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Effect of Legume-Based Intercropping on Crop Yield: A Review

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ABSTRACT---- ***Effect of intercropping with legume on yields of some crops was reviewed. Significantly high yield number of tillers in sugarcane was obtained in sole cropping and cropping at 100% sugarcane (S) + 25% cowpea (C). The least yield number of tillers was obtained at 50, 75 and 100% C grown with 100% S. Sugarcane and cowpea intercrop at 100% each, produced cane yield comparable (P=0.05) to that of; sole sugarcane and cowpea grown at 25, 50 and 75% in combination with sugarcane grown at 100%. Yields of cereals recorded were comparably higher than those obtained in the legume components. Yields of the component legumes were negatively influenced as they declines in the intercropped with high percentage losses. Yield of wheat-vetch intercropped was significantly higher than the sole-grown crop in the first year of intercropping. The same trend was further observed as years of intercropping wheat and vetch increases. Grain yields in soybeans were increased by different proportions of maize + soybean (M+SOY) population. This trend was also recorded in maize yields intercropped with cowpea varieties. In intercropping soybean and sorghum cultivars, results in the first season showed that, seed yields of early and medium maturing cultivars of soybeans (TGX536-02D and SAMSOY-2) were at par, however, significantly higher than the late maturing ones (TGM 344 and Malayan). Soybean seed yields in the second and third seasons of intercropping differed significantly with TGX536-02D cultivar producing higher yields, when cropped with a semi-dwarf sorghum (SAMSORG-17) variety. The land equivalent ratios (LERs) based on the sole crop yields of individual crop and legume components, provides a quantitative evaluation of the yield advantage due to intercropping. Total LER observed, ranged from 1.11 to 2.60; indicating a greater advantage in legume based-intercropping.***

Keywords--- Legume-based, intercropping, crop yields

1. INTRODUCTION

Many and diverse cropping systems have been used and in some cases continue to be used to bring about increased world food production (Addo-Quaye *et al.*, 2011). Seran and Brintha (2010) defined cropping system as the combination of crops grown on a given area within a year. One of these systems is intercropping (Addo-Quaye *et al.*, 2011), the growing of two or more crop species simultaneously in the same field during a growing season (Ofori and Stern, 1987), is important for the development of sustainable food production (Eskandari *et al.*, 2009), particularly in cropping systems with limited external inputs (Adesogan *et al.*, 2000). In terms of land use, growing crops in mixed stands is regarded as more productive and profitable than growing them separately (Andrew and Kassam, 1976; Willey, 1979; Yildirim and Guvence, 2005).

Crops in mixed stands have the advantage of exploiting environmental resources more efficiently (Francis, 1989; Zhang and Li, 2003; Li *et al.*, 2003 and 2006). Intercropping is practiced traditionally in many parts of the world (Alhaji, 2008; Ouma, 2009; John and Mini, 2005; Seran and Brintha, 2010; Ouma and Jeruto, 2010; Kureh *et al.*, 2006; Yilmaz *et al.*, 2008; Eskandari *et al.*, 2009;Sarunaite *et al.*, 2010; Addo-Quaye *et al.*, 2011; Kadziuliene *et al.*, 2011; Ahmad and Rao, 1982; Lithourgidis *et al.*, 2011) and interest in intercropping with legumes is wide spread in temperate regions with warm climates such as Australia and United States (Chui, 1977) as well as tropics (Hauggaard-Nielsen *et al.*, 2001; Tsubo *et al.*, 2005; Yilmaz *et al.*, 2008) and rain-fed areas of the world (Ghosh, 2004; Banik *et al.*, 2000; Agegnehu *et al.*, 2006; Dhima *et al.*, 2007). This is due to its advantages for yield increment, yield stability (by producing some yield, even though component crop failed), greater land use efficiency per unit land area, soil conservation and improvement of soil structure, organic contents and fertility through the addition of nitrogen by fixation and excretion from the component legume, reduced damage caused by pests, diseases and weeds, lodging resistance, hay curing, forage preservation, high crude protein percentage and protein yield (Andrews, 1972; Biederbeck and Bouwman, 1994; Eaglesham *et al.*, 1981; Anil *et al.*, 1998; Poggio, 2005; Banik *et al.*,2006; Chen *et al.*, 2004; Qamar *et al.*,1999; Karadag and Buyukburc, 2004; Javanmard *et al.*,2009; Dahmardeh *et al.*, 2010; Hauggaard-Nielsen *et al.*, 2001).

