Assessment of weed infestation and economic returns of maize/cowpea intercrop under different tillage systems in northern Ghana

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ABSTRACT

The cost of crop production is mostly attributed to soil tillage and weed control. Against this background, a field experiment was conducted at Nyankpala in the northern Ghanaian savanna ecology in 2000 and 2001 to assess the effects of tillage and cropping systems (CRPSYT) on weed infestation and economic returns of maize (*Zea mays* L) intercropped with cowpea (*Vigna unguiculata* L Walp). The results showed that the tractor-ploughed conventional tillage system (Con) and bullock plough (BP) with tillage depths more than 12 cm significantly ($P<0.05$) increased grain yields of both crops and also significantly reduced weed score, weed count, and the subsequent weed dry matter, probably through deep burying of weed seeds as compared to hand hoe (HH) and zero tillage (ZT) practices. Tillage systems did not influence weed flora, but cropping systems increased the grass composition in maize to about 70 per cent and significantly decreased the broad leaf weeds. The reverse situation was observed in the cowpea and the maize/cowpea intercrop. The predominant grass weed species found on the field were *Eleusine indica* and *Digitaria* spp., while the broad leaf weeds were *Amaranthus spinosis* and *Tridax procumbens*. The highest cost was incurred under ZT due to high cost of herbicides and labour for spraying while the least was in HH, but the highest net benefits and the highest benefit-cost ratio (BCR) were recorded under BP. The maize component yielded higher BCRs in the sole and the intercrops. However, poor rainfall distribution had negative impact on the yield of both crops, resulting in negative BCRs in the inter-row cropping systems in both years.

RÉSUMÉ

KOMBIOK, J. M., SAFO, E. Y., QUANSAH, C. & IBANA, S.: *Evaluation de l'infestation de mauvaises herbe et les rentabilités économiques de maïs/dolique en lignes alternantes sous les différents systèmes de labour au nord du Ghana.* Une part importante du coût de production de culture est attribuée au labour du sol et au désherbage. Dans ce contexte, une expérience au terrain s'est déroulée à Nyankpala dans l'écologie de la savane au nord du Ghana en 2000 et 2001 pour évaluer les effects de labour et les systèmes de culture (SYTCUL) sur l'infestation de mauvaise herbe et les rentabilités économiques de maïs (*Zea mays* L) semé en lignes alternantes de dolique *(Vigna unguiculata* L. Walp). Les systèmes de labour se composaient de labour de tracteur comme système de labour conventionnel (Con), labour à bœufs (LB), houe à main (HM), et labourage zéro (LZ); alors que les systèmes de culture consistaient de maïs seul, dolique seule, système de culture de maïs/dolique inter-ligne et une jachère en 2000 avec la jachère étant remplacé par la système de culture de maïs/dolique intra-ligne en 2001. Les résultats révélaient que Con et LB avec les profondeurs de labour de plus que 12 cm augmentaient considérablement ($P < 0.05$) les rendements de grain des deux cultures et également reduisaient considérablement nombre de mauvaise herbe, le compte de mauvaise herbe et la matière sèche suivante de mauvaise herbe probablement à cause de l'enterrement profond de graines de mauvaise herbe comparée aux pratiques de labourage de HM et LZ. Les systèmes de labour n'ont pas influencé la flore de mauvaise herbe mais les systèmes de culture augmentaient la composition des graminées en maïs à 70 % alors qu'ils diminuaient considérablement les mauvaises herbes à feuille large. La situation inverse était observée en dolique et en maïs/dolique en lignes alternantes. Les espèces des graminées herbeuses prédominantes rencontrées sur le terrain étaient *Eleusine indica* et *Digitaria* spp. alors que les mauvaises herbes à feuilles larges étaient *Amaranthus spinosis* et *Tridax procumbens*. Le coût le plus élevé était encourru sous LZ à cause de coût élevé des herbicides et du travail des pulvérisations alors la moindre était en HM mais le plus élevé des avantages nets et la plus élevée de proportion avantage - coût (PAC) étaient obtenus sous LB. La partie de maïs rendait PAC plus élevée en maïs seul et en maïs en lignes alternantes que la dolique en dépit d'un prix plus bas du maïs, suggérant une productivité plus élevée du maïs sur la dolique. Toutefois, la distribution inégale de pluie avait un effet négatif sur le rendement de deux cultures menant à PAC negative dans les systèmes de culture en lignes alternantes pendant les deux années.

