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Review on Maize Based Intercropping

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Abstract: World population is growing exponentially and it has to fulfill their food requirements. An attractive strategy for increasing productivity and labour utilization per unit area of available land is to intensify land use. Intercropping is advanced agro technique of cultivating two or more crops in the same space at the same time have been practiced in past decades and achieved the goal of agriculture. It increases in productivity per unit of land via better utilization of resources, minimizes the risks, reduces weed competition and stabilizes the yield. Several factors influence the intercropping such as maturity of crop, selection of compatible crop, planting density, time of planting as well as socio economic status of farmers and the region. In intercropping, land is effectively utilized and Land Equivalent Ratio (LER) is used to measure the productivity of land. Several findings show the advantages of intercropping by using LER. Cereal-legume intercropping is commonly practiced in world wide. Maize has reorganized as a component crop in most intercropping. In this study, the work carried out by various researches in maize based intercropping are discussed. This work would be useful to the researchers who involves in this field.

Key words: Intercropping, maize, maturity of crop, plant density

INTRODUCTION

The cropping system is defined as the combination of crops grown on a given area within a year. The forms of agriculture and cropping system found throughout the world are the results of variation in local climate, soil, economics and social structure. Water balance, radiation, temperature and soil conditions are the main determinants of the physical ability of crops to grow and cropping system to exist (Beek and Bennema, 1972; Harwood, 1975). Therefore, the cropping system varies from place to place in the world. It used to design improved system for a given agro ecological situation based on their superiority over the existing systems which is adapted by the farmers of the area in terms of their biological productivity and stability of production with the least harm to the ecosystem. Farmers generally take decisions on the technologies to be adopted on the basis of cost, risk and return calculation. In small farms, the farmers raise crops as a risk minimizing measures against total crop failures and to get different produces to take of his family's food, income, etc. World population is growing exponentially and it has to fulfill their food requirements. An attractive strategy for increasing productivity and labour utilization per unit area of available land is to intensify land use. This can be increased by growing several crops simultaneously or in succession with each other in farms devoted to short maturing annual crops.

INTERCROPPING

Intercropping is a type of mixed cropping and defined the agricultural practice of cultivating two or more crops in the same space at the same time (Andrew and Kassam, 1976). The important reason to grow two or more crops together is the increase in productivity per unit of land. In intercropping system, all the environment resources utilized to maximize crop production per unit area per unit time. Risk may be minimized in intercropping (Woolley and Davis, 1991). Biological efficiency of intercropping due to exploration of large soil mass compared to monocropping (Francis, 1989). This advanced agro technique has been practiced in past decades and achieved the goal of agriculture. There are some socio economic (Ofori and Stern, 1987), biological and ecological advantages (Aggarwal *et al*., 1992; Fininsa, 1996) in intercropping over monocropping. Several scientists has been worked with intercropping (Mandal *et al*., 1990; Natarajan, 1992; Kalarani, 1995; Aravazhi *et al*., 1997; Balan, 1998; Sadashiv, 2004; Yildirim and Guvenc, 2005; John and Mini, 2005; Suresha *et al*., 2007; Seran and Jeyakumaran, 2009; Brintha and Seran, 2009). And most studies on intercropping have focused on the cereal based intercropping (Ofori and Stern, 1987; Ali *et al*., 2000; Langat *et al*., 2006; Hugar and Palled, 2008a) and proved the success of intercropping.

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MAIN ASPECTS TO BE CONSIDERED IN INTERCROPPING SYSTEM

Successful intercropping needs several considerations before and during cultivation. Silwana and Lucas (2002) found intercropping affects vegetative growth of component crops, therefore have to consider the spatial (Willey and Rao, 1981a), temporal and physical resources. Economically viable intercropping largely depends on adaptation of planting pattern and selection of compatible crops (Seran and Brintha, 2009a). Cereal-legume intercropping, potential to provide nitrogen depends in densities of crop, light interception, crop species and nutrients (Francis, 1989). Compatible crop selection is vital in intercropping. The choice of compatible crops for an intercropping system depends on plant growth habit, land, light, water and fertilizer utilization (Brintha and Seran, 2009). Hardarson and Atkins (2003) found legume-cereal intercropping increase the fixation of nitrogen by legumes. Silwana and Lucas (2002) reported different crop species in mixtures increased capture of growth limiting resources and Andrews (1972) stated that different planting time of component crops improve the resource utilization and reduce the competition.

