Chapter

# Potential and Advantages of Maize-Legume Intercropping System

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## Abstract

Intercropping provides enough scope to include two or more crops simultaneously in same piece of land targeting higher productivity from unit area. Maize, a cereal crop of versatile use, as planted in wide rows offers the opportunity for adoption of intercropping. The intercropping system with maize and legume is beneficial in multifaceted aspects. The success of maize-legume intercropping system largely depends on choice of crops and their maturity, density, and time of planting. Advantage of maize-legume combination of intercropping system is pronounced in the form of higher yield and greater utilization of available resources, benefits in weeds, pests and disease management, fixation of biological nitrogen by legumes and transfer of N to associated maize, insurance against crop failure to small holders, and control of erosion by covering a large extent of ground area. Though maize-legume intercropping system exhibits limitations like less scope of farm mechanization, dependence on more human workforce, and chance of achieving less productivity from maize, the system implies more advantages for small holders in developing countries where human workforce is not a constraint. The chapter has focused on beneficial impacts of maize-legume intercropping system.

**Keywords:** intercropping, maize, legume, advantages, productivity, sustainability

## 1. Introduction

The cropping system is growing of crops on an area interacting with resources and time and intercropping system is raising of two or more crops simultaneously in the same piece of land [1, 2]. This a common practice in developing countries and it is mostly practiced by small and marginal famers. In tropical world, intercropping is prominently visible with food grain cultivation, whereas in temperate countries forage based intercropping is very much common [3]. Intercropping is generally practiced on small farms with limited resources and it has been observed to enhance yields with greater stability in a variety of crop combinations. Moreover, intercropping system is known by less use of inputs, namely, fertilizers, plant protection chemical, and thus healthy, safe, and high quality food under ecologically sound production system. On-farm biodiversity is also promoted by diversification of crops in through mixed cropping, intercropping and agroforestry systems resulting in variation of diet and net return, higher level of production stability, proper utilization of limited resources human labour-force under low levels of technological intervention [3] and all these ultimately lead to achieve production sustainability in agriculture.

Maize (*Zea mays* L.), also termed as 'corn' and 'queen of cereals', is the third most important cereal of the world, ranks at third position amongst the cereals after rice and wheat and it is a member of Poaceae family. The very cereal has been a staple food for many people in Mexico, Central and South America and parts of Africa. In Europe and rest of the North America, maize is grown mostly as animal feed. Maize is widely cultivated throughout the world having a production of 1147 million tonnes [4]. In various cropping systems as well as in intercropping maize can be fit due to its wider adaptability in different seasons and agro-climatic conditions. Maize is a widely spaced crop and offers ample scope for adoption of intercropping and combination of maize legume in intercropping benefits the agricultural production system by many ways with enhancement of productivity from unit area [2]. This chapter focuses on different aspects of maize based intercropping system, such as considerations, advantages and limitations.

## 2. Considerations for choosing intercropping system

The success of intercropping depends on different considerations before and during cultivation as because crops grown in mixture may compete spatially and temporally amongst species for available resources. An efficient intercropping system in terms of economic benefits depends on adaptation of planting geometry and choice of compatible and suitable crops. The features of an intercropping system differ with soil and climatic conditions, economic situation and preferences of the farmers. In cereal-legume intercropping system, choice of crop species, density of planting, planting geometry, time of planting and maturity of crops are the key considerations and the success of the system largely depends on these factors.

### 2.1 Choice of crops

Choice of crops is important in intercropping, because severe competition in mixed culture may not be beneficial and even harmful if proper plant species are not chosen. In this way competition amongst plants can be minimized and better utilization of available resources can be assured. The combination of cereal and legume is considered an ideal because cereals can utilize a portion of biologically fixed nitrogen by legumes. In maize based intercropping system, groundnut is chosen as intercrop maize in South East Asia and Africa [5]. Maize can provide shade to associated legumes and the legume species should be to some extent tolerant to shade. Legume species like black gram (*Vigna mungo*), cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogea*) and green gram (*Vigna radiata*) have much less effect on maize and these are tolerant to maize shade [6, 7]. Cereal-legume intercropping is very common in the continents of Asia, Africa and South America [8], however, in tropical countries, maize based intercropping is practiced with a preference to cowpea [9]. In Central and South America and parts of East Africa intercropping of maize and bean is widely practiced [10]. Maize and dwarf red gram intercropping combination is known as a suitable option in managing cereal component [11].