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Introduction

The need for tillage in the semi-arid zone of West Africa to alleviate soil compaction has been widely shown (Nicou & Chopart, 1979; Chopart, 1981; Kanton *et al.*, 2000). According to them, such soils which have been left bare during the long dry seasons due to annual bush fires or removal of the residues for other purposes, require mechanical loosening to increase water infiltration for higher crop yields. Additionally, several reports have shown that ploughing increased soil porosity which conserved water for deep root development, decreased the risk of erosion, and subsequently improved crop yields in arid and semi-arid zones (Gupta & Gupta, 1986; Ofori, 1993, 1995).

The most common tillage practice in the savanna zone of West Africa is the hoe-farming method. The hoe is used mainly for weed control, probably because it is not deep enough to pulverise the soil to provide other beneficial effects (Ofori, 1993). Even though the use of bullock for soil tillage is not new, bullock-drawn ploughs are not extensively used (Ike, 1986).

In recent times, policy makers in the West African savanna zone have advocated the use of tractor-powered and zero-tillage systems as faster alternative tillage systems for increasing food production to cope with the rising population.

Several reports also indicate that different tillage practices modify weed flora (Pollard & Cussans, 1981; Froud-Williams, 1988), and this shift in species composition could also have an effect on the weed seed bank. Higher weed densities in zero- and reduced-tillage systems compared to conventional tillage have been widely observed (Johnson, Wyse & Lueschen, 1989; Gill & Arshad, 1995; Jensen, 1995). They further found that weed seedling emergence was inversely related to the intensity of soil disturbance which also has implications on cost of production.

The cost of crop production is mostly attributed to soil tillage and weed control. The comparatively high prevalence of zero and reduced tillage practices in places where soil erosion and lack of water are critical could be for reducing soil degradation and for conserving water (Swaton, Clement & Derksens, 1993). This could also help reduce cost of crop production.

Freshly dispersed weed seeds on crop fields are commonly buried by cultivation, and several seeds may germinate if they are exposed to light after spending some time in the soil (Soriano, de Elberg & Suiro, 1970). Jensen (1995) found that the germination of common pigweed was higher when buried 4 mm than 8 mm in a pot, thereby suggesting that deeper burying of weed seeds during tillage would help reduce weed infestation on crop fields.

However, farmers would choose to adopt an alternative practice if the net benefit is higher and the cost of production is lower than the one in use. A practice that requires higher cost may be unattractive to the farmers even if the benefit is high. Such a practice would mean an extra investment which they cannot afford due to the high level of poverty in the savanna zone of Ghana.

Therefore, this study aimed to assess the level of weed infestation among the tillage practices in use, and to compare the costs and benefits of producing maize intercropped with cowpea under these tillage systems to enable the farmers make informed decisions.

Materials and methods

Experimental site

A field experiment to assess weed infestation in maize/cowpea intercrop under different tillage practices was started in 2000 and repeated in 2001 wet seasons on the Nyankpala farm of the Savanna Agricultural Research Institute (SARI).

Nyankpala (lat. 9° 25' N, long. 1° 00' W; altitude 183 m) is 16 km west of Tamale, within the northern savanna agro-ecological zone of Ghana.

The climate of the area is warm, semi-arid, with an annual average rainfall of 1200 mm between May and September, followed by a dry windy season (harmattan) from September to April.

The vegetation is grassland regrowth which is interspersed with short non-canopy forming shrubs and trees such as the shea (*Butyrospermum parkii*) and dawa dawa (*Parkia biglobosa*).

The land is gentle sloping (<2 %) and has been left fallow for 3 years after being cropped to sorghum/soybean in 1997. The soil is well-drained voltaian sandstone, locally known as the *Tingoli* series and classified as ferric luvisol (FAO/ UNESCO, 1977).

Soil samples were taken using a soil auger to a depth of 30 cm in a zigzag manner across each plot. A 50-gram composite sample was taken from the quantity mixed in each plot and analysed for *p*H, nitrogen, available phosphorus, and exchangeable potassium before planting of crops.

Treatment and design

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

For the tractor-tillage system, the land was prepared with a disc plough and harrowed once by using a tandem disc harrow. For the bullock-tillage system, a bullock plough was pulled by a pair of bullocks. A large hoe was used to loosen the top soil by digging to a depth of about 5 cm for the hand hoe-tillage system. With the zero tillage, a herbicide (gramoxone) was used to kill all vegetation at the rate of 5 l ha^{-1}.

The cultivars of the test crops were maize (Obatanpa) and cowpea (Sul-518-2). Each sub-plot measured 8.1m × 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 to assess final yield.

The spacing in sole maize was 90 m × 40 cm with two plants per stand while in sole cowpea, it was 60 m × 25 cm with one plant per stand. With the maize/cowpea inter-row cropping, the maize population was maintained at 100 per cent with cowpea planted in rows midway (45 cm) between each two rows. In the intra-row cropping, the maize population was again maintained but instead, the copwea was planted on the same row with maize, but in-between each two maize stands. Bush fallow was included in 2000 to find out whether it was a better water conservation technique.

