Effects of tillage and cropping systems on yield and nitrogen fixation of cowpea intercropped with maize in northern Guinea savanna zone of Ghana

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ABSTRACT

Published information is scanty on the response of crops in mixed cropping systems to the various tillage systems practised by farmers in the northern savanna zone of Ghana. A field experiment assessed the yield and nitrogen (N) fixation of cowpea (*Vigna unguiculata* (L.) Walp) intercropped with maize (*Zea mays* L.) on four different tillage systems at Nyankpala in the Northern Region of Ghana. The experiment was laid in a split-plot design with four replications. The main factor was tillage systems comprising conventional (Con), bullock plough (BP), hand hoe (HH) and zero tillage (ZT). The sub-factor was cropping systems (CRPSYT) which consisted of sole maize, sole cowpea, maize/cowpea inter-row cropping system, and bare fallow in 2000. The last-named was replaced by maize/cowpea intra-row cropping system in 2001. The results showed that Con and BP, which produced over 10 cm plough depth, significantly reduced soil bulk density that favoured significant (P<0.05) increases in the number of nodules per plant and nodule weight. However, ZT with the highest bulk density significantly (P<0.05) reduced the N content in both crops, but phosphorous (P) and potassium (K) contents were unaffected by tillage systems. Percent N fixed by cowpea at 8 weeks after planting (WAP) was not different between Con and BP, but both were significantly lower (P<0.05) than in the HH and ZT treatments. Grain yields of maize and cowpea on Con and BP were similar but significantly higher (P<0.05) than on HH and ZT, which were also not different. Cropping systems had no significant effects on nodule number per plant, nodule weight, and N, P and K contents in both crops; but N, P and K yields and also percent N fixed by cowpea were significantly higher (P<0.05) in the sole than in the intercrops. Grain yields of both crops were also significantly higher (P<0.05) in the sole than in inter- or intra-row cropping systems. The land

RÉSUMÉ

KOMBIOK, J. M., SAFO, E. Y. & QUANSAH, C.: *Les effets de labourage et des systèmes de culture sur le rendement et la fixation d'azote de dolique semé en lignes alternantes de maïs dans la zone au nord de savane-guinéenne du Ghana.* Information publiée sur la réaction de cultures sous les systèmes de polyculture aux différents systèmes de labourage pratiqués par les agriculteurs dans la zone au nord de la savane du Ghana est maigre. Une expérience au champ a été entreprise à Nyankpala dans la région au nord du Ghana pour évaluer le rendement et la fixation d'azote (A) de dolique (*Vigna unguiculata* (L.) Walp) semé en lignes alternantes de maïs (*Zea mays* L.) sur quatre différents systèmes de labourage. L'expérience était faite sur le dessin d'un lot-divisé avec quatre reproductions. Le facteur majeur était les systèmes de labourage comprenant conventionnel (Con), le bœuf de labour (BL), la houe à amin (HM) et labourage zero (LZ). Le sous-facteur était les systèmes de culture (STYCUL) comprennent le maïs seul, la dolique seule, le système de culture de maïs/dolique en lignes alternantes et la terre nue en jachère en 2000. La dernière était remplaçée par le système de culture de maïs/dolique en rangée intra-laient en 2001. Les résultats révélaient que Con et BL, qui produisaient plus que 10 cm de profondeur de labour de grosseur du sol qui favorisait les augmentations considérables (P < 0.05) du nombre de nodules par plante et le poids de nodule. Toutefois, LZ avec la densité de grosseur plus élevée reduisait considérablement (P < 0.05) la teneur d'Adans les deux cultures mais les teneurs de P (phosphore) et K (potassium) n'étaient pas influencés by les systèmes de labour. Le pourcentage d'A fixé pat la dolique à 8 semaines après la plantation (SAP) n'était pas différent entre Con et BL mais étaient tous les deux considérablement plus faibles (P < 0.05) que dans les traitements de HM et LZ. Les rendements de grain de mais et de dolique sur Con et BL étaient semblables mais considérablement (P <0.05) plus equivalent ratios (LERs) of both mixtures were not significantly different, but each was greater than one (LER>1). The LERs ranged from 1.43 to 1.79 in 2000, and from 1.23 to 1.24 in 2001 for Con and ZT, respectively. These indicate 33 and 52 per cent mean increases in productivity of cowpea and maize, respectively, over their pure stands across the 2 years. However, grain yields of both crops from the inter- and intra-row cropping systems were not different.