### 2.2 Maturity of crop

Maturity of crop is another important consideration in adoption of intercropping. Generally, crops grown in intercropping should have different peak period of growth, otherwise there will be competition amongst the crop species for available resources. The complementary effects benefit the system and these are reflected into yield advantage when the component species in intercropping have different growing period for major demands on available resources. Therefore crops with different duration maturity are chosen to get complementary effects. Maize has been recognized as a common crop in cereal-based intercropping and treated as base crop in additive series and dissimilar legumes are preferably considered as intercrop. In maize-based intercropping system choosing short duration legumes as intercrops is an ideal option. For example, in maize + green gram intercropping system, initial growth of maize is slow and it reaches at knee-height stage after 6–7 weeks and peak light demand starts from 55 to 60 days after sowing and by this period green gram sown at the same time will be in reproductive stage or in close to harvest. In this way green gram completes its major growth period and maize starts the same and thus high level of complementarity is observed.

### 2.3 Plant density and maturity of component crops

Optimum plant stand is synonymous to optimum yield. But in intercropping system two or more crops are accommodated in the same land at the same time and thus there may be reduction in population of crops compared to pure stand of individual species. On the basis of plant density, intercropping may be categorized into two groups, namely, additive series and replacement series. The additive series is comprised of addition of intercrop within fullest population of base crop. Another crop known as intercrop and it is sown into the base crop population by adjusting row spacing or changing planting geometry. Sometimes, paired row planting of maize is done to accommodate greater space for intercrops. But in replacement series of intercropping, there is not the concept of base crop and the crops (two or more) considered are termed as component crops or intercrops. In such type of intercropping, introduction of a component crop is made by replacing another and none of the component crops are sown with 100% population as recommended in their pure stands. It is very clear that certain proportion of population of one crop component is sacrificed and another component is introduced in that place. In many intercropping situations with replacement series, yield advantages are maximized by increasing population density in excess than their recommended population in the sole cropping. Here, the competition is relatively lesser in between component crops as compared to additive series. As maize is widely spaced crop and generally row spacing ranges between 60 to 90 cm and intercrops can easily be raised in uniform rows of planting. The planting geometry, particularly, paired row planting of maize may enhance the efficiency of growth parameters as well as yield of maize and associated legumes by efficient accommodation of crops. Prasad and Brook [12] observed an enhanced LAI per unit area with increase in plant population of maize in maize-soybean intercropping system. Under the major demand for resources at different times of system duration, the long duration cereal crop maize can recover its resource needs in combination with short duration legumes during remaining phase of growth that is after harvest of legumes [13].

### 2.4 Time of planting

Maize is recognized as a very common crop in intercropping system in which legumes can be sown easily. Generally, in maize based intercropping systems, as maize has slower initial growth rate up to knee height stage (6–7 weeks of sowing), if short duration legumes are sown simultaneously can reach into their reproductive stage can start their reproductive period and hence competition for common natural resources do not appear at the same period. Maize has diverse use and if maize is considered as fodder in intercropping, competition does not come into figure because of enhance biomass yield and mixture of grass-legume combination enhances the quality of forage in terms of dietary value. Moreover, maize has higher potential for accumulation of carbohydrate, a source of energy as fodder, from unit area on daily basis. However, legumes can be planted in maize at the same time can also register higher growth attributes because of wider spacing of maize as grain crop.

## 3. Advantages of intercropping

Maize and legume intercropping system has advantages in many ways and so preferred by small and marginal farmers. Experimental results showed that maize-legume intercropping can assure higher yield, soil restoration and greater impact of system productivity.

### 3.1 Advantage in improving productivity and soil fertility

In Intercropping, more crops are grown simultaneously in unit area which results not only greater productivity but also utilizes natural resources more efficiently. Management of pests, diseases and weeds is easier because of less incidence which leads to greater yield. Another important aspect of maize-legume intercropping is restoration of soil fertility.

#### *3.1.1 Higher yield and greater resource utilization*

Yield is the basic consideration for assessing benefits of intercropping. In maize-legume intercropping maize is treated as based crop without much variation in plant stand of cereal component. In additive series of intercropping, legumes add plant population per unit area and benefits are achieved as total yield of crops, namely maize and legume yields. Further, in a combination of legume and non-legume, generally non-legume component is benefited by sharing atmospheric nitrogen fixed by legumes. In assessing efficiency of an intercropping system, some competition functions are considered. Of which land equivalent ratio (LER) is a very common index used to measure productivity of intercropping system. Willey and Osiru [14] proposed the concept of the LER and it is defined as the proportionate land area required under pure stand of crop to produce the same productivity as obtained in an intercropping at the same management level. Actually, LER is the summation of ratios of the yield of each crop species involved in intercropping system to its corresponding pure stand yield. Experiments carried out in different countries clearly exhibited higher LER values in maize-legume intercropping system (**Table 1**).

