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Full Length Research Paper

Effects of low input tillage and amaranth intercropping system on growth and yield of maize (*Zea mays*)

Awe, G. O.[1]* and Abegunrin, T. P.[2]

[1]Department of Crop, Soil and Environmental Sciences, Faculty of Agricultural Sciences, University of Ado Ekiti, Nigeria.
[2]Agricultural Engineering Department, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

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Field experiments were conducted to find out the effects of tillage practices and intercropping on the growth and yield of maize at the teaching and research farm, university of Ado Ekiti, southwest Nigeria during the 2006 early and late growing seasons. The experiment was laid out in a randomized complete block design (RCBD) with 3 replication with tillage practices (CT, MT, NT) assigned to main plots and cropping systems to subplots. At 8 WAP, the tallest plants of 134 cm were got with CT and sole cropping while the shortest plant, about 84 cm, was obtained from NT and intercropping. Application of CT and solecropping also had the widest leaf of 451cm ^{2} per plant while a leaf about 231 cm ^{2} was obtained from NT and intercropping. The same trend was obtained for the number of leaves per plant with CT and solecropping having the highest 11 leaves per plant. Land equivalent ratio was greater than unity in all treatments during both seasons. Aggressivity was negative for CT and MT and positive for NT while relative crowding coefficient was positive for all treatments. Maize grain yield was significantly highest, about 3 tonsha^{-1}, under CT and solecropping while the least yield, 2.12 tonsha^{-1}, was obtained from NT and intercropping. The results indicated that maize growth, intercropping efficiency and yield were well supported with CT.

Key words: Tillage, intercropping, growth, yield.

INTRODUCTION

Maize plays an important role in terms of food security, employment and income generation for families in parts of the humid tropics where hunger and starvation are prevalent (Ayoola and Makinde, 2007). It is a major staple food of the people and a very important constituent of animal feed that had led to an increase in its utilization resulting in the huge demand to expand production through modern tillage practices and intercropping (Lal, 1991). Tillage practices have been reported to have a significant and positive impact on crop production, especially through the improvement of soil properties with attendant provision of a suitable seed bed for good seed germination, ease emergence and good establishment of seedling through enhanced root growth by encouraging vertical and horizontal proliferation of roots through reduction in soil strength in the sub-soil (Okeleye and Oyekanmi, 2003; Baunt, 2006; Barry, 2007). Many researchers have studied maize performance under different tillage treatments (Wilhelma et al., 1991; Scope et al., 2001; Biaf, 2003; Areb, 2004; Kosutic et al., 2005; Kaulen, 2005; Chian, 2007). In all these studies, significant differences in growth and yield of maize between no – till and conventional tillage was reported. However, Lee (2006), Ogan (2007) and Asie (2007) noted non-significant effects of tillage treatments on the growth and yield of maize. On the other hand, maize is not usually planted sole under the traditional cropping system in order to minimize soil erosion and loss in fertility. It is usually intercropped with a variety of crops, such as amaranth, for a variety of purposes such as cultural weed control, fertility and moisture conservation, land use maximization, vitamin generation and improved cash returns from limited land holding. Some researchers (Ofori and Stern, 1987; Olukosi et al., 1991, Amanullah et al., 2006) have evaluated the effects of intercropping on maize based crops and significant difference in growth and yield was reported. However, there exist paucity of information on the effects of tillage practices and intercropping on the performance of crops. In particular, interaction between tillage practices and intercropping of maize based crops has not been accorded attention in

*Corresponding author. E-mail: gabrielolaawe@yahoo.com.

Table 1. Layout of the experimental plots.

Block I	SA	SM	MA
CT	SM	MA	SA
	MA	SA	SM
Block II	SM	MA	SA
MT	MA	SM	SA
	SA	SM	MA
Block III	MA	SA	SM
NT	SM	MA	SA
	SA	SM	MA

Nigeria.

An investigation was therefore undertaken to study the effects of tillage practices and intercropping on the performance of maize in maize-Amaranth cropping system.