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élevés que sur HM et LZ, qui aussi n'étaient pas différent. Les systèmes de culture n'avaient pas d'effets considérables sur le nombre de nodule par plante, poids de nodule et les teneurs de P, K et A dans les deux cultures mais les rendements de P, K et A ainsi que le pourcentage d'A fixé par la dolique étaient considérablement plus élevés (P < 0.05) dans les monocultures que dans les cultures semées entre les lignes d'une autre culture. Les rendements de grains de deux cultures étaient aussi considérablement (P < 0.05) plus élevés dans la nonoculture que dans les systèmes de cultures entre-lignes ou intra-lignes. Les Proportions Equivalentes de Terre (PET) de deux mélanges n'étaient pas considérablement différentes mais chacun étaient plus élevées qu'un (PET>1). Les PETs variaient entre 1.43 et 1.79 en 2000 et entre 1.23 et 1.24 en 2001. pour Con et LZ respectivement. Celles-ci indiquent 33 et 52 % des augmentations moyennes de la productivité de dolique et de maïs respectivement au-dessus de leur culture assolée pure pendant les deux jours. Toutefois, les rendements de grain de deux cultures des systèmes de culture entre-lignes et intra-lignes n'étaient pas différents.

Introduction

The low nitrogen and phosphorus status of the savanna soils of northern Ghana reported by several researchers, including Acquaye (1973) and Tiessen (1988), have been attributed to annual bushfires or the removal of crop residues for use as fuel wood, livestock feed, and for building purposes (Halm & Asiamah, 1992). These actions usually lead to the exposure of the soil to erosion, which subsequently reduces the availability of most soil nutrients including N and P.

Tillage is any physical loosening of the soil applied in a range of cultivation operations which increases the surface storage capacity (SSC) of the soil, thereby reducing erosion and enhancing soil water storage (Ahn & Hintze, 1990). Farmers in northern Ghana prepare their lands for crop production by tilling the soil using the tractor, bullock, hand hoe (manual) and, to some extent, the slash and burn method (no-till). The attributes of these different tillage methods have implications on the soil nutrients and crop yields, which need to be investigated.

Studies in the temperate and tropical rainforest regions have shown that continuous no-till improved soil structure and reduced erosion, which led to an increase in maize yields (Lal, 1978; Papendick & Parr, 1997; Ermani *et al.*, 2002). It has also been found that due to increased soil bulk density in no-till soils, the rooting depth was significantly reduced, resulting in lower crop yields than on conventionally tilled soils (Onstad, 1984; Arshad, 1999). In Ghana, Kanton *et al.* (2000) found significantly low sorghum yields and high weed infestation in the hand hoe compared to bullock and tractor-ploughed treatments.

Intercropping cereals with legumes helps in maintaining soil fertility. Reddy, Visser & Buckner (1992) observed that soil fertility was maintained through nitrogen fixation, and a differential uptake of nitrogen by plants was also recorded in maize/cowpea intercropping system. Although the increase in yield was not significant, large amount of nitrogen was transferred to the maize crop when maize was intercropped with cowpea in Nigeria (Agboola & Fayemi, 1972). Cowpea is limited by light in the intercrop but when soil is poor in nitrogen, the cereals develop poorly and intercept less light, which results in poor yields of the crop. However, the understorey cowpea is at an advantage to intercept more light for higher grain yields (Tsay, 1985; Terao *et al.*, 1997). Therefore, enough information is available on crop mixtures and the response of crops in monocultural systems to the various tillage methods in crop yields. However, information is scanty on the effects of tillage methods on crops grown in mixtures, the most common cropping system in northern Ghana (Andrews & Kassam, 1976; Willey, 1979; Fisher, 1979).

To bridge this gap in knowledge, in 2000 and 2001 a study compared the productivity of maize/ cowpea mixture and the percent N fixed by cowpea on the conventional (tractor plough), no-tillage, bullock, and the traditional hoe farming methods. It also aimed at providing farmers in the savanna ecology of northern Ghana with the necessary information on different tillage systems to enable them adopt the methods that best suit the various cropping systems they practise.

Materials and methods

Study site

The Nyankpala farm of the Savanna Agricultural Research Institute (SARI) was used for a field experiment in the 2000 and 2001 wet seasons. Nyankpala is situated on Latitude 9° 25" N and Longitude 1° 00" W at 183 m above sea level in the northern Guinea savanna zone of Ghana. The experiment assessed the response of maize/ cowpea mixture to different tillage methods.

The site falls within the Guinea savanna agroecological zone. It is semi-arid with monomodal annual rainfall of 800-1100 mm, which falls mostly between June and September each year. This short rainy season is followed by a pronounced dry season between October and May annually. The average daily atmospheric temperatures range from a minimum of 26 °C to a maximum of 39 °C, with a mean of 32 °C (Table 1).

The soil was analysed before the start of the experiment in 2000. The analysis showed a *p*H of 5.06 in calcium chloride solution (0.01M). Other soil chemical properties of the site were 0.055% N; available P, 24.5 mg kg^{-1}; and exchangeable K, 40 mg kg^{-1}. The land has a gentle slope of about 2 per cent and is strongly disturbed by sheet erosion. The soil is a well-drained voltaian sandstone unit locally referred to as the *Tingoli* series. Detailed soil profile study and characterization undertaken in the 2000 cropping season showed that it is a ferric Luvisol (FAO/ UNESCO, 1977).

