Yield and Nitrogen Fixation of Cowpea as Affected by Tillage and Cropping Systems in the Northern Savanna Zone of Ghana

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Abstract

Published information on the response of crops in mixed cropping systems to tillage systems in the northern savanna zone of Ghana is scanty. A field experiment to assess the yield and nitrogen (N) fixation of cowpea (*Vigna unguiculata* (L.) Walp) intercropped with maize (*Zea mays* L.) on four tillage practices was conducted in 2000 and 2001 at Nyankpala (9° 25' N, 1° 0' W at 183 m above sea level). The experiment was laid in a split-plot design with four replications. The major factor was tillage systems made up of conventional (Con), bullock plough (BP), hand hoe (HH) and zero tillage (ZT). The sub-factors were cropping systems (CRPSYT) comprising of sole maize, sole cowpea, maize/cowpea inter-row cropping system and bare fallow in 2000, which was replaced by maize/cowpea intra-row cropping system in 2001. The results revealed that Con and BP, which had tillage depth of more than 10 cm, led to a significant ($P < 0.05$) reduction of soil bulk density. The leaf area index (LAI), plant shoot height, dry matter and the subsequent grain yields of maize and cowpea were also higher on Con and BP than HH and ZT practices. Phosphorus (P) and potassium (K) contents of both crops, nodule number, nodule weight and N_2 fixation of cowpea were not affected by tillage systems but N contents in maize on Con and BP practices were similar but were 29% higher than on HH and ZT which were also not different. Cropping systems had no effects on LAI, nodule weight, nodule number and the subsequent N fixed by cowpea. The semi-erect cowpea (*Sul-518-2*) in the mixed cropping systems became viny and climbed the maize associated with it due to shading. This led to a reduction in the dry matter content of maize by 26%. Maize/cowpea intercropping is more productive than the sole (LER > 1) but no significant difference in yields was obtained between the inter- and the intra-row cropping systems.

Introduction

Nitrogen and phosphorus deficiencies in the savanna soils of northern Ghana have been widely reported (FAO, 1967; Acquaye, 1973, Tiessen, 1988). Some of the causes of this situation include the fact that most soils in Ghana are developed on well-weathered parent materials that have been leached over a long period of time (Halm and Asiamah, 1992). The annual burning of crop residues or their removal for various uses such as for fuel, animal feed and for building purposes also prevents the build up of organic matter in this ecological zone. The soil is exposed to long dry season where erosion by wind and also by water in wet season occur which further reduces the available soil nutrients. Also, the long bush fallow periods of about 15 years, which were previously used by peasant farmers to replenish soil fertility have been reduced to about 3 years in some parts of the Northern Region of Ghana due to population pressure on the land.

The use of inorganic fertilizers for soil fertility maintenance is also becoming increasingly difficult, as the price of the commodity is far beyond the reach of most peasant farmers. This situation might have compelled most farmers in recent times to intensify the practice of the age-long cropping systems such as mixed cropping and crop rotation with high legume component to fix nitrogen that consequently reduces the mineral nitrogen requirements.

The existence of mixed cropping system involving mostly cowpea and cereals among the small scale farmers of the West African savanna has long since been identified (Norman, 1975) and studied by many workers including Andrews & Kassam (1976), Fisher (1979) and Willey (1979). Some of the reasons advanced for the persistence of this system of cropping have been precautions against uncertainty and instability of income, and unstable soil fertility maintenance (Abalu, 1977).

Due to the importance of cowpea as an organic fertilizer (Eaglesham *et al.*, 1977), a dietary protein source in the northern savanna zone of West Africa, and in some areas as a cash crop, it has received a lot of attention by several researchers. Efforts have been made to increase cowpea grain yields by fertilizing poor soils, breeding and selecting varieties for high grain yields in inter-cropping systems with cereals (Isenmilla *et al.*, 1981), and finding appropriate time of planting the crop in an intercropping system (Terao *et al.*, 1997; Zuofa *et al.*, 1997). Manipulating the row spacing or the geometry of cowpea with other crops to increase yield in intercropping systems has also been done (Adetiloye, 1980; Tsay, 1985). Efficient methods used for the identification and selection of genotypes for high nitrogen fixation has also been determined (Danso *et al.*, 1993). Levels of phosphorus required to increase yields and nitrogen fixation of cowpea to raise the N level of the savanna soils has also been known and reported (Ankomah *et al.*, 1996).

