Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/4378
DOI URL: http://dx.doi.org/10.21474/IJAR01/4378

RESEARCH ARTICLE

CONTRIBUTION TO THE DETERMINATION OF THE OPTIMAL PLOUGHING DEPTH ON TROPICAL FERRUGINOUS SOIL IN NORTHERN BENIN: IMPACT ON SOIL STRUCTURE AND YIELD OF A CORN CULTURE.

***Zokpodo Koéssi Lié Barnabé[1], Akossou Arcadius Yves Justin[2], Dayou Ephrème Dossavi[1] and Dognon Fulgence Baudelaire[2].**

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

Manuscript Info

Manuscript History

Received: 01 april 2017
Final Accepted: 03 june 2017
Published: june 2017

Key words:-
motorized ploughing, structure of soil, depth of ploughing, agricultural output, Benin.

Abstract

Effects of three different types of ploughing (light, middle and deep) on physical parameters of a tropical ferruginous soil of the Northern Benin, and their consequences on the growth and grain yield of two varieties of maize has been examined. The ploughing was achieved with a disk plow and the other cultural operations achieved manually. Results showed that tillage to important depth manipulates important quantity of soil, what makes it vulnerable to the deterioration. The impact of the ploughing depths was very important on the crumbling of soil, the profusion and especially the infiltration of water. Two varieties of corn TZEE-W-SR and DMR-ESR-WS have been experimented to the different depths of ploughing. The cultures showed a better vegetative development and an optimal output around 20 cm depth of ploughing.

Introduction:-

Agriculture is a major sector of Benin's economic development. 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). The area under cultivation in 2005 is estimated at about 2.82 million of the 7 million hectares of arable land (FAO, 2006). This is explained by the precariousness of the material and technical means available to the rural world. While over the past five years there has been a marked political commitment to promote agricultural mechanization through the provision of tractor and other agricultural equipment producers, it is clear that the use of mechanical energy is mainly limited to operations. The other cultivation operations are carried out manually. New users of agricultural engines are faced with problems of organization, control of use, maintenance of these equipment and their adaptation to environmental or environmental conditions. Moreover, there is currently no study on the influence of the use of agricultural equipment on the modification of the soil structure in Benin. Solving these problems will enable these actors to reduce the hardly of work, increase yields and profitability, increase the productivity and preserve our soil against erosion; All of which contribute to enhanced food security and development.

Thus, this study proposes to evaluate the structural changes following the variation of the depth of ploughing to the disc plow and to analyze their impact on the vegetative development and the grain yield of a maize crop.

Corresponding Author:- Zokpodo Koéssi Lié Barnabé.
Address:- School of Environmental Management, Faculty of Agronomic Sciences, University of Abomey-Calavi, 01 BP 526 Cotonou, Benin.

Material and Methods:-

Experimental protocol:-

The trials were carried out on a plot in Guéré, a village in Bembèrèkè township, with poorly drained tropical ferruginous soil, characterized by a rather undeveloped structure, a structural instability index around 1 on the surface, a soil depth often (<1 m) and a low to medium water reserve with values of 70 to 90 mm (Azontondé, 1991).

The split-plot experimental device used for real area studies was mounted on a 5000 m^2 field with three (03) blocks of 1350 m^2 each. A block is divided into six elementary plots of 225 m^2 (45m x 5m) each. In the absence of slope, the division of the plots was done in the direction of the previous plow while taking into account the crop's cultural background. Ploughing was done by a 3 disc plow with a working width of 1.20 m, coupled to a 60 Horsepower tractor. The ploughing was carried out according to three depths of ploughing: P1 = 10cm, P2 = 20cm and P3 = 30cm. Each depth is tested on an elementary parcel of the same block and also forms sub-blocks in which the varieties are randomly distributed.

The two corn varieties tested (V1 = TZEE-W-SR and V2 = DMR-ESR-W) were randomly distributed within the sub-blocks. Corridor of 0.8 m in width are arranged between the blocks.