Maturity of crop: When two or more crops are grown together the peak period of growth of components do not coincide. The biggest complementary effects and thus biggest yield advantages seen to occur when the component crops have different growing periods so make their major demands on resources at different times. Crops of varying maturity duration should be chosen therefore a rapidly maturing crop completes its life cycle before the major growth period of other crop commence. Selecting crops or varieties with different maturity time can also assist staggered harvesting and separation of grain commodities. By this, the time of peak nutrient demands of component crops should be differed. Crops which mature at different times thereby separating their periods of maximum demand to nutrient and moisture aerial space and light could be suitably intercropped (Enyi, 1977). In maize-greengram, peak light demand for maize is around 60 days after planting, while greengram is ready to harvest (Reddy and Reddi, 2007).

Compatible crops: Choosing of the crop combination plays vital role in intercropping. Plant density, shading and nutrition competition between plants reduce the yield of monocrop. Plant competition could be minimized not only by spatial arrangement, but also by choosing those crops best able to exploit soil nutrients (Fisher, 1977b). Kassam (1976) reported groundnut is usually intercropped with maize in South East Asia and Africa. Agboola and Fayemi (1971) reported that popondo (*Phaseolus lunatus*) and mucuna (*Mucuna utilis*) lowered maize yield, while calopo (*Calopogonium tnucunoides*), cowpea (*Vigna sinensis*) and greengram (*Phaseolus aureus*) had much less effect on maize and were themselves tolerant to maize shade. Baker and Norman (1975) stated that increased yield from better use of space in mixture are complimentary to utilizing time with crops in sequences. Therefore, maximum cropping should be obtained with sequences of high yielding crops in compatible mixtures. Cereal-legume intercropping is commonly practiced in Asia, Africa and South America (Vandermeer, 1992; Maluleke *et al*., 2005). In tropics, maize-cowpea intercropping is often practiced (Van Kessel and Roskoski, 1988; Mpangane *et al*., 2004). Krantz (1981) found maize is easy to manage in maize-pegionpea intercropping. Singh *et al*. (1998) stated in Central and South America and parts of East Africa, maize is intercropped with bean.

Plant density: Low plant population per unit area leads to low yield (Jeyakumaran and Seran, 2007). The seedling rate of each crop in the mixture is adjusted below its full rate to optimize plant density. If full rates of each crop were planted, neither would yield well because of intense overcrowding. By reducing the seedling rates of each, the crops have a chance to yield well within the mixture. The challenge comes in knowing how much to reduce the seedling rates. Modification of planting pattern of capsicum in intercropping system is feasible for vegetable cowpea cultivation (Jeyakumaran and Seran, 2007). Planting of pearl millet in paired row may provide additional space for an intercropping (Sivaraman and Palaniappan, 1996). Keeping the plant population per unit area of the base crop constant, no deviation of its yield has been noted by altering the orientation of the rows (Sivaraman and Palaniappan, 1996). Brintha and Seran (2009) stated that in radish-vegetable amaranth us intercropping, yield of radish was not significantly affected due to constant plant density of radish in monocropping and intercropping. The planting pattern of the maize and legumes (intercropping or growing maize after the legume harvest) did not affect the yield of maize (Agboola and Fayemi, 1971). A reasonable Leaf Area Index (LAI) is critical to maintain high photosynthetic rates and yield (Xiaolei and Zhifeng, 2002). In radish-vegetable amaranths intercropping, higher density of vegetable amaranths produced more LAI in radish (Brintha and Seran, 2009). Prasad and Brook (2005) reported that increasing maize plant density had significant effect on LAI in maize soybean intercropping. Maluleke *et al.* (2005) found maize dry matter was reduced with increasing lablab population (6-10 plants per m^2). In maize-okra intercropping, high plant density reduced number of leaves due to competition for light and other resources (Muoneke and Asiegbu, 1997). It was agreed with Prashaanth *et al.* (2009) in brinja -groundnut intercropping.

