Available Online at http://www.journalajst.com

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 08, Issue, 05, pp.4828-4834, May, 2017

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

IMPACT OF THE MOTORIZED PLOUGHING ON THE STRUCTURE OF TROPICAL FERRUGINOUS SOILS AND THE EFFICIENCY OF A CORN CULTURE (ZEA MAYS, L.) IN THE N'DALI TOWNSHIP IN NORTH-BENIN

[1]Zokpodo Koessi Lié Barnabé, [2]Akossou Arcadius Yves Justin, [1]Dayou Ephrème Dossavi and [2]Meadan Wilfrid

[1]School of Environmental Management, Faculty of Agronomic Sciences, University of Abomey-Calavi, 01 BP 526 Cotonou
[2]Faculty of Agronomy, University of Parakou B.P. 123 Parakou

ARTICLE INFO

Article History:
Received 09th February, 2017
Received in revised form
22nd March, 2017
Accepted 28th April, 2017
Published online 30th May, 2017

Key words:

Motorized ploughing, Ploughing depth, Tropical ferruginous soils, Agricultural yield, Benin.

ABSTRACT

Agriculture has an important role in the development of the Beninese economy. Now, the sector has a major change with the agricultural motorization. In order to contribute to the sustainable management of farms, this study evaluated the effect of four motorized ploughing depths on soil structure and vegetative growth of maize. Results show that ploughing at 15 cm depth provides the best agricultural yield and does not adversely affect the physical, mechanical and hydrodynamic characteristics of the soil. The optimum yield is estimated at 2.98 t / ha with a plow depth of 14.66 cm for the DMR-ESR-W variety. The TZEE-W-SR variety was 3.29 t / ha obtained with a plow depth of 14.39 cm.

INTRODUCTION

Outside of Europe and North America, where agricultural production is overfishing the food needs of the population, thanks to stabilized agriculture, the rest of the world is under the burden of inadequate production (N. E. Brady, 1996). Food production is a major concern and a crucial challenge in developing countries. In the economy of these countries, agriculture occupies an important place. It accounts for up to 50% of gross domestic product (GDP), contributes more than 80% to the value of trade, and provides industry with more than 50% of raw materials (FAO, 2008). However, this activity is essentially slash-and-burn, often with low yields that cannot meet the food needs of local populations. According to N. E. Brady (1996), about 410 million hectares of tropical forests are affected by this form of agriculture, and 30% of the arable land of the world is affected, showing the importance of the affected areas. Moreover, in these regions where access to chemical fertilization is not within the reach of the peasant population, because of their very modest economic situation, the practice of burning appears unavoidable given the poor fertility of most soils.

Corresponding author: Zokpodo Koessi Lié Barnabé,
School of Environmental Management, Faculty of Agronomic Sciences, University of Abomey-Calavi, 01 BP 526Cotonou.

The lush forest vegetation which lives on its own reserves and recycling (B. Dupuy, 1995) constitutes, in fact, the main potential reservoir of soil fertility (R. Moreau and L. Godefroy, 1985). Burning makes it possible to restore to the soil, by ashes, the nutrients accumulated in plant biomass (R. Moreau, 1983, 1986, L. Collinet *et al*., 1984). In Benin, the area cultivated in 2005 is estimated at about 2.82 million of the 7 million hectares of arable land (FAO, 2006). This explains the precariousness of the material and technical means available to the rural world. Ploughing once, essentially manual becomes more and more motorized. But the introduction of new technology into a system almost always entails new risks and dangers (G. Van der Meijden, 1994). Misalignments of agricultural machinery lead to problems of soil degradation after cultivation; Which dangerously affects their production capacities (ProCGRN, 2005). The lack of professionalism of rural actors leads to an abusive use of land, a production capital, which must be managed for the preservation of its fertility, since the degradation of the soil resources presents itself as the most perilous risk of the motorisation (G. Van der Meijden, 1998). The degree of technicality and the types of techniques must be adapted to the needs, ie local, agronomic, socio-economic, environmental and industrial particularities. This will maintain soil fertility in the long term, ensure human food needs and conserve ecosystems of high biodiversity (Hoogmoed, 2008). The aim of this study is to evaluate the structural changes following the variation of the ploughing depth to the disc plow and to analyze their impact on the vegetative development and the yield of a maize crop.

MATERIALS AND METHODS

Experimental site

The study was carried out in N' Dalitownship covering an area of 3748 km^2 and located in the North-East of Benin. Its climate is sudano-guinean, characterized by uni-moderate precipitation and annual rainfall ranging from 1100 mm to 1200 mm, down to 900 mm with an average annual temperature ranging between 30 ° C and 39 ° C, average maximum relative humidity of 98% and a minimum of 31%. The main types of soils are tropical ferruginous with a more or less important ploughing depth and their permeability and porosity are generally good.