Conduct of Culture:-

Two varieties of maize, TZEE-W-SR and DMR-ESR-W were tested on the plots. Sowing was done manually with gauges of 80 cm between lines and 40 cm on lines the day after ploughing. Herbicidal spraying was done the next day after planting to limit the invasion of plots by weeds from the first days. The products used are Alazine (3L / ha) and Calanche (1L / ha). Fertilization with NPK (N 14%, P205 23%, K20 14%, S 5%, B203 1%) was brought to the crop two weeks after sowing. The crops were given 75 kg in small pockets made at the base of the corn feet using stakes. Weeding was done three (03) weeks after fertilization. Fertilization with urea (46% N) occurred 45 days after sowing. Fifty kilograms (50 kg) of this fertilizer were sufficient for the 18 plots. The ploughing-butting were harvested five (5) weeks after the application of NPK with a Canadian in a harness. The harvest was done manually on the standing cobs.

Measures and Observations:-

At ground level:-

The crumbling of the soil is examined on the surface by estimating the size of the clods visible in comparison with the meshes of a reference grid. The selected clod classes are: c1> 200 mm; C2 Є] 200 mm; 100 mm]; C3 Є] 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 soil surface S covered by the class ball I and (Iei) the coefficient of crumbling (Ester, 2003).
The profusion resulting from the passage of the tractor is obtained by difference between the thickness of the ground worked and the depth of work measured in the same place. It is determined by the formula:

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

With (F) the expansion, (E) the thickness of the soil worked and (P) the depth of the work (Ester, 2003).

The dry soil density (g / cm^3) is measured using undisturbed samples taken with a ring (cylinder) of about 135 cm^3. These samples were taken before ploughing, on the day of ploughing and then 35 and 80 days later, between 5 and 10 cm deep, given the superficial location of the maize roots. The weight of a 135 cm3 sample of dried soil gives the "dry bulk density" (Yoro *et al.,* 1990).

The infiltration capacity of the soil was determined by the infiltration technique of a surface water slide. For this purpose we used 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. After having been pushed in slightly and filled with water, the infiltration time of a water slide of 5 to 10 mm in the small cylinder is noted. Successive fillings make it possible to repeat the measurements until the steady state is reached (three successive identical readings)

(De Blic, 1995). The measurements were made by depth before ploughing, on the day of ploughing and then 35 and 80 days later. It is expressed in dm^3 / h.

At the plant level:-
The behavior of the crop was studied by evaluating some agronomic parameters. The emergence was assessed by counting the young shoots the first seven days after sowing. Growth of corn stands is evaluated by measuring the height and counting the number of leaves at 10-day intervals from NPK fertilization. To do this, a sample of 4 times 10 linear meters per plot was selected and observations were made per pooled; As an indication, this gives an average of 22 pockets over 10m or 88 pockets per 225m² plot (45m x 5m). Finally, the yield of the two varieties was determined per plot in squares of density of 4 m²

Statistical Analysis:-
These analyzes were carried out using SAS software. The analysis of variance was performed on the data. Newman and Keuls test was used for the multiple comparison of means. Differences are considered significant at 95% confidence level (p<0.05).

Results and Discussions:-
Physical parameters:-
The crumbling of the soil obtained after the three ploughing operations was shown by figure 1.

