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Effects of tillage methods on soybean growth and yield in a tropical sandy loam soil

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A b s t r a c t. This study investigated the effects of different tillage methods on the growth response of soybean (*Glycine max.* (L.) Merr.) in order to determine the most suitable tillage method for optimizing soybean production in tropical sandy loam soils. A replicated complete randomized design with treatments consisting of no-tillage (NT), no-tillage plus hoeing (NTH), ploughing only (P) and ploughing and harrowing (PH) operations established at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria was used for the study. The soil was Oxic Tropudult, according to the USDA Soil Classification. The plant height, number of leaves per stand, leaf area, number of pods per stand and seed yield were determined for each of the treatments for 2004 and 2005 seasons. The plant height, number of leaves per stand and leaf area were determined fortnightly over a period of 14 weeks after tillage operations while number of pods per stand and seed yield were determined at maturity. The results show that all the tillage treatments were significantly ($P < 0.05$) different in their effects on plant height, number of leaves per stand, leaf area, number of pods per stand and seed yield. In general, conventional tillage (P and PH) produced a significantly ($P < 0.05$) better soybean growth response (plant height, leaf area, number of pods per stand and seed yield) than that obtained for the conservation tillage (NT and NTH) methods. Furthermore, the highest average seed yield (932.1 kg ha^{-1}) for both seasons was recorded on plots treated with ploughing only (P). Considering the yield, comparative cost implication(s) and energy requirements, ploughing only (P) was found to be more suitable than ploughing and harrowing (PH) for the cultivation of soybean on tropical sandy loam soils.

K e y w o r d s: tillage, soil, soybean growth, plant height, leaf area, yield

INTRODUCTION

Soybean (*Glycine max.* (L.) Merr.) is an important 'staple' legume in the diets of Nigerians. It is a major source of protein and vegetable oil in the tropics. Soybean is a native crop of Eastern Asia where it has constituted an important part of the diet for centuries. Soybean, a photoperiod sensitive plant (Yayock *et al*., 1988), has tremendous potential to reduce malnutrition (Adekayode, 2004). Indeed, it is considered to be the protein hope of the future as its seeds provide high quality protein and oil. The oil is used primarily for food purposes – margarine, cooking oils and salad oils (Ajav and Oyelami, 2001). The cultivation of soybean in Nigeria is on the increase when compared to other foods of vegetable origin. Most of the soybean producing areas are located in the Guinea Savanna ecological zone. A high proportion of the soybean output in Nigeria is produced in Benue, Kwara, Niger, Kaduna, Katsina and Oyo States and the crop has been introduced to some other parts of Nigeria owing to its economic importance. There is ample evidence in the literature that a particular tillage method, which gives optimum crop production under certain soil and climatic conditions, may not produce the same result under different soil and climatic conditions (Anazodo, 1983; Lal, 1982). Although some work has been done on the effects of different tillage methods on the growth and yield of some crops like maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) (Juo and Lal, 1979; Lal, 1974, 1976; Maurya and Lal, 1980; Ojeniyi and Adekayode, 1999), information is lacking on the most suitable method(s) for achieving optimum soybean production on the tropical sandy loam soils of southwestern Nigeria. An understanding of how different tillage methods affect soybean growth and yield on these soils will be of importance in their proper management for sustainable productivity. The study reported in this paper was carried out to identify the most suitable tillage method that would give optimum soybean growth and yield (with least cost implication) in tropical sandy loam soils.

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MATERIALS AND METHODS

Field studies were conducted at the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria for two seasons, 2004 and 2005. The soil on the experimental site was a sandy loam (sand – 67, silt – 16, and clay – 17%) and was classified as Oxic Tropudult, according to the USDA Soil Classification (Soil Survey Staff, 1992). In each year, the crop (soybean) was grown between July and October during the rainy season. The average minimum temperature ranged between 21 and 24°C while the average maximum temperature ranged between 27 and 35°C. The mean annual rainfall of the study area is about 1350 mm. The total rainfall during the growing season of the crop for the two years studied is shown in Table 1.

Table 1. Rainfall distribution at Ile-Ife during the experimental seasons of 2004 and 2005

Month	Growing season	
	2004	2005
	Rainfall (mm)	
July	181.9	186.4
August	197.6	63.2
September	212.3	215.3
October	162.9	100.6
Total	754.1	565.5

Source: Meteorological Station, Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife.