Time of planting: Mongi *et al.* (1976) found planting cowpea simultaneously with maize gave better yield. Amede and Nigatu (2001) stated that simultaneously planting maize and sweet potato not influenced maize grain yields, whereas late planting of sweet potato negatively affects maize yield. Several researches have been focused on bush bean and maize planted simultaneously in alternate rows (Francis *et al.*, 1978; Pilbeam, 1996; Santalla *et al.*, 1999).

Maize has diverse uses and the diversity of environment under which it is grown (Doswell *et al.*, 1996). It has high potential for carbohydrate accumulation per unit area per day (Aldrich *et al.*, 1975). Also maize has been recognized as a common component in most intercropping systems. It seems to dominate as the cereal component of intercrop and it is often combined with different legumes (Anil *et al.*, 1998; Maluleke *et al.*, 2005). It is the third most important cereal crop of the world and used as food, feed and forage. Intercropping with maize is a way to grow a staple crop while obtaining several benefits from the additional crop.

BENEFITS OF INTERCROPPING

Resource utilization: The main reasons for higher yields in intercropping is that the component crops are able to use natural resources differently and make better overall use of natural resources than grown separately (Willey, 1979). The efficient use of basic resources in the cropping system depends partly on the inherent efficiency of the individual crops that make up the system and partly on complimentary effects between the crops (Willey and Reddy,1981a). Biological basis for intercropping involves complementarily of resources used by the two crops (Barhom, 2001). One of the main yield advantages in intercropping those crops sown as intercrop combination may be able to make better overall use of resources than when growing separately (Willey and Osiru, 1972). The partitioning of limiting resources among crop plants occurs whenever plants are grown in association (Blade *et al.*, 1997).

Soil fertility problems are not only an agronomic issue, but also strongly related to economical and social issues. Poor farmers are typically risk adverse and cannot afford to make large investments in relation to fertility management. Number of pods per capsicum plant were lower in capsicum-vegetable cowpea intercropping compared to monocropping due to nutrition and light competition (Seran and Jeyakumaran, 2009). Integrated nutrient management adopts a holistic approach to plant nutrient management by considering the totality of the farm resources that can be used as plant nutrients. Vesterager *et al.* (2008) found maize and cowpea intercropping is beneficial on nitrogen poor soils. Maize-cowpea intercropping increases the amount of nitrogen, phosphorous and potassium contents compared to mono crop of maize (Dahmardeh *et al.*, 2010). Suryanta and Harwood (1976) reported that nutrient uptake and utilization more efficient in corn-rice and corn-soybean intercrops than in those crops as monocrop.

Different root and leaf systems are able to harmless more light and make use of more water and nutrients than when the roots and leaves of only one species are present. When only one species is grown, all the roots tend to compete with each other since they are all similar in their orientation and below surface depth. Similarly, the leaves of plants of the same species are directly opposite and growing at the same rate as each other, whereas the leaves of a plant of another species do not compete therefore directly for sunlight in space and time. In the tropics, multistorey plants harvested in sequence can utilize the sun's energy on a year round basis. A combined leaf canopy might make better special use of light (Waddington and Edward, 1989). Intercropping between high and low canopy crops is a common practice in tropical agriculture and to improve light interception and hence yields of the shorter crops requires that they be planted between sufficiently wider rows of the taller once. Intercropping create microclimate favour the lower plant growth (Azam-Ali *et al.*, 1990). Jiao *et al.*(2008) found maize-groundnut intercropping enhanced the efficient utilization of strong light by maize and weak light by groundnut lead to provide yield advantages. Soybean and maize intercropping has been attributed to better use of solar radiation (Keating and Carberry, 1993), nutrients (Willey, 1990) and water (Morris and Garrity, 1993) over the mono crop. When two morphologically dissimilar crops with different periods of maturity are intercropped light is the vital factor that determines the yield (Willey, 1979). Competition of light affected the plant height in capsicum-bushitao intercropping (Jeyakumaran and Seran, 2007).