Weeds were controlled, including the fallow in 2000, by hand pulling and occasionally by using cutlass when the weeds were too young and tender to be hand picked; but making sure the surface of the soil was undisturbed.

In both years, crops were planted on flat without ridging. Maize and cowpea were planted on 6 June 2000. Cowpea matured earlier than maize and was harvested on 11 August, but maize was harvested on 30 September. In 2001, both crops were again planted simultaneously on 11 June.

Cowpea was harvested on 18 September and maize on 5 October .

The amount of rainfall and the number of rainy days during the experimental period from June to October each year were higher in 2000 than in 2001 (Table 1).

TABLE 1

Climatological Data Collected 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

Tillage depth

The depth to which each of the tillage implements penetrated the soil was measured by gently pressing a metre rule into the soil of each treatment. The reading at the surface of the soil on the rule at a point where it could not penetrate the soil any further was recorded as the depth of that tillage practice.

Bulk density

Bulk density of the soil in each of the treatments was measured by the core method. Undisturbed soil samples in known volumes of cores were collected at 0-15 and 15-30 cm depths of soil. Each of the cores was weighed (W_2) and the soil samples collected were dried at 105 °C for 48 h, and the dry soil weighed (W_3). The difference between the weight of the core (W_2) and the dry sample was divided by the volume of the core to determine the bulk density:

$Pb = W_3 - W_2/V$, where

Pb = bulk density;

V = volume of core; and

W_2 and W_3 being the weights of the core and dry soil, respectively.

Weed score, count and dry matter

At 2 weeks after planting crops, a meter-square (1 m^2) quadrat was used randomly at four places on each plot and marked out. At that stage, the weeds were very tiny but very visible on the field. The scoring was as follows: 0= not weedy, 1 = moderately weedy, 2 = weedy, 3 = very weedy, and 4 = highly weedy.

Subsequently, at every time the plots were weeded, the number of weeds was counted per quadrat area, and the average determined per plot or treatment.

The weeds were carefully pulled out, after counting, and separated into narrow leaf and broad leaf weeds and the percentage per category calculated. They were put in brown envelopes and oven dried at 65 °C for 48 h, and the average weed dry matter per treatment determined on a sensitive scale (Mettler PE 6000) with a maximum capacity of 6 kg.

Grain yields and yield components of maize and cowpea

Each crop in the sole and mixed situations was harvested as soon as the crop reached physiological maturity. The ears and pods from the net plots were shelled and threshed for maize and cowpea, respectively. The grains were put into open bags and dried to moisture content of 14 per cent. These were then weighed per plot and converted to per hectare for each crop on each tillage system.

Land equivalent ratio

Land equivalent ratio (LER) was calculated as affected by the various tillage practices. It was calculated by expressing the intercrop grain yield on each tillage practice as a ratio of the sole crop as described by Willey & Osiru (1972) as:

LER = La + Lb = Ya/Sb + Yb + Sb

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

Economic returns

Partial budgeting, a method of organizing experimental data and information about costs and benefits of various treatments (CYMMYT, 1988), was used. This deals with the variable cost of crop production under the various treatments and the net benefit derived from these operations after harvesting the crops.

The crop enterprise budget technique developed by Wesley, Smith & Spurlock (1993) was used to assess the economic returns to management. The cost of all variables, recommended inputs used in the study on all the treatments, were considered. Crop prices and operational costs used in the budgeting were seasonal averages for the study area during the cropping season.

No capital costs such as land and management charges, interest on operational capital, depreciation of machinery and equipment, and other overheads were considered.

The value of each crop was considered at harvesting period; therefore, no cost was borne for storage. This was determined annually by the product of treatment yields and average prices at the time. Variable costs were the actual prices paid by farmers each year, including the cost of land preparation, planting and harvesting as well as the cost of materials such as seeds and insecticides.

Net returns per hectare were then calculated as the difference between the gross income and total cost of variables. Average net returns were calculated as the mean of the annual net returns over the study period.

The benefit-cost ratio, which is the net benefit divided by the operational cost, was used to compare tillage and cropping systems (CYMMYT, 1988; Wesley *et al.*, 1993).

The benefit-cost ratio of individual crops as affected by cropping systems was calculated as follows:

Net benefit = Gross returns - total variable cost of production of the crop.

Benefit-cost ratio = Net benefit/ total variable cost.