Burton *et al.* (1983) further observed that nitrogen leaching from leaves, and the decomposition of legume vines and leaves may also result in nitrogen transfer to the associated crop. On the basis of morphology and growth duration, Lithourgidis *et al.* (2011) distinguished several intercropping patterns, all of which vary in temporal and spatial mixtures (Herrera and Harwood, 1973; Andrews and Kassam, 1976). The degree of spatial and temporal overlap in the component crops can vary somewhat (Lithourgidis *et al.*, 2011), but both requirements must be met for a cropping system to be an intercrop. Thus, there are several different modes of intercropping, ranging from regular arrangements of the component crops to cases where the different component crops are intermingled (Figure 1-3). Intercropping also uses the practice of sowing a fast-growing crop with a slow-growing crop, so that the first crop is harvested before the second crop starts to mature (Lithourgidis *et al.*, 2011).

This practice requires some kind of temporal separation, for instance, different planting dates of the component crops so that the differential influence of weather and in particular temperature on component crop growth can be modified (Midmore, 1993). Further temporal separation is found in relay intercropping, where the second crop is sown during the growth, often near the onset of reproductive development or fruiting of the first crop, so that the first crop is harvested to make room for the full development of the second crop (Andrews and Kassam, 1976).

Common index of mixed cropping productivity is the land equivalent ratio (LER) which is the ratio of the area needed under sole cropping to one of intercropping at the same management level to produce an equal amount of yield (Francis, 1986). The land equivalent ratio (LER) was used as index for mixed stand advantage for both legume and non-legume. LER values were calculated as fallow:

$LER = LER_{legume\ (leg)} + LER_{non\text{-}legume\ (non\text{-}leg)}$

$LER_{legume} = (Y_{(leg)\ non\text{-}leg} / Y_{leg})$, $LER_{non\text{-}leg} = (Y_{(non\text{-}leg)\ leg} / Y_{non\text{-}leg})$

Where Y_{leg} and $Y_{non\text{-}leg}$ were the yields of common legume and non-legume as sole crop, respectively, and $Y_{(leg)\ non\text{-}leg}$ and $Y_{(non\text{-}leg)\ leg}$ were yields of common legume and non-legume in the mixture, respectively. When LER is greater than 1, the mixed growing favours the growth and yield of species. In contrast, when LER is lower than 1, the mixed growing negatively affects the yield of crops grown in mixture (Caballero *et al.*, 1995; Dhima *et al.*, 2007). Such a situation indicates the potential for over yielding (Willey, 1979). This work however, provides an overall view and evaluation of some key legume-based intercropping models in the literature, which could serve as a benchmark for scientific research.

2. DISCUSSION

High and significant yield number of tillers was obtained in sole sugarcane and 100%S + 25% C. The least yield number of tillers was obtained at 50, 75 and 100% C grown with 100% S. Sugarcane + cowpea intercrop at 100% produced cane yield comparable (P=0.05) to that of; sole sugarcane and cowpea grown at 25, 50 and 75 with 100% sugarcane (Table 1). Tiller yield in sugarcane is central to cane yield. Nickel (1984) reported earlier that, of many yield variables in the production of sugar from the cane plant, the most significantly related factor is the number of tillers, which is affected by variety, fertilization, cultural and environmental factors (Vandilewijn, 1952). Yield number of tillers in this study at all cropping combinations compared favourably with those reported by Agbana (1991) as suitable for commercial cane production and therefore supports these findings. Similar result on cane yield was reported by Gana (2008). He showed that sugarcane yield obtained with fertilizers and or incorporated-live legumes were significantly greater than the sole cane. The reason for increased yield may be attributed to nutrient fixing ability of legumes (Yilmaz *et al.*, 2008). Soils in which legumes are either grown or incorporated contains enough and suitable forms of phosphoric acid, potash, lime and nitrogen (Rao and Sharma, 1981; Lithourgidis *et al.*, 2011).