The vegetation of the area consist of short, deciduous widely spaced fire-resistant trees such as the shea butter (*Butyrospermum parkii*) and the dawadawa (*Parkia biglobosa*) trees, which do not form a close canopy. The ground flora comprise different species of grasses of varying heights.

The climatic data at the site of the experiment (Table 1) indicated that the number of rainy days and the amount of rainfall were higher, came in earlier, and was more evenly distributed in 2000 than in 2001 during the experiment.

TABLE 1

Climatological Data Taken at Experimental Site During the Experimental Period at Nyankpala

	Mean temp. °C		*Rainfall (mm)*		*Rel. hum. (%)*		*Rainy days*	
Month	*2000*	*2001*	*2000*	*2001*	*2000*	*2001*	*2000*	*2001*
Jun	27.8	28.2	260.4	62.9	83	68	13	7
Jul	26.3	27.0	96.9	182.0	80	73	6	10
Aug	26.1	26.0	165.1	134.5	84	62	13	13
Sep	26.5	26.0	212.7	249.4	76	61	18	15
Oct	27.6	28.6	27.5	9.2	60	63	4	1
Total			762.6	638			54	46

Experimental design and treatments

The field experiment was laid out in a split-plot design with four replications. The main plot factor was tillage systems and the sub-plot factor was cropping systems. The tillage systems evaluated were conventional (Con), bullock plough (BP), hand hoe (HH), and zero tillage (ZT). Cropping systems (CRPSYT) representing the sub-factor were sole maize, sole cowpea, maize/cowpea (inter-row), and a bare fallow in 2000. However, in 2001, the bare fallow was replaced by maize/ cowpea (intra-row) cropping system.

In the conventional tillage system, the land was prepared using disc plough, and harrowed once using a tandem disc harrow to a mean depth of 18 cm. For the bullock tillage system, a bullock plough was pulled by a pair of bullocks to a mean depth of 12 cm. A large hoe was used manually in digging and loosening the soil to a depth of about 5 cm. With the zero tillage, a herbicide (gramoxone), at a rate of 5 l ha^{-1}, was used to kill all the vegetation on the plots.

The test crops were maize ('Obatanpa') and cowpea (Sul-518-2). The maize is an open-pollinated medium-maturing variety while the cowpea is also medium-maturing and semi-erect. Each sub-plot measured 8.1 m × 5.0 m. A net plot of 5.4 m × 5.0 m taken from the middle for final yield assessment had six rows of maize each in the sole maize, maize/cowpea intra-row, and maize/ cowpea inter-row cropping systems. The same measurement had nine rows of cowpea in the sole, five in the inter-row, and six in the intra-row cropping systems.

The spacing in sole maize was 90 cm × 40 cm with two plants per stand, giving a plant population of 55,556 plants ha^{-1}. In sole cowpea, it was 133,333 plants ha^{-1} spaced at 60 cm × 25 cm with two plants per stand. With the maize/cowpea inter-row cropping system, maize population was maintained at 100 per cent and cowpea planted in alternate rows midway (45 cm) between each two rows of maize. In the intra-row cropping system, maize population was again maintained, but the cowpea was planted on the same row in alternate hill arrangement with maize, but in between each two maize stands. Each intercropping system was the additive model, which had 55,556 cowpea plants ha^{-1}. Bare fallow was included in 2000 to find out whether it was a better water conservation technique. In both years, crops were planted on flat without ridging. In 2000, the planting was done on 6th June while in 2001, it was on 11th June.

Tillage depth and bulk density

The depth to which each tillage implement reached in the soil was measured before the crops were planted by gently pressing a metre rule into each practice or major treatment till the rule was no more penetrating. The reading at the surface of the soil on the rule was recorded for each as the depth of tillage.

Bulk density was measured by taking soil samples in a known volume of cores at 0-15 and 15-30 cm. Each core was weighed (W_2) and dried at 105 °C in an oven for 72 h and the dry soil weighed (W_3). The difference between the weight of the core and the dry sample was divided by the volume of the core to determine the bulk density as follows:

ñÜ = $(W_3 - W_2) / V$...(1)

where

ñÜ = Bulk density

W_2 = Weight of wet soil before drying

W_3 = Weight of oven-dried soil

V = Volume of core used in soil sampling (cm^3) (Blake & Hartge, 1993)

Nutrient analyses (N, P and K)

Four plants of each species were cut at ground level at podding and cobbing stages of cowpea and maize, respectively (in the sole and intercropping systems), from the two border rows in each plot. These were kept in brown envelopes and arranged in an electric oven at 65 °C for 48 h. The samples were removed and milled to a fine material and packaged according to crop species and treatment to determine N, P and K contents at the laboratory of SARI.

Hydrogen peroxide was used as an oxidation agent in digestion of the milled materials with concentrated sulphuric acid, and selenium as a catalyst was added to accelerate the process. An aliquot was pipetted and distilled for percent total N by steam distillation of the ammonium liberated by adding 30 per cent sodium hydroxide. Titration was carried out on the distillate using boric acid solution as indicator with a known concentration of sulphuric acid.

