilibrate their needs in terms of water, light, and nutrients during their different maturity time and these plants are very useful for intercropping (Seran and Jeyakumaran, 2009). In this case Rana and Rana (2011) found that green gram matured at 60 days after planting while maize peak sunlight was fitting demand in maize-green gram intercropping.

Compatible crops

Compatible crops in intercropping are very important because they can easily diminish competition by their arrangement in the field and by exploiting the soil nutrients (Gebru, 2015). Cereals-legumes cropping system is the most used in small scale farmers in SSA because it is compatible and component plants can use N from the soil from different origins (Lithourgidis *et al.*, 2011). Competition for soil water, light and nutrients is greater for cereals than legumes in cereals–legumes intercropping (Thobatsi, 2009).

Plant density

Planting density for each crop is adapted under its normal rate. However, in the intercrop plant density is adjusted below its full rate density. Furthermore, if full density of each crop could be applied the way it is, any yield could be found because of excess population of plants (Thyamini *et al.*, 2010). Morgado and Willey, (2003) obtained that bean plant population can decrease dry matter yield for maize and bean for each plant separately. Muoneke *et al.* (2007) also reported that soybean yield decreases by 21 and 23 percent by enhancing maize plant population at 44,440 and 53,330 plants/ha, successively. Another study conducted by Bulson *et al.* (1997) found that wheat grain and all the biomass can increase nitrogen content when the population of bean is increased in wheat-bean intercropping system; and it increased also the grain protein harvested. Egbe, (2010) reported that increasing density of soybean increases the value of soybean by (0.76 - 1.15) in the intercrop with sorghum, showing greater effectiveness at the biggest population densities than the sorghum component, while the effectiveness ratio of sorghum increased negatively (1.23 - 0.76). Prasad and Brook, (2005) found that increasing maize population can increase maize dry matter but also decreasing quantity of light which could reach the soybean in intercropping. N_2 fixation can be influenced also by plant density. In this case, Kessel and Roskoski, (1988) said that biological nitrogen fixed in cowpea at 30 to 50% depends on the spacing used considering the light interception ability of each legume species.

Time of planting

Planting time is among the major factors determining the loss or the gain of the yield in intercropping system and it has been highlighted by previous studies.

However, Mongi *et al.,* (1976) found that growing cowpea-maize instantaneously provided efficient production. Barbosa *et al.,* (2008) also showed that planting cowpea with maize together increases the yield per unit area, and at the same time cowpea controls bad herbs at certain levels. In addition, Addo-Quaye *et al.* (2011) reported that maize-soybean grown instantaneously or earlier soybean presented greater values of leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR), than to when it was late planted.

Promiscuous soybeans and its importance

Soybeans which can produce effective nodules with diverse native rhizobia are referred to as promiscuous soybeans (Kueneman *et al.,* 1998). Promiscuous soybean allows smallholder farmers to get seeds which can produce high yield, maintaining cropping system, increasing soil fertility, producing more protein and oil content, while soybean which need artificial inoculant increase input decreasing productivity per unit of area (Mpepereki *et al*., 2000; Habineza *et al*., 2017; Habineza *et al*., 2018b and Habineza *et al*., 2018a).

Nodulation formation

Atmospheric N fixation can be effective if suitable populations of soil N-fixing bacteria (*Bradyrhizobium japonicum* in the genus Rhizobium) are either available in the soil or applied to soybean grains so nodules can form on roots. The first step in nodulation is the good penetration of the bacteria into the root hair of soybean seedling and the formation of an infection thread. Nodules from the root can result from many infection threads or double infection from the single thread. A round 10 to 14 days, the N fixation begin to happen in the nodule. Rhizobium bacteria convert atmospheric N to ammonium (NH_4) which is a form of N available to the crops, and in turn the crops provide carbohydrates to the bacteria to survive. The following conditions are most likely to cause the failure of nodulation and reduce N fixation: Fields with poor soil rhizobia bacteria populations or fields with previous forage legume, Low quality inoculants due to inappropriate storage and conditions, Dry conditions, excessive moisture or flooding for several days.