Accordingly, sugarcane morphological descriptors (stalk length, stalk girth and number of chewable stalks) which resembles that of stalk-maize, sorghum and millets (plant height, stem diameter and number of productive tillers) benefited positively from nitrogen transfer by the associated legume intercrop (Adu-Gyamfi *et al.*, 2007). Singh (1963) also reported a beneficial effect on sugarcane from incorporated legumes in North India. The fact that intercropping of legumes and stalk-cereals has produced higher yields than sole cereal crops without nitrogen fertilization was noticed by several researchers (Alhaji, 2008, Ofori and Stern, 1987; Ali *et al.*, 2000; Langat *et al.*, 2006; Hugar and Palled, 2008a and b).

Yields of cereals recorded were comparably higher than those obtained in the legume components. Yields of the component legumes were affected as they continued to decline in the intercropping with high percentage yield loss (Tables 2 and 3). In this study, it appeared that maize, sorghum and millet (the cereals) are stronger competitor towards the legumes (cowpea, soybeans, beans, groundnut, green gram and pigeon pea). The result agrees with Hauggaard-Nielsen *et al.* (2001) and Andersen *et al.* (2004) who showed barley a typical cereal crop as stronger competitor towards pea when intercropped. The trend of increasing yields in the cereals, revealed a much better utilization of plant growth resources (Sarunaite *et al.*, 2010) which is attributed to growth height of the cereals (high canopy crops) over the legumes (low canopy crops). Jiao *et al.* (2008) reported yield advantage in maize-groundnut intercropping as a result of efficient utilization of strong light by maize and weak light by ground nut. But earlier, Gardiner and Cracker (1981) sees yield reduction in cereal- legume intercropping as sorely due to mutual-shading effect caused by high plant densities in the cereal companion crops. His point of view seems to go well with studies of several researchers (Sivaraman and Palaniappan, 1996; Jeyakumaran and Seran, 2007; Seran and Brintha, 2009).

These researchers reported that seedling rate of each crop in mixture is adjusted below its full rate to optimize plant density, that if full rates of each crop were planted, neither would yield well because of intense overcrowding. Looking at the trends in yield of the cereals and legume intercrops (Tables 2 and 3); it is presumed that cereals were the dominant component in the intercrop. The results of investigation in Tables 4 and 5 showed diverse grain yield response among soles and the intercrop mixtures in the three year experiments. In 2007, the yield of wheat intercropped with vetch was significantly higher compared with grown as a sole crop (Table 4). Similar trend was observed with soles and intercrop mixtures in all the years of experiments in Table 5. Already, the fact that intercropping legumes and cereals has produced higher yields than sole cereal crops without nitrogen fertilization was noticed by several workers in the literature (Jensen, 1996; Lauk and Lauk, 2005; Corre-Hellon *et al.*, 2006; Sarunaite *et al.*, 2010; Kadziuliene *et al.*, 2011).

Explanations advanced by Gardiner and Cracker (1981), Hauggaard-Nielsen *et al.* (2001), Andersen *et al.* (2004) and Sarunaite *et al.* (2010) may presumably be the reasons for yield variation recorded in the current report. Hence, choosing of crop combination plays vital role in intercropping. Plant density, shading and nutrition competition between plants reduce the yield of soles and crops disadvantaged in the cropping mixture (Seran and Brintha, 2010). Plant competition could be minimized not only by spatial arrangement therefore, but also by choosing those crops best able to exploit soil nutrients (Fisher, 1977). Andrews and Kassam (1976) reported groundnut is usually intercropped with maize. Agboola and Fayemi (1971) reported that popondo (*Phaseolus lunatus*) and mucuna (*Mucuna utilis*) lowered maize yield, while calopo (*Calopogonium tnucunoides*), cowpea (*Vigna sinensis*) and green gram (*Phaseolus aureus*) had much less effect on maize and were themselves tolerant to maize shade (Seran and Brintha, 2010). Baker and Norman (1975) stated that increased yield from better use of space in mixture are complementary to utilizing time with crops in sequences. It was therefore suggested that, maximum cropping should be obtained with sequences of high yielding crops in compatible mixtures (Seran and Brintha, 2010).

