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Review

In support of a well-planned intercropping systems in south eastern soils of Nigeria: A review

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Soil is the medium for all crop production activities and many of the tropical soils especially soils of South Eastern Nigeria show nutrient deficiency problems after only a short period of cultivation because of the fragile nature and prevailing environmental condition. Land available for further crop production purposes in this area is very limited. To offset some of these problems and boast crop production and yields as well as economic returns, farmers use chemical fertilizers extensively on their field. These chemical fertilizers have their attendant problems ranging from non-availability, high cost, and nutrient imbalances to soil acidity. Consumers of agricultural products and farmers are getting more aware of the dangers caused by these chemicals in soil, environment, and health problems in consuming heavily chemically fertilized crops. An alternative to these chemicals is intercropping due to its environmentally friendly approach. Beside the labour management and adequate use of resources available, intercropping system promotes soil fertility maintenance, conservation and balanced nutrient which will improve crop quality and yield. It ensures farmers' flexibility, reduction against crop failures, weed control and profit maximization. This paper reviews the various contributions of intercropping system to soil fertility enhancement, nutrient recycle, and transfers among intercrop species; its effect on growth and yield of crop species as well as enlightenment on the various terms used to describe the intercropping system.

Key words: Intercropping, nutrient recycle and transfer, sole cropping, soil nutrients.

INTRODUCTION

Intercropping is a system of growing two or more crops in available piece of land and is as old as man in agricultural activities especially in tropical countries. Every peasant farmer in Nigeria practice intercropping in one form or another. They inter crop a lot of crops such as cowpea, groundnut, Bambara groundnut, melon, etc., with cassava, yam, maize, millet, sorghum, etc.

According to WGM (2003), there are a number of ways people do intercropping. In one form, crops are planted in alternating rows or strips, with the crops being kept separated, but still interacting as a result of proximity. In another, an intercrop or intercrops are planted between the rows after a main crop has started to mature. Intercrops which grow quickly can also be grown in

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several cycles while a primary crop matures. Intercropping can as well be done with crops which are totally intermixed rather than being separated. Intercropping is also known as under sowing system whereby a secondary crop or less desired crop is sown underneath the primary cash crops already established so that both will develop at the same time to cover the ground. The under sown species are always leguminous crops with the capacity of quick growing dense layer of vegetation underneath the cash crops and adds nutrients to maintain the fertility of the soil. Another terminology for intercropping is poly culture practices which involve growing of two or more plant species on the same piece of land. Depending on the plant species and their arrangement by the farmer within the farm field available, poly culture practices can take different forms. Other forms of intercropping systems are mixed cropping, cultivation of two or more crops together without any district row arrangement. Relay cropping is a system of planting a second crop alongside already cultivated crops at a time when the cultivated crops is at its reproductive stage or has completed its development, but before harvesting. Alley-cropping is a system of growing arable crops in alley formed by trees or shrubs, multiple cropping is a traditional farming system of growing more than one crop on the same piece of land during one calendar year.

Intercropping system takes advantage of interdependent relationships between crops with the intercrops providing shade, cover, nutrients, a trellis to grow on, and other wholesome benefits. Some crops in the intercropping may even have insecticidal and pathogenicidal effect and keep pests from vulnerable crops and suppress weeds infestation. For soils intercropping hasten soil fertility restoration and enhance soil productivity for sustainable agricultural activities. With these attributes, intercrop promotes yield and healthy crops. Onwueme and Sinha (1991) stated that among other things farmers derive yield advantage and yield stability than growing each crop separately. Thus, intercrop system can guarantee crop yield stability and bring additional income to the farmers, thereby encourage the sustainability of farming community especially with most African farmers where poverty is prevalent.

Also, decline in soil fertility from continuous cultivation on a tropical soil of which many are highly weathered, low activity clays, nutrient deficiency and nutrient imbalances, and soil acidity, makes the practice of intercropping very attractive with the poor resource farmers especially with inherent cost and non-availability of fertilizers. This has rekindled the interest of farmers in the use of natural and local (within reach) nutrient resources to build and conserve soil fertility and biodiversity management of their farm fields to sustain crop production. Thus, this review intends to report the contributions of intercropping system to improve soil productivity, crop growth, and yield in crop production activities.