The LER indicates the advantage of an intercropping with efficient resource utilization compared to pure stands of respective crops. The value of LER greater than unity (1.0) is indicative of the advantages in intercropping system [2].

The LER indicates on efficiency of using land area, but time factor is not considered for which the crop occupies the land area. To rectify the limitation of the LER, the concept of area time equivalent ratio (ATER) has been developed considering the occupancy of land by the crops for certain periods [23]. Like the LER, values of the ATER more than unity also indicate advantage of intercropping. Different researchers noted beneficial ATER values with maize-legume intercropping systems (**Table 2**).

However, researchers comment that the LER overestimates and the ATER underestimates the land-use efficiency [27].

Crop equivalent yield is another expression for evaluating the efficiency of intercropping system [25]. Actually, in maize-legume intercropping system, total

| Intercropping system | Ratio/proportion | LER | Country | References |
|---|---|---|---|---|
| Maize + bean | 2:1 | 2.60 | Kenya | [15] |
| Maize + cowpea | 1:1 | 1.72 | Turkey | [16] |
| Maize + French bean | 1:2 | 1.66 | India | [17] |
| Maize + soybean | 1:1 | 1.54 | Nigeria | [18] |
| Maize + groundnut | 2:2 | 1.42 | Ghana | [19] |
| Maize + garden pea | 1:2 | 1.56 | Bangladesh | [20] |
| Maize + soybean | 100% + 75% | 1.60 | Turkey | [21] |
| Maize + groundnut | 2:2 | 1.82 | India | [7] |
| Maize + soybean | 2:2 | 1.90 | China | [22] |

**Table 1.**
*Land equivalent ratio (LER) in maize-legume intercropping systems.*

| Intercropping system | Ratio | ATER | Country | References |
|---|---|---|---|---|
| Maize + black gram | 1:2 | 1.37 | India | [24] |
| Maize + black gram | 1:2 | 1.47 | India | [17] |
| Maize + soybean | 2:6 | 1.32 | India | [25] |
| Maize + black cowpea | 2:2 | 1.51 | India | [26] |

**Table 2.**
*Area time equivalent ratio (ATER) in maize-legume intercropping systems.*

yields are converted in the form of base crop (maize) equivalent yield by considering the intercrop yield and market price of maize (base crop) and associated intercrops. In maize-legume intercropping system it is termed as maize equivalent yield (MEY) and expressed in $kg^{-ha}$. If the base crop equivalent yield is obtained higher in intercropping combinations than base crop yield, then intercropping is considered advantageous. **Table 3** indicates advantageous MEYs as obtained by the researchers in experiments.

The greater yields in intercropping is recorded when the component crops show complementary effects amongst themselves and use natural resources efficiently than raised as sole crops [28]. The crops with inherent capability can only utilize natural resources efficiently and complementarity plays important role in resource utilization [2]. Further, higher yield of both the crops in maize-cowpea intercropping combination was noted than pure stands [29].

In soils with low nitrogen content, maize legume intercropping performed well [30]. Yield advantage in intercropping is expressed by crops because of greater use of growth resources like light, water, and nutrients and this efficient use is

| Intercropping system | Ratio | MEY ($kg^{-ha}$) | Sole maize yield ($kg^{-ha}$) | Sole legume yield ($kg^{-ha}$) | References |
|---|---|---|---|---|---|
| Maize + soybean | 2:6 | 9470 | 7092 | 5450 | [25] |
| Maize + black cowpea | 2:2 | 7699 | 5062 | 4785 | [26] |
| Maize + garden pea | 1:2 | 20,220 | 8200 | 6450 | [20] |

**Table 3.**
*Maize-equivalent yield (MEY) in maize-legume intercropping systems.*

converted into biomass [2, 31]. The combination of maize-cowpea intercropping can assure greater light interception and check evaporation loss of soil moisture than pure stand of maize [32].

Maize and legumes are morphologically dissimilar and their time of peak demand and requirement of light, nutrients and water are different. Therefore, complementary effect between component crops is very common. Jiao et al. [33] noted that maize used strong light and groundnut preferred weak light (because maize provided partial shade) in maize-groundnut intercropping system and the system registered yield advantage. Further, soybean-maize intercropping has been known for efficient utilization of light, nutrients and available soil moisture [2, 34]. Soil moisture or water availability to plants is a determining factor in intercropping systems and efficient water use leads to use of other resources. Cereal-legume combination is known to use available water resources more efficiently than pure stands of crops. Scientific investigations showed that maize-legume combination registered greater water use efficiency than that of sole crops and under water stress conditions, it could be one of the best options [35] as soybean as a deep rooted crop having efficiency to use soil moisture from deeper layer (below 1 m) of the soil [36].