Soybean grain yields were influenced by different proportions of maize + soybean (M+SOY) populations. Values of grain yields were observed to increase profusely from M+SOY 50, up to 100%, except in 1998 (Table 6). This trend was further recorded in maize grain yields with intercropping with different cowpea varieties (Tables 7 and 8). However, yields of different soybean cultivar intercropped with different sorghum varieties (Table 9) revealed that, yields of early and medium maturing cultivars (TGX536-02D and SAMSOY-2) were at par and significantly higher than those of the late maturing cultivars (TGX 344 and Malayan) in 1988. Yields in 1989 and 1990 differed significantly among soybean cultivar with TGX536-02D producing high yield. Soybean yielded significantly better only in 1990, when intercropped with a semi-dwarf sorghum variety (SAMSORG-17). These findings corroborate those of Alhaji (2008), Ofori and Stern (1987), Ali *et al.* (2000), Langat *et al.* (2006) and Hugar and Palled (2008a and b) mentioned in stalk-cereal intercrops, and the views opined by Gardiner and Cracker (1981), Hauggaard-Nielsen *et al.* (2001), Andersen *et al.* (2004) and Sarunaite *et al.* (2010) confirms the present results.

The land equivalent ratios (LERs) based on the sole crop yields of individual crop and legume components, provides a quantitative evaluation of the yield advantage due to intercropping. An LER greater than 1 indicates that the intercrop is more productive than the comparative sole crops (Willey, 1979). The total LER here, however, ranged from 1.11 to 2.60 (Tables 10a - c); indicating a greater advantage in legume based-intercropping.

3. CONCLUSION

Due to ever increasing human population especially in Africa leading to diminishing land sizes, intercropping with its advantages of risk minimization, improved soil conservation, increased food security should be practiced (Ouma and Jeruto, 2010), with careful considerations before and during cultivation. Intercropping affects vegetative growth of component crops depends on adaptation of planting pattern and selection of compatible crops. The choice of compatible crops for an intercropping system depends on growth habit, land, light, and water and fertilizer utilization. Legume-based intercropping critically reviewed showed that crops are grown in mixtures without detrimental effect to yield. However, much careful considerations are needed in intercropping systems. The LER values observed revealed greater potential for yield advantage in cropping with legumes. It can therefore be suggested that intercropping with legumes is a desirable agronomic practice towards boosting crop production.

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Table 1: Effect of intercropping cowpea (C) and plant cane (S) on tiller yield number and cane yield of sugar cane variety Co 957

Component crop population ratio	Yield number of tillers ('000/ha)	Cane yield (t/ha)
Sole sugarcane	360a	37.8a
Sole cowpea	-	-
100% S + 25% C	360a	30.6b
100% S + 50% C	300c	30.6b
100% S + 75% C	300c	30.8b
100% S + 100% C	290d	36.8a
LS	*	*
SE ±	4.15	4.84

Source: Afolabi (1999). LS. Level of significant *Significant at 5%
Means followed by the same letter (s) in a column are not significantly different from each other according to DMRT

Table 2: Yields of component crops and relative yield loss due to intercropping in various cereal- legume intercrop systems

Crop combination	Sole crop yield (kg/ha)		Yield loss due to intercropping (%)[a]		References
	Cereal	Legume	Cereal	Legume	
Maize- Cowpea	7408	1500	18	46	Ofori and Stern (1986)
Maize-Soybeans	3467	2290	4	72	Chetty and Reddy (1984)
Maize- Beans	4126	1493	8	39	Francis (1985)
Maize- Ground nut	8189	1742	3	74	Searle *et al.* (1981)
Sorghum-Green gram	2794	704	5	44	Singh and Jain (1984)
Sorghum-Cowpea	3568	676	2	40	Singh and Jain (1984)
Sorghum-Pigeon pea	2853	1380	14	40	Rego (1981)
Millet- Pigeon pea	2354	1244	7	22	Rao and Willey (1983)

[a] Percentage of sole crop yields

Table 3: Mean grain yield of component crops in maize-legume crop mixtures

Crop mixtures	Grain yield (kg/ha)		References
	Maize	Legume	
Maize-Beans	7320	1620	Fisher (1977)
Maize-Soybeans	7200	3278	Chui and Shibles (1984)
Maize – Cowpea	6500	2035	Wanki *et al.*(1982)
Maize- Beans	5591	2986	Davis and Garcia (1983)
Maize-Soybeans	4117	1824	Ahmed and Rao (1982)
Maize- Pigeon pea	3170	1195	Yadav (1982)
Maize-*Calopo*	2080	1159	Agboola and Fayemi (1971)
Maize-Cowpea	782.5	697	Kureh *et al.* (2006)
Maize-Cowpea	1400	680	Kureh *et al.* (2006)