Availability of water in cropping system is vital to determine the growth of plant. Improvement of water use efficiency in intercropping leads to increases the uses of other resources (Hook and Gascho, 1988). Intercrops have been identified to conserve water largely because of early high leaf area index and higher leaf area (Ogindo and Walker, 2005). Under normal condition cereal-legume intercropping uses water equally (Ofori and Stern, 1987). Various root systems in the soil reduces water loss, increases water uptake and increases transpiration, leads to create microclimate cooler than surroundings (Innis, 1997). Morris and Garrity (1993) mentioned that water capture by intercrops is higher by about 7% compared to mono crop. Willey (1979) stated cereal-legume use water more efficiently than monocropping. Barhom (2001) reported that water use efficiency was the highest under soybean-maize intercropping compared with monocropping maize and monocropping soybean. Soybean-maize intercropping was the best combination system during water scarcity periods (Tsubo *et al.,* 2005). In area where water scarcity, intercropping is suitable methods (Lynam *et al*., 1986). Biological efficiency of intercropping due to exploration of large soil mass compared to monocropping (Francis, 1989).

Weed control: Intercropping might better control of weeds, pests and diseases. Evidence of better weed control is reasonably clear where intercropping provides a more competitive effect against weeds either in time or space than does monocropping. Weed population was reduced in brinjal-groundnut intecropping (Srikrishnah *et al*., 2008). The nature and magnitude of crop-weed competition differs considerably between mono and inter crop combinations. The crop species, population density, sowing geometry, duration, growth rhythm of the component crop, the moisture and fertility status and tillage influence weed flora in cropping system. Crop-weed competition is determined by growth habit of crop. Increased leaf cover in intercropping systems helps to reduce weed populations once the crops are established (Beets, 1990). Shading showed considerable potential as a means of reducing the spread of *Cyperus rotundus* (Patterson, 1982). This reemphasizes the possible importance of growing more than two crops in same land at same time. Mixed cropping reduces weed incidence (Altieri and Liebman, 1986; Zuofa *et al*., 1992). Makindea *et al.* (2009) found leafy greens can be intercropped with maize to control weeds in the tropics and increase productivity. Weed suppression in maize-groundnut intercropping was reported by Steiner (1984). Intercropping maize and legumes considerably reduced the weed density compared with the monocropping maize by decrease in available light for weeds compared to mono crops (Dimitrios *et al*., 2010). Maize-cowpea intercropping suppresses weeds and insures against total crop failure when one crop fails (Mongi *et al*., 1976). Maize-pumpkin and maize-bean intercropping reduced weed biomass by 50-66% when established at a density of 12,300 and 222,000 plants ha^{-1} for beans (Mashingaidze, 2004). Mugabe *et al.* (1982) noted intercropping controlled weed effectively and reduce the harvestable biomass. Advantages from intercropping in weed control under low input conditions and increases in components crop yields leads to improved weed control (Leihner, 1979). Maize-rye intercropping reduces weed biomass by 50% (Samson, 1991).