Data analysis

The data collected on soil, weeds, and crops were subjected to statistical analysis using the SAS Program Software (SAS, 2002). The analysis of variance procedure for split-plot was used to determine whether differences existed among treatments. The least significant difference (LSD) at 5 per cent probability level was used to compare all treatments.

Results

The chemical soil analysis of the soil at the site before planting in 2000 showed a *p*H of 5.06 in calcium chloride solution (0.01M), total nitrogen value of 0.055 per cent, 24.5 mg kg^{-1} of available phosphorus, and 40 mg kg^{-1} exchangeable potassium.

Tillage depth and bulk soil density

The trend in tillage depth in both years was similar. In decreasing order, it was Con>BP>HH>ZT. With the exception of the ZT practice where tillage depth was the same in both years, values for the other tillage practices were higher in 2001 than in 2000 (Table 2).

Within the soil depth of 0 - 15 cm in both years, bulk density was highest in ZT which was not significantly different from the HH practice with bulk density values of 1.47 g cm^{-3} in 2000 and 1.50 in 2001. The least bulk density value was recorded for Con, which was also not significantly different from that of BP in both years (Table 2).

No significant differences in bulk density values were observed within the 15 - 30 cm depth in 2001; but in 2000, within the same range, the

TABLE 2

Depth of Tillage and Bulk Density as Affected by Tillage Practices

Tillage	Soil depth (cm)		Bulk density (g cm^{-3})			
			0-15 cm		15-30 cm	
	2000	2001	2000	2001	2000	2001
Con	18.17	19.20	1.25	1.25	1.56	1.60
BP	12.32	12.45	1.26	1.28	1.64	1.62
HH	5.77	6.24	1.47	1.50	1.62	1.64
ZT	0.00	0.00	1.49	1.52	1.65	1.68
LSD $_{(0.05)}$	1.16	1.12	0.16	0.18	0.14	0.18
CV (%)	8.06	9.13	5.61	7.24	4.65	6.32

value for Con was significantly (P<0.05) lower than those for BP, HH and ZT, which were all similar. The bulk density values for all the tillage practices were higher within the 15 - 30 cm soil depth than within 0 - 15 cm.

Tillage effects on weeds in maize

Weed score. From visual observation within the marked quadrat areas, at 2 weeks after planting, the difference in weed score between Con and BP was not significant. This was followed by HH, which was significantly (P<0.05) lower than ZT in weed score in both years (Table 3).

Weed count. Weeds counted on the HH and ZT practices were not statistically different but were significantly (P<0.05) higher than Con and BP. However, Con significantly (P<0.05) reduced the number of weeds counted on it better than the BP practice (Table 3).

TABLE 3

Weed Score, Weed Count, and Weed Dry Matter in Maize as Affected by Tillage Systems

Tillage	Weed score (m^{2})		Weed count (m^{2})		Weed dry matter (kg ha^{-1})	
	2000	2001	2000	2001	2000	2001
Con	1	1	768	800	1671.6	1860.3
BP	1	1	935	920	1311.8	168.4
HH	2	2	1080	1129	2237.8	2650.6
ZT	3	3	1141	1260	2627.2	2816.7
LSD $_{(0.05)}$	0.33	0.48	169	172	444.5	480.4
CV (%)	8.20	9.54	7.12	6.82	9.32	8.24

Weed score: 0 = not weedy, 1 = moderately weedy, 2 = weedy, 3 = very weedy, 4 = highly weedy

Weed dry matter. Weed dry matter in maize was significantly (P<0.05) higher for HH and ZT than for Con and BP. The highest was found in ZT, which was not different from that for HH. The least dry matter was found in Con, which was also statistically similar to that for BP (Table 3).

Tillage effects on weeds in cowpea

Weed score. Comparatively, the trend of weed score in cowpea as affected by tillage systems was not different from what was observed in maize at 2 weeks after planting crops. Weed score in Con and BP were similar but lower than the score for HH, which was also significantly higher (P<0.05) than the weed score observed in the ZT practice (Table 4).

Weed count. It was observed that weed count in cowpea as affected by tillage practices in both years were similar. Con and BP recorded similar weed count that was significantly (P<0.05) lower than the weed count in maize for HH and ZT. However, the weed count in cowpea for HH and ZT was also statistically similar (Table 4).

Weed dry matter. The influence of tillage practices on weed dry matter in cowpea showed that Con and BP had similar dry matter which was significantly (P<0.05) lower than the dry matter for HH and ZT, which were also at par (Table 4).

Weed flora. In general, the two most prominent broad leaf weeds identified were *Amaranthus spinosis* (pig weed) and *Tridax procumbens*. For the grasses, *Eleusine indica* and *Digitaria* species were predominant.

Tillage had no significant influence on weed flora in maize and cowpea crops in the study (Tables 5 and 6).