Experimental device

The experimental device used is the split-plot with six replications. Two factors were studied. The main factor is plow depth, with four (4) modalities (10 cm, 15 cm, 20 cm and 30 cm) and the secondary factor is the maize variety, with two (2) modalities (DMR-ESR-W = Downy Mildew Resistant to white endosperm and TZEE-W-SR = Tropical Zea Extra-Early to white endosperm). The total area used for this experiment is 4,000 m^2 (50mx 80 m). The blocks are arranged perpendicularly to the direction of the natural heterogeneity of the ground which has a slight slope of 0.5%. In each block, a depth is tested on four juxtaposed tillage lines. A block consists of 16 plow lines. Each block is then subdivided into two sub-blocks in which the two varieties of corn were randomly distributed. Aisles of 1 m between the blocks were also provided. Strip ploughing was the technique adopted. It was made by a plow with three (03) disks with a working width of 1,20 m coupled to a tractor of power 60 horse powers. The sowing was carried out manually in line at a depth varying from 3 to 5 cm with 2 grains of corn per pooled. The spacing between lines is 80 cm and between plants on the same line is 40 cm. Maintenance operations consisted of herbicides with ALAZINE 350/200 SE Herbicide applied the day after sowing at a rate of 4 liters per hectare. Weeding is done two (02) weeks after sowing. For plant growth and development, after weeding, NPK SB fertilizer (16-16-16) at a rate of 200 kg per hectare was applied in pockets about 5 cm of plants. Three weeks after the application of NPK, the ploughing-butting of the maize plants was carried out. After the second weeding, at the exit of the panicles (male flowering), the Urea was applied to the dose of 100 kg per hectare. Harvesting is carried out manually on the dried-up spikes.

Data collected

Two categories of data were collected. One relates to the soil characteristics after ploughing at different depths and the other category concerns the growth and development of the maize varieties under consideration.

Soil characteristics

An analysis of the soil studied was carried out on the horizon from 0 to 30 cm in order to determine some soil characteristics such as clay content, sand equivalent, loam content, dry density, Specific gravity of solid grains and compaction energy. This last parameter is determined by the formula:

$$E = \frac{N \times H \times m \times G}{V}$$

Wiht : (E) compaction energy, (H) height of fall, (m) mass of the mold, (G) force of gravity and (V) compacted volume of the mold. The crumbling of the soil was examined on the surface by estimating the size of the visible clods in comparison with the meshes of a reference grid. The selected clod classes are: c1> 200 mm; C2 €] 200 mm; 100 mm]; C3 €] 100 mm; 50 mm] and c4 <50 mm. A crumbling index is calculated from the following formula:

$$Ie = \frac{\sum S_i \times Ie_i}{100}$$

With (Ie) the crumbling index, (Si) the percentage of the surface S covered by the clod of class i and (Iei) the coefficient of crumbling. The profusion resulting from the passage of the tractor was obtained by difference between the thickness of the soil ploughed and the depth of ploughing measured in the same place. It was determined by the formula:

$$F = \frac{(E - P)}{P} \times 100$$

With (F) the profusion, (E) the thickness of the soil ploughed and (P) the depth of the ploughing. Roughness was evaluated from the measurement of the altitude (expressed to within cm) of the points of intersection of the surface of the soil with a vertical plane perpendicular to the direction of movement of the tractor. The measure was repeated, in each plot, on 6 representative zones to obtain average values.

Soil infiltration

Three categories of infiltration measurements were carried out: at the beginning of the cycle (at ploughing), at mid-cycle and at the end of the maize crop cycle. For each of the three stages of the cycle, water infiltration into the soil was assessed at three locations within each plot. The infiltration capacity of the soil was determined by the infiltration technique of a surface water slide. An infiltrometer consisting of two (02) cylinders, one large, with an internal diameter equal to 37.6 cm and the other smaller, with an internal diameter equal to 19.4 cm was used. The cylinder pressed into the ground to a depth of 5 cm is filled with water. The amount of water in the cylinder is renewed every 5 minutes for each test. The soil infiltration capacity was estimated from water motions measured during regular periods of five (5), ten (10), fifteen (15), twenty (20), twenty-five (25) Thirty (30) minutes.

Plant growth

The behavior of the crop was studied by evaluating some agronomic parameters. The emergence was assessed by counting the young shoots on the 3rd, 5th, 7th and 9th day after sowing. Forty (40) plants of each treatment randomly selected on the central lines while avoiding border effects were observed for growth study.