Pest and disease: Maize is susceptible to many insects (Drinwater *et al*., 2002) and diseases (Flett *et al*., 1996). Intercropping appears to be a very promising cultural practice for this purpose. It is generally believed that one component crop of an intercropping system may act as a barrier or buffer against the spread of pests and pathogen. Intercropping maize-cowpea reduces the stem borer (Henrik and Peeter, 1997). Maize leafhopper (*Dalbus maindis* L.) was reduced under intercropping reported by Power (1990). Brown (1935) noted that in Louisiana, bud worm infestation in pure maize was greater than in maize associated with soybean. Sastrawinata (1976) working at IRRI found that maize-groundnut and maize-soybean mixed crop reduced the number of corn borer in maize. Insect problems are less on crops grown in mixture, especially with cowpea, pigeon pea, maize and some legumes (Caswell and Raheja, 1972; Hayward, 1975). Trenbath (1993) noted that pest and diseases were high in monocropping compared to intercropping. In chilli-maize intercropping, the incidence of *Anthonomus eugenii* was lower and yield was greater compared to chilli alone (Gutierrez, 1999). Pino *et al.* (1994) found pest and disease were less in tomato maize intercropping. Soybean and groundnut are more effective in suppressing termite attack than common beans (Sekamatte *et al*., 2003). Umarajini and Seran (2008) stated incidence of white fly and leaf hopper were lower in brinjal groundnut intercropping compared to monocropping. Singh and Adjeigbe (2002) stated monocropping needs more chemical to control pest and disease than intercropping.

Erosion control: Intercropping controls soil erosion by preventing rain drops from hitting the bare soil where they tend to seal surface pores, prevent water from entering the soil and increase surface erosion. Maize-cowpea intercroping, cowpea act as best cover crop and reduced soil erosion (Kariaga, 2004). Reddy and Reddi (2007) mentioned taller crops act as wind barrier for short crops. In brinjal-groundnut intercropping, pod weight of brinjal in monocropping was low due to absence of intercrop

Table 1: Land equivalent ratio in intercropping

Intercropping	Spacing / ratio	LER	Country	References
Maize-frenchbean	1:2	1.48	India	Hugar and Palled (2008a)
Maize-pigeonpea	2:1	1.51	India	Marer *et al.* (2007)
Maize-soybean	90 cm spaced double row strips	1.62	India	Ullah *et al.* (2007)
Maize-Cowpea	1:2	1.35	India	Hugar and Palled (2008a)
Maize-Coriander	1:2 or 1:5	1.42	India	Hugar and Palled (2008a)
Maize-bean	2:1	2.6	Kenya	Odhiambo and Ariga (2001)

which leads to high water evaporation in soil surface(Prashaanth *et al.*, 2009). Rows of maize in a field with a shorter crop will reduce the wind speed above the shorter crops and thus reduce desiccation (Beets, 1990). Siddoway and Barnett (1976) suggested that multiple cropping systems increase the soil protection by increased vegetative growth during critical erosion periods.

Yield advantages: Yield is taken as primary consideration in the assessment of the potential of intercropping practices (Anil *et al.*, 1998). In legume and non legume intercropping, yield of non legume increased in intercropping as compared with monocropping (Brintha and Seran, 2008). Mashingaidze (2004) found that by intercropping land was effectively utilized and yield was improved. The crops are grown together because of higher yields and greater biological and economic stability in the system (Francis, 1986). Land Equivalent Ratio (LER) is the most common index adopted in intercropping to measure the land productivity. It is often used as a indicator to determine the efficacy of intercropping (Seran and Brintha, 2009b). LER greater than one indicates greater efficiency of land utilization in intercropping system. It is due to greater efficiency of resource utilization in intercropping (Willey and Osiru, 1972) or by increased plant density (Fisher, 1977a). Mandal *et al.* (1990) LER shows advantages of cereal-legume intercropping. Tsubo *et al.* (2005) stated legume-cereal intercropping is generally more productive than monocrop. When two crops are grown together yield advantages occurs because of differences in their use of resources (Willey *et al.*, 1983). Intercropping gives a greater stability of yield over monoculture (Willey and Reddy, 1981b) and intercropping was more productivity than sole crop grown on the same area of land (Anil *et al.*, 1998). LER value exceeding unity in radish-vegetable amaranths intercropping indicates yield advantages from intercropping compared to monocropping (Seran and Brintha, 2009a). Legume non legume intercropping increases total grain and nitrogen yield (Barker and Blamey, 1985; Singh *et al.*, 1986). In intercropping higher yield, greater yield stability over monocropping was reported by Ofori and Stern (1987). Evans and Wardlaw (1976) reported in intercropping shading and reduced assimilate production have least effect on yield, while competition prevails during vegetative periods. Amede and Nigatu (2001) consistently received LER of 1.5 or greater when using the early maturing variety of maize. Maize-Kenaf-African Yam bean gave LER of 1.12 (Adeniyan *et al.*, 2007). Mohta and De (1980) stated that LER increased to a maximum of about 48% by intercropping maize with soya beans compared with the cereal sole crops. Maize yield was not affected by intercropping with soya beans (Mehta and Dey, 1980). Maize-soy bean intercropping gave LER of 1.18 reported by Putnam *et al.* (1985) (Table 1).