MATERIALS AND METHODS

Experimental site

Two field experiments were conducted at the teaching and research farm, university of Ado Ekiti, (7°31'N and 7° 41'E) in southwest Nigeria during the 2006 early and late cropping seasons (ECS and LCS). The location is characterized by a bimodal rainfall pattern with a long early rainy season which usually starts in early March to mid-July while the late rainy season extends from mid August to late November after a short dry spell in mid-July to mid-August with annual rainfall of about 1,367 mm. The soil belongs to the broad group alfisol (SSS, 2002) of the basement complex. The study site had earlier been cultivated to a variety of arable crops such as cassava, yam, maize, vegetables, etc before it was left fallow for about 4 years prior to establishment of the experiment.

Experimental design

The experiment was laid out in a randomized complete block design (RCBD) (3 blocks) with a split plot arrangement of treat-ments. Tillage treatments were applied to main block and cropping systems randomly assigned to subplots. The tillage treatments were conventional tillage (CT: disk plough, disk harrow and plant); minimum tillage (MT: disk plough and plant) and zero tillage (NT: clear and plant) while the cropping systems consist of sole maize (SM): Sole Amaranth (SA) and maize–amaranth intercrop (MA) making nine (9) treatments with 3 replications. Each plot was 2 x 3m (6 m^2) separated 1 m apart. The field layout is as shown in Table 1.

Soil sampling and analysis

Prior to planting, 10 core samples, randomly collected from 0 – 15 cm top soil from the experimental plots were mixed to form a composite which was analyzed for physico-chemical properties. Before collecting the soil samples, soil surface plant litter was carefully removed. Soil samples were air-dried, visible plant roots removed and then gently crushed to pass through a 2 mm sieve. The < 2 mm fraction was used for the analysis. Determinations of pH (1:1 soil/water), total N (dry combustion) and available P (Bray-1) were made following the procedures in the soil survey laboratory soil. Methods manual (USDA/NRCS, 2004). Organic C was determined colorimetrically after wet oxidation with acidified potassium dichromate and external heating (Anderson and Ingram, 1993).

Exchangeable K, Ca and Na were determined by flame photometry while Mg was by atomic absorption spectrophotometry. Determination of exchangeable acidity was by extraction-titration method described by Mclean (1965) while effective cation exchangeable capacity (ECEC) was obtained by summation of exchangeable bases and acidity. Particle size distribution was done by the hydrometer of soil mechanical analysis as outlined by Bouyoucous (1951).

Establishment and management

The experiment was established in March 2006 for the early cropping season (ECS) and mid-August 2006 for the late cropping season (LCS). Seeds of maize (SUWAN –ISR – Y – early maturing variety) were sowed to the prepared beds at a spacing of 50 x 75 cm, 3 seeds per hole and later thinned to 2, giving a plant population of 53.34 plants/m^2. Amaranth seeds (*Amaranthus hybridus* spp) at 6 kg/ha were mixed with fine sand and drilled in rows at 20 cm apart. In the maize–amaranth combination, there were 12 rows of the vegetable to 5 rows of maize. The zero tillage plots were treated with atrazine at 224 mgm^{-2} + gly-phosate at 336 mgm^{-2} while the tilled plots were treated only with atrazine at 224 mgm^{-2} before planting was done. Fertilizer was applied uniformly within each plot at the rate of 30 $kgha^{-1}$ N, 30$kgha^{-1}$ P_2O_5 and 30 $kgha^{-1}$ K_2O in form of compound fertilizer NPK 15:15:15 (Blanket application) 3 weeks after planting. Weed escapes were later hoed manually.

Data collection

Plant height, number of green leaves and average leaf area were assessed 4 and 8 weeks after planting (4 WAP and 8 WAP) respectively. Plant height was taken by measuring, with a flexible tape, the height from the ground level to the top-most leaf. The number of leaves per plant was a visual count of the green leaves while the green leaf area was estimated as a product of the leaf length (L) and the widest middle portion of the leaf, the width (W) corrected to 0.75, as described by Saxena and Singh (1965) as given below:

$$LA = 0.75\ (L \times W) \quad \ldots\ldots 1$$

Where:
L = leaf length, cm
W = width of widest portion of leaf, cm
LA = leaf area, cm^2

Amaranth was harvested at 5WAS by uprooting, weighed using top loading balance to obtain the yield. Maize was left to mature and dry on the field. The cobs were later harvested, shelled, sun dried to 14% moisture content and weighed to give the grain yield. The yields were then converted to tons per hectare.