Table 4: Grain yield of wheat and legume grown as sole and dual intercrops

Treatment	Grain yield (kg ha^{-1})		
	2007	2008	2009
Wheat	4132	2811	2496
Pea	3370	1107	2626
Lupin	2731	469	1323
Bean	3218	1011	1727
Vetch	2265	2214	1165
*Wheat + pea	3876	2509	2406
Wheat	3509	1932	2058
Pea	367	577	348
*Wheat + lupin	4037	1632	2654
Wheat	3933	1614	2235
Lupin	104	18	419
*Wheat + bean	3493	2668	2348
Wheat	2872	2308	1875
Bean	621	360	473
*Wheat + vetch	4387	2645	2982
Wheat	3860	1821	2002
Vetch	527	824	980
LSD (0.05)	246.7	446.5	382.3

*Total yield
Source: Sarunaite *et al.* (2010)

Table 5: Grain yield (kg ha^{-1}) in intercrops and in sole pea or spring cereals

Treatment	Grain yield (kg ha^{-1})		
	2007	2008	2009
Peas + wheat	4491	2139	2225
Peas	722	559	369
Wheat	3769	1580	1854
Pea + barley	3951	1851	2448
Peas	649	783	265
Barley	3302	1068	2183
Pea + oat	3010	2379	2277
Pea	634	514	188
Oat	2376	1865	2089
Pea + triticale	3567	2089	2549
Peas	838	414	310
Triticale	2729	1675	2239
Pea	4232	2342	2236
Wheat	4650	2210	2149
Barley	3304	2114	2332
Oat	3241	2924	2526
Triticale	3773	2341	2039
LSD (0.05)	373.7	565.8	275.4

*Total yield
Source: Kadziuliene *et al.* (2011)

Table 6: Performance of soybeans intercropped with maize

Cropping system	Year	Grain yield (kg/ha)

Soybean- sole	1998	2011.8
	1999	1632.9
Maize + soy (100%)	1998	754.6
	1999	1849.8
Maize + soy (75%)	1998	883.5
	1999	1076.7
Maize + soy (50%)	1998	659.5
	1999	299.1
LSD (0.05)	1998	1166.9
	1999	914.27

Source: Olowe *et al.* (2003)

Table 7: Effect of intercropping cowpea varieties on grain yield (kg/ha) of maize

Treatment	Maize	
	1997	1998
Sole	2298	3005
IT89KD-391	1991b	2070b
IT93K-452-1	1485a	1412a
IT90K-277-2	2558c	2668c
IT86D-719	1720a	1930b
IT89KD-349	1500a	1623b
IT88D-867-11	2262c	2425c
IT93-734	2046bc	2288c
IT93K-273-2-1	1623a	1700b
IT90K-372-1-2	2600c	2467c
Yar Dunga (Local)	1676a	1477a
SE±	193.2	282.0

Source: Alhaji (2008)

Table 8: Effect of intercropping cowpea varieties on grain yield (kg/ha) of maize

Planting patterns	Mix- proportions (%)	Grain yield (Mg ha^{-1})	
		Maize	Legume
Maize	100	11.02	-
Bean	100	-	2.01
1 Maize:1Bean	50:50	12.20	0.99
1 Maize:1Bean	67:50	13.17	0.83
1 Maize:1Bean	100:50	11.00	0.73
2 Maize:2Bean	50:50	11.97	0.79
2 Maize:2Bean	67:50	13.30	0.64
2 Maize:2Bean	100:50	10.45	0.59
Cowpea	100	-	1.18
1 Maize:1Cowpea	50:50	12.15	0.68
1 Maize:1Cowpea	67:50	13.40	0.60
1 Maize:1Cowpea	100:50	10.68	0.54
2 Maize:2Cowpea	50:50	12.20	0.57
2 Maize:2Cowpea	67:50	12.98	0.51
2 Maize:2 Cowpea	100:50	9.86	0.49
Mean		11.95	0.664
LSD (0.05)		0.43	0.05