An experiment consisting of four treatments and four replicates was laid out in a complete randomized block design. Different tillage methods were used to provide four treatments as follows:

- no tillage (NT) treatment in which vegetation on the plots was manually cleared with cutlasses. Herbicides were subsequently applied to control the remaining weeds;
- no tillage plus hoeing (NTH) treatment in which vegetation on the plots was also manually cleared with cutlasses. The remaining weeds were controlled manually with the use of traditional hoes rather than herbicides;
- ploughing only (P) treatment which entailed the use of a tractor-mounted disc plough to plough the soil after the vegetation on the plots had been manually cleared. Herbicides were subsequently applied to control the remaining weeds;
- ploughing and harrowing (PH) treatment which entailed the use of a disc plough to plough the soil and a disc harrow to harrow the soil one week after ploughing. Herbicides were subsequently applied to control the remaining weeds.

The experimental site measured 52 x 36 m and consisted of four blocks. Each block measured 44 x 4 m and was divided into four plots. Each plot measured 8 x 4 m and adjacent plots were separated by an intervening space of 4 m, which enabled the tractor to turn conveniently without encroaching on the NT and NTH plots.

The site was under vegetation fallow for more than three years before the initiation of the experiment and guinea grasses dominated the bush. TGX 1448-2E variety of soybean seeds was obtained from the International Institute of Tropical Agriculture (I.I.T.A.), Ibadan, Nigeria. The soybean seeds were of the early maturity group and were sown in July of each year for the two seasons. The seeds were planted at a spacing of 5 cm within rows and 60 cm between rows. Weeding was done by applying both pre-emergence and post-emergence herbicides to all the plots with the exception of the NTH plots where manual weeding was carried out at 4, 8 and 12 weeks after planting.

Plant parameters measured in this study include plant height, number of pods per stand, number of leaves per stand and leaf area. Seed yield was also measured after harvesting. Plant height was measured from ground level to the top of the terminal bud two weeks after planting and every fortnight thereafter. This was done using a metre rule. The heights of ten plants per plot were measured and their average values were determined. Leaf area was determined using ten plants randomly selected from each plot. A measure of the perimeter of the largest leaf of each plant was obtained by using a thread. By considering a circle having a circumference equal to the measured perimeter, the equivalent radius and leaf area were determined from the following relationships:

$$\text{measured perimeter} = \text{circumference} = 2\pi r_e \quad (1)$$

$$A_1 = \pi r_e^2 \quad (2)$$

where: A_1 – leaf area, and r_e – equivalent radius of the leaf.

Ten plants were randomly selected from each plot. The leaves on each plant were counted and the average number of leaves per stand was determined for each plot using the selected plants. This was done two weeks after planting and every fortnight thereafter for 14 weeks. This was also carried out for four treatments and four replicates for each treatment. At maturity (before harvesting), ten plants from each plot were randomly selected for the determination of number of pods per stand. The pods on each plant were counted and the average value for the ten plants per plot was determined. This was done for four replicates on each treat ment. At maturity, the soybean pods for each plot were harvested leaving out pods within a distance of 50 cm from each edge to preempt any extraneous border influence. The total weight of the harvested soybean pods for each plot was determined by weighing them on an electronic balance. Threshing was then done to remove the seeds from the pods.

The total weight of the seeds for each plot was also determined to give the seed yield per plot. This procedure was done for all the sixteen plots (i.e. four treatments, four replicates). The average value for each treatment was then determined.

The data collected were subjected to statistical analyses using SAS software (SAS, 1988). Significant difference between treatments was established at 0.05 probability level using Duncan's multiple range test.

RESULTS AND DISCUSSION

Figure 1 shows the values of soybean plant height for the 2004 and 2005 seasons, each season spanning a period of 14 weeks. For both seasons, the results showed that soybean plant height values increased with time in all the tillage treatments. During both growing seasons, soybean plant height values were found to be highest on plots treated with ploughing and harrowing (PH) and lowest on plots treated with no tillage (NT) (Fig. 1). For the 2004 season, it was observed that the first 10 weeks of the soybean plant recorded a more rapid growth rate in all the tillage treatments than the latter 4 weeks (Fig. 1a). For the 2005 season, however, the initial period of rapid growth was concentrated in the first 6 weeks (Fig. 1b). Soybean plant height was relatively higher on conventionally tilled plots (P and PH) than on the untilled plots (NT and NTH) for both 2004 and 2005 seasons. This can be attributed to the higher soil porosity and lower penetration resistance obtained on the conventionally tilled plots in comparison to the untilled plots (Lasisi, 2008). Higher soil porosity and lower penetration resistance enhance better plant root development and nutrient absorption within the soil, which in turn, enhance better plant growth. This agrees with previous studies (Lindsay *et al*., 1983; Cook *et al*., 1996; Tardieu, 1994; Tsegaye and Mullins, 1994), which attributed poor initial root establishment to the occurrence of high values of soil bulk density and penetration resistance. Soybean plant height was significantly ($P < 0.05$) affected by tillage method, plant height increasing with increasing degree of tillage.