Cropping system effects on weeds

For the 2 years, it was observed that

TABLE 4

Weed Score, Weed Count, and Weed Dry Matter in Cowpea as Affected by Tillage Systems

Tillage	Weed score (m^2)		Weed count (m^2)		Weed dry matter (kg ha^{-1})	
	2000	2001	2000	2001	2000	2001
Con	1	1	502	610	1525.2	1692.6
BP	1	1	831	840	1460.5	1545.2
HH	2	2	1093	1260	2560.2	2260.2
ZT	3	3	1198	1320	2716.5	2415.2
$LSD_{(0.05)}$	0.36	0.32	301.4	330.2	412.3	395.2
CV (%)	8.20	9.54	7.12	6.82	9.32	8.24

TABLE 5

Weed Flora in Maize as Affected by Tillage Systems

Tillage	Broad leaf (%)		Narrow leaf (%)	
	2000	2001	2000	2001
Con	55.4	53.4	44.6	46.6
BP	56.6	55.2	43.4	54.8
HH	54.5	53.6	45.5	54.5
ZT	58.3	54.3	41.7	46.7
$LSD_{(0.05)}$	6.5	5.8	6.3	6.8
CV (%)	10.23	12.02	10.60	13.21

TABLE 6

Weed Flora Under Cowpea as Affected by Tillage Systems

Tillage	Broad leaf (%)		Narrow leaf (%)	
	2000	2001	2000	2001
Con	54.2	48.2	45.8	51.8
BP	49.8	52.6	50.2	47.4
HH	50.5	50.4	49.5	49.6
ZT	52.6	52.8	47.4	47.4
$LSD_{(0.05)}$	6.3	6.7	8.1	5.8
CV (%)	10.23	12.02	10.60	13.21

sole maize had significantly ($P<0.05$) higher weed score, weed count, and weed dry matter among the cropping systems tested (Table 7).

Sole cowpea also had similar weed score, weed count, and weed dry matter with the maize/cowpea mixtures, but no significant ($P<0.05$) differences in these variables were observed between the inter- and the intra-cropped maize and cowpea (Table 7).

Weed flora. The sole cowpea and maize/cowpea intercrop had significantly ($P<0.05$) higher percentage broad leaf weeds than the sole maize. Sole maize had significantly ($P<0.05$) higher percentage narrow leaf weeds than did the other cropping systems (Table 8).

Maize yield and yield components

Tillage practices significantly increased the number of kernels per cob and the subsequent total grain yield of maize under Con and BP, but had no influence on the 100-seed weight of maize. However, even though the maize grain yield and grains/cob were lower under HH and ZT, no statistical difference was observed between them (Table 9).

With the exception of grain yield, which was higher in maize monoculture than in mixed cropping systems, none of the variables were affected by cropping systems. There was also no difference in yield between inter- and intra-row maize (Table 9).

Cowpea yield and yield components

The differences among tillage systems in cowpea grain yield and number of pods per plant were significant. Both variables were significantly ($P<0.05$) higher under Con and BP than under HH and ZT treatments. While no significant differences were recorded between grain yield and pods/plant of cowpea under Con and BP, the values of these plant variables under HH and ZT were also at par (Table 9). Hundred-seed weight of cowpea was not influenced by tillage practices (Table 10).

Sole cowpea produced significantly higher pods/plant and grain yield than cowpea in the mixed cropping systems, but the difference between the inter-row and intra-row cropped

TABLE 7

Weed Score, Weed Count, and Weed Dry Matter as Affected by Cropping Systems

CRPSYT	*Weed score* (m^2)		*Weed count* (m^2)		*Weed dry matter* ($kg\ ha^{-1}$)	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Sole maize	3	3	1128	1210	2128.7	2630.2
Sole cowpea	2	2	980	869	1435.6	1500.6
Inter	2	2	827	915	1493.3	1620.1
Intra	-	2	-	925	-	1320.1
Fallow	4	-	2160	-	2985.4	1650.3
$LSD_{(0.05)}$	0.42	0.48	182	198	384.9	402.2
CV (%)	8.20	9.54	7.12	6.82	9.32	8.24

CRPSYT = cropping system: Inter = inter-row maize/cowpea, Intra = intra-row maize/cowpea

TABLE 8

Weed Flora as Affected by Cropping Systems

CRPSYT	*Broad leaf (%)*		*Narrow leaf (%)*	
	2000	*2001*	*2000*	*2001*
Sole maize	25.8	30.5	74.2	69.5
Sole cowpea	70.1	82.5	29.9	49.4
Inter	50.6	52.6	49.6	47.4
Intra	-	54.6	-	45.5
Fallow	34.5	-	65.5	-
$LSD_{(0.05)}$	7.2	6.8	8.4	6.9
CV (%)	10.23	12.02	10.60	13.21

cowpea was not significant. The 100-seed weight was also not affected by cropping systems (Table 10).