Table 1. Analytical data of the studied soil

Granulometry (%)			Real density (g/cm^3)	Maximal specific weight (t/m^3)	Compaction energy(kN / m^2)
Clay	Sand	Loam			
0	37	63	2,55	2,02	2,55.10^5

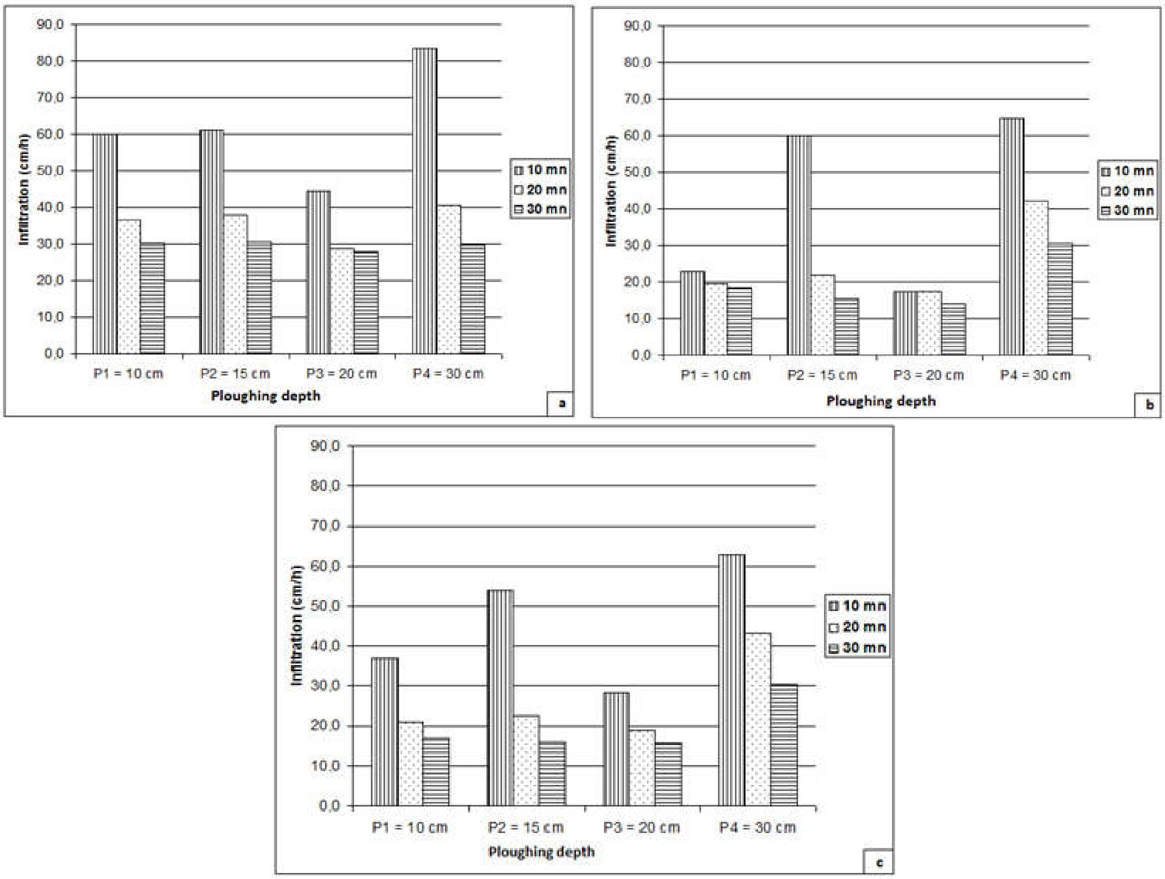

Figure 1. Evolution of infiltration as a function of depth: (a) at ploughing, (b) at mid-cycle, (c) at the end of the cycle