CONTRIBUTIONS OF INTERCROPPING SYSTEM TO NUTRIENT COMPOSITION OF SOIL, NUTRIENT RECYCLE AND TRANSFER

Proper and adequate utilization of natural resources is the main item in practicing intercropping as the component crops are able to use natural resources to their ability differently and complementarily for the overall development of the two crops. Therefore, for success to be achieved, intercropping needs several considerations before and during cultivation. Intercropping systems according to Ibeawuchi and Ofoh (2003) limits soil losses and run-off and provides a nearly continuous cover thus preventing soil from the direct impact of the rains, and that it produces a dense and diversified root system which reduces leaching of nutrients. Gosh et al. (2006) in their study found that intercropping was beneficial for the soil microbial community of sorghum, addition of nitrogen by fixation and transferring to the cereals, and soil fertility improvement. Legume crops in intercropping system support the growth of cereal crops by improving the organic matter content and physical characteristics of the soil like structure and texture of the soil (Aslam and Mahmood, 2003). Legume-cereal inter cropping enhanced soil faunal activity resulting in more organic substrates accumulation in the soil; it could improve the soil fertility status of a less fertile soil by fixing atmospheric nitrogen and the intercrop legume will not compete with cereal crop for nitrogen resources (Gosh et al., 2006; Adu-Gyamfi et al., 2007).

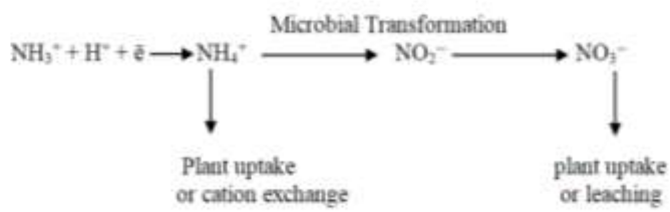
Dahmardeh et al. (2010) in Iran investigated the influence of maize-cowpea intercropping on soil chemical properties and found out that intercropping increased the amount of nitrogen (N), phosphorous (P), and potassium (K) content of the intercrop maize compared to the sole maize. According to Fatokum et al. (2000), cowpea can fix up to 88 kgN/ha and in an effective cowpea rhizobium symbiosis more than 150 kgN/ha of N is fixed which can supply 80 to 90% of plants total nitrogen requirements. Ibeawuchi and Ofoh (2003) found out that the combination of base-crops and legumes intercrop generally increased soil P, soil organic matter (SOM), and soil pH, while soil N and K were reduced. Okigbo and Lal (1979) reported that relatively simple intercropping system as maize/cassava can increase the cation exchange capacity (CEC) and pH as well as increase in manganese (Mn) content in the soil. Intercropping of cotton and cowpea was found by Rusinamhodzi et al. (2006) as wonderful opportunity to improve carbon (C) sequestration and N-use efficiency in the short-term compared with monoculture. Caballero et al. (1995) and Assefa and Ledin (2001) revealed that there was competition for resources such as nutrients in the rhizosphere and light in intercropping system. Vesterager et al. (2008) observed that maize and cowpea intercropping is beneficial in nitrogen poor soils.

In pearl millet-cowpea intercrops, Bathiono et al. (1996) and Van der Pol (1992) reported low soil pH, K, calcium (Ca), magnesium (Mg), and CEC than the fallow system suggesting that the cropping system studied was mining the soil nutrients. Whereas Shave et al. (2012) in their studies with mucuna intercropped with maize showed positive impact on the chemical properties of soil, especially when it was introduced 6 weeks after planting (WAP) of maize and that clay, organic matter (OM), total N, P and CEC were improved by 8-14, 25-27, 43-50, 70-83, and 24-26%, respectively when compared with control, whereas sand and soil pH declined by 17-4 and 6-3%, respectively during the study. Nitrogen fixation by grain legumes in intercropping is importance as it contributes to a cereal to get higher yield and substantial amount of nitrogen in agricultural ecosystem (Cochran and Schlentner, 1995; Giller and Cadish, 1995; Izaurande et al., 1992; Giller et at., 1991; Herchel, 1987; Dakora and Keya, 1997). There was equally evidence of direct transfer of fixed N to cereal components in many controlled studies (Frey and Schuepp, 1993; Chu et al., 2004). Also, available report showed that mineralization of decomposing legumes in rhizosphere enhanced nitrogen availability of cereal crop in intercropping system (Evans et al., 200l; Dubach and Russelle, 1994; Scroth et al., 1995). When the configuration of the row are wider than the rate of N fixation activity by the legumes, Fujita et al. (1990) and Handerson and Alkins (2003) observe that the depletion of soil N by cereal stimulates legume crops to fix more N. Manna and Singh (2001) observed that coconut (*Cocos nucifera* L.) intercropped with guava (*Psidium guajava* L.) enhanced the soil microbial activities approximately 2-fold after 38 years; over 10 years of the same intercropped system, soil organic carbon (OC) increased from 38 and 10 years, respectively. Also, the report of Gosh et al. (1989) revealed that OC content of the soil was improved when cassava were intercropped with tree crops *Leucaena* and *Eucolyptus* compared to the tree crops monoculture. Even surface run off and soil erosion were effectively reduced with the intercrop due to better canopy coverage of the soil surface. Handerson and Alkins (2003) found that legume-cereal intercropping increased the fixation of N by the legumes. Maize-Cowpea intercropping was observed by Vesterager et al. (2008) to be beneficial on N poor soils and that amount of N,P,K content of the was increased compared to the mono crop maize. Intercropping control 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.