### *3.1.2 Weed management*

Intercropping is an effective practice for weed management because enough of ground area is covered by crops which suppress weed growth. Combination of maize and legumes in intercropping is known to reduce weed population and weed biomass compared to pure stands of maize. Research evidences clearly show benefits of intercropping as it provides competitive effect against weeds both spatially and temporally than pure stands of maize. Reduced weed growth in maize-cowpea intercropping system than sole cropping of maize. Chalka and Nepalia [37] mentioned that in maize-legume intercropping systems, maize + cowpea and maize + soybean reduced NPK removal through weeds by 37.4 and 38.0% respectively and the two intercropping combinations registered higher biological yield of maize. Rahimi et al. [38] reported that maize-black gram intercropping combination of either 1:1 or 2:2 recorded lower densities of total weeds compared to pure stand of maize. Shah et al. [39] opined that weed smothering efficiency was higher in intercropping of maize with soybean than the combination of maize with green gram and it was due to the lower availability of space and light leads to reduce the weeds population with maize-soybean intercropping system. Weed biomass is reduced in intercropping as reported by researchers for maize–legume combinations [40, 41]. In studies it has been claimed that enhancement of diversity of crop species in intercropping system maintains a highly asymmetric competition over weeds resulting in less weed biomass [42, 43]. Weeds compete with crops for available resources and less weed occurrence assures ultimately higher productivity.

### *3.1.3 Pest and disease management*

Intercropping systems can influence the pest and pathogen population dynamics. The population of beneficial insects such as parasites and predators are enhanced in polyculture due to diversity of crops [2] and presence of harmful pests may remain below the economic threshold level. Thus, plant protection becomes easy and use of chemicals for crop protection comes down which ultimately reduces the chemical pollution to agricultural ecology, however, monoculture of maize requires more chemical pesticides [44]. In intercropping system, two or more crop species are cultivated which creates complexity in food and habitat of pests. Further, intercropping of maize with legumes is known to increase population of beneficial insects and decrease the population of bud worm, corn borer, leaf hopper and maize stalk borer [1, 45]. The intercropping system has also an impact against disease management, because in mixture of crops functional diversity is created that checks population increase of pathogen. Some diseases of legume crops like angular leaf spot (*Phaeoisariopsis griseola*) of beans and ascochyta blight (*Mycosphaerella pinodes*) were observed with less severity when these were intercropped with maize [46, 47] than pure stand of legumes. Reduction of pest-disease incidence not only saves the crop loss and better yield but also assures less use of chemicals for plant protection and thus minimizes the chance of pollution in crop ecology.

#### *3.1.4 N-fixation by legumes and transfer to associated non-legume*

Legumes are known to fix atmospheric nitrogen biologically. The biological nitrogen fixation (BNF) is a process where some bacteria convert atmospheric $N_2$ into ammonia ($NH_3$) and making it available to plants. In maize-legume intercropping system, both the crops acquire N from the common soil pool and compete and thus deficit of mineral N may occur in the rhizosphere which promotes legume to fix atmospheric N [48, 49]. Maize is an exhaustive crop and legumes are soil replenishing crops and decomposition of legumes residue improves soil fertility. In the soils with poor available nitrogen status, the biologically fixed nitrogen plays an important role. Under the situation of limited supply of nitrogenous fertilizer also intercropping legume and non-legume may a suitable option of nutrient management. Further, chemical N fertilizers are responsible for degradation of ecosystem in the form of nitrate pollution and legumes grown as intercrops help in environmental sustainability [50]. In maize-soybean intercropping system, soybean supplements nitrogen to cereal component [51]. Maize grown as forage in intercropping with legumes is known to improve quality parameters of forage like higher crude protein and mineral content and digestibility [48, 52]. Biologically fixed N by pigeon pea was transferred to associated maize and N content and uptake by maize was improved in maize-pigeon pea intercropping system [53]. The associated non-legume crop (maize) gets benefit of fixed N by legumes [1]. Thus, maize-legume intercropping system is beneficial in terms of N economy too. Leaf defoliation of legumes is known to increase productivity of maize–soybean intercropping system [22].

#### *3.1.5 Erosion control*

Intercropping is advantageous in terms of erosion control because of coverage of more ground area than monocropping of cereals. The striking actions of rain drops can erode the bare or uncovered soil, but the coverage of soil by legumes can check it. In maize-cowpea intercropping combination, ground area is mostly covered, thus soil erosion is reduced [54]. Taller crop like maize also plays a vital role as wind break and protects the crops with shorter canopy (like legumes) as well as erosion caused by wind [45].