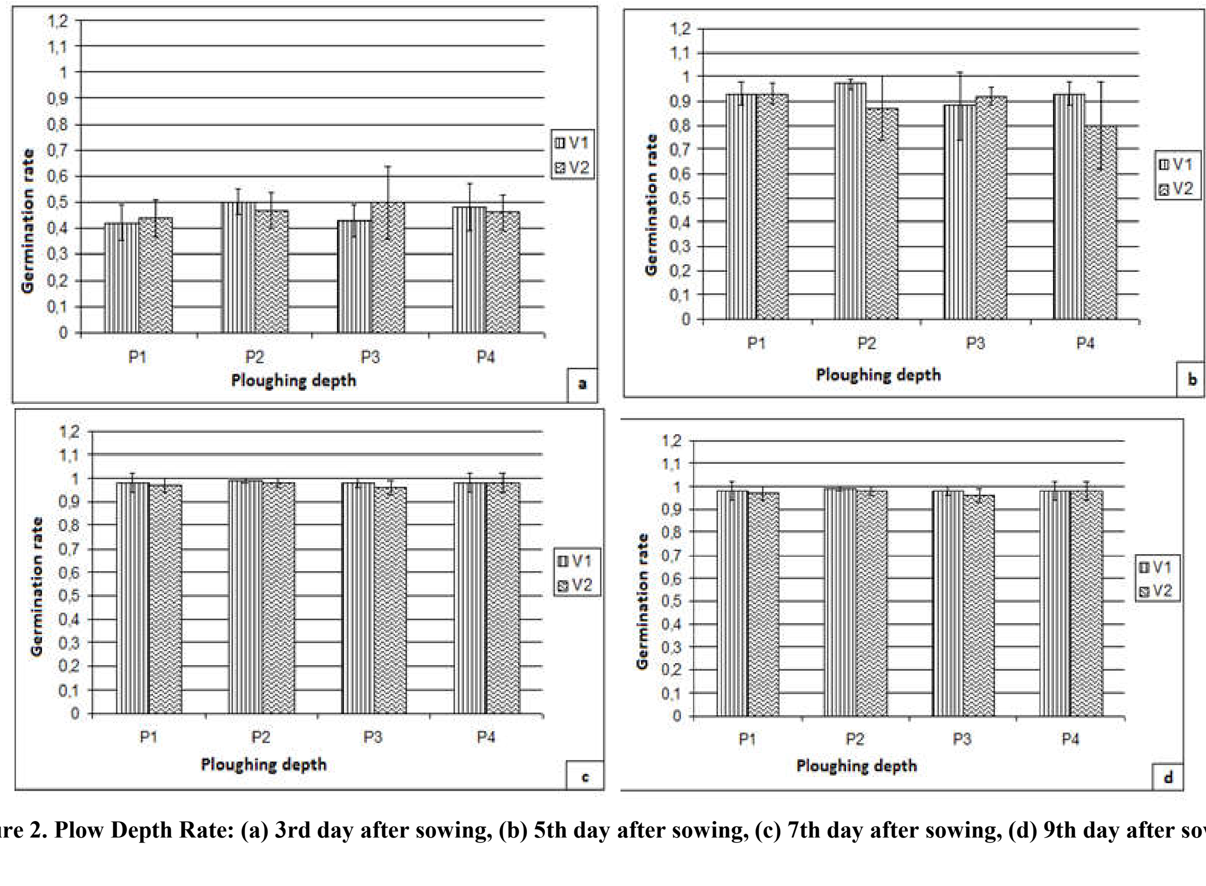

Figure 2. Plow Depth Rate: (a) 3rd day after sowing, (b) 5th day after sowing, (c) 7th day after sowing, (d) 9th day after sowing

Growth measurements related to the height and count of the number of leaves at intervals of 20 days after spreading the urea. Finally, the yield of the two varieties was determined per plot from the density squares of 4 m².

Statistical analysis

The analys of variance with three criteria of classification were used on the data with the SAS software. The means were separated by the Ducan method. The response surfaces of the different characteristics as a function of the dose for each type of fertilizer and for each variety were studied by the regression method in order to determine the optimum dose.

RESULTS

Physical and hydrodynamic characteristics of soil

Soil structure studied

The results of the analysis of the first 30 centimeters of the soil which served as a support for the experiment are shown in Table 1. From this table, it emerges that the soil studied consists essentially of loam and sand. The ratio of the mass of a sol to the volume occupied by the solid (actual density) is 2.55 g / cm^3, the maximum specific weight is 2.02 t / m^3 and the compaction energy is 2, 55.105 kN / m^2.

Crushing index, Maximum profusion and surface roughness of the soil

Table 2 shows the mean values and standard deviations of crumb indices by plow depth.

Table 2. Mean values and standard deviations of crumb indices by plow depth

Depth	Crumblingindrex	Maximal profusion	Surface Roughness
P1	0,50^a (0,011)	90,00^a (81,73)	7,75^a (6,21)
P2	0,52^a (0,006)	122,5^a (46,07)	6,67^a (6,35)
P3	0,49^a (0,02)	130,00^a (32,52)	12,08^a (13,9)
P4	0,45^b (0,013)	147,78^a (32,58)	18,01^a (21,92)

Each value is a mean with (standard deviation). In the same column, values followed by a same letter are not significantly different (p>0.05) according to Ducan test.

The highest value of the crumbling index is obtained with the plow depth of 15 cm and the lowest value is obtained with ploughing at a depth of 30 cm. The optimum is reached for a crush index of 0.51 and a plow depth of 15.75 cm. The results of the proliferation showed an increase of this parameter as a function of the depth. Compared to the unworked surface, ploughing at 10 cm depth induces a surface increase of 8 cm, those of 15, 20 and 30 cm depth respectively lead to an increase in height of 21.75 ; 32 and 58.67 cm. However, the comparison of the mean values of the proliferation does not show any difference in the large variability of the values. The same trends were noted for surface roughness values.

Water infiltration

The evolution of infiltration as a function of depth is showed by Figure 1.