The calculated values of LER of the mixture under each of all the tillage practices were more than one. In both years, ZT had the highest LER (1.79 in 2000 and 1.24 in 2001) while the least was recorded for Con, with 1.43 in 2000 and 1.23 in 2001.

Tillage system effects

Variable cost. In both years, the highest cost of production was under ZT, followed by Con, BP and HH. However, variable cost was generally higher in 2001 than in 2000 (Table 11).

Net benefit and BCR. The highest net benefits in 2000 and 2001 were recorded under the BP practice while the ZT practice offered the least. The Con tillage practice was the second in value and HH the third (Table 11).

Benefit-cost ratio of maize/cowpea intercrop. The benefit-cost ratio followed a similar trend like the net benefits, as it is the outcome of the net benefit of each tillage system divided by the cost incurred under each tillage treatment. In the descending order in value, it was BP> Con > HH > ZT for both years (Table11).

Cropping system effects

Maize component BCR. The BCR of maize showed positive values in both years, with the values in 2000 measuring more than one. The highest was recorded under HH, followed by BP, Con and ZT. However, in 2001, the values were all less than one, but BP and HH produced the highest, followed by Con and ZT (Table 12).

The BCR of the crops in the mixed cropping system showed that the inter-row cropped maize in both years were less than unity, with negative values in 2001 indicating that more cost was incurred in all the tillage practices compared to income from the produce. Even though the intra-row cropped maize produced positive BCR, none measured up to one (Table 12).

Cowpea component BCR. None of the BCRs in the sole and the mixed cropped cowpea measured up to unity. The BCR of the sole crop in both years, however, showed that HH was highest and the least was ZT (Table 13).

Between the inter- and intra-row cropped cowpea, the BCRs for the intra-row cropped cowpea were higher, while the inter-row cropped cowpea produced negative values in 2001. In mixed cropped cowpea, the highest BCR was recorded under BP while the least was under the ZT practice (Table 13).

TABLE 9

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

Tillage	Grain yield (kg ha^{-1})		Grains/cob		100-seed wt (g)	
	2000	2001	2000	2001	2000	2001
Con	2591.4	2325.0	470	490	22.5	28.8
BP	2761.9	2316.7	495	498	22.4	28.2
HH	1640.0	1925.0	321	378	22.4	27.5
ZT	1239.8	1825.0	315	350	19.8	28.2
$LSD_{(0.05)}$	563.4	410.1	112	110	1.1	1.3
CV (%)	20.22	22.10	17.78	19.21	4.67	5.36
CRPSYT						
Sole	2733.9	2400.0	482	465	22.3	27.3
Inter	1068.7	1731.3	404	425	22.5	27.8
Intra	-	1937.5	-	425	-	29.4
$LSD_{(0.05)}$	397.9	355.2	198	185	1.9	1.9
CV (%)	20.22	22.10	17.78	19.21	4.67	5.36

TABLE 10

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

Tillage	Grain yield (kg ha^{-1})		100-seed wt (g)		Pods/plant	
	2000	2001	2000	2001	2000	2001
Con	1296.4	791.7	18.8	16.8	19	15
BP	1323.1	804.2	18.0	16.2	17	16
HH	1060.0	664.6	17.9	17.3	10	8
ZT	1074.4	633.3	15.9	16.6	9	9
$LSD_{(0.05)}$	235.9	105.2	0.9	0.9	5	3
CV (%)	20.22	22.10	4.67	5.36	18.25	17.85
CRPSYT						
Sole	1401.5	1153.4	18.4	16.5	15	9
Inter	954.0	543.8	17.4	17.0	13	7
Intra	-	473.4	-	16.2	-	8
$LSD_{(0.05)}$	166.7	91.1	1.6	0.8	9	7
CV (%)	20.22	22.10	4.67	5.36	18.25	17.85

Discussion

Tillage effects on soil and crops

In this study, Con in both years maintained the highest working depth followed by BP. This observation agrees with the results of work done by Mutua & Conwell (1999) who found that the depth which a tillage implement reaches in the soil depends on the size, angle of attachment, and the force applied to it. Therefore, the larger Con and BP implements, compared to HH, and the greater force applied to them by the tractor and bullock, compared to human force, could have created the deeper depths.