The number of leaves per stand of soybean plant obtained for both 2004 and 2005 seasons over a period of 14 weeks is shown in Fig. 2. For the 2004 season, the highest values of the number of leaves per stand were obtained on plots treated with ploughing only (P) whilst the lowest values were obtained on plots subjected to the no-tillage (NT) treatment (Fig. 2a). For the 2005 season, the highest values of the number of leaves per stand were also obtained on plots treated with ploughing only (P). However, the lowest values were obtained on plots subjected to the no-tillage plus hoeing (NTH) treatment (Fig. 2b). For both seasons, the rate of production of leaves increased with time up to about 8 weeks after planting and thereafter decreased with time (Fig. 2). Thus, the effective cover for the crop is about 8 weeks after planting. Between the 12 and 14th week after planting, the number of leaves per stand remained constant in all the treated plots for both seasons (Fig. 2). The non-production of additional leaves at this stage can be attributed to the attainment of soybean plant maturity. Generally, the number of leaves per stand of soybean was relatively higher on conventionally tilled plots (P and PH) than on the untilled plots (NT and NTH) for both seasons. This can also be attributed to the higher soil porosity and lower penetration resistance obtained on the conventionally tilled plots in comparison with the untilled plots (Lasisi, 2008). Statistical analysis of the results showed that the number of leaves per stand was significantly ($P < 0.05$) affected by tillage treatment.

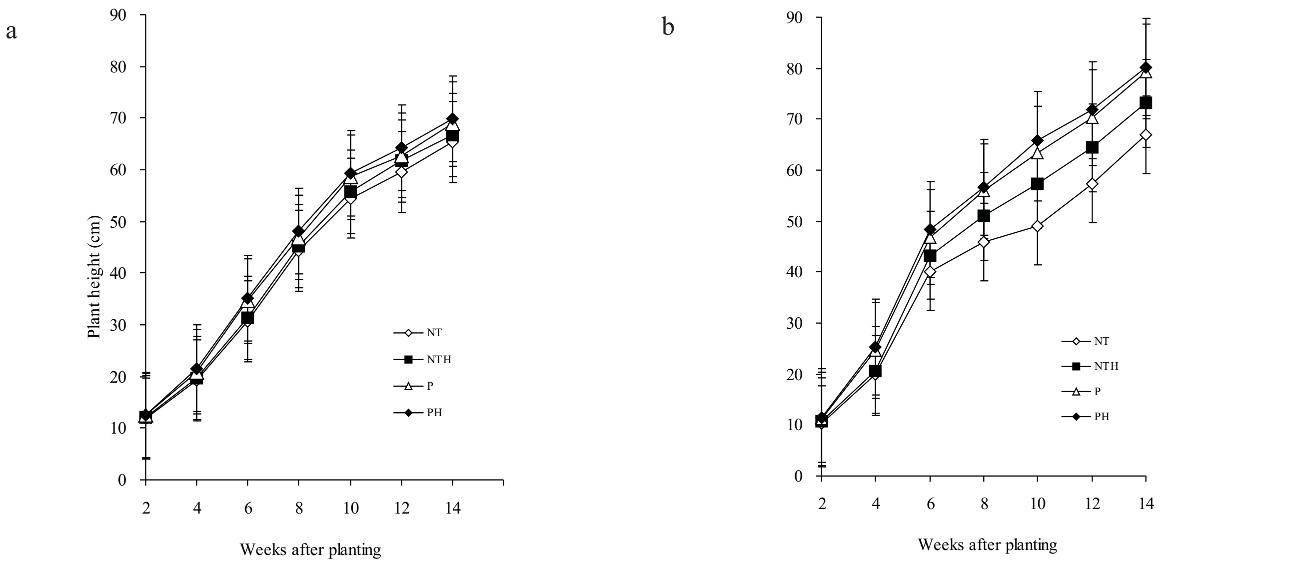

Fig. 1. Effect of tillage methods on plant height of soybean: a – 2004, b – 2005 seasons.