The analysis of figure 1 shows that infiltration is higher at the beginning of the cycle than at mid and at the end of the cycle. The infiltration capacity increases with the duration of the operation. Differences are more pronounced at the beginning of the cycle than at mid and at the end of the cycle. At mid-cycle and at the end of the cycle, the evolution of the infiltration capacity as a function of the depth presents the same appearance. The closer examination of figure 1 shows that at the beginning of the cycle the depths P1 and P2 have almost identical infiltration capacity throughout the experiment, ie approximately 60 cm per hour. At mid-cycle and at the end of the cycle, there is a difference between the infiltration capacity for these two depths of ploughing. The difference is more pronounced for the duration of 10 mn. It is estimated at 23 and 60 cm / h for P1 and P2 at mid-cycle and 37 and 54 cm / h respectively for P1 and P2 at the end of the cycle. The lowest values are observed at the depth of plow P3 regardless of the development phase considered. On the other hand, the highest values are obtained with the depth of plow P4 whatever the duration of the experiment and the phase of the cycle considered. For this depth of plow the highest value is obtained at the beginning of the cycle with the experiment of 10 mn or a capacity of 83.4 cm per hour.

Growth and yield

Germination rate of seed

On the 3rd day after sowing, the rate of emergence does not exceed 50% whatever the depth and the variety (Figure 2). The highest germination rates (50%) are obtained for the P2V1 and P3V2 combinations. On the 5th day after sowing, a good emergence was noted for all combinations of variety and depth. The different combinations have a germination rate of more than 75% (Figure 2). The highest rates are 97% and 93% respectively for the P2V1 and P1V2 combinations. On the 7th and 9th day after sowing the rates are identical. The highest values are obtained with the P2V1 (99%), P2V2 and P4V2 (98%) combinations. It emerges that ploughing to the depth of 15 cm gives the best rate of emergence.

Growth 20 days after urea spreading

For a given plow depth, the height of the stem, the number of leaves and the number of ears are identical for both varieties (Table 3). The height of the stems increases with the depth of ploughing. Thus, the highest values of heights are obtained with depth P4 = 30 cm for the two maize varieties. About 217 cm high for each of the stems of the two varieties. The depth P2 = 15 cm has the lowest value in number of leaves but gives the highest value in number of heads, ie about two heads per corn stalk.

Agricultural yield

Analysis of the device shows that there is no interaction between depth and variety (p = 0.819). From the analysis of the performance results for the varieties, it appears that variety V2 (DMR-ESR-W) is more productive than V1 (TZEE-SR-W) whatever the depth of plow considered (Table 4). Evaluation of the effect of depth shows that the highest yield values are obtained with depth P2 and P4, respectively 2.98 t / ha and 2.81 t / ha for V1 and 3.29 t / Ha and 3.03 t / ha for V2.

Table 3. Mean values and in brackets standard deviation of agronomic parameters as a function of varieties and depths of ploughing

Ploughing depth	Stalkelongation (cm)		Number of leaves appeared		Number of spikes per plant	
	V1	V2	V1	V2	V1	V2
P1	178,78^{aA} (14,68)	177,07^{aA} (17,21)	14,08^{aA} (1,18)	13,96^{aA} (1,20)	1,51^{aA} (0,50)	1,65^{aA} (0,50)
P2	195,36^{bcA} (24,00)	195,47^{bA} (23,41)	13,74^{cA} (1,34)	13,83^{aA} (1,34)	1,94^{bA} (0,64)	1,84^{aA} (0,60)
P3	193,22^{bA} (18,84)	189,35^{bA} (20,03)	13,79^{acA} (1,33)	13,65^{aA} (1,38)	1,62^{aA} (0,56)	1,67^{aA} (0,56)
P4	217,02^{cA} (31,32)	217,13^{cA} (30,15)	14,56^{bA} (0,93)	14,53^{bA} (0,90)	1,58^{aA} (0,51)	1,64^{aA} (0,61)

Each value is a mean with (standard deviation). In the same column, values followed by a same miniscule letter are not significantly different (p>0.05) according to Ducan test. On the same line, by depth and by parameter, values followed by a same capital letter are not significantly different (p>0.05) according to Ducan test.

The depth P3, on the other hand, has the lowest yields, ie 2.74 t / ha for V2 and 2.55 t / ha for V1.