To determine total P, an aliquot of the digest was taken and the phospho-molybdate and ascorbic acid reduction method used. The solution was measured on a spectrophotometer, Pye Unicam (PU8600 UV/VIS), at 850 nm wave-length when the colour turned blue.

A third aliquot of the digest was also taken to determine K on a flame photometer (*Ependorf, Germany).

Total shoot dry matter

Two rows of plants of each crop were taken from the borders on each side of each plot and cut at ground level to determine shoot dry matter at 8 WAP. Total fresh shoot weight was taken using a *Mettler PM 600 balance in the laboratory of SARI. The plant materials were then put in large brown envelopes and oven-dried at 65 °C for 72 h. The dried materials were again weighed and the shoot dry weight per hectare was determined.

Nodule number per plant nodule weight and N fixation

Four cowpea plants from each of the sole and intercropped plots were dug out for the nodule count and to determine nodule dry weight. The process consisted of loosening the soils around the plants to a reasonable depth with a hand hoe, making sure plant roots were not disturbed. The plants were pulled out gently and kept in polythene bags. They were then sent to the laboratory and washed with water to remove all the soil particles on the roots. The nodules were removed and those that fell off during washing were added and counted. These were then put in envelopes and oven-dried at 65 °C for 48 h after which they were weighed on a sensitive scale and the average weight per nodule was calculated.

The percent N fixed by cowpea was estimated using the Total Nitrogen Difference (TND) method as described by Hassen (1994):

Thus, N_2 fixed = N $yield_{fix}$ - N $yield_{ref}$

$$\% \text{ Ndfa} = \frac{100\,(\text{N yield}_{fix} - \text{N yield}_{ref})}{\text{N yield}_{fix}} \quad ......(2)$$

where

% Ndfa = Percentage of plant N derived from atmosphere

N $yield_{fix}$ = N yield by N-fixing crop (cowpea)

N $yield_{ref}$ = N yield by reference crop (maize)

This method is based on the assumption that the N-fixing and non-N-fixing crops assimilate identical amounts of soil and fertilizer nitrogen.

Nitrogen yield is estimated as the product of total dry matter yield and nitrogen concentration of the crop at a stage in crop growth.

Grain yield and yield components of maize and cowpea

In 2000, cowpea matured earlier and was harvested on 11th August while that of maize was on 30th September. However, in 2001, cowpea and maize were harvested on 18th September and 5th October, respectively. The ears from the net plot of maize and the pods of cowpea were each put in open bags after harvesting and dried before shelling and threshing, respectively. The shelling and threshing percentages were then calculated. Five randomly selected ears of maize were taken before shelling (x g), and a known weight of pods of cowpea was also taken before threshing (y g).

The shelling percentage was calculated as the weight of the maize grains from the selected ears (z) divided by the ear weight (x) and expressed as a percentage as:

Shelling percentage = z g / x g × 100 % ..... (3)

The threshing percentage for the cowpea was the weight of the grains after threshing (s g) divided by the weight of pods before threshing (y g) as:

Threshing percentage = s g / y g × 100 %..... (4)

Hundred seeds from each crop were randomly picked and replicated four times and weighed. The average weight for maize and cowpea of 100 seeds per crop were considered as the 100-seed weight of maize and cowpea. The total weights of maize and cowpea from the net plots were determined after shelling and threshing, respectively, at a moisture content of 13 per cent determined by Kongskilde moisture meter (MK IV) manufactured by *Kongskilde Maskinfabrik A/S, Denmark. The weights of maize and cowpea from each net plot were then extrapolated to per hectare basis.

The LER of the mixture was calculated for each of the tillage practices as described by Willey & Osiru (1972) as:

LER=La+Lb=Ya/Sa+Yb/Sb ……........……(5)

where La and Lb are the LERs of crop species *a* and *b*, Ya+Yb are the individual crop yields in the mixture, and Sa and Sb are their sole crop yields.

Data collected were then subjected to statistical analysis using the SAS programme software (SAS, 2002); means were separated using the Least Significant Difference (LSD) at 5 per cent probability.

Results

Tillage depth and bulk density

For the tillage treatments, Con maintained the highest working depth during the 2 years of experimentation. This was followed by BP treatment, HH and ZT (Con>BP>HH>ZT) in order of decreasing depth (Table 2). The mean depth for the 2 years followed the same pattern.

Soil bulk density varied among tillage treatments in the 0-15 cm soil depth, ranging from 1.25 and 1.35 under Con to 1.49 and 1.50 under ZT in 2000 and 2001, respectively (Table 2). The treatment means separation of the bulk density in the 0-15 cm depth indicated that values under Con and BP were similar but significantly lower (P<0.05) than values under HH and ZT, which were also not different. However, in the 15-30 cm depth, no significant differences were observed among tillage treatments in bulk density (Table 2). The mean for the 2 years also showed that the highest bulk density in the 0-15 and 15-30 cm depths was in the ZT and the lowest in the Con treatments.