Economic benefits: Intercropping often provides higher cash return than growing one crop alone (Grimes *et al.*, 1983; Kurata, 1986). Intercropping occupies greater land use and thereby provides higher net returns (Seran and Brintha, 2009a). Kalra and Gangwar (1980) reported that intercropping helps in increasing farm income on sustained basis. Intercropping commonly gave greater combined yields and monetary returns than obtained from either crop grown alone (Ahmad and Rao, 1982). Net return of radish and vegetable amaranths intercropping correlated with vegetable amaranths (intercrop) plant density (Seran and Brintha, 2009a). Intercropping capsicum and vegetable cowpea gave high net return compared to monocropping (Seran and Brintha, 2009b).

MAIZE BASED INTERCROPPING

Maize legume intercropping: Intercropping of legumes and cereals is an old practice in tropical agriculture that time back to ancient civilization. Snaydon and Harris (1979) found legume-cereal is the most popular intercropping system in the tropics. Systems that intercrop maize with a legume are able to reduce the amount of nutrients taken from the soil as compared to a maize monocrop. During absence of nitrogen fertilizer, intercropped legumes will fix nitrogen from the atmosphere and not compete with maize for nitrogen resources (Adu-Gyamfi *et al.* 2007). The mixture of nitrogen fixing crop and non fixing crop give greater productivity than monocropping (Seran and Brintha, 2009b). Banik and Sharma (2009) reported that cereal-legume intercropping systems were superior to monocropping. Maize-french bean gave high maize equivalent yield over sole maize yield (Hugar and Palled, 2008b) and kernel yield of maize was unaffected in maize-french bean intercropping (Pandita, 2001) and this finding agree with Hugar and Palled (2008b). Akinnifesi *et al.* (2006) revealed without nitrogen fertilizer application, gliricidia-maize intercropping system gave high maize yield. West and Griffith (1992) observed maize yield was increased by 26% in maize-soybean strip intercropping. This was agreed with Ghaffarzadeh *et al.* (1994). Tsubo *et al.* (2005) found in maize-bean intercropping, maize yield was not affected.

Maize vegetable intercropping: Sharma and Tiwari (1996) reported tomato intercropped with maize increased the number and weight of fruit per plant, total yield. In maize-okra intercropping, yield and yield components of okra was increased (Muoneka and Asiegbu, 1997). Cauliflower in maize produced 7 t ha^{-1}, cauliflower in conjuction with 2.1 t ha^{-1} maize (Khatiwada, 2000). Maize-Kenaf-African yam bean intercropping gave highest value of LER compared to monocroppings. (Adeniyan *et al.*, 2007). Maize with pumkins gave high LER was reported by Cortes and Los (1997). Maize-cassava intercropping gave LER advantages (Mutsaers *et al.*, 1993). Maize-potato intercropping performed better than sole potato reported by Begum *et al.* (1999). Ifenkwe *et al.* (1989) found maize yield not affected by maize-potato intercropping.

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