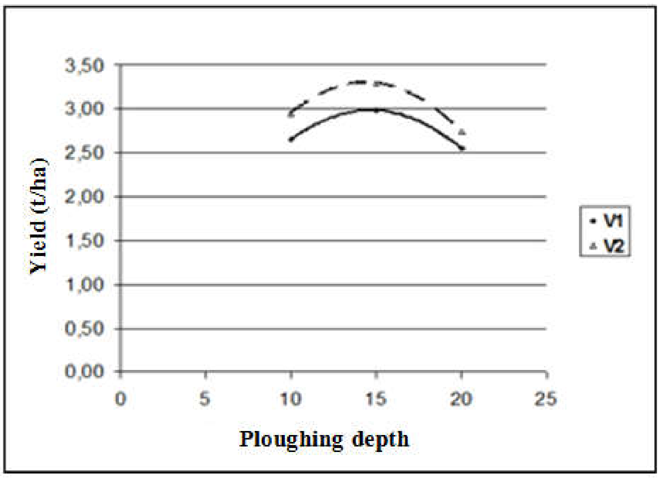

Figure 3. Evolution of yields according to ploughing depths

The search for the optimum between the depth of tillage of 10 cm and the depth of tillage of 20 cm made it possible to determine for the variety V1 an optimum of 14.66 cm of ploughing depth with a yield of 2.98 t / ha. For variety V2 the optimum is obtained for a plow depth of 14.39 cm with a yield of 3.29 t / ha.

Table 4. Mean values and in brackets mean errors of yields

Ploughing deph (cm)	Varieties	
	V1	V2
P1=10	2,65^{a} (0,06)	2,95^{a} (0,02)
P2=15	2,98^{b} (0,04)	3,29^{b} (0,09)
P3=20	2,55^{a} (0,06)	2,74^{a} (0,15)
P4=30	2,81^{ab} (0,04)	3,03^{ab} (0,03)

Each value is a mean with (standard deviation). In the same column, values followed by a same miniscule letter are not significantly different (p>0.05) according to Ducan test.

DISCUSSION

The essential role of tillage is to obtain a structural state necessary for good germination and normal root development essential for the water and mineral supply of crops. The crumbling of the soil makes a good mixture between the plant debris and favors a good root development. However, current tillage techniques sometimes produce excessive fragmentation, leading to fragile soils and a low rate of emergence. Ploughing with the disc plow results in a crumbled soil (FAO, 2008) and consequently a good crumbled seedbed, a favorable condition for a good germination (D. Andrade *et al.,* 2003). The highest values were obtained with a depth of 15 cm (table 2). This confirms that soil tillage of 0 to 15 cm allows a crumbled state of the soil (J. Peigne*et al.,* 2007). Indeed, at this depth, the ploughing instruments do not have a large area of contact with the soil to return a large quantity of soil compacted into rocks because, beyond 20 cm of depth, the soil horizons are characterized by the presence of compacted clods (S. Chehaibi, 2008). Thus, ploughing beyond the first 20 centimeters returns the layer of soil different from that of the humiferous horizon, thus more compacted leading to the appearance of large clods on the ploughed surface. The thickness of the inverted soil depends on the ploughing depth and the measurement period. This highlights the variations observed in the hydrodynamic characteristics of the soil. Indeed, the permeability decreases from the surface to the depth (figure1). The infiltration is relatively good regardless of the depth of ploughing. The observed values are higher than the one evoked by A. Tamia (1997) on a ferralitic soil of Côte d'Ivoire forest estimated at 8.10 cm / h. The hydrodynamic behavior of this soil unit could be related to the predominant texture of loam and sand, and to the measurement period (wet season). Although this type of soil allows a very dense rooting, it has some limitations. Indeed, when it is struck by rain or too heavy watering, a very hard crust is formed which penalizes the young shoots. Ploughing makes it possible to have a good structured soil for good germination of the seeds and a good root development of the plants. In addition, tillage involves burial of plant debris, loosening of the soil, formation of the seedbed, distribution of fine soil and clods, controlling the spread of weeds, Parasites and diseases, incorporation of fertilizers, etc. (L. Seguyl, 1994).

It also increases the structural porosity of the soil (B. Outtara*et al*., 1998), reduces soil resistance to root penetration (I. O. Vitlox, 1985) and facilitates gas exchange. A. Tamia *et al.* (1999) have shown that in uncomplicated horizons the root density may be 3 to 5 times greater than in packed horizons. Moreover, according to C. Charreau and R. Nicou (1971) and R. Nicou (1977), work Of the soil has a favorable effect on root systems. It improves in particular the growth rate at the beginning of the cycle and the colonization of the soil at depth. This explains the high emergence rates observed. Germinative energy being 75% higher, emergence is considered effective and good (N. Aho and D. Kossou, 1993). As a result, all tillage depths have been successful in that maize is a demanding plant in terms of heat and water. Moreover, it does not till and the development of its roots is quickly thwarted in packed or hollow soil. Their thwarted or reduced development causes serious problems of water and mineral supply for the plant. Production is therefore reduced. This effect of good results is attributed to a change in soil porosity and to a reduction in the mechanical resistance of the soil to the penetration of roots, the two physical properties of the soil being the most modified by the Ploughing. The work of G. Gaultney *et al*. (1982) showed that in more flexible structures crop yield can be improved by 25%. P. Lajoux, (2003) showed that there is a strong correlation between the crumbling index and the germinative energy. The larger the index, the better the lift. The best results are obtained with depth P2 = 15 cm. Chopart (1994) and Chopart and Nicou (1976) observed in Côte d'Ivoire and Senegal a slightly favorable effect of ploughing on the capacity of the maize root system to deplete deep water reserves. It emerges from these different studies that the immediate effect of plow tillage is to dramatically improve the permeability of the soil surface (Charreau and Nicou, 1971). These results can also be explained by the use of the insecticide for maintenance, which inhibits herbaceous competition, which may affect the germination rate. However, these ploughing actions on the soil itself and the behavior of the crops depend on the nature of the tool used for tillage (T. Anken *et al.*, 1999, Dufey and Prade, 1985).