Farmers in northern Ghana, however, prepare their land for crop production manually using the hoe, tractor, bullocks and, to some extent, by the slash and burn method (no-till). The use of these various implements result in different tillage depths, different levels of pulverisation and weed control (Unger, 1984) which also have implications for soil moisture, nutrient availability and crop yield, and this must be investigated. Published information especially on the response of crops in mixed cropping systems to these tillage practices in the northern Ghanaian savanna region is lacking. In attempt to bridge this gap in knowledge, a study was initiated in 2000 to assess and compare the yield and nitrogen fixation by cowpea in sole and intercropped with maize on four different tillage systems in the northern savanna zone of Ghana.

Materials and methods

Study site description

A field experiment to determine the influence of tillage on maize/cowpea cropping system was conducted at the Savanna Agricultural Research Institute farm, Nyankpala (lat. 9° 25' N and long. 1°00' W, at 183 m above sea level) in the northern savanna zone of Ghana in the 2000 and 2001 wet seasons. The climate is warm, semi-arid with monomodal annual rainfall of 800–1100 mm, which occurs mostly between June and September. 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.

The vegetation is short, deciduous, widely spaced with 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 is made up of different species of grasses of varying height.

Soil analysis of the site before the start of the experiment in 2000 showed a *p*H of 5.1 in calcium chloride solution (0.01*M*). Other soil chemical properties of the site determined were total N, 0.06%, available P, 24.5 mg kg^{-1}, and exchangeable K, 40 mg kg^{-1}.

The land has a gentle slope of about 2% and is strongly disturbed with sheet erosion. The soil unit is well drained and locally referred to as the *Tingoli series*. Detailed soil profile study and characterization undertaken in the 2000-cropping season revealed that it is a Ferric Luvisol (FAO/UNESCO, 1977). The climatic data collected at the site of the experiment in 2000 and 2001 as shown in Table 1 indicates that both the number of rainy days and the amount of rainfall were higher in 2000 than in 2001 during the experimental period.

Experimental design and treatments

The field experiment was laid in a split plot design with four replications. The main plot treatment was tillage system and the sub-plot treatment was cropping system. The tillage systems evaluated were conventional (Con), bullock plough (BP), hand hoe (HH) and zero tillage (ZT). The cropping systems (CRPSYT) were sole maize, sole cowpea, maize/cowpea (inter-row) and a bare fallow plot in 2000. In 2001, however, 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. In the bullock tillage system, a bullock plough was pulled by a pair of bullocks in the land preparation. In the third tillage system (hand hoe), a larger hoe was used manually. A herbicide (gramoxone) was used to kill all vegetation on the zero tillage plots at the rate of 5l ha^{-1}.

The cultivars of the test crops were maize (*obatanpa*) and cowpea (*Sul-518-2)*. Each sub-plot measured 8.1 m × 5 m from which a net plot of 4 m × 5 m representing six rows of crops were taken out from the middle of each plot for final

TABLE 1

Climatological data taken at experimental site during the experimental period at Nyankpala

Month	*Mean temp. (°C)*		*Rainfall (mm)*		*Relative humidity (%)*		*Rainy days*	
	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

yield analysis.

The spacing in sole maize was 90 cm × 40 cm with two plants per stand while in sole cowpea, it was 60 cm × 25 cm with one plant per stand. With the maize/cowpea inter-row cropping, maize population was maintained at 100% with cowpea planted in rows midway (45 cm) between each two rows of maize. In the intra-row cropping, maize population was again maintained but instead, the cowpea was planted on the same row with maize but in between each two maize stands. Bare fallow was included in 2000 to find out whether it is a better water conservation technique. In both years, crops were planted on flat surface without ridging. Planting of crops was done on the 6 Jun 2000 and on the 11 Jun 2001.

Tillage depth

The depth to which each tillage implement reached in the soil was measured before the planting of crops. This was done by gently dipping a metre rule into the soil of each practice or major treatment till the rule touched the bed. The reading at the surface of the soil on the rule in each case was recorded as the depth of tillage.