Intercropping efficiency was evaluated by comparing the productivity of a given area of intercropping with that of sole crops using the competition functions described below:

(1) Land equivalent ratio, $LER = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$ ………………2

Where Y_{ab} and Y_{ba} are the individual crop yield in intercropping and Y_{aa} and Y_{bb} are their yields as sole crop (Willey, 1979).

(2) Aggressivity, $AGG_{ab} = \underline{Y_{ba}} - \underline{Y_{ab}}$

Table 2. Physico-chemical properties of the study site before planting during the early cropping season.

Parameters	Values	Parameters	Values
pH	5.30	Na ($cmolkg^{-1}$)	1.12
Organic C (gkg^{-1})	3.72	Acidity ($cmolkg^{-1}$)	0.68
Total N (gkg^{-1})	1.99	ECEC ($cmolkg^{-1}$)	5.33
Avail. P ($mgkg^{-1}$)	1.90	Sand (%)	60.0
K ($cmolkg^{-1}$)	0.86	Silt (%)	25.0
Ca ($cmolkg^{-1}$)	1.23	Clay (%)	15.0
Mg ($cmolkg^{-1}$)	1.44	Texture	Sandy loam

Table 3. Effects of tillage and intercropping on the plant height of Maize.

Maize height (cm)	4WAP			8WAP		
Treatment	ECS	LCS	AVE	ECS	LCS	AVE
A_1B	68.17a	67.20a	67.69	135.27a	132.77a	134.02
A_1B_2	67.00a	63.87b	65.44	132.27a	129.37a	130.82
A_2B_1	60.47b	56.43bc	58.45	120.67b	119.63b	12015
A_2B_2	59.43b	44.87c	57.15	117.80b	116.57b	117.19
A_3B_1	44.57c	41.17d	42.87	86.80c	86.83c	86.82
A_3B_2	42.87c	37.30e	40.09	85.03c	83.17d	84.10

Values followed with the same alphabet in a column do not differ significantly.
A_1B_1 = Conventional tillage + Solecropping; A_1B_2 = Conventional tillage + Intercropping; A_2B_1 = Minimum tillage+ Solecropping; A_2B_2 = Minimum tillage + Intercropping; A_3B_1 = no-till + Solecropping; A_3B_2 = no-till + Intercropping.

$Y_{bb} \times Z_{ba} \quad Y_{aa} \times Z_{ab}$ ……………………….3

Where Z_{ab} and Z_{ba} were proportion of land area occupied on intercropping when compared to sole crop for species "a" and "b" respectively (Mc Gilchrist, 1965).

(3)Relative crowding coefficient, RCC = $K_{ab} \times K_{ba}$ ….. …………...4

$$K_{ab} = \frac{Y_{ab}}{Y_{aa} - Y_{ab}}; \quad K_{ba} = \frac{Y_{ba}}{Y_{bb} - Y_{ba}} \text{ ……………………..…………..5}$$

Where K_{ab} and K_{ba} are the RCC for species "a" and "b" respectively (de Wit, 1960).

Data analysis

Analysis of variance (ANOVA) procedure was used to determine the differences in growth and yield parameters. Mean values were compared using Duncan's multiple range tests (DMRT) at 0.05 level of probability.

RESULTS

Soil properties

The physico-chemical properties of soil of the study site before the early cropping are presented in Table 2.

Plant height

Average plant height increased significantly with the different treatments. At 4 WAP, CT and solecropping gave the tallest plants of about 68 and 67 cm for the ECS and LCS respectively when plants 67 and 64 cm tall were obtained with CT and intercropping in the ECS and LCS in that order. MT and solecropping had plants 60 and 56 cm tall during the ECS and LCS respectively while the same tillage treatment and intercropping gave plants 59 and 55 cm high also for the 2 seasons respectively. However, under NT treat-ments, plants 45 and 41 cm high were obtained under sole cropping which is significantly taller than 43 and 37 cm obtained under intercropping in the 2 growing seasons res-pectively (Table 3).