Figure 3 shows the values of soybean plant leaf area for the 2004 and 2005 seasons, each season spanning a period of 14 weeks. During both growing seasons, leaf area values were found to be highest on plots treated with ploughing and harrowing (PH) and lowest on plots treated with no-tillage plus hoeing (NTH) (Fig. 3). For the 2004 season (Fig. 3a), a rapid increase in leaf area occurred during the first 4 weeks after planting. Subsequently, leaf area increased at a more gradual rate between the 4 and 12th week after planting. For the 2005 season, however, leaf area increased rapidly during the first 8 weeks after planting and then more gradually between the 8 and 12th week after planting (Fig. 3b). The rapid development of leaf area promotes better plant growth through enhanced food production. For both seasons, higher values of leaf area were obtained on the conventionally tilled plots (P and PH) than on the untilled plots (NT and NTH) (Fig. 3). This can be attributed to the development of more favourable soil structural conditions *ie* aeration, porosity, density on conventionally tilled plots, which in turn enhance better plant growth. The values of leaf area remained constant during the last two weeks after planting for both 2004 and 2005 seasons (Fig. 3). This indicates that the soybean

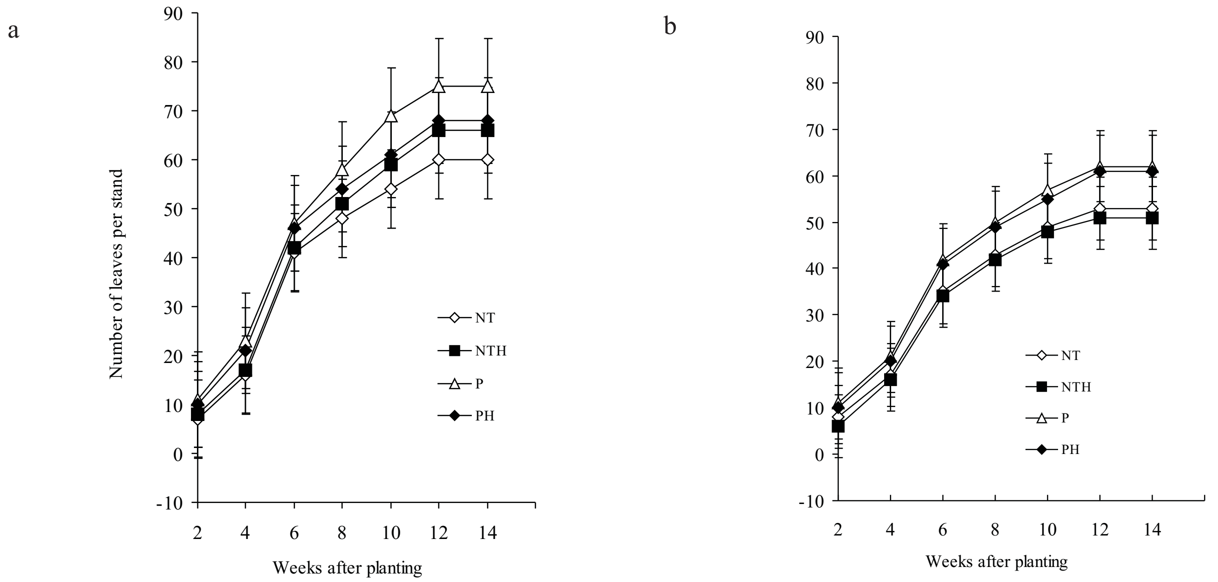

Fig. 2. Effect of tillage methods on number of leaves per stand of soybean plant: a – 2004, b – 2005 seasons.