### 3.2 Advantage in enhancement of system productivity

#### *3.2.1 Insurance against crop failure to small holders*

Intercropping is a common practice of small and marginal farmers in developing countries of Asia and Africa and in risky and fragile ecological conditions which is known as a suitable practice to provide natural insurance and thus provides a profitable shape to farm economy. Under moisture stress conditions, more of ground area is covered under maize-legume intercropping than sole cropping of maize which leads to less evaporation loss of soil moisture. Under extreme conditions, may be due to either biotic or abiotic factors, a crop may fail, but there will be less chance of failure of more crops grown in intercropping, which are morphologically dissimilar and if so happened some yield and return will be earned to save small holders' economic interest. Thus stability in yield and return are achieved due to creation of crop diversity in the intercropping systems. In economic point of view, it may be stated that small farmers may face problem of seasonal price variability of commodities which often can destabilize net realization, but diversification in the form of intercropping can stabilize farm income to a great extent. Experimental results indicated superiority of intercropping maize-beans in soil fertility restoration and income enhancement than monocropping of the component crops [55]. Yield enhancement of crops is another basis to strengthen the economy of small and marginal farmers adopting intercropping system [56]. Though intercropping of maize-grain legumes is labour and cost intensive, small holders of central Mozambique prefer it because of reduced risk of crop failure and enhanced productivity [57].

#### *3.2.2 Sustainability of the system*

Intercropping is now in the centre of attention targeting sustainability in agriculture. The negative impacts of industrialized and modern agriculture have already been realized and issues are very crucial in crop ecology to achieve sustainability. On the other side, maize-legume intercropping has enough potential in the form of more yields from limited resource, proper utilization of resources, and restoration of soil fertility, efficient pest management and creation of above and below ground diversity. In the moisture stress or resource poor conditions, intercropping provides natural insurance against crop failure caused by biotic and abiotic factors and thus ascertains economic stability of small holders. Considering the multiple advantages, it can be stated that maize-legume intercropping system is one of the suitable options for achieving production sustainability for small holders.

## 4. Limitations of intercropping

Despite a number of benefits of maize-legume intercropping over monocropping, sometimes intercropping may exhibit some limitations especially in terms of agronomic management. In the field where farm mechanizations have been adopted, intercultural operations and harvest become difficult with two dissimilar crops. However, there is no problem where the intercrops are harvested for forage or grazed [13]. It may be mentioned that where human workforce is sufficient, particularly in developing countries, there is no need for investment in costly machines for agronomic management and harvest of crops in intercropping and in this regard intercropping does not express any disadvantages. Intercropping may cause yield loss of the base crop (maize) compared to its sole stand, but MEY become more and thus intercropping may be considered more productive than monoculture. Further in intercropping, crowded crop canopy may create a microclimate which may be congenial to spread of fungal pathogens, but in maize-legumes intercropping combination, such incidences are not common.

## 5. Conclusion

Considering the importance of maize in cereal basket of the world, production sustainability is a prime concern. Maize is an exhaustive crop by nature that requires enough nutrient inputs to achieve target yield. Under small holders' practices in poor soil and fragile ecological conditions continuous growing of maize may create further depletion of soil nutrients causing a threat to production sustainability. In this regard, maize-legume intercropping system is considered a suitable option as it has enough potential to replenish the soil nutrients, produce more yield and economic benefit by utilizing limited resource, check damage caused by pests, diseases and weeds to a large extent, control soil erosion by covering ground and provide natural insurance to small holders under risky conditions against crop failure. Thus, in true sense, maize-legume intercropping system can boost yield as well as production sustainability of the system as a whole.

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## References


[1] Seran TH, Brintha I. Review on maize based intercropping. Journal of Agronomy. 2010;**9**(3):135-145. DOI: 10.3923/ja.2010.135.145

[2] Maitra S, Palai JB, Manasa P, Kumar DP. Potential of intercropping system in sustaining crop productivity. International Journal of Agriculture, Environment and Biotechnology. 2019;**12**(1):39-45. DOI: 10.30954/0974-1712.03.2019.7

[3] Anil L, Park J, Phipps RH, Miller FA. Temperate intercropping of cereals for forage: A review of the potential for growth and utilization with particular reference to the UK. Grass and Forage Science. 1998;**53**:301-317. DOI: 10.1046/j.1365-2494.1998.00144.x