Performance is a determining factor in judging the effectiveness of practices tested on agricultural production. The amount of grain corn per unit area, ie yield, is the result of all soil preparation, good seeding and maintenance (INRAB, 2005). At the end of the harvest, there was a variation between yields between the two varieties and between the four plow depths (figure 3, table 4). The best yields are obtained with ploughing at a depth of 15 cm whatever the variety. This confirms that at this depth the physical and mechanical properties of the soil and the water infiltration capacity of the worked soil are satisfactory. The difference between the two varieties is related to their performance (INRAB, 2005). Moreover, surface tillage of 15 cm depth makes it possible to better bury the crop residues and weeds in the soil conditioning the increase of soil micro-organisms favorable for a better agricultural yield (M. Metzke*et al.,* 2007). So, agronomic ploughing (10 to 15 cm deep) returning the soil makes it possible to bury plant debris favoring the activity of earthworms qualified by certain "engineers of the soil" (Cannavacciuolo, 2007) because the biomass Microbial growth develops preferentially within horizons where crop residues are buried (D. S. Andrade *et al.*, 2003) .The presence of turricules (earthworm excrement) on the soil surface during the experiment confirms this action, Beneficial aeration for the plant.

Conclusion

It is often difficult to appreciate the behavior of tillage machines in the mechanization of agriculture. Indeed, information on the energy aspects of the use of tillage tools (tensile force, torque at the power take-off, etc.) can be obtained, but the quality of the result obtained in the various layers of the soil is lacking. A good structured soil allows good germination of the seeds and a good root development of the plants. In addition, tillage involves burial of plant debris, loosening of the soil, formation of the seedbed, distribution of fine soil and clods, controlling the spread of weeds, parasites and diseases, incorporation of fertilizers, etc. The best results were achieved with the plow depth of 15 cm.

REFERENCES

Aho, N. and Kossou, D. 1993. Précis d'Agriculture Tropicale : Bases et Eléments d'Application. Les éditions du Flamboyant ; Cotonou, Bénin 463 p.

Andrade, D.S., Colozzi-Filho, A. and Giller, K.E. 2003. The soilmicrobialcommunity and soil tillage. In: A. El Titi (Ed.), Soil Tillage in Agroecosystems, CRC Press LLC Boca Raton, p. 51-81

Anken, T., Irla, E., Amman, H., Heusser, J. and Scherrer, C., 1999. Travail du sol et mise en place des cultures. Rapport FAT n° 534, 3 p.

Billot, J.F. and Marionneau, A. 1985. Visualisation de l'action qualitative des outils au moyen de la pénétrométrie. Colloque international: le travail du sol. Faculté des Sciences Agronomiques de l'Etat de Gembloux.

Brady, N.E. 1996. Alternatives to slash-and-burn - a global imperative. Agriculture, Ecosystems and environement. 58, 3-11.

Cannavacciuolo, 2007. Les vers de terre, discrets mais efficaces. In Mieux connaitre son sol ;

Charreau, C. and Nicou, R. 1971. Amélioration du profil cultural dans les sols sableux et sablo-argileux de la zone tropicale sèche ouest-africaine et ses incidences agronomiques. L'Agronomie Tropicale 26(2) 209-255, 26(5) 565-631, 26(9) 903-978, 26(11) 1184-1247.

Chehaibi, S., Hannachi, C., Pieters, J.G. and Verschoore, R.A. 2008. Impacts de la vitesse d'avancement du tracteur sur la structure du sol et le rendement d'une culture de pomme de terre. Tropicultura, 26, 3, 195-199.

Chopart, J.L. 1994. Techniques de gestion du sol *et al*imentation hydrique des cultures annuelles tropicales. Rapport de fin de contrat CEE DGXII. CIRAD CA, BP 5035 34032 Montpellier France, 77 p.

Chopart, J.L. and Nicou, R. 1976. Influence du labour sur le développement radiculaire de différentes plantes cultivées au Sénégal. Conséquences sur leur alimentation hydrique. L'Agronomie Tropicale 31(1): 7-28.

Collinet, L., Couturier, G., Guillaumet, J.L., Kanhn, F., Moreau, R. and Sangaré Y. 1984. Le système cultural et ses contraintes. In - Recherche et aménagement en milieu forestier tropical humide - Le projet Taï de Côte d'Ivoire. Rapport technique du MAB 15, UNESCO. 184.