Maize total dry matter yield at 8 WAP

In both years, the maize total dry matter yields at 8 WAP on CON and BP were not different but were significantly higher (P<0.05) than the dry matter yields determined on HH and ZT (Table 3). In 2000, the total dry matter yield of maize on ZT was significantly higher (P<0.05) than that on HH treatment by about 0.14 t ha^{-1}; but in 2001, the yields in the last two tillage treatments were not significantly different.

The total dry matter yield of sole maize was

TABLE 2

Tillage Depth and Bulk Density as Affected by Tillage Practices

Tillage system	*Tillage depth (cm)*			*Soil bulk density (g cm^3)* 0-15 cm			15-30 cm		
	2000	*2001*	*Mean*	*2000*	*2001*	*Mean*	*2000*	*2001*	*Mean*
Con	18.2	19.2	18.7	1.25	1.35	1.30	1.56	1.60	1.58
BP	12.3	11.5	11.9	1.26	1.38	1.32	1.64	1.62	1.59
HH	5.8	6.3	6.05	1.42	1.50	1.46	1.62	1.64	1.63
ZT	0.0	0.0	0.0	1.49	1.52	1.51	1.65	1.68	1.67
LSD $_{(0.05)}$	1.2	1.1	-	0.15	0.11	-	0.14	0.18	-

significantly higher ($P<0.05$) than that for the intercrop maize. In 2000, intercropping maize with cowpea reduced the maize dry matter yield by over 19 per cent; and in 2001, the reductions were 15 and 14 per cent in the inter-row and intra-row cropping systems, respectively (Table 3). The maize dry matter yield at 8 WAP in the inter-row did not differ significantly from that recorded for the intra-row cropping system. No interaction effect was observed on total dry matter of maize between tillage and cropping systems at 8 WAP.

Cowpea total dry matter yield at 8 WAP

Tillage treatments did not influence cowpea total dry matter yield at 8 WAP in 2000 and 2001 (Table 3). The differences in cowpea dry matter attributed to the tillage treatments were not significant in both years.

The total dry matter yield of the cowpea intercropped with maize was significantly lower ($P<0.05$) than in the sole by 65 and 67 per cent in 2000 and 2001, respectively (Table 3). The cowpea total dry matter yield produced from the inter-row was not significantly different from that of the intra-row cropping system. The interaction effect of tillage and cropping systems on cowpea dry matter was not significant.

N, P and K contents in cowpea and maize

Tillage treatments did not significantly change the P and K contents in cowpea, but N content was significantly lower ($P<0.05$) under ZT compared to other tillage treatments (Table 4).

With the exception of ZT treatment, which significantly ($P<0.05$) lowered the N content in maize in both years, N content values in maize for the rest of the tillage treatments were similar (Table 5). However, P and K contents in maize were unaffected by tillage treatments (Tables 4 and 5).

Cropping systems had no significant effects on the N, P and K contents in cowpea and maize, though the maize intercropped with cowpea had slightly higher values; they were not significantly different (Tables 4 and 5). The interaction effect of tillage and cropping systems on nutrient contents of maize and cowpea was not significant.

N, P and K yields in cowpea at 8 WAP

Nutrient yield is the product of nutrient content of a crop and the dry matter yield at a stage in plant growth. The N yield values of cowpea at 8

TABLE 3

Dry Matter Yield of Maize and Cowpea at 8 WAP as Affected by Tillage and Cropping Systems

Tillage system	*Total dry matter yield (t ha^{-1})*			
	Maize dry matter at 8 WAP		*Cowpea dry matter at 8 WAP*	
	2000	*2001*	*2000*	*2001*
Con	1.08	0.94	1.93	1.60
BP	1.16	0.97	1.85	1.52
HH	0.63	0.47	1.76	1.68
ZT	0.77	0.53	1.84	1.55
LSD $_{(0.05)}$	0.13	0.12	0.25	0.22
CRPSYT				
Sole	1.12	1.03	1.93	1.81
Inter	0.90	0.88	0.63	0.59
Intra	-	0.89	-	0.60
LSD $_{(0.05)}$	0.08	0.11	0.19	0.68

TABLE 4

Total N, P and K Contents in Cowpea as Affected by Tillage and Cropping Systems

Tillage	*Shoot N (%)*		*Shoot P (%)*		*Shoot K (%)*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	3.38	3.63	20.83	23.85	17.27	11.51
BP	3.30	3.37	19.64	24.88	17.70	11.71
HH	3.32	3.16	19.23	24.84	15.81	12.10
ZT	2.39	2.16	17.58	24.60	15.10	12.20
LSD $_{(0.05)}$	0.69	0.42	4.42	6.49	1.88	1.36
CRPSYT						
Sole	3.35	3.95	24.79	25.95	19.58	15.92
Inter	3.13	3.37	23.38	24.80	19.51	15.72
Intra	-	3.42	-	25.88	-	14.68
LSD $_{(0.05)}$	0.82	1.23	2.32	5.61	8.38	2.38