[4] FAOSTAT. Maize Production. Crops/Region/Production Quantity from Pick Lists, United Nations, Statistics Division [Internet]. 2018. Available from: http://www.fao.org/faostat/en/#data/QC [Accessed: 10 February 2020]

[5] Shalim Uddin M, Rahaman MJ, Bagum SA, Uddin MJ, Rahaman MM. Performance of intercropping of maize with groundnut in saline area under rainfed condition. Pakistan Journal of Biological Sciences. 2003;**6**(2):92-94. DOI: 10.3923/pjbs.2003.92.94

[6] Mandal MK, Banerjee M, Banerjee H, Alipatra A, Malik GC. Productivity of maize (Zea mays) based intercropping system during kharif season under red and lateritic tract of West Bengal. The Bioscan. 2014;**9**(1):31-35

[7] Manasa P, Maitra S, Reddy MD. Effect of summer maize-legume intercropping system on growth, productivity and competitive ability of crops. International Journal of Management, Technology and Engineering. 2018;**8**(12):2871-2875

[8] Layek J, Das A, Mitran T, Nath C, Meena RS, Yadav GS, et al. Cereal+legume intercropping: An option for improving productivity and sustaining soil health. In: Meena RS et al., editors. Legumes for Soil Health and Sustainable Management. Singapore: Springer Nature; 2018. pp. 347-386. DOI: 10.1007/978-981-13-0253-4_11

[9] Van Kessel C, Roskoski JP. Row spacing effects on nitrogen fixation, nitrogen yield and soil nitrogen uptake of intercropped cowpea and maize. Plant and Soil. 1988;**111**:17-23

[10] Singh SP, Singh RA, Singh UN. Yield and economics of sesame and blackgram, intercropping under dryland conditions of Vindhyan plateau, India. Indian Journal of Agronomy. 1998;**43**:321-324

[11] Gallo ADS, Fontanétti A, Guimarães NDF, Morinigo KPG, de Souza MDB, da Silva RF, et al. Agronomic characteristics, nutritional status and yield of corn intercropped with dwarf pigeon pea in different spatial arrangements of plants. Revista de Ciências Agrárias. 2018;**41**(2):356-366. DOI: 10.19084/RCA17297

[12] Prasad RB, Brook RM. Effect of varying maize densities on intercropped maize and soybean in Nepal. Experimental Agriculture. 2005;**41**:365-382. DOI: 10.1017/S0014479705002693

[13] Lithourgidis AS, Dordas CA, Damalas CA, Vlachostergios DN. Annual intercrops: An alternative pathway for sustainable agriculture. Australian Journal of Crop Science. 2011;**5**(4):396-410

[14] Willey RW, Osiru DSO. Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular reference

to plant population. The Journal of Agricultural Science. 1972;**79**:517-529

[15] Odhiambo GD, Ariga ES. Effect of intercropping maize and beans on striga incidence and grain yield. In: Proc. 7th Eastern Southern Africa Regional Maize Conf., 11-15 February 2011. Vol. 7. 2011. pp. 183-186

[16] Yilmaz S, Atak M, Erayman M. Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the East Mediterranean region. Turkish Journal of Agriculture. 2008;**32**:111-119

[17] Choudhary VK. Suitability of maize-legume intercrops with optimum row ratio in mid hills of eastern Himalaya, India. SAARC Journal of Agriculture. 2014;**12**(2):52-62. DOI: 10.3329/sja.v12i2.21916

[18] Kamara AY, Tofa AI, Ademulegun T, Solomon R, Shehu H, Kamai N, et al. Maize-soybean intercropping for sustainable intensification of cereal-legume cropping system in northern Nigeria. Experimental Agriculture. 2017;**55**(1):73-87. DOI: 10.1017/S0014479717000564

[19] Kermah M, Franke AC, Samuel AN, Benjamin DKA, Abaidoo RC, Giller KE. Maize-grain legume intercropping for enhanced resource use efficiency and crop productivity in the Guinea savanna of northern Ghana. Field Crops Research. 2017;**213**:38-55. DOI: 10.1016/j.fcr.2017.07.008

[20] Khan MAH, Sultana N, Akter N, Zaman MS, Islam MR. Intercropping gardenpea (Pisium sativum) with maize (Zea mays) at farmers field Bangladesh. Journal of Agricultural Research. 2018;**43**(4):691-702. DOI: 10.3329/bjar.v43i4.39166

[21] Aydemir SK. Maize and soybean intercropping under different seed rates of soybean under ecological condition of Bilecik, Turkey. International journal of Environmental Science and Technology. 2018. DOI: 10.1007/s13762-018-1986-2