Plant dry matter and nutrient analysis (NPK)

Four plants of each species were cut at ground level (in the sole and intercropping systems) from two border rows in each plot. These were kept in brown envelops and dried in an electric oven at 65 °C for 48 h. The samples were removed and the dry matter weighed on a sensitive scale (Mettler PM 600) manufactured by Toledo Ltd., UK, with a capacity of 6.10 kg. The plant materials were milled to a very fine material and packaged according to crop species and treatment for the determination of total N, P and K at the Savanna Agricultural Research Institute laboratory.

Using hydrogen peroxide as an oxidizing agent, the milled materials were digested with concentrated sulphuric acid, and selenium (a catalyst) was added to accelerate the process. An aliquot was pipetted out from the digest after it was topped up to a known volume and distilled for total nitrogen by steam distillation of the ammonium liberated by the addition of 30% sodium hydroxide. Titration was carried out on the distillate using boric acid solution with a known concentration of sulphuric acid.

For the determination of total P, the phospho-molybdate and ascorbic acid reduction method was used. The absorbance was measured on a spectrophotometer model Pye Unicam (PU8600 UV/VIS) at 850 nm wave-length. An aliquot of the digest was also taken for the determination of K on a flame photometer (Ependorf, Germany) as described by van Reeuwijk (1992). These analyses were done at green pod and cobbing stages of cowpea and maize, respectively.

Nodule count, weight and N fixation

Four cowpea plants from each of the sole and intercropping plots were dug out for the nodule count and nodule dry weight determination. The process involved initially loosening the soils around the plants to a reasonable depth with a hand hoe making sure their roots were not disturbed. The plants were then pulled out gently and kept in polyethylene bags. These were then sent to the laboratory and washed with water to remove all the soil particles on the roots. The nodules were then removed and those that fell off during the process of 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 an average weight per nodule calculated. The percent nitrogen fixed by cowpea was estimated using the total nitrogen difference (TND) method as described by Hassen (1994).

$$\%Ndfa = \frac{TN_{fix} - TN_{ref}}{TN_{fix}} - 10e$$

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

Ndfa = N derived from the atmosphere

TN_{fix} = Total N accumulation by the N- fixing crop (cowpea)

TN_{ref} = Toal N accumulation by the reference crop (maize)

Plant measurements

Plant data collected included plant height at maturity, crop yield and yield components of both maize and cowpea in sole and in their inter-crop situations. Grain yield taken per plot were expressed in kg ha^{-1}. Land Equivalent Ratio (LER) of the mixture was calculated on each of the tillage practices as described by Willey & Osiru (1972) as LER=La+Lb=Ya/Sa+Yb/Sb; where La and Lb are 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 (SAS, 2002), where means were separated using the least significant difference (LSD) at 5% probability.

Results

Tillage depth and bulk density

Among the tillage treatments, Con maintained the highest working depth during the 2 years of experimentation. This was followed by BP treatment with a depth of about 12 cm, HH of about 6 cm and ZT (i.e. Con > BP > HH > ZT) in order of decreasing depth (Table 2).

Soil bulk density varied among tillage treatments in the 0-15 cm soil depth ranging from less than 1.34 under Con to more than 1.50 g cm^3 under ZT treatment. Soil bulk density under Con was not different from BP but was significantly (P <0.05) lower than HH and ZT, which were also similar. However, in the 15-30 cm depth, there were no significant differences observed among tillage treatments (Table 2).

Cowpea shoot height

Cowpea shoot height was not affected by tillage practices in 2000 but in 2001, cowpea under ZT was significantly (P < 0.05) shorter than cowpea under the other tillage practices (Table 3). Cowpea in

TABLE 2

Tillage depth and bulk density as affected by tillage practices

Tillage system[a]	*Tillage depth (cm)*		*Soil bulk density (g cm^3)*			
			0-15 cm		*15-30 cm*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	18.2	19.2	1.25	1.35	1.56	1.60
BP	12.3	11.5	1.36	1.38	1.64	1.62
HH	5.8	6.3	1.42	1.50	1.62	1.64
ZT	0.0	0.0	1.49	1.52	1.65	1.68
$LSD^b_{(0.05)}$	1.2	1.1	0.16	0.11	0.14	0.18