TABLE 5

Total N, P and K Contents in Maize as Affected by Tillage and Cropping Systems

Tillage	*Shoot N (%)*		*Shoot P (%)*		*Shoot K (%)*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	2.16	2.19	21.54	23.85	20.35	54.70
BP	2.17	2.14	24.99	24.88	17.29	56.72
HH	2.15	2.17	23.58	24.84	17.25	54.71
ZT	1.66	1.73	18.54	24.50	14.54	50.25
LSD $_{(0.05)}$	0.84	0.38	9.30	6.49	7.78	5.95
CRPSYT						
Sole	2.17	1.92	18.02	25.95	20.40	65.54
Inter	2.35	2.03	35.68	24.80	19.50	60.92
Intra	-	2.01	-	25.88	-	61.31
LSD $_{(0.05)}$	0.72	0.32	7.53	5.62	4.11	2.48

WAP on Con, BP and HH were not different but were each significantly higher (P<0.05) than the yield on ZT treatment in both years (Table 6). Phosphorus and K yields of cowpea in 2000 were similar on Con and BP treatments. The values on HH and ZT were also not statistically different, but were significantly lower (P<0.05) than the values of the first two treatments. Phosphorus and K yields of cowpea were not significantly different among the tillage treatments in 2001.

Cropping systems significantly influenced N, P and K (nutrient) yields in both years. Nitrogen, P and K yield values for sole cowpea were significantly higher (P<0.05) than the nutrient yield of cowpea intercropped with maize in both years (Table 6). However, N, P and K yield values of cowpea in the inter-row and intra-row cropped with maize were not significantly different. Tillage

TABLE 6

Nutrient Yield of Cowpea as Affected by Tillage and Cropping Systems at 8 WAP

Tillage system	*Nutrient yield (kg ha⁻¹)*					
	N		*P*		*K*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	65.20	58.10	40.10	38.2	333.30	184.20
BP	61.10	57.20	36.30	37.80	327.50	178.10
HH	58.40	53.10	33.90	41.70	278.30	203.30
ZT	43.90	33.50	32.40	38.10	278.00	189.10
$LSD_{(0.05)}$	7.72	6.92	4.10	4.40	17.22	28.99
CRPSYT						
Sole	64.70	71.5	47.90	47.10	377.90	288.20
Inter	21.30	19.90	15.90	14.60	132.70	92.70
Intra	-	20.50	-	15.50	-	88.10
$LSD_{(0.05)}$	7.55	8.40	4.30	3.80	15.90	15.80

and cropping systems interaction on the N, P and K yields of cowpea was not significant.

N, P and K yields in maize

Nitrogen yield of maize on ZT was significantly lower (P<0.05) than that on Con treatment, but there were no significant differences among the yields determined in the Con, BP and HH treatments in both years (Table 7).

Phosphorus and K yield values of maize were not significantly different between Con and BP. The yields on HH and ZT were also similar, but were significantly lower (P<0.05) than those for the first two treatments in both years.

Maize intercropped with cowpea had N, P and K yield values which were significantly lower than those for maize in the monoculture (Table 7). The N, P and K yields in the sole maize were about 12 and 8 per cent for N, 30 and 19 per cent for P, and 23 and 9 per cent for K higher than the values for the intercropped maize in 2000 and 2001, respectively. No significant effect of tillage and cropping systems was observed on the NPK yields of maize in the study.

Nodule number, weight and percent N fixed by cowpea

There were significantly lower (P<0.05) nodules per plant and weight per nodule of cowpea on ZT, but no significant differences were found among the rest of the tillage treatments (Table 8). The percent N fixed by cowpea depended on tillage treatments. The differences in percent N fixed by cowpea on Con and BP treatments were not significant, and the values of N fixed on HH and ZT were also not different. However, the percent N fixed in the last two were significantly higher (P<0.05) than in the first two treatments.

The nodule number per plant and nodule weight were unaffected by any of the cropping systems in the study, but the percent N fixed by cowpea in the sole was significantly higher (P<0.05) than that in the intercropped cowpea in both years (Table 8). None of the variables was affected by the interaction of tillage and cropping systems.

Cowpea yield and yield components

Tillage treatment means separation indicated

TABLE 7

Nutrient Yield of Maize as Affected by Tillage and Cropping Systems at 8 WAP

Tillage system	*Nutrient yield (kg ha^{-1})*					
	N		*P*		*K*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	23.30	20.60	23.20	22.50	219.80	530.20
BP	25.20	20.80	29.00	24.20	200.60	550.73
HH	13.50	10.20	14.90	11.70	108.70	257.10
ZT	12.30	9.60	14.20	11.50	112.00	266.30
LSD $_{(0.05)}$	2.62	1.45	7.20	3.00	10.11	7.14
CRPSYT						
Sole	24.30	19.80	20.20	26.80	228.50	541.20
Inter	21.20	18.10	14.10	21.80	175.50	536.10
Intra	-	17.90	-	32.10	-	537.70
LSD $_{(0.05)}$	1.57	0.35	1.60	2.61	3.28	2.72