[22] Raza MA, Khalid MHB, Zhang X, Feng LY, Khan I, Hassan MJ, et al. Effect of planting patterns on yield, nutrient accumulation and distribution in maize and soybean under relay intercropping systems. Scientific Reports. 2019;**9**:4947. DOI: 10.1038/s41598-019-41364-1

[23] Hiebsch CK. Interpretation of yields obtained in crop mixture. In: Agronomical Abstracts, American Society of Agronomy. Madison, Wisconsin; 1978. p. 41

[24] Kheroar S, Patra BC. Advantages of maize-legume intercropping systems. Journal of Agricultural Science and Technology. 2013;**3**:733-744

[25] Yogesh S, Halikatti SI, Hiremath SM, Potdar MP, Harlapur SI, Venkatesh H. Light use efficiency, productivity and profitability of maize and soybean intercropping as influenced by planting geometry and row proportion. Karnataka Journal of Agricultural Sciences. 2014;**27**(1):1-4. DOI: 10.23910/IJBSM/2017.8.6.3C0363

[26] Jan R, Saxena A, Jan R, Khanday M, Jan R. Intercropping indices and yield attributes of maize and black cowpea under various planting pattern. The Bioscan. 2016;**11**(2):1-5. (Supplement on Agronomy)

[27] Maitra S, Ghosh DC, Sounda G, Jana PK, Roy DK. Productivity, competition and economics of intercropping legumes in finger millet (*Eleusine coracana*) at different fertility levels. Indian Journal of Agricultural Sciences. 2000;**70**(12):824-828

[28] Willey RW. Intercropping—Its importance and research needs. Part 1: Competition and yield advantages. Field Crops Research. 1979;**32**:1-10

[29] Kimou SH, Coulibaly LF, Koffi BY, Toure Y, Dede KJ, Kone M. Effect of row spatial arrangements on agromorphological responses of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.). African Journal of Agricultural Research. 2017;**12**(34):2633-2641. DOI: 10.5897/AJAR2017.12509

[30] Vesterager JM, Nielsen NE, Hogh-Jensen H. Effects of cropping history and phosphorus source on yield and nitrogen fixation in sole and intercropped cowpea-maize systems. Nutrient Cycling in Agroecosystems. 2008;**80**:61-73. DOI: 10.1007/s10705-007-9121-7

[31] Reddy AS, Palled YB. Effect of intercropped fodder cowpea on maize and system productivity in maize + fodder cowpea intercropping systems. Journal of Farm Science. 2016;**29**(2):265-267

[32] Ghanbari A, Dahmardeh M, Siahsar BA, Ramroudi M. Effect of maize (*Zea mays* L.)—cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in and environment. Journal of Food, Agriculture and Environment. 2010;**8**:102-108. DOI: 10.1234/4.2010.1458

[33] Jiao NY, Zhao C, Ning TY, Hou LT, Fu GZ, Li ZJ, et al. Effects of maize-peanut intercropping on economic yield and light response of photosynthesis. Chinese Journal of Applied Ecology. 2008;**19**:981-985

[34] Raji JA. Intercropping soybean and maize in a derived Savana ecology. African Journal of Biotechnology. 2007;**6**(16):1885-1887

[35] Tsubo MS, Walker, Ogindo HO. A simulation model of cereal-legume intercropping systems for semi-arid regions: II. Model application. Field Crops Research. 2005;**93**:23-33. DOI: 10.1016/j.fcr.2004.09.002

[36] Maitra S. Soyabean. In: Hedayetullah M, Zaman P, editors. Forage Crop of the World. Vol. **2**. USA: Apple Academic Press; 2018. pp. 101-120

[37] Chalka MK, Nepalia V. Nutrient uptake appraisal of maize intercropped with legumes and associated weeds under the influence of weed control. Indian Journal of Agricultural Research. 2006;**40**:86-91

[38] Rahimi IM, Amanullah M, Ananthi T, Mariappan G. Influence of intercropping and weed management practices on weed parameters and yield of maize. International Journal of Current Microbiology and Applied Sciences. 2019;**8**(4):2167-2172. DOI: 10.20546/ijcmas.2017.604.175

[39] Shah SN, Shroff JC, Patel RH, Usadadiya VP. Influence of intercropping and weed management practices on weed and yields of maize. International Journal of Science and Nature. 2011;**2**(1):47-50

[40] Bilalis D, Papastylianou P, Konstantas A, Patsiali S, Karkanis A, Efthimiadou A. Weed-suppressive effects of maize-legume intercropping in organic farming. The International Journal of Pest Management. 2010;**56**:173-181. DOI: 10.1080/09670870903304471