Intercropping benefits non-legumes in the mixture as legumes fix nitrogen in the soil (Portes, 1989; Areioglu et al., 2003). Intercropping when properly practiced maintain high soil fertility (Opeke, 2006). Maize-Soybean intercrop helps in efficient utilization of renewable atmospheric N since they contribute to the maintenance of soil fertility as these had been shown to be usually increased in an intercropping system (Scott and Darl, 1987). Increase in the inclusion of herbaceous and wordy forage legumes in crop production systems, improves soil structure and texture and controls erosion and supplementary browse to develop sustainable and low-input production systems (Brewbaker et al., 2012; Sumberg, 2004; Kang and Duguma, 2005). This is because legumes are notable to have symbiotic N fixing bacteria in structure called root nodules and the symbiotic bacteria called rhizobia within the root nodules of legume root systems. These bacteria have exclusive ability of fixing N from atmospheric molecular N_2 into ammonia (NH_3) as follows:

$$N_2 + 8H^+ + 8\bar{e} \longrightarrow 2NH_3 + H_2$$

Ammonia is then converted by oxidation-reduction to the forms NH_4 + N and NO_3 – N, respectively which are available and useable by plants. The first step of the reaction is that Ammonia is converted to Ammonium (NH_4^+) and then nitrate (NO_3^{-}) by the following reaction, thus:



The illustration shows the microbial transformation of N in the soil. Nitrogen in the form of ammonium ion (NH_4^+) may be taken up by plants or adsorbed on the exchange sites, while as the nitrates ion (NO_3^{-}) it may be taken by plants or leached through the soil profile. Other nutrients suffer similar fate in the soil and the reaction processes take place better in well aerated soils.

According to Wood (2006), when the legume plant dies in the field after harvesting all of its remaining nitrogen incorporated into amino acid inside the remaining plants parts and are released back into the soil, the amino are converted to nitrate (NO_3) making the N available to other plants (in case a cereal crop in the intercrop), thereby serving as fertilizer for future crops in the soil. A number of studies have shown that forage and grain legume mixture increase the OM and N contents of the soil. Leguminous crops improved soil physical parameters such as texture, bulk density, moisture, and soil chemical properties and gave better protection against erosion (Nweke, 2016). The use of legumes intercropping system had been shown by Sharma and Churby (1991) to be advantageous especially in improving the N-economy of the soil by fixing atmospheric N. Total grain and plant N yield can often be increased by intercropping legumes with non-legumes (Baker and Blamey, 1985), however, conflicting reports exist about whether a non-legume benefits from N supplied by an intercropping legume. In some instances, the N contribution of the intercropping legume to maize has been estimated to be up to 40 kg/ha (Willey, 1979), while other investigators did not find any evidence for such N benefits (Wahua and Muller, 1978). Maize-legume intercrop is wide spread. This production system has traditionally enabled farmers to cope with soil erosion and with declining levels of soil organic matter (SOM) and available N_2 (Scott et al., 1987).