Source: Yilmaz *et al.* (2008)

Table 9: Grain yield soybean (tha^{-1}) as affected by intercropping with sorghum

Treatment	Soybean yield (tha^{-1})		
	1988	1989	1990
Intercrops			
Soybean cultivars			
TGX 536-02D	1.36a	1.09a	1.92a
SAMSOY-2	1.25a	0.88b	1.38b
TGX 344	0.84b	0.57c	1.10c
MALAYAN	0.80b	0.43d	0.73d
LS	*	*	*
SE±	0.051	0.042	0.068
Sorghum cultivars			
SAMSORG-16	1.01	0.70	1.20
SAMSORG-17	1.11	0.78	1.37
LS	NS	NS	*
SE±	0.036	0.029	0.048

Source: Olufajo (1995) LS. Level of significant *Significant at 5%
Means followed by the same letter (s) in a column are not significantly different from each other according to DMRT

Table 10a: Summary of land equivalent ratio (LER) of intercrops

Cropping system	LER	References
Sorghum-pigeon pea	1.65	Enyi (1973)
Sorghum-soybean	1.11	Wahua and Miller (1978)
Sorghum-soybean	1,57	Olufajo (1995)
Sorghum-groundnut	1.47	Singh(1981)
Sorghum-cowpea	1.87	Singh(1981)
Maize-bean	1.39	Ofori and Stern (1987)
Maize-bean	1.72	Davis and Garcia (1983)
Maize-cowpea	1.26	Fawusi *et al.* (1982)
Maize-soybean	1.14	Chui and Shibles (1984)
Maize-soybean	1.41	Olufajo (1992)
Maize-soybean	1.60	Olowe *et al.* (2003)
Millet-green gram	1.32	May (1982)
Maize-French bean	1.48	Hugar and Palled (2008a)
Maize-Pigeon pea	1.51	Marer *et al.* (2007)
Maize-Soybean	1.62	Ullah *et al.* (2007)
Maize-Cowpea	1.35	Hugar and Palled (2008a)
Maize-Coriander	1.42	Hugar and Palled (2008b)
Maize-Bean	2.6	Odhiambo and Ariga (2001)

Table 10b: Summary of land equivalent ratio of intercrops

Treatment	Maize	
	1997	1998
	Land equivalent ratio (LER)	
Sole	-	-
IT89KD-391	1.86	1.61
IT93K-452-1	1.62	1.40
IT90K-277-2	2.09	1.78
IT86D-719	1.70	1.62
IT89KD-349	1.63	1.42
IT88D-867-11	2.01	1.60
IT93-734	1.78	1.51
IT93K-273-2-1	1.73	1.49
IT90K-372-1-2	2.11	1.54
Yar Dunga (Local)	1.66	1.51

Source: Alhaji (2008)

Table 10c: Summary of land equivalent ratio of intercrops

Planting patterns	Mix- proportions (%)	Total LER

1 Maize:1Bean	50:50	1.60
1 Maize:1Bean	67:50	1.61
1 Maize:1Bean	100:50	1.36
2 Maize:2Bean	50:50	1.48
2 Maize:2Bean	67:50	1.53
2 Maize:2Bean	100:50	1.24
1 Maize:1Cowpea	50:50	1.68
1 Maize:1Cowpea	67:50	1.73
1 Maize:1Cowpea	100:50	1.43
2 Maize:2Cowpea	50:50	1.59
2 Maize:2Cowpea	67:50	1.61
2 Maize:2 Cowpea	100:50	1.31

Source: Yilmaz *et al.* (2008)

Figure 1**:** Row-intercropping, where two plant species (maize-bean) are cultivated in separate alternate rows.
Adapted from Lithourgidis *et al.* (2011)

Figure 2: Mixed-intercropping within rows, where the component crops (maize-bean) are planted simultaneously within the same row. Adapted from Lithourgidis *et al.* (2011)

Figure 3: Strip intercropping, where several rows of a plant species are alternated with several rows of another plant species (1 broomcorn row-2 bush bean rows). Adapted from Lithourgidis *et al.* (2011)