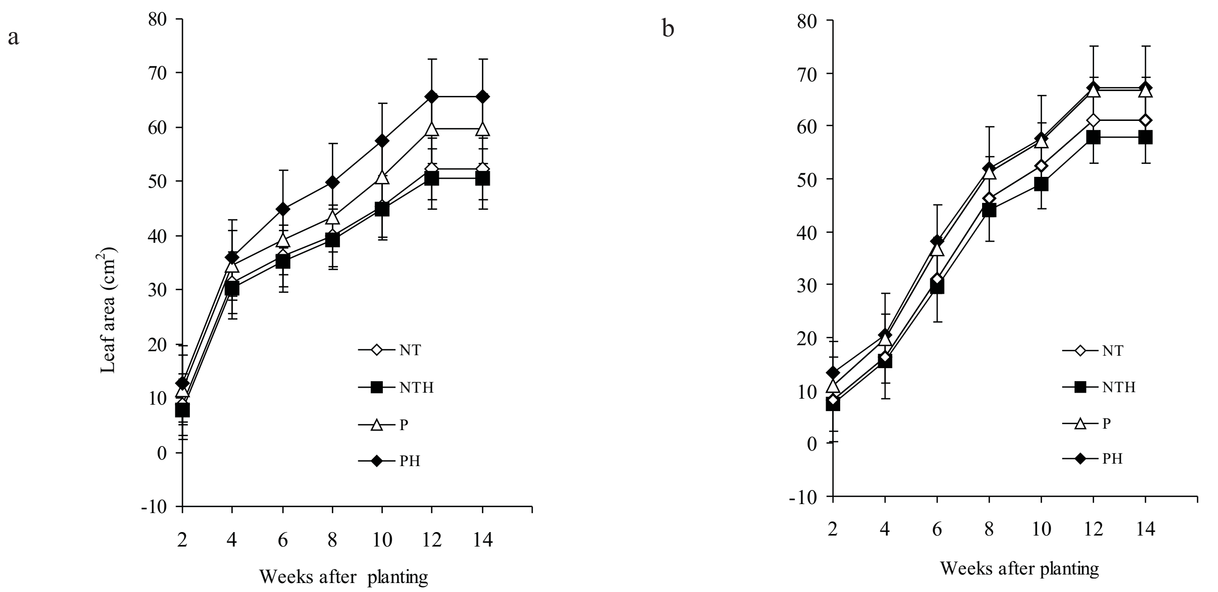

Fig. 3. Effect of tillage methods on leaf area of soybean plant: a – 2004, b – 2005 seasons.

plant had attained maturity 12 weeks after planting. In general, leaf area was significantly ($P < 0.05$) affected by tillage method, leaf area increasing with increasing degree of tillage. Furthermore, leaf area generally increased with weeks after planting until plant maturity was attained (Fig. 3).

Table 2 shows the mean values of the number of pods per stand obtained for the 2004 and 2005 seasons. For the 2004 season, the number of pods per stand was found to be highest on plots treated with ploughing only (P) and lowest on plots treated with no-tillage plus hoeing (NTH). For the 2005 season, however, the highest record of the number of pods per stand was obtained on plots subjected to the ploughing and harrowing (PH) treatment whilst the lowest was obtained on plots subjected to the no-tillage plus hoeing (NTH) treatment (Table 2). In general, for both seasons considered, the number of pods per stand was relatively higher on the conventionally tilled plots (P and PH) than on the untilled plots (NT and NTH) (Table 2). The results show that tillage treatment had a significant ($P < 0.05$) effect on the number of pods per stand of soybean plant.

The mean values of soybean seed yield for the 2004 and 2005 seasons are shown in Table 3. The highest (942.7 kg ha^{-1}) and the lowest (703.0 kg ha $^{-1}$) mean values of seed yield for the 2004 season were obtained on plots subjected to the ploughing only (P) treatment and plots subjected to the no-tillage plus hoeing (NTH) treatment, respectively. For the 2005 season, the highest (934.7 kg ha^{-1}) and lowest (687.4 kg ha $^{-1}$) mean values of seed yield were obtained on plots treated with ploughing and harrowing (PH) and plots treated with no-tillage plus hoeing (NTH), respectively. For both seasons (Table 3), the seed yield was relatively higher on the conventionally stilled plots (P and PH) than on the untilled plots (NT and NTH). This can be attributed to the impact of more favourable soil structural conditions on the conventionally tilled plots, as pointed out earlier. The combination of higher soil porosity, infiltration rate, lower penetration resistance and lower bulk density enhances better nutrient absorption within the soil, ultimately leading to better seed yield. Ojeniyi and Adekayode (1999) reported similar results for maize and cowpea yields.