Filho (2000) observed that intercropped maize is more competitive than cowpea in terms of use of available resources mainly soil water. Innis (1997) opined that various root systems in the soil reduce water loss, increase water uptake, and increase transpiration leading to creation of microclimate cooler than surroundings. Soil water use efficiency was observed to be the highest under soybean-maize intercropping when compared with either of the mono cropping maize or soybean (Barhom, 2001). In water scarcity, Tsubo et al. (2005) observed that soybean-maize intercropping was the best combination system during water scarcity periods. Thus, availability of water is one of the most important factors determining productivity in legume/cereal cropping systems. According to Ofori and Stern (1987), cereals and legumes use water equally and competition for water may not be important in determining intercrop efficiency except under favourable conditions. Water use by intercrop is mostly been studied in terms of water use efficiency (WUE). The work of Willey (1979) has shown that an intercrop of two crop species such as legumes and cereals may use water more efficiently than a monoculture of either species through exploring a greater total soil volume for water especially if the component crops have different rooting pattern. The WUE in a maize/cowpea intercrop was found to be higher than in the sole crops when soil water was not limiting; however, under water limiting conditions, WUE in the intercrop compared to sole maize was higher resulting in retarded growth and reduced yield. Another possible advantage of intercropping is the efficient use of soil nutrients. If both species have different rooting and uptake patterns, more efficient use of available nutrients may occur and higher total N-uptake in intercropping system compared to monoculture system have been reported by Dalal (1974), though Willey (1979) opined that it is unclear if better use of nutrient uptake is the course of the effect of higher yield potentials.

Solar radiation provides energy for photosynthesis which ultimately sets the potential for crop productivity and also determines water use by the process involved in evaporation and transpiration (Goudrian, 1982; Keating and Carberry, 1993). Photo synthetically active radiation which green plants utilize, according to Szeicz (1974) conservatively makes up about 50% of global short wave radiation compared to high variable that occurs in the supply of water and nutrients to the plant, solar radiation is more reliable and used sufficiently by intercrops as they form a complete cover to allow full interception. Solar radiation cannot be stored for later use; it must be intercepted and utilized instantly to energize the photosynthesis process. Therefore, close plants compete for solar radiation by direct interception. Soybean and maize intercropping have been shown to have better use of solar radiation, soil nutrients, and water over the mono crop (Keating and Carberry, 1993; Willey, 1990; Morris and Garrity, 1993).

The difference between species, plant density, developmental pattern, plant height, canopy architecture, foliage overlap, and photosynthetic rate and in the assimilated reserves can cause great structural complexity in mixed-species canopies. Leaf area index (LAI) is the amount of green leaf area per unit land area, which is a parameter commonly used to describe the profitability of light interception in relation to crop canopies. Therefore, great diversity in intercrop canopies is possible according to Keating and Carberry (1993), resulting from various combination in space and time of planting date and spatial distribution, leaf size, shape and orientation, and plant height. Reddy and Willey (1981) opined that where the components of an intercrop are in direct competition for light, increased total biomass production by the crop could result in improved yield. The capturing of radiant energy drives crop evapotranspiration and the pattern of its interception determines the ratio of water use through crop transpiration to that lost in soil evaporation. N_2 which occurs in the atmosphere and released through decomposition of organic materials converted to ammonia by the process of biological nitrogen fixation in legume-cereal cropping system. This process is done through rhizobial fixation in legume by free-living diazotrophs. The plant furnishes the necessary energy that enables the bacterial to fix gaseous N_2 from the atmosphere and transfer it onto the plant for use in producing proteins. However, the quantity of N fixed by the legumes is difficult to quantify and varies with respect to the species involved and the location (Webster and Wilson, 1998). Yang et al. (2010) also observed that the radiation use efficiency of maize in intercrop 3.14 gMJ^{-1} was slightly less than the value obtained in sole maize 3.18 gMJ^{-1} and concluded that radiation was not a major factor in producing the competition results in maize/soybean intercropping system. Based on the fact that plants rarely compete for light without simultaneously competing for water (Cannell and Grace, 1993; Wallace, 1995).

Biological nitrogen fixation (BNF) has been exploited extensively by researchers concerned with plant nutrition in crop production practice studies which emphasized on environmental sustainable development on the use of renewable resources including the role of BNF for supplying N for agriculture (Peoples and Craswell, 1992).

The subject of BNF is of plant practical importance because the use of nitrogenous fertilizers has resulted in unacceptable level of water-pollution increasing concentration of toxic nitrates in drinking water supplies and the eutrophication of lakes and rivers, soil acidity and nutrient imbalance resulting in not only a waste of energy and money, but also leads to serious pollution problems. Nitrogen fixation is an energy demanding process and is dependent on photosynthesis (Bech et al., 1985). Therefore, if the intercrop non-legume is taller than the legume crop, shading will occur and photosynthesis and subsequently N_2 fixation will be reduced (Wahua and Muller, 1978), plant density also has an effect on N_2 fixing activity. A reduction of N_2-fixation per plant at increasing plant density has been reported by Haidy and Hauelka (1976) and bulk total N_2-fixing activity per area appeared to be less variable (Haidy and Hauelka, 1976). The value compiled by Peoples and Harridge (1990) and Peoples and Craswell (1992) showed that the rate of N fixation by a range of legumes varies between 5 and 300 kg N/ha/year with an average of about 100 kg N/ha/year. The amount of biological fixed N_2 that is actually taken up by the main crops is difficult to determine with accuracy.