Dufey, V. and Prade, J. 1985. Technico-économique du travail du sol. Colloque international: le travail du sol. Faculté des Sciences Agronomiques de l'Etat de Gembloux. 11p.

Dupuy, B. 1995. La place des arbres forestiers fixateurs d'azote dans l'entretien ou la régénération de la fertilité des milieux tropicaux humides. In. - Fertilité du milieu et stratégies paysannes sous les tropiques humides. Actes du séminaire 13-17 Nov. 1995, Montpellier. 350-357.

FAO, 2006. Sols et potentialités agricoles du Bénin ; documents Bénin 68 p.

FAO, 2008. Aider à construire un monde libéré de la faim ; collection FAO, Rome, pp 40-120

Gaultney, G., Krutz, W., Steinhardt, G.C. and Liljedahl, J.B. 1982. Effects of subsoil compaction on corn yields. Transactions of the ASAE, 25, 3, 563-569.

Hoogmoed, 2008. Travail du sol. In Les techniques de conservation des eaux et des sols dans les pays du Sahel.

J.C.J. Vlaar (ed.). CIEH, Burkina Faso et Université Agronomique, Wageningen, Pays Bas. pp. 27-43.
INRAB, 2005. Fiche technique de la culture du maïs infestée de striga au Bénin ;N°18 p20
Lajoux, P. 2003. Guide d'essais de terrain : matériels de travail du sol, version n° 1, 87 p.
Metzke, M., Potthoff, M., Quintern, M., Hess, J. and Joergensen, R. G. 2007. Effect of reduced tillage systems on earthworm communities in a 6-years organic rotation. *European Journal of Soil Biology,* 43, 209-215;
Moreau, R. 1983. Evolution des sols sous differents modes de mise en culture en Côte d'Ivoire forestière. Cab. ORSTOM., *Sér. Pédol.,* Vol. XX, n04 - 311-325.
Moreau, R. 1986. Effects of methods of deforestation and soil management on properties of some soils in Ivory Coast. In - Land clearing and developmentt in the tropics; Edited by R. LaI, P. A. Sanchez, R. W. Cllmmings, JR A. A. Balkema. Rotterdam. 247-264.
Moreau, R. and Godefroy, L. 1985. Problèmes des zones tropicales et équatoriales forestières. CR. Acad. Agr. de France nO 10, 71, 1169-1179.
Nicou, R. 1977. Le travail du sol dans les terres exondées du Sénégal. Motivations, contraintes. Doc. mult ISRA CNRA, Bambey, Sénégal. 52 p.
Ouattara, B., Sédogo, F.L., Assa, A., Lompo, F., Ouattara, K. and Fortier, M. 1998. Modifications de la porosité du sol après trete-trois années de labour d'enfouissement du fumier au Burkina Faso. Cahiers Agriculture, Volume 7, Numéro 1, pp. 9-14.
Peigné, J., Ball, B., Roger-Estrade, J. and David, C. 2007. Is conservation tillage suitable for organicfarming? A review. Soil Use and Management 23, 129-144.
Pro CGRN, 2005. Toward control of desertification in African drylands : problems, experiences, guidelines; 60 p.
Seguy, L. 1994. Contributions à l'étude et la mise au point des systèmes de cultures en milieu réel: petit guide d'initiation à la méthode de «création-diffusion» de technologie en milieu réel-résumé de quelques exemples significatifs d'application. Montpellier, CIRAD-Ca, 191 p.
Tamia, A. J. 1997. Modifications physiques d'un sol ferralitique sous différents modes de mise en culture en Côte-d'Ivoire forestière: Conséquence sur le développement du maïs. Thèse de doctorat de l'université Paris XII-Val-deMarne, spécialité Sciences du sol, Document Orstom Montpellier. n° 3, 271 p.
Tamia, A., Moreau, R., Fortier, M. and Yoro, G. 1999. Influence du travail du sol sur l'évolution physique d'un sol forestier ferralitique après défrichement motorisé. *Etude et Gestion des sols,* 6, 1, 27-39.
Van Der Meijden, G. 1994. Soil tillage with tractors in a small village in the Gambia, a broad study on various consequences of soil tillage with tractors, concentrating on soil and water conservation, thesis, Wageningen Agricultural University, Soil Tillage Departement, Wageningen.
Van Der Meijden, G. 1998. La motorisation en Afrique de l'Ouest; enquête sur l'utilisation actuelle et les conséquences du labour fait avec des machines propulsées par moteur, 90 p.
Vitlox, I.O. 1985. Compaction des sols. Colloque international: le travail du sol. Faculté des Sciences Agronomiques de l'Etat de Gembloux., AGRAR, 692 p.

****