Tillage system[a]: Con = Conventional tillage, BP =Bullock plough, HH=Hand hoe, ZT= Zero tillage

$LSD^b(0.05)$ = Least significant difference at 5% probability level

TABLE 3

Cowpea shoot height, dry matter and LAI as affected by tillage and cropping systems

Tillage system[a]	*Shoot height (cm)*		*Dry matter (g/plant)*		*LAI*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	59.58	55.58	47.31	35.10	2.24	2.49
BP	58.18	55.59	41.87	31.97	2.26	2.52
HH	58.18	53.71	37.33	31.87	2.22	1.95
ZT	54.75	45.39	26.75	25.65	1.26	1.60
$LSD^b_{(0.05)}$	6.27	6.87	6.12	4.28	0.30	0.74
CRPSYT[c]						
Sole	54.05	48.22	30.30	39.47	2.63	2.80
Inter	58.99	54.87	32.82	35.86	2.65	2.65
Intra	-	55.86	-	39.62	-	2.83
$LSD^b_{(0.05)}$	2.44	4.86	3.21	5.30	0.53	0.66

Tillage system[a]: Con = Conventional tillage, BP = Bullock plough, HH = Hand hoe, ZT = Zero tillage $LSD^b(0.05)$ = Least significant difference at 5% probability level.
CRPSYT[c] = Cropping system: Inter = Inter row cropping system; Intra = Intra row cropping system

mixed cropping systems was significantly ($P < 0.05$) taller than in pure stands. It became more viny and climbed the maize in association with it. However, no difference in height was observed between the inter-row and intra-row cropped cowpea in the trial (Table 3).

Cowpea dry matter

With the exception of ZT treatment, which significantly reduced cowpea dry matter per plant, all the other tillage practices produced statistically similar dry matter in both years (Table 3). Cropping systems did not change the dry matter per plant as the dry matter of cowpea in the mixed cropping systems was similar to that in pure stands. Also no difference was observed between the inter-row and intra-row cropped cowpea (Table 3).

Cowpea LAI

The effect of tillage treatments on LAI differed between years. In 2000, only ZT significantly reduced the LAI of cowpea. In 2001, however, while Con and BP produced similar cowpea LAI, they were significantly ($P < 0.05$) higher than the LAI under HH and ZT treatments. No statistical difference existed between the LAI values of the HH and ZT treatments (Table 3). Cropping systems did not significantly change the LAI of cowpea. The LAI values of both inter-row and intra-row cropped cowpea were also similar (Table 3).

Maize shoot height

Tillage practices had no significant effect on maize shoot height in 2000. However, in 2001, the increase in maize height was of the order ZT < HH < BP < Con (Table 4). ZT and HH produced maize with similar shoot height, which was significantly ($P < 0.05$) shorter than those on the Con and BP, which were also not different. The effect of cropping systems on maize indicated no significant difference in height between sole and inter-cropped maize. Also

TABLE 4

Maize shoot height, dry matter and LAI as affected by tillage and cropping systems

Tillage system[a]	Shoot height (cm)		Dry matter (g/plant)		LAI	
	2000	2001	2000	2001	2000	2001
Con	191.09	195.53	89.32	59.90	3.20	2.74
BP	190.94	186.30	90.97	48.93	3.60	2.74
HH	186.90	167.71	88.38	47.54	2.20	1.51
ZT	180.92	156.32	59.27	28.47	2.29	1.91
$LSD^{b}_{(0.05)}$	10.65	9.99	10.20	7.95	0.58	0.80
CRPSYT[c]						
Sole	197.00	179.23	88.27	57.97	4.21	2.91
Inter	196.34	176.39	61.92	47.61	3.96	2.65
Intra	-	181.28	-	43.03	-	2.85
$LSD^{b}_{(0.05)}$	7.52	8.66	9.45	6.89	1.91	0.33

Tillage system[a]: Con = Conventional tillage, BP = Bullock plough, HH = Hand hoe, ZT = Zero tillage LSD[b](0.05) = Least significant difference at 5% probability level.
CRPSYT[c] = Cropping system: Inter = Inter row cropping system; Intra = Intra row cropping system

no difference in height was found between the inter-row and intra-row cropped maize (Table 4).