Ofori and Stern (1986) opined that in cereal-legume intercropping, BNF sole crops without applied N, large application results in excessive vegetative growth of cereal, causing it to shade and suppress the legumes yield; also similar observation was made on melon intercrop where seed yield was significantly reduced by 25 kg/ha. Stern (1993) opined that conflicting reports exist about the transfer of N from legumes to cereals intercropping studies. Nitrogen transfer refers to the movement of biologically fixed nitrogen from the legume crop to the non-legume crops and encompasses interactions within the soil OM, reduced into a mineral form, directly taken up the companion crop or lost from the system and one affected by physical and biological factors at that time. This as was revealed by Ofori and Stern (1987) can be directly transferred to the companion non-legume crop residually available to the subsequent crops. The mechanism of the transfer depends on the species, proportion of component crops in the stand, relative maturities of the associated crops and their vigour and duration of growth. Harridge et al. (1994) emphasized that a problem faced by farmers everywhere is that the capacity of soils to supply N declines rapidly once agricultural activities commence and N derived from the breakdown of soil matter must be sustainable production, N_2 reward must be replaced by N fertilizer.

The movement of fixed N from legume to the companion crop during the current growing season is said to be direct N transfer (Stern, 1993), however, an assumption exists stating that a portion of N_2 fixed by an intercropping legume is more available to an associated non-legume crops during the growing season. Depending on the biomass of the legume crop, Stern (1993) stated that mycorrhiza can help on the direct transfer of N from plant to plant because intercropping is one season duration (annual), Peoples and Harridge (1990) argued that direct transfer of N from legume to non-legume might not be a rapid or spontaneous phenomenon. Ofori and Stern (1987) observed no direct transfer from cowpea or rice bean (*Vigna umbleleta*) to maize. When the fixed N becomes subsequently available to the companion non-legume crop during the current season it is referred to as indirect N transfer (Stern, 1993). Decaying of roots and nodules are thought to be an important factor that determines the N transfer, generally, there is a small amount of N transfer during a current season and most movement occurs during the end of the legume crop cycle. The proportion of root system that might be decomposing during growth has not been estimated (Peoples and Craswell, 1992). The possibility also exists that N exudation from roots should not be ignored (Poth et al., 1986). Indirect transfer of N has been reported by Eaglesham et al. (1981), but it was not confirmed by Ofori and Stern (1987). Nitrogen contribution of legumes in the intercropping is very vital for maintaining soil productivity over long periods.

The nature and manner of root spread in soil among the intercrops determines the uptake of water and nutrients and their utilization. Root distribution among intercropping plays an important role in interactions between the intercrop species. Studies of Zhang et al. (2002), Zhang and Huang (2003), and Lie et al. (2006) investigated root distribution in intercropping system and found out that yield advantages of the intercropping system are due to both aboveground and belowground interactions between intercrop species and when the roots of the two crops does not overlap it reduced competition for water and nutrients between the two crops which results in higher yields. Zhang et al. (2002) investigated the root distribution in wheat/faba bean intercrop and observed that the growth stages of the two crops when root weight is maximum did not overlap, reduced the competition between the maize and faba bean for nutrients and water which resulted in higher yields of both crops. Root distribution in a maize/cabbage intercropping system showed clearly unbalanced distribution according to the observation of Zhang and Huang (2003), with the roots of maize extending horizontally to greater distances than those of cabbage, while Adiku et al. (2001) in their own studies were able to discover that the roots of maize and cowpea has extended into the rhizospheres of each other but the encroachment on part of maize was much greater. This scenario definitely affects the uptake and utilization of water and nutrients of both crops. Lie et al. (2006) observed that the roots of maize penetrated deeper than those of the faba bean and spread under the faba bean strip in a maize/faba bean intercropping system. In intercropping system, availability of soil water and all that dissolve there in are the limiting factor to the roots arrangement and distribution in soil. Roots tend to grow profusely into all sections of soil when water is not a limiting factor, but under water stress they clump within their own zone and under severe water stress the roots do not intermingle at all (Ozier-lafontaine et al., 1998; Adiku et al., 2001; Lie et al., 2006). Root distribution in intercropping therefore influences strongly water and nutrient uptake and invariable the yield of the component crops. Yang et al. (2010) attributed the difference in grain yield and N uptake of maize in maize/soybean intercrop to faster development and deeper reach of maize roots and a higher N uptake capacity under non-limiting conditions. The inconsistency of cereal and legume intercropping performance requires critical investigation in areas where farmers are to benefit from intercropping in that specific locality (Mpangene et al., 2004), like the south eastern soils of Nigeria that are suffering from various degrees of degradation and the farmers are poor.