[41] Stoltz E, Nadeau E. Effects of intercropping on yield, weed incidence, forage quality and soil residual N in organically grown forage maize (*Zea mays* L.) and faba bean (*Vicia faba* L.). Field Crops Research. 2014;**169**:21-29. DOI: 10.1016/j.fcr.2014.09.004

[42] Connolly J, Sebastia MT, Kirwan L, Finn JA, Llurba R, Suter M, et al. Weed suppression greatly increased by

plant diversity in intensively managed grasslands: A continental-scale experiment. Journal of Applied Ecology. 2018;**55**:852-862. DOI: 10.1111/1365-2664.12991

[43] Elsalahy H, Döring T, Bellingrath-Kimura S, Arends D. Weed suppression in only-legume cover crop mixtures. Agronomy. 2019;**9**:648. DOI: 10.3390/agronomy9100648

[44] Singh BB, Adjeigbe HA. Improving cowpea cereals-based cropping systems in the dry Savannas of West Africa. In: Fatokun A, Tarawali SA, Singh BB, Kormawa PM, Tamo M, editors. Challenges and Opportunities for Enhancing Sustainable Cowpea Production. Ibadan, Nigeria: IITA; 2002. pp. 276-284

[45] Kinama MJ, Pierre HMJ. A review on advantage of cereals-legumes intercropping system: Case of promiscuous soybeans varieties and maize. International Journal of Agronomy and Agricultural Research. 2018;**12**(6):155-165

[46] Vieira RF, de Paula TJ Jr, Teixeira H, Vieira C. Intensity of angular leaf spot and anthracnose on pods of common beans cultivated in three cropping systems. Ciénc. Agrotec. 2009;**33**:1931-1934. DOI: 10.1590/S1413-70542009000700040

[47] Schoeny A, Jumel S, Rouault F, Lemarchand E, Tivoli B. Effect and underlying mechanisms of pea-cereal intercropping on the epidemic development of ascochyta blight. European Journal of Plant Pathology. 2010;**126**:317-331. DOI: 10.1007/s10658-009-9548-6

[48] Dwivedi A, Dev I, Kumar V, Yadav RS, Yadav M, Gupta D, et al. Potential role of maize-legume intercropping systems to improve soil fertility status under smallholder farming systems for sustainable agriculture in India. International Journal of Life Sciences Biotechnology and Pharma Research. 2015;**4**(3):145-157

[49] Massawe PI, Mtei KM, Munishi LK, Ndakidemi. Existing practices for soil fertility management through cereals-legumes intercropping systems. World Research Journal of Agricultural Sciences. 2016;**3**(2):80-91

[50] Fustec J, Lesuffleur F, Mahieu S, Cliquet JB. Nitrogen rhizo deposition of legumes—A review. Agronomy for Sustainable Development. 2010;**30**:57-66. DOI: 10.1051/agro/2009003

[51] Owusu A, Sadick A. Assessment of soil nutrients under maize intercropping system involving soybean. International Research Journal of Agricultural and Food Sciences. 2016;**1**(3):33-43

[52] Dahmardeh M, Ghanbari A, Syasar B, Ramrodi M. Intercropping maize (zea mays L.) and cow pea (*Vigna unguiculata* L.) as a whole-crop forage: Effects of planting ratio and harvest time on forage yield and quality. Journal of Food, Agriculture and Environment. 2000;**7**:505-509. DOI: 10.3923/AJPS.2009.235.239

[53] Olujobi OJ, Oyun MB, Oke DO. Nitrogen accumulation, growth and yield of maize in pigeon pea/maize intercrop. Global Journal of Biology, Agriculture and Health Sciences. 2013;**2**(1):42-48

[54] Kariag BM. Intercropping maize with cowpeas and beans for soil and water management in Western Kenya. In: Proc. of the 13th International Soil Conservation Organization Conference, July 4-9, 2004. Brisbane: Conserving Soil and Water for Society; 2004. pp. 1-5. DOI: 2010.135.145

[55] Onduru DD, Du Preez CC. Ecological and agro-economic study

of small farms in sub-Saharan Africa. Agronomy for Sustainable Development. 2007;**27**:197-208. DOI: 10.1051/agro:2007003

[56] Lulie B. Intercropping practice as an alternative pathway for sustainable agriculture: A review. Academic Research Journal of Agricultural Science and Research. 2017;**5**(6):440-452. DOI: 10.14662/ARJASR2017.057

[57] Rusinamhodzia L, Corbeels M, Nyamangara J, Giller KE. Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in Central Mozambique. Field Crops Research. 2012;**136**:12-22. DOI: 10.1016/j.fcr.2012.07.014