TABLE 8

Nodule Number, Nodule Weight, and Percent N Fixed by Cowpea as Affected by Tillage and Cropping Systems

Tillage system	*Nodule number per plant*		*Weight per nodule (mg)*		*N fixed (%)*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	10	8	9.21	6.20	64.26	64.54
BP	11	9	8.65	6.00	58.66	63.64
HH	10	8	7.71	6.30	76.88	80.79
ZT	6	4	2.65	2.12	71.98	71.34
LSD $_{(0.05)}$	2	2	2.26	2.20	6.66	7.94
CRPSYT						
Sole	15	18	3.65	4.80	62.44	72.31
Inter	18	15	3.64	4.25	14.55	9.05
Intra	-	16	-	5.25	-	12.68
LSD $_{(0.05)}$	5	4	5.20	5.20	7.96	9.58

significant effects on cowpea grain yield and number of pods per plant. Both variables on Con and BP were similar but significantly higher (P<0.05) than those on HH and ZT treatments, which were also not different from each other (Table 9). Threshing percent and 100-seed weight of cowpea were unaffected by tillage practices in the study (Table 9).

Cowpea in pure stands produced significantly higher (P<0.05) pods per plant and grain yield per hectare than cowpea mixed with maize. However, no significant differences in these variables were found between the inter- and intra-row cropped cowpea with maize (Table 9). Threshing percent and 100-seed weight were unaffected by cropping systems (Table 9). The

TABLE 9

Yield and Yield Components of Cowpea as Affected by Tillage and Cropping Systems

Tillage system	*Grain yield (kg ha^{-1})*		*100-seed wt (g)*		*Pods/plant*		*Threshing %*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*	*2000*	*2001*
Con	1396.40	791.67	18.80	16.76	19	15	70.11	61.09
BP	1323.10	804.17	18.00	16.23	17	16	71.45	69.97
HH	1060.00	664.58	17.89	17.34	10	8	70.53	70.36
ZT	1074.40	633.33	16.90	16.56	9	9	76.51	67.39
$LSD_{(0.05)}$	235.96	105.24	0.89	0.9	5	3	7.71	7.85
CRPSYT								
Sole	1401.56	1153.4	18.36	16.94	15	9	72.68	65.64
Inter	954.00	543.75	17.39	17.01	13	7	70.81	66.74
Intra	-	473.44	-	16.22	-	8	-	69.23
$LSD_{(0.05)}$	166.66	91.14	1.55	0.78	9	7	13.62	6.79

yield and yield components of cowpea measured were not significantly affected by the interaction of tillage and cropping systems.

Maize yield and yield components

Tillage practices significantly ($P<0.05$) increased the number of grains per cob and the subsequent total grain yield of maize on Con and BP, but had no influence on the 100-seed weight and shelling percent of maize (Table 10). Although the maize grain yield and grains per cob were lower on HH and ZT, no significant difference was observed between them (Table 10).

With the exception of grain yield, which was higher in sole maize than in the mixture, none of the other variables were affected by cropping systems. No significant difference in yield was recorded between the inter- and intra-row cropped maize with cowpea (Table 10). Tillage and cropping systems interaction did not significantly affect the yield and yield components of maize.

The calculated values of LER of the mixture on all the tillage treatments were not significantly different, but each was more than unity (>1). In both years, ZT had the highest LER (1.79 in 2000 and 1.24 in 2001) while Con had the lowest (1.43 in 2000 and 1.23 in 2001).

Discussion

Tillage effects

In this study, Con recorded the highest working depth compared to the others because the depth to which a tillage implement reaches in the soil depends on the size and the angle of attachment of the implement, and on the force applied to it (Mutua & Conwell, 1999). The deeper tillage depths created by Con and BP might have alleviated soil compaction through mechanical loosening of the soil, which resulted in increased water infiltration and conservation. These conditions might have favoured rooting development and the subsequent biomass measured at 8 WAP which was higher in Con and BP than in HH and ZT treatments.

With differences in soil depth created by different tillage practices in the study, it was also found that soil bulk density was lower within the various tillage depths than below, thereby making Con the deepest system with the least bulk density. The lower N content in maize and cowpea on ZT could, therefore, be attributed to the higher bulk density under this treatment compared to the others. The high mechanical impedance