CONTRIBUTIONS OF INTERCROPPING TO THE SOIL, GROWTH AND YIELD OF INTERCROPPED SPECIES AND EFFICIENT UTILIZATION OF ENVIRONMENTAL FACTORS

Many researchers have explored the use of intercropping system for forage production and quality. Maize/Cowpea intercropping system resulted in significant effect on forage dry weight and digestive dry matter yield and amino protein content was increased by intercropping when compared with maize and cowpea sole crops (Dahmardeh et al., 2007), significantly higher crude protein content of maize-soybean intercropping than that of mono-cropped maize (Toniolo et al., 1987). The authors showed that the result was related with higher consumption of environmental resources such as photosynthetic active radiation and soil moisture by intercropping. Maize forage quality in terms of crude protein was improved by intercropping. It was probable because of more nitrogen availability for maize in intercropping compared with its sole crop. Javanmard et al. (2009) worked on intercropping of maize with different legume; their findings showed that dry matter yield and crude protein yield of forage were increased by all intercropping compositions as compared to the maize mono culture. Intercropping system is an important factor that influences the quantity of N fixed by legumes (Rerkasem et al., 1988). However, the differences in the depth of rooting and spread of the intercrops, lateral root and rooting densities are some of the factors that affect competition between the component crops in an intercropping system for water and nutrients. In this regard, Carr et al. (1998) and Carruthers et al. (2000) in their studies found cereal component maize to be competitively advantageous for soil nitrogen as compared to the component crop in the intercropping because the cereal is taller, has faster growing and more extensive root system particularly a large mass of fine roots. This competition for N forces the legume component cowpea according to the work of Jensen (1996) and Huaggard et al. (2001) to fix nitrogen from the atmosphere. This effectively influences the growth and yield of the intercrop components as maize and cowpea benefit from the biological fixation of atmospheric N. This scenario will end in more uptakes of N and crude protein content in maize intercrop compared to the sole maize. The forage quality or maize was improved by intercropping due to more nitrogen availability for maize in intercropping. Intercropping system is an option for diversification of crop production system by increasing the number of cultivated crop species in the same piece of land; this is usually justified by the better use of environmental resources as compared to mono cultures (Vandermeer et al., 1998). Intercropping advantages include higher yield and yield stability and more efficient use of environmental resources, probably due to less intra-specific competition between the intercrops which is also an insurance against crop failure (Viljoen and Allemann 1996). This is a more balance food supplies for both human and livestock. Yang et al. (2010) found out that grain yield and N uptake of maize in intercrop were significantly greater than those of sole maize and grain yield of soybean as an intercrop which is significantly lower than sole soybean and their N uptake relatively, thus indicating that intercropping favoured nutrient uptake and growth of maize and the growth of soybean significantly.