Nodules can be viable and available with 8 to 20 nodules at the flowering stage (Mosanto, 2014). Madimba *et al.* (1994) reported that, nodulation can be effective depending on different strains of Rhizobia and environmental conditions so their study showed that the soybean strain (FN_3) gave 27 to 51 nodules per plant while the soybean strain (IRAT274) gave 19 to 45 nodules per plant. The control gave 3 to 40 nodules per plant.

Effect of intercropping on productivity and Land Equivalent Ratio (LER)

Enhancing the productivity of the component plant per unit of surface is among the major aims for intercropping system (Sullivan, 2003). On the other hand, utilizing Land Equivalent Ratio (LER) in cereal-legume cropping system, Khan *et al.* (1988) found cooperation among crops and higher yield than monocrop. Muoneke *et al.* (2007) obtained yield advantage from intercropping productivity of 2-63% as presented by LER of 1.02-1.63 showing effective utilization of land resource in intercropping system than in sole crop. Raji, (2007) found great effective production in intercropping systems of maize-soybean. Addo-Quaye *et al.,* (2011); Dariush, Ahad, and Meysam (2006) reported that LER gave efficient productivity in maize-soybean intercropping than sole crop. They also demonstrated, LER of 1.22 and 1.10 for maize-soybean intercrop in two successive years. Matusso, *et al*., (2012) reported higher productivity among pearl millet-cowpea cropping system than in their monocrops where LER was 1.2. Dariush *et al*., (2006) found LER alternated from 1.15 to 1.42 showing land use efficacy of maize and great efficiency of climbing bean in intercrop per unit area than sole crop. In addition, Habineza *et al*., (2017) reported that, maize-soybean intercropping system gave LER higher than 1 which was advantageous for the component crops.

Effect of intercropping on grain quality

Ayu *et al.,* (2004) found that, sorghum gave maximum protein yield intercropped with soybean than sorghum monocrop. In many cereal- legumes intercropping systems, there is emanation of favourable exudates from the component legume to the associated cereal and this is suspected to have effects on the quality of the cereal in terms of protein yield.

However, William (2012) reported that varieties with early maturity give poor seed quality especially for those varieties whose maturity are not uniform. Wet conditions, shading by component crops, pressures of some diseases, poor conditions between pysisological maturity and harvest can enhance the decrease of seed quality. In addition Habineza *et al.*, (2018a) found that, maize-soybean intercropping system affected negatively soybean protein content while it increased maize biomass and grain yield.

Disadvantage of intercropping

The roots of crops in association compete for growth factors such as nutrients, light and moisture which may affect the associated crop negatively (Rana and Rana, 2011). Sarkodie and Kahaman (2012) reported that legumes could become pest in an intercropping system by shading the components crop(s) and thereby reducing yield.

The main issue of intercropping is that, the component in that cropping system cannot be harvested by machine because the machine cannot separate the crops associated. So, farmers must separate those component crops by hand and arrange it by hand. In addition, some association systems permit harvest at different dates and that save crop species divided (Rana and Rana, 2011). In addition, a competition in sunlight, air, rainfall and nutrients has been done by maize on soybean in maize-soybean intercropping system in the experiment conducted in Kinya (Habineza *et al.*, 2017).

Conclusion

Considering the reviewed results obtained, intercropping cereals–legumes has shown advantages among component crops. This has been assessed by higher land equivalent ratio values higher than 1.0, higher proportion of land saved and higher incomes obtained than in monocrop. However, intercropping cereal-legumes system was found to be mostly complementary and adequate in mixture. Resource poor farmers will most likely benefit from intercropping systems and more research on intercropping will produce more results to support the poor rural communities. This will improve food and nutritional security at household level.

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