At 8 WAP, the same trend was maintained with CT and sole-cropping having significantly higher plants (Table 3). The difference in plant height at 4WAP during both sea-sons was significant while the difference was not significant at 8WAP.

Average of leaves per plant

Average plant height increased significantly with the diffe-rent treatments. At 4 WAP, CT and both sole- and inter-cropping had plants with about 8 leaves during the ECS and LCS respectively while MT and solecropping had

Table 4. Effects of tillage and intercropping on the number of leaves per plant of Maize.

No. of Leaf	4 WAP			8WAP		
Treatment	ECS	LCS	AVE	ECS	LCS	AVE
A_1B_1	8.33a	8.33a	8.33	11.00a	10.33a	10.67
A_1B_2	8.33a	7.67a	8.00	10.33a	9.67a	10.00.
A_2B_1	8.00a	7.33ab	7.67	10.33a	8.67ab	9.50
A_2B_2	8.00a	7.00ab	7.50	9.67a	8.33b	9.00
A_3B_1	6.67b	6.33b	6.50	8.33c	7.67c	8.00
A_3B_2	6.67b	6.33b	6.50	8.67b	7.67c	8.17

Values followed with the same alphabet in a column do not differ significantly.

Table 5. Effects of tillage and intercropping on the average leaf area of Maize.

	4WAP			8WAP		
	ECS	LCS	AVE	ECS	LCS	AVE
1)A_1B_1	216.46a	214.64a	215.55	459.62a	442.36a	450.99
2) A_1B_2	190.86b	189.41b	190.14	437.21b	427.74b	432.48
1) A_2B_1	181.18c	180.3c	180.76	378.13c	372.68c	375.41
2) A_2B_2	151.05d	155.2d	153.15	359.45d	351.55d	355.50
1) A_3B_1	96.47e	91.8e	94.15	233.33e	226.86e	230.10
2) A_3B_2	80.47f	81.22f	80.85	233.49e	229.07f	231.28

Values followed with the same alphabet in a column do not differ significantly.

had plants with about 8 leaves in the ECS while the same tillage treatment and intercropping gave plants with 8 and 7 leaves for the 2 seasons respectively (Table 4). For NT treatments, plants with about 7 leaves were obtained under both sole- and inter-cropping in the 2 growing seasons. At 8 WAP, the same trend was maintained but with higher no of leaves (Table 4).

Leaf area

This was also significantly affected by the treatments. At 4 WAP, CT had plants with leaves 216.5 and about 191 cm^2 wide for solecropping and intercropping respectively during the ECS. These were significantly higher than 181.2 vs 151.1 cm^2 and 96.5 vs 80.5 cm^2 wide leaves obtained under MT and NT with solecropping versus intercropping systems respectively. During the LCS, leaf area was a bit reduced, albeit, the difference was not significant. At 8WAP, the same trend was recorded but the leaves were much wider (Table 5).

Intercropping efficiency

In all tillage treatments, LER was greater than unity. The highest LER (1.67) was obtained from CT while NT recorded the lowest LER value (1.61) during the LCS. However this difference was not significant (Table 6). Negative aggressivity values (-0.06 and -0.08) were obtained from CT and MT respectively during the ECS while positive AGG value (0.004) was recorded from NT. The result was contrary during the LCS as only CT gave negative AGG (-0.102) while MT and NT yielded positive AGG. The differences recorded were statistically significant (Table 6). Positive RCC values were obtained for all tillage treatments during both seasons. The highest RCC (41.31) was recorded from CT during the LCS while the least (18.08) was obtained from NT during the ECS (Table 6).

Grain yield

A comparison of the data presented in Table 7 showed that maize yield was significantly highest in CT and sole-cropping during both seasons. The highest maize yield of 3.07 ton/ha was obtained from CT and sole-cropping during the ECS while the least yield of 2.17 ton/ha was obtained from NT and intercropping. During the LCS season, the same trend was obtained but the yield values were a bit lower.

Net returns

This was also significantly affected by tillage and inter-cropping. The highest net returns of ₦122,800 /ha was also obtained from CT and solecropping during the ECS while least net returns of ₦86,800 /ha was obtained from NT and intercropping (Table 7). During the LCS season, the same trend was obtained but the yield values were

Table 7. Effects of tillage and intercropping on the grain yield and net returns of maize.