According to Ghaffarzadeh et al. (1997), the basic ideas are based on how different species interact during intercropping competition for resources which arise from varying time of planting, root growth patterns and different resource demands. At high levels of N, under intercropping, Ezumah et al. (1987) and Ofori and Stern (1987) observed that grain and legume yield was reduced by the maize intercrop. The decrease in maize yield under intercrop was also reported by Shumba et al. (1990). Faulknar (1994) estimated that the increase in yield of a maize crop following a mucuna crop or cowpea or groundnut was in the order of 200 to 900 kg/ha. Agboola and Fayemi (2001) investigated maize/*Mucuna pruriens* intercrop and observed that maize yield was reduced but intercropping with *Calopogonium mucunoides*, groundnut, pigeon peas did not affect the maize yield, their studies equally indicated that *C. mucunoides*, groundnut, pigeon pea and cowpea fixed 370 kg N/ha when intercropped with maize. Maize-potato intercropping performed better than the sole potato as was observed by Begum et al. (1999) and in maize-okra intercropping Muoneke and Asiegbu (1997) observed that yield and yield components of okra was increased. Sharma and Tiwani (1996) reported that maize/tomato intercrop increased the number and weight of fruit. The mixtures of cereal and legumes produce higher grain yield than crops grown individually or together; in such crop mixtures the yield increases were not only due to enhanced N nourishment of the cereal component, but also to other unexplored causes, thus intercropping ensures yield stability (Onwueme and Sinha, 1991). Alom et al. (2009) observed that maize yield under intercropping was higher than that of mono crop, though the population of maize was constant regardless of the intercropping and pod yield of groundnut in the intercropping situation was considerably reduced. On the contrary, Nweke et al. (2013) investigated the intercropping system of ground/maize/okra and observed that the intercropping system did not influence the plant height, number of leaves and number of branches and that groundnut sole crop recorded the highest value in these parameters when compared with the intercrops. Equally the yield of pods of groundnut was the highest in sole cropping compared to groundnut-maize-okra intercropping and conversely, the values of weight of pod obtained from groundnut-maize-intercrop and groundnut-maize-okra intercrop were also similar which indicated that the effect of intercropping system were not effective in the intercrop. Addo-Quenye et al. (2011) reported the reduction in cob growth and net assimilation rate in maize/soybean intercrop, where shaded by already established soybean. Atilola (2007) revealed in his study that there was non-significant effect of groundnut intercropped with maize on growth and yield parameters of groundnut. In maize/cowpea intercropping, Dahmardeh et al. (2010) found increased yields of cereal succeeding cowpea. Pod weight of brinjal in brinjal/groundnut intercropping was low in mono culture compared to intercrop and reddish vegetable amaranths intercropping indicate yield advantages from intercropping compared to mono cropping (Prasharanth et al., 2009; Seren and Brintha, 2009). Ennih et al. (2002) revealed that there was increase in plant height reduced number of branches, leaves and leaf area index of soybean when inter cropped with maize, Chiezey et al. (2004) found no significant response to crop arrangement in number of days to 50% flowering in soybean or sorghum grown as intercrops. Quayyum and Maniruzzaman (1995), Nag et al. (1996) and Uddin et al. (2003) opined that higher yield of maize was obtained in the mono culture as compared to the yield of intercropping of groundnut. They attributed the result to no intercrop competition for light, moisture and space. The result of Koli (1975) on pure and mixed cropping of maize and groundnut in Ghana showed that yields of groundnut in the mixed intercropping were from one third to one half the yields obtained from the pure culture but the yield of maize was not reduced to the same extent. Similarly, Khatiwada (2000) found cauliflower in maize intercrop produced 7 t/ha cauliflower in conjunction with 2.1 t/ha maize. Seran and Jegakumaran (2009) however reported lower number of pods per capscum plant in capsicum-vegetable cowpea intercropping compared to mono cropping probably due to nutrient and light competition. Cereal-legume intercropping is superior to mono cropping, maize/French bean gave higher maize equivalent yield over sole maize yield (Hugar and Palled, 2008) and Kernel yield of maize was unaffected in maize-French bean intercropping (Hugar and Palled, 2008). The study of Akinmfesi et al. (2006) revealed that without N fertilizer application, gliricidia-maize intercropping gave high maize yield. In maize-bean intercropping, Tsubo et al. (2005) found maize yield not affected by the production system. Cassava/Maize intercrop yield better than the component crops due to greater biological advantages over sole cropping and temporal complementarily of those species. Muoneke et al. (2001) reported yield reduction in Roselle/cowpea intercrop and the reduction was the highest when intercropped with Roselle planting density of 37,000 Roselle plant/ha. The authors attributed yield reduction to competition for growth resources as reported in other crops in mixtures by other various workers (Willey, 1979; Muoneke and Asiegbu, 1997). Ikeh et al. (2013) noted yield increase in water yam/vegetable cowpea. An increase of 64 to 84% of ware tubers (tubers of 1 kg and above) was recorded over what was obtained from sole cropped yam; however, they found non-significant difference between both cropping systems in sprouting percentage and in numbers of leaves per plant in all the month under study. High leave retention of 32.17 and 65.92 over sole crop of 23.87 and 57.17 was recorded at 2 and 3 months after planting.

Onyekwere et al. (2013) observed that all the leguminous food crops, namely, pigeon bean, groundnut, and vegetable cowpea intercropped with *Dioscorea dumetorum* and maize gave significantly ($P < 0.05$) higher yield than sole *D. dumentorum* and that of *D. dumentorum*/maize intercrops, with the highest yield value obtained from *D. dumentorum*/maize/groundnut. Thelma (2002) and Esekhade et al. (2003) found out that intercropping rubber with arable crops had growth and yield advantages and capable of increasing the returns of the rubber enterprise. In a four-year study of rubber and cassava intercropping, Esekhade et al. (2013) found yield of rubber to be zero of which they attributed it to have not attained tappable maturity, but the yield of cassava in the intercrop was superior to the sole crop with a value of 2.19, 42.80, 19.44, and 19.44 t/ha of cassava tuber for 1, 2, 3, and 4 years, respectively as against sole crop of 20.90, 37.73, 16.52, and 16.52 t/ha of cassava tuber in 1, 2, 3, and 4 year, respectively. Singh and Sharma (1987) evaluated yield stability in intercropping in India and found out that intercrops gave additional yields and increased the net returns.