Maize dry matter

Among the tillage practices, only ZT treatment reduced maize shoot dry matter per plant in both years. The rest of the tillage practices had no significant effect on maize shoot dry matter (Table 4). Maize dry matter in mixed cropping system was significantly ($P < 0.05$) lower compared to the maize in pure stands, but no significant difference was observed between the inter-row and intra-row cropped maize (Table 4).

Maize LAI

The LAI of maize on ZT and HH treatments were similar but significantly ($P < 0.05$) lower than on Con and BP treatments. However, there was no difference between the LAI values of HH and ZT and also, the LAI values on Con and BP were not different (Table 4). Maize had similar LAI in both the sole and in the mixed stand. There was also no difference in the LAI between the inter and the intra-row cropped maize with cowpea (Table 4)

NPK content in cowpea and maize

Tillage practices and cropping systems had no significant effects on the NPK contents in cowpea (Table 5). With the exception of HH and ZT in both years, where N content in maize was lower than the other treatments, tillage treatments had similar N content in maize. Tillage practices did not have any effect on the content of P and K in maize (Table 6). Cropping systems had no significant effects on the NPK content in maize though the mixed cropped maize had slightly higher values (Table 6).

Cowpea yield and yield components

Tillage treatment means separation indicated significant effects on cowpea grain yield and number of pods per plant. Both variables were significantly ($P<0.05$) higher

TABLE 5

NPK content in cowpea as affected by tillage and cropping system

Tillage system[a]	*N %*		*P %*		*K %*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	3.38	3.63	0.21	0.24	1.73	1.15
BP	3.30	3.37	0.20	0.25	1.77	1.17
HH	3.32	3.16	0.21	0.25	1.58	1.21
ZT	3.39	4.16	0.18	0.25	1.51	1.22
$LSD^b_{(0.05)}$	0.69	1.42	0.04	0.06	0.29	0.36
CRPSYT[c]						
Sole	3.35	3.95	0.25	0.26	1.96	1.59
Inter	3.13	3.37	0.23	0.25	1.95	1.58
Intra	-	3.42	-	0.26	-	1.47
$LSD^b_{(0.05)}$	0.82	1.23	0.03	0.06	0.83	0.23

Tillage system[a]: Con = Conventional tillage, BP = Bullock plough, HH = Hand hoe, ZT = Zero tillage $LSD^b(0.05)$ = Least significant difference at 5% probability level.
CRPSYT[c] = Cropping system: Inter = Inter row cropping, Intra = Intra row cropping.

TABLE 6

NPK content in maize as affected by tillage and cropping systems

Tillagesystem[a]	*N %*		*P %*		*K %*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	2.03	2.19	0.22	0.24	2.03	3.47
BP	2.16	2.11	0.25	0.25	1.73	3.67
HH	1.60	1.72	0.24	0.25	1.73	3.47
ZT	1.56	1.73	0.19	0.25	1.66	3.03
$LSD^b_{(0.05)}$	0.34	0.28	0.09	0.06	0.78	0.59
CRPSYT[c]						
Sole	2.17	1.92	0.18	0.26	2.04	3.53
Inter	2.35	2.03	0.16	0.25	1.95	3.61
Intra	-	2.01	-	0.26	-	3.41
$LSD^b_{(0.05)}$	0.72	0.32	0.08	0.06	0.41	0.25

Tillage system[a]: Con = Conventional tillage, BP = Bullock plough, HH = Hand hoe, ZT = Zero tillage $LSD^b(0.05)$ = Least significant difference at 5% probability level.
CRPSYT[c] = Cropping system: Inter = Inter row cropping, Intra = Intra row cropping.

under Con and BP than under HH and ZT treatments. There were no significant differences between the grain yield and number of pods/plant of cowpea under Con and BP. Grain yield and number of pods per plant under HH and ZT were also not different (Table 7). Threshing percent and 100 seed weight of cowpea were not influenced by tillage practices.