The differences in soil working depths created by these systems in the study also significantly ($P<0.05$) affected the soil bulk density. Because soil bulk density was lower within the tillage depth than below, so that Con with the highest tillage depth had the least bulk density. Tillage is very important to the easily compactable soils of the semi-arid zones (Gupta & Gupta, 1986). Such soils, according to them, require mechanical loosening to alleviate soil compaction, increase water infiltration capacity, and conserve water for deep root development of crops for higher grain yields.

Klute (1982) and Ike & Aremu (1990) made similar observations. They found very low bulk density and increased porosity of surface soil due to tillage; but below the plough depth, bulk density increased due to the compaction imposed by tillage machinery and implements.

The Con and BP practices had higher grain yields and yield components than HH and ZT for maize and cowpea. This was attributed to the deeper tillage practices of Con and BP. Soils of the semi-arid zones require loosening to increase water storage that could lead to increase in crop yields (Charreau, 1977; Nicou, 1977; Gupta & Gupta, 1986). The higher grain yields observed in 2000 could be

TABLE 11

Cost-benefit of Maize/Cowpea Intercrop as Affected by Tillage Systems

Tillage	Variable cost (¢ '000)		Net benefit (¢ '000)		Benefit/cost ratio	
	2000	2001	2000	2001	2000	2001
Con	2667.5	3662.5	6795.1	6215.5	2.5	1.7
BP	2580.0	3537.5	7313.5	6373.9	2.8	1.8
HH	2555.0	3525.0	3272.0	4696.2	1.3	1.3
ZT	2830.0	3775.0	3199.6	4032.0	1.1	1.0

TABLE 12

Benefit-cost Ratio of the Maize Component as Affected by Cropping Systems

Tillage	Sole maize		Inter-cropped maize		Intra-cropped maize	
	2000	2001	2000	2001	2000	2001
Con	1.05	0.80	0.20	-0.29	-	0.45
BP	1.12	0.87	0.17	-0.34	-	0.50
HH	1.14	0.87	0.16	-0.35	-	0.41
ZT	0.97	0.71	0.24	-0.26	-	0.41

TABLE 13

Benefit-cost Ratio of the Cowpea Component as Affected by Cropping Systems

Tillage	Sole cowpea		Inter-cropped cowpea		Intra-cropped cowpea	
	2000	2001	2000	2001	2000	2001
Con	0.73	0.37	0.18	-0.35	-	0.43
BP	0.79	0.41	0.22	-0.32	-	0.41
HH	0.81	0.51	0.23	-0.32	-	0.41
ZT	0.61	0.42	0.11	-0.37	-	0.45

These were calculated based on the following prices in 2000/2001: cowpea, 3302.8/4403.7 kg^{-1}; maize, ¢1600/2200 kg^{-1}; Wage price of labour, ¢3000/5000 manday^{-1}; Land preparation: Con (plough+1 harrow ha^{-1}), ¢187.5/262 ha^{-1}; BP, ¢100/137; HH, ¢75/125; Chemicals: Karate, ¢60/100 l^{-1}, Gramoxone, ¢40/100 l^{-1}, Apronplus, ¢20/35 sachet^{-1}. All in thousands of cedis (the official Ghanaian currency). ¢6400/8000=1 USD.

due to the higher rainfall which was more evenly distributed compared to 2001 characterised by low, erratic, and poor distribution.

Zero tillage and HH with shallow tillage depths had higher weed score, weed count, and weed dry matter. This confirmed the reports by Johnson *et al.* (1989), Gill & Arsad (1995) and Jensen (1995). The higher weed infestation in the HH and ZT practices could be attributed to the inability to bury the weed seeds properly, thereby exposing them to light. This suggests that, deeper burying of weed seeds can reduce weed infestation. In a similar study in the dry savanna of Ghana, Kanton *et al.* (2000) observed more weeds on plots with manual land preparation (HH) compared to those ploughed with bullock (BP) or tractor (Con). They attributed this to the superficial effects of the hoe on the soil. A similar observation was also made by Ofori (1995).

Even though tillage had significant effects on the level of weed infestation, no significant influence was observed on the composition of the weed flora. The non-significant effect of tillage on weed flora probably reflects the low variations in the different weed flora within the highest tillage depth in this study. Tillage depth of less than 20 cm may be less important to consider in predicting that a particular weed flora would occur in a soil (Oryokot & Swaton, 1997).

Tillage effects on economic returns from maize/cowpea mixture

The cost of production in 2001 was generally higher than in 2000 in the study, due to the increase in the cost of goods and services as a result of inflation.

The significantly higher cost of production in ZT followed by Con, as compared to HH and BP, was attributed to the high cost of herbicides, labour for spraying, and higher cost of fuel and spare parts for tractor repairs. This agrees with the findings of Ndaeyo, Aiyelari & Agboola (2000). The cost of production was also the highest under ZT due to the high cost of herbicides. Couper, Lal & Classen (1979) found the cost of production under ZT to be rather lower than the conventional tractor tillage in Nigeria. These differences could be due to differences in location of site, cost and type of herbicide used, and cost of tractor services.