Adetiloye and Adekunle (1989) working in Southwest Nigeria, reported that intercropping of cassava-maize-cowpea gave higher agronomic yield advantage than any of the crops planted in pure culture. Although, the total productivity of an intercropping system can be greater, Rees (1986) observed that the productivity of at least one or even both component crops is usually less than that of respective sole crops in popular binary system. Roy et al. (1990) reported fibre yield reduction in Roselle intercropping with black gram, cowpea, soybean, groundnuts, and sesame. Samsri et al. (1987) work on groundnut/Roselle intercropping and reported yield reduction. Roselle a fibre crop, the fibre yield, was found to be reduced by 4 to 18%. In groundnut/sorghum intercropping, a yield reduction of 50 to 52% in groundnut was reported (John et al., 1943) and higher yield increase was obtained from intercropping than sole cropping. In an experiment conducted by Evans (1960) in East Africa, almost all experimental combinations of groundnuts with sorghum recorded positive benefits as the combinations gave yield advantages as high as 38% (Rao and Willey 1980), while yield advantages up to 57% was already reported by Tarhalkar and Rao (1979). Anthony and Wilmott (1957) reported higher yield from groundnut and cotton intercropped together. Evans and Sreedharan (1962) and Tarhalkar and Rao (1975) worked on castor bean/groundnut intercropping and found out that the intercrop performed exceedingly better and higher monetary returns was higher than what was obtained from pure castor crop. Increasing maize density three-fold from 18,000 to 55,000 plants/ha caused reduction of 24% in leaf area index and 70% in seed yield of the associated bean (Gardiner and Cracker, 1981). Addo-Quaye et al. (2011) recorded higher yield in sole maize than the intercropped maize in a study of maize/soybean intercropping system as affected by time of planting and spatial arrangement. They attributed the reduction in the yield of the cereal component of the intercrop to inter specific competition and shading of maize seedling by the already established soybean plants that led to reduction in leaf area, crop growth rate, and net assimilation rate (Caballero et al., 1995; Assefa and Ledin, 2001; Misbahulmumir et al., 1989; Addo-Quaye et al., 2011). Alom et al. (2009) investigated performances of different hybrid maize (*Zea mays* L) varieties under intercropping systems with groundnut (*Arachis hypogaeu* L) and found out that all yield and yield components of hybrid maize were significantly influenced by maize/groundnut intercropping system in the years under study. The grain yield of maize showed almost similar pattern to its yield contributing characters observed in sole and at different intercropping system studied though the result of their maize yield was found to be higher in monoculture compared to their yield in intercropping situation of which they attributed to no intercrop competition for light, nutrients, moisture, and space. Their findings corroborated with the works of Uddin et al. (2003), Nag et al. (1996), and Quayyum and Maniruzzaman (1995). The shading effect of maize on the groundnut according to the authors contributed considerable to the reduced pod yield observed in the intercropping situation of which similar results were reported by Razzaque et al. (2007) and Karim et al. (1990). Nweke (2015) however, found higher grain yield in intercrop than sole crop of which the percentage increase in grain yield per plot over sole crop on the average was 28.6% when he investigated the effect of intercropping panicum maximum with maize.

CONCLUSION

Intercropping cost effective and eco-friendly with the advantage of intercropping species together; and their associated microbes has many advantages over sole cropping. Intercropping system can be an excellent sources of bio fertilizer especially when leguminous crop is used, of which their addition improves the biophysical, biochemical and physiochemical and biological properties of agricultural soil. Although, there are some insinuations and challenges that intercropping systems is not well adapted to dry, poorly drained and heavy clay soils and difficult in mechanisation such as in sowing, weeding, fertilizer application, and harvesting. Hence, intercropping on large scale using machinery is generally believed to be impossible. These challenges not withstanding adequately planned and full implementation of intercropping system can act as a panacea for soil fertility enhancement, soil reclamation, crop growth and yield and for sustainable agriculture in south eastern soils of Nigeria.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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