Cowpea in pure stands produced significantly ($P < 0.05$) higher number of pods/plant and grain yield than in the mixed

TABLE 7

Yield and yield components of cowpea as affected by tillage and cropping systems

Tillage system[a]	*Grain yield (kg ha⁻¹)*		*100 seed weight (g)*		*Pods/plant*		*Threshing (%)*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*	*2000*	*2001*
Con	1296.40	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	15.90	16.56	9	9	76.51	67.39
$LSD^b_{(0.05)}$	235.96	105.24	0.89	0.9	5	3	7.71	7.85
CRPSYT[c]								
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
$LSD^b_{(0.05)}$	166.66	91.14	1.55	0.78	9	7	13.62	6.79

Tillage system[a]: Con = Conventional tillage, BP = Bullock plough, HH = Hand hoe, ZT = Zero tillage $LSD^b(0.05)$ = Least significant difference at 5% probability level.
CRPSYT[c] = Cropping system: Inter = Inter row cropping, Intra = Intra row cropping.

crop but the difference between the inter-row and intra-row cropped cowpea was, however, not significant. Threshing percent and 100 seed weight were not affected by cropping systems (Table 7).

Maize yield and yield components

Tillage practices significantly increased the number of grains per cob and the subsequent total grain yield of maize under Con and BP. Tillage practices had no influence on the 100 seed weight and shelling percent of maize. Even though the maize grain yield and grains/cob were lower under HH and ZT, no difference was observed between them statistically (Table 8).

With the exception of the grain yield which was higher in maize monoculture than in mixed cropping system, none of the above variables were affected by cropping systems. There was no difference in yield too between the inter and intra-row cropped maize (Table 8). The calculated values of LER of the mixture under all the tillage practices were more than unity (>1). In both years, ZT had the highest LER (1.79 in 2000 and 1.24 in 2001) while the lowest came from Con with 1.43 and 1.23 in 2000 and 2001, respectively.

Nodule weight, number and percent N fixed by cowpea

Tillage practices had no significant influence on cowpea nodule number per plant, nodule weight and the subsequent percent N fixed. These variables (nodule number, nodule weight and N percent fixed) were also not changed by the cropping system in the study (Table 9).

Discussion

Tillage effects on soil and crop variables

The highest tillage depth recorded by Con followed by BP in this study supports the findings of Mutua & Conwell (1999) that the depth at which a tillage implement reaches

Table 8

Yield and yield components of maize as affected by tillage and cropping systems

Tillage system[a]	*Grain yield (kg ha^{-1})*		*Grains/cob*		*100 seed weight (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
$LSD^{b}_{(0.05)}$	563.41	410.14	112	110	1.09	1.27	4.61	3.93
CRPSYT[c]								
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
$LSD^{b}_{(0.05)}$	397.93	355.19	198	185	1.91	1.91	8.09	3.40

Tillage system[a]: Con = Conventional tillage, BP = Bullock plough, HH = Hand hoe, ZT = Zero tillage $LSD^{b}(0.05)$ = Least significant difference at 5% probability level.
CRPSYT[c] = Cropping system: Inter = Inter row cropping, Intra = Intra row cropping.

Table 9

Nodule number, weight and percent N fixed by cowpea as affected by tillage and cropping systems

Tillage system[a]	*Nodule number*		*Nodule weight*		*N fixed*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Con	10	8	5.21	5.20	41.60	40.60
BP	12	9	3.65	6.00	34.45	38.20
HH	9	8	5.71	6.30	39.53	30.50
ZT	12	6	7.65	5.12	45.17	38.20
$LSD^{b}_{(0.05)}$	9	2	4.26	4.20	9.6	12.30
CRPSYT[c]						
Sole	15	18	3.65	4.80	36.78	39.18
Inter	18	15	3.64	4.25	38.62	41.32
Intra	-	16	-	5.25	-	40.50
$LSD^{b}_{(0.05)}$	5	4	5.20	5.20	7.65	8.15

Tillage system[a]: Con = Conventional tillage, BP = Bullock plough, HH = Hand hoe, ZT = Zero tillage $LSD^{b}(0.05)$ = Least significant difference at 5% probability level.
CRPSYT[c] = Cropping system: Inter = Inter row cropping, Intra = Intra row cropping.

in the soil depends on the size of the implement and the force applied to it. Therefore, the tractor and the bullock ploughs being larger than hand hoe and providing bigger forces than the human force could have been the reasons for such greater tillage depths recorded.