The higher net benefits recorded under BP could, therefore, be due to the cost of land preparation using bullock being low compared to ZT which produced the least net benefit. A fixed price is paid for land tilled by bullock while for ZT, apart from the high cost of the herbicide, labour is needed for spraying. In some instances, water is bought to prepare the right concentration, thereby increasing the cost of production which lowers the net benefit. Kanton *et al.* (2000) also recorded the highest net benefits under BP compared to manual and conventional practices. The differences in cost of production and grain yield under these tillage practices subsequently led to the highest BCR for BP and the least under ZT in the study.

Cropping system effects on crops and weeds

The higher weed score, weed count, and weed dry matter observed in the sole cropping system compared to the mixed system were expected. The requirements for weed germination, growth, and development include light just as in crop plants. Crops in pure stands provided comparatively less ground cover, as maize was held at 100 per cent with cowpea in an additive model of intercropping system in the study. Therefore, the sole maize intercepted less light, thereby transmitting reasonable amounts of light to the surface of the soil to promote weed growth and development.

The sole maize also had significant weeds compared to the sole cowpea, as maize, being an open row crop plant, intercepted less light than the cowpea, which is considered a cover crop (Wilkinson, 1975).

The non-significant difference in weed infestation observed between the inter- and intra-row cropping systems and also between the sole cowpea and the mixtures could be attributed to similar level of ground cover. This supports the findings of Andrews (1972) which did not also record any difference between the inter- and intra-row cropped cowpea with sorghum. However, both types of mixed cropping systems significantly reduced weed infestation better than the monocultures.

Maize in pure stands significantly ($P<0.05$) increased the percent narrow leaf weeds (*E. indica* and *Digitaria* spp.) compared to sole cowpea or maize/cowpea mixed cropping systems, which also produced more than 70 per cent broad leaf weeds (*A. spinosis* and *T. procumbens*). Crops differing substantially in weed flora also suggest that varied crop rotation or mixtures would prevent species of weed build up, dense infestation, and seed bank in the soil (Anderssen & Milberg, 1998).

Yield reductions were obvious in the mixed cropping systems due to adverse competitive and allelopatic effects (Rice, 1974). However, studies on maize/cowpea mixture (Andrews, 1972) indicate that even though yields are reduced in the mixtures compared to the yields in pure stands, economically, the losses are compensated by the total yields of the component crops in the system.

The lack of significant difference in grain yield between the inter-row and intra-row cropping systems suggests that in both crop arrangements, the conditions necessary for crop growth, development, and yield are similar.

The results of this study indicated that the LERs of maize/cowpea mixture in both years on all the tillage practices were each more than unity. According to Willey (1979), the LER of more than 1 indicates that intercropping is more productive than their monocultures.

Cropping system effects on economic returns from component crops

The highest BCRs of maize crop in both years were recorded under HH, implying a relatively lower cost of land preparation, with reasonably high grain yields compared to the rest of the practices. Unlike the BCRs of sole maize, the BCRs of sole cowpea did not measure up to 1 in both years, suggesting that higher cost was incurred compared to the gross returns from cowpea on each of the tillage practices. The negative BCRs recorded in 2001 for both crops in the inter-row cropping systems could be attributed to the poorly distributed rainfall. Even though the intra-row cropping systems had positive BCRs, none of them measured up to unity.

Conclusion

Grain yields of maize and cowpea in the study did not differ significantly between the Con and BP practices, but variable cost was lower for BP than for Con. The net benefit and BCR were also higher for BP than for Con. With the high cost of tractor services in the Northern Region as a result of the high cost of spare parts, farmers can rely more on the use of bullock plough, which is readily available to increase their crop yields and family incomes.

The lack of significant difference in grain yield between the inter- and intra-cropped maize and cowpea also implies that farmers adopting any of the cropping systems would have similar results. However, the LER of more than 1 also means that inter-cropping maize with cowpea is more producti·. than the sole cropping system.

·.ın low, erratic and poorly distributed rainfall years, inter-row cropping of maize and cowpea would result in lower grain yields that would give negative BCRs, as cost of production would be far higher than revenue. This makes the inter-row cropping of maize and cowpea a better option than the intra-row cropping.

The contrast in grain yield, costs, and benefits reported in this study and by different researchers for different years clearly shows that the benefits of tillage are location and time specific. Consequently, caution needs to be used in extrapolating results from one agro-ecological zone to the other.

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