TABLE 10

Yield and Yield Components of Maize as Affected by Tillage and Cropping Systems

Tillage system	*Grain yield (kg ha^{-1})*		*Grains cob^{-1}*		*100-seed wt (g)*		*Shelling %*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*	*2000*	*2001*
Con	2591.40	2325.00	470	490	22.48	28.75	77.79	72.90
BP	2761.90	2316.70	495	498	22.39	28.21	77.63	71.61
HH	1640.00	1925.00	321	378	22.38	27.49	78.99	73.00
ZT	1239.80	1825.00	315	350	19.83	28.23	77.62	69.12
LSD $_{(0.05)}$	563.41	410.14	112	110	1.09	1.27	4.61	3.93
CRPSYT								
Sole	2733.90	2400.00	482	465	22.27	27.34	76.61	71.07
Inter	1068.70	1731.30	404	425	22.51	27.75	77.64	72.39
Intra	-	1937.50	-	425	-	29.42	-	71.50
LSD $_{(0.05)}$	397.93	355.19	198	185	1.91	1.91	8.09	3.40

offered by the higher bulk density in the ZT treatments might have reduced N mobility and also restricted the crop roots, thereby reducing N uptake by the crops (Tardieu, Zhang & Davies, 1992). The higher N content in cowpea compared to maize on all the tillage practices in the study was due to the additional N fixed by cowpea.

Phosphorus and K contents in maize and cowpea were unaffected by tillage treatments. This suggests that these immobile elements, unlike mobile N, were in abundant quantities as observed in the initial soil analysis in the upper soil profile. This might have provided the roots of crops on the various tillage treatments the opportunity to absorb similar quantities of the elements.

Similarly, the significantly lower nodule number per plant and nodule weight in the ZT treatment could be due to higher soil bulk density. The possible reduction in root length due to mechanical impedance offered by the high bulk density in ZT might have resulted in the low number of nodules per plant and nodule weight. This agrees with the findings of Ayanaba & Nangju (1992) that reduction in root length due to high soil bulk density could also reduce available potential infection sites of *rhizobi* for nodule formation.

However, the significantly higher percent N fixed by cowpea in the HH and ZT treatments compared to Con and BP in this study could possibly be due to differences in tillage depth and N content in the former than the latter two treatments. Soon, Clayton & Rice (2001) compared the N contents of shallow with deep-ploughed plots at planting and found lower N contents in the shallow than in the deep-ploughed treatments, but percent N fixed was in the reverse. They, therefore, concluded that the initial lower N content in the former treatment was responsible for the higher percent N fixed by cowpea.

Ploughing had been shown to increase porosity and root growth, and improved crop yields in the arid and semi-arid zones of West Africa (McCartney *et al.*, 1971; Nicou, 1974; Chopart, 1981; Kanton *et al.*, 2000). It was, therefore, not surprising that Con and BP tillage treatments of over 10 cm depth increased the 100-seed weight of both crops, number of pods per plant of cowpea and grains per cob of maize, which subsequently resulted in significantly higher (P<0.05) grain yields than in HH and ZT. It has been observed that tillage causes only transient improvement in the soil because it gets re-compacted owing to raindrops before the end of the cropping season (Baffoe-Bonnie & Quansah, 1975). Follow-up restorative measures have been advocated to sustain these benefits after tillage.

The LER values were unaffected by tillage treatments, but the values were each more than unity (>1), suggesting that the intercrop is more productive than the pure stands of cowpea and maize (Willey & Osiru, 1972).

Cropping system effects

The significant differences in the percent N fixed by cowpea and NPK yields between sole crops and the intercrops suggest that the crop species competed for these elements. However, the LER values of over unity (>1) recorded by crop species in intercropping is attributed to the large differences in the maturity periods of the component crops. This suggests that competition for the underground resources between crop species in the intercropping system was not intense through- out the growing periods. Although both crops were planted simultaneously, the cowpea matured earlier within 65 days, which reduced the competition for the resources. This agrees with the findings of Parish (1973) that one of the ways to avoid competition for soil nutrients and to increase productivity in mixtures is to choose component crops with varying maturity periods.

The significantly higher grain yields produced by sole maize and cowpea crops compared to their intercrops could be attributed to competition for light and nutrients (Rice, 1974). Because as an additive model of intercropping system, maize population was held at 100 per cent in each case, with about half of the cowpea population added into the system. However, the results showed that although yields are reduced in the component crops in mixture compared with grain yields in pure stands, the losses are compensated for by the combined yields of the component crops. This is shown by the higher LER values on each tillage system (greater than one (>1), which shows higher productivity in the intercrop than in the sole cropping systems.

Conclusion

Tillage reduced the bulk density of soil, possibly favouring the development of crop plant roots, and increased the availability of and access to resources such as water and nutrients for crop development compared to no-tillage. However, among the tilled treatments, Con was comparable to BP in favouring higher crop grain yield owing to the deeper tillage produced by both treatments compared to the zero and traditional hoe farming methods. Shallow tillage treatments such as HH and ZT favoured higher percent N fixed by cowpea than Con and BP treatments.

Cowpea in sole fixed higher percent N, and NPK yields were also higher than those for cowpea intercropped with maize; but the NPK contents in both crops were unaffected by cropping systems. Grain yields in the mixed cropping systems were lower than those in pure stands of each crop species, but the LERs calculated for each of the tillage treatments showed that each was more than unity. This situation implies that it is more advantageous to produce maize and cowpea in mixture than in pure stands, but inter- or intra-row cropping systems would produce similar grain yields.

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