With differences in soil depth created by different tillage practices, it was also found that soil bulk density was lower within the various tillage depths than below. Con as the deepest system also had the least soil bulk density in both years. Similar observations have been made by Klute (1982) and Ike & Aremu (1990) when they found very low bulk densities and increased porosities of the surface soil due to tillage. At the same time, the soil just below the tillage depth had increased bulk densities as a result of compaction imposed by tillage machinery and implements used.

Tillage as performed by Con and BP is important to the easily compactible soils of the semi-arid zones such as found in the northern savanna region of Ghana. According to Gupta & Gupta (1986), such soils require mechanical loosening to alleviate soil compaction; increase water infiltration capacity, conserve water for deep rooting development and decrease the risk of soil erosion. Ploughing has been shown to increase porosity, root growth and improve 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 practices of more than 10 cm depth increased crop shoot height, the dry matter and LAI which, subsequently, gave significant higher grain yields than in HH and ZT of less than 6 cm tillage depth. However, the values of the LER under each of the tillage practices being more than 1(>1) indicate that the intercrop is more productive than the pure stands of cowpea and maize (Willey & Osiru, 1972).

Grain yields of maize and cowpea and their attributes such as grains/cob and pods per plant, respectively, were higher in 2000 than 2001. This could be attributed to the early onset of rains, which were adequate and more evenly distributed in 2000 than 2001. The lower quantity, late onset and poor distribution of rain throughout the growth period in 2001 made the effects of Con and BP tillage practices on crop yields and other crop parameters more pronounced than in 2000.

The non-significance of P and K contents in both maize and cowpea indicated perhaps adequate supply of these elements in the upper soil profile to meet their requirements. The lower N content in maize under ZT and HH could be attributed to the higher bulk densities under these treatments. The roots were probably restricted by the high impedance offered by the higher bulk densities in those tillage practices (Tardeau *et al.*, 1992).

The same reason cannot be advanced for the non-significance in nodule number, nodule weight and the subsequent percent fixed by cowpea. This is because the reduction in root length due to physical impedance offered by the high bulk densities would have caused a reduction in the number of nodules under ZT due to the reduction of the available potential infection sites of rhizobia (Ayanaba & Nangju, 1992). This, therefore, suggests that there were no serious restrictions in root length, and the low N content in maize under HH and ZT could be due to low mobility of N in HH and ZT as a result of high bulk densities.

Cropping systems effects on crop variables

Cowpea as an under storey in mixed cropping systems is always limited by light. Light becomes more available to cowpea intercropped with cereals when the soil is poor and the cereal is poorly developed and intercepts less light (Terao *et al.*, 1997). The taller cowpea plant observed in the mixed cropping system than in the sole could, therefore, be attributed to shading by the maize, especially when maize population in the mixture was held at 100%. Similar observation has been made by Koli (1975) when groundnut intercropped with maize in Ghana was etiolated as a result of shading by the maize component.

The non-significant difference in crop dry matter, N fixed, LAI and NPK contents of sole crops and their mixed species showed that the competition for resources was not very intense as to significantly result into low values of these plant variables. This suggests that the higher yields obtained in the pure stands of maize and cowpea could be mostly due to the higher population per unit area of these crops in sole than in the mixtures. The apparent less competition for resources could also be attributed to the large differences in maturity periods of cowpea (66 days) compared to maize (116 days).

Conclusion

Tillage in this study generally reduced the bulk density of soil, favouring the availability of resources such as water and nutrients for crop uptake. These favoured the increase in LAI, shoot height and dry matter which subsequently raised the crop yields in the tilled treatment. Under the tilled treatments in the year with low and poorly distributed rainfall, the deeper tillage systems such as Con and BP (>10 cm depth) significantly affected dry matter, height and yield of crops than under HH of less than 6 cm tillage depth.

Tillage systems in the study had no effects on nodule number, nodule weight and the subsequent percent N fixed by cowpea. The upper storey (maize) in the mixed cropping system was found to shade the under storey cowpea, which altered the growth character of the cowpea from semi - erect to creeping. These made the cowpea in the mixed cropping system to be taller than cowpea in the sole.

Cropping systems had no significant effects on LAI, dry matter and NPK content in crops. While it is necessary for some amount of tillage to be carried out to improve upon soil conditions for higher crop yields in the northern savanna zone of Ghana, inter-row or intra-row cropping systems may produce similar grain yields of both crops.

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