Comparison of average seed yield(s) for both seasons showed that the ploughing only (P) treatment had a higher value of 932.1 kg ha^{-1} than the ploughing and harrowing (PH) treatment, which had a value of 919.2 kg ha^{-1}. Consideration of the cost implication(s) for the different tillage treatments (Table 4) showed that for the 2004 season, the highest input cost of 162.39 USD was obtained on plots subjected to the PH treatment whilst the lowest input cost of 82.91 USD was obtained on plots subjected to the NTH treatment. Similarly, for the 2005 season, the highest (170.94 USD) and lowest (86.32 USD) input costs were obtained on PH and NTH plots, respectively. The NTH treatment had a lower input cost than the NT treatment because herbicides are more expensive in Nigeria than manual labour. The PH treatment had a higher input cost than the P treatment because the latter involved only one tillage operation. In addition to increasing the input cost, the additional tillage operation increases the energy requirement of the PH treatment relative to that of the P treatment. The income generated for a particular tillage treatment is directly related to the seed yield for that tillage treatment. Table 5 shows the income analysis for the different tillage treatments for the 2004 and 2005 seasons. As expected, the highest income of 966.87 USD was obtained on P plots for

T a b l e 2. Mean values of number of pods per stand of soybean plant in response to tillage methods (2004 and 2005 season)

Treatment	2004	2005
	Number of pods per stand*	
NT	60 a	55 a
NTH	58 b	54 b
P	62 c	56 c
PH	61 d	59 d

*Values are means of 4 replicates. Means in the same column followed by the same letter are not significant at 5% probability level.

T a b l e 3. Mean values of seed yield (kg ha^{-1}) of soybean in response to tillage methods (2004 and 2005 seasons)

Treatment	2004	2005
	Seed yield (kg ha^{-1})*	
NT	820.5 a	809.6 a
NTH	703.0 b	687.4 b
P	942.7 c	921.5 c
PH	903.6 d	934.7 d

*Explanations as in Table 2.

T a b l e 4. Input cost analysis of different tillage treatments

Cost (USD ha^{-1})	2004	2005
Ploughing	38.46	42.74
Harrowing	34.19	38.46
Manual labour*	32.48	35.90
Herbicides	39.32	39.32
Soybean seed ($)	20.51	20.51
Insecticide	12.82	12.82
Harvesting	17.09	17.09

*Manual labour was hired for weeding in NTH.

T a b l e 5. Income analysis of different tillage treatments

Treatment	2004		2005	
	Yield (kg ha^{-1})	Amount (USD ha^{-1})*	Yield (kg ha^{-1})	Amount (USD ha^{-1})*
NT	820.5	841.54	809.6	830.36
NTH	703.0	721.02	687.4	705.02
P	942.7	966.87	921.5	945.13
PH	903.6	926.77	934.7	958.67
Total	3 369.8	3 456.20	3 353.2	3 439.18

*Cost of soybean seed is 1.03 USD kg^{-1} at the farm gate.

T a b l e 6. Profit margins analysis of different tillage treatments

Treatment	Income		Cost		Profit	
	(USD ha^{-1})					
	2004	2005	2004	2005	2004	2005
NT	841.54	830.36	89.74	89.74	751.80	740.62
NTH	721.02	705.02	82.91	86.32	638.11	618.70
P	966.87	945.13	128.21	132.48	838.66	812.65
PH	926.77	958.67	162.39	170.94	764.38	787.73

the 2004 season. For the 2005 season, however, the highest income of 958.67 USD was obtained on PH plots. The profit associated with each tillage treatment, derived as the difference between the income generated and the input cost, is shown in Table 6. It can be seen that the highest profits of 838.67 USD and 812.65 USD for the 2004 and 2005 seasons, respectively, were obtained on P plots. The lowest profits of 638.12 USD and 618.70 USD for the 2004 and 2005 seasons, respectively, were obtained on NTH plots. Considering the average seed yield over both seasons, the cost implication(s), the profit and the relative energy requirements, the ploughing only (P) treatment was found to be the most suitable tillage method for the optimum cultivation of soybean on tropical sandy loam soils.

CONCLUSIONS

1. Soybean cultivation on conventionally tilled plots (P and PH) gives better plant height, number of leaves per stand, leaf area, number of pods per stand and seed yield than on untilled plots (NT and NTH).

2. Plant height, number of leaves per stand, leaf area, number of pods per stand and seed yield were significantly ($P < 0.05$) affected by tillage treatment.

3. Considering the relative cost implication(s), seed yield, energy requirements and profit margins, the ploughing only (P) treatment was found to be the most suitable tillage method for the optimum cultivation of soybean on tropical sandy loam soils.

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