	Maize Yield (ton/ha)		Net Returns (₦'000/ha)	
Treatment	ECS	LCS	ECS	LCS
A_1B_1	3.07a	2.97a	122.8a	118.8a
A_1B_2	2.80ab	2.79ab	112.0ab	111.6ab
A_2B_1	2.74ab	2.68ab	109.6ab	107.2ab
A_2B_2	2.53b	2.43b	101.2ab	97.2b
A_3B_1	2.53b	2.30b	101.2ab	92.0b
A_3B_2	2.17c	2.06c	86.8b	80.0c

Values followed with the same alphabet in a column do not differ significantly.

Table 6. Effects of tillage and intercropping on land equivalent ratio (LER), aggressivity (AGG) and relative crowding coefficient (RCC).

	ECS			LCS		
	LER	AGG	RCC	LER	AGG	RCC
CT	1.65a	2.22a (-0.06)	1.90a (29.36)	1.67a	2.22a (-0.102)	1.96a (41.31)
MT	1.65a	2.22a (-0.08)	1.92 (32.54)	1.65a	2.23a (0.05)	1.86a (22.80)
NT	1.61a	2.24a (0.004)	1.83a (18.08)	1.61a	2.23a (0.023)	1.84a (19.04)

Values followed with the same alphabet in a column do not differ significantly. The AGG values in the parentheses were transformed to (x + 5) while RCC values were transformed to log(x + 50) John and Mini (2005).

bit lower.

Discussion

Maize growth parameters were most supported with CT and solecropping. The better performance of maize associated with CT compared to MT and NT emanated from the fact that CT considerably improves soil physical properties with resultant provision of good soil tilth for crops. The significantly higher values of growth and yield parameters of maize in CT than those in the MT and NT agreed with the findings of Khan et al. (2001) and Rashidi and Keshavarzpour (2007) who concluded that annual disturbance and pulverizing caused by tillage practices produce a finer and loose soil structure which in turn enhance seedling emergence, plant population density and crop yield. The significant differences in the growth of maize among CT, MT and NT show the sensitivity of maize to tillage treatments. The better performance obtained under solecropping may be attributed to lesser degree of competition for various resources except intra–species competition while in intercropping, the reduction might be attributed to both inter -and intra- species competition for nutrients, space and nutrients. These findings have also been reported by Mestra, 1990, Chittapur et al. (1994), Olasantan et al. (1997) and Amanullah et al.

(2006) who found that maize performed better in sole-cropping than intercropping. On intercropping efficiency, the greater than unity LER is an indication of yield advantage for the intercropped plots when the yields of both crops are combined. This is in consistence with the findings of John and Mini (2005) who found LER > 1 when okra was intercropped with amaranth, cowpea and cucumber. The LER of 1.65 obtained under CT in the ECS implied that 65% more land would be required as sole crops to produce the yield under intercropping situations. The negative aggressivity values from CT and MT during the ECS is an indication that amaranth was aggressive and can be dominant over maize especially during the early growth stage while the positive aggressivity value from NT showed that amaranth was not aggressive and maize is dominated. However, during the LCS, aggressivity value was negative for CT only while it was negative for both MT and NT. This verified that maize could not dominate over amaranth under CT practices as a result of favourable environment for crop growth and nutrient use. This implies that amaranth may not be suitable as an intercrop in this situation. The positive RCC values obtained for all tillage treatments implied that there was no yield potential reduction in maize in the intercropping situations compared to that of the sole crops. This is in contrast to the findings of John and Mini (2005) who obtained negative RCC when okra was intercropped with amaranth but positive RCC when it was intercropped with cowpea and cucumber. The significantly highest yield and net returns obtained from CT is consistence with the general trend in growth indices during both seasons. A plausible explanation for this is the better utilization of site resources.

Conclusion

Maize growth, intercropping efficiency and yield were well supported with tillage practices. CT exerted the highest influence on the growth and yield of maize, resulting in significant difference, compared to MT and NT. Based on the present results, CT can be advocated as a promising tillage practice when maize-based cropping systems.

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