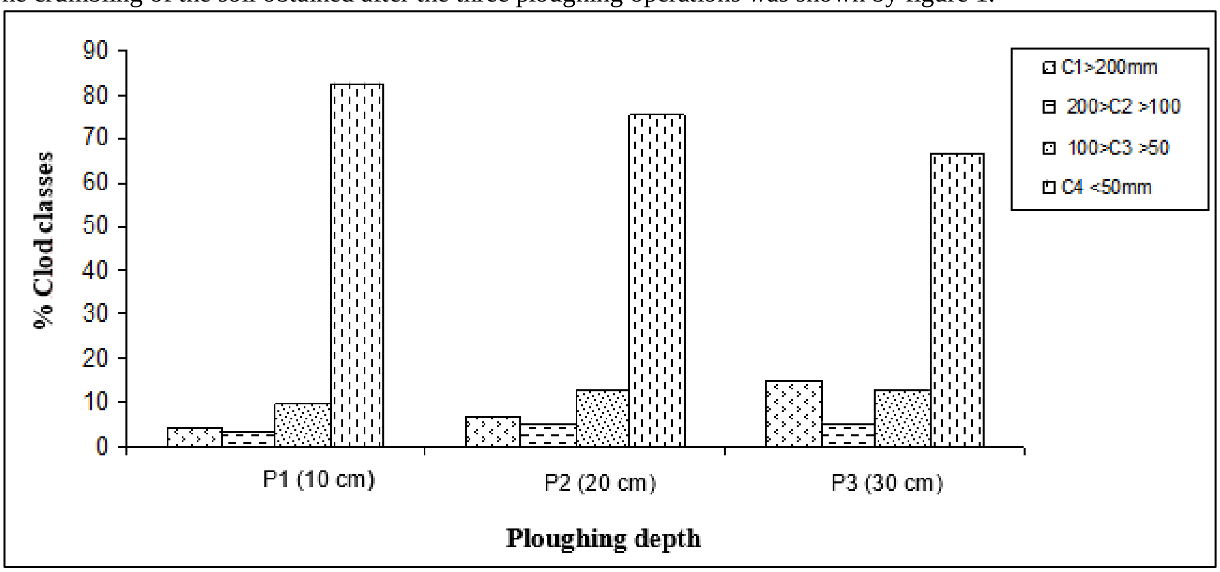

Figure 1:- Distribution by diameter class of clods in surface of three ploughing depths

The indices of crumbling are high and, regardless of the depth of ploughing, the ccloding class with a diameter of less than 50 mm presents a greater large proportion. In fact, the amount of fine soil produced by the disc plow in tropical environments is very important (CEEMAT, 1977). In addition, the examination of Table 1 shows that the mean index recorded for the depth 10 cm does not differ significantly from that of 20 cm while that of 30 cm is statistically different and lower compared to the others. This low value is due to a greater presence of large clod of soil (diameter greater than 200 mm) generated by deep ploughing. These results are confirmed by those recorded for the profusion.

Table 1:- Mean values and standard deviations of surface soil crumbling for the three plow depths of the soil.

Depth (cm)	10	20	30
Mean Standard deviation	0,71a *(0,00)*	0,67a *(0,03)*	0,61b *(0,02)*

Each value is a mean with (standard deviation). In the same line, values followed by different letter are significantly different (p<0.05) according to test of Newman and Keuls.

Table 2:- Mean values and standard deviations of the soil profusion obtained with three depths of ploughing.

Depth (cm)	10	20	30
Mean (cm)	15,67a	22,14a	30,80b
Standard deviation	*(4,31)*	*(2,85)*	*(8,08)*

Each value is a mean with (standard deviation). In the same line, values followed by different letter are significantly different ($p<0.05$) according to test of Newman and Keuls.

According to Table 2, the profusion presents a significant difference from the depth 20 cm. It is low for the 10 cm depth because of the superficial work of the plow and then, from 20 cm, the amount of sand becomes important, raising the level of the surface of the worked soil compared to the unworked surface of 30 cm approximately for 30 cm of ploughing depth. At the latter depth, the plow brings the inner layers back to the surface and in large quantities in the form of a large clod of earth. This reduces the crumbling as seen in the previous paragraph, raises the surface roughness and causes the burial of a large part of the plant debris on the surface. The abundance has therefore considerably influenced the circulation of water in plowed soils. The structure of tropical ferruginous soils is described essentially in terms of macroporosity and the infiltration capacity is a relevant criterion for assessing their structural state for these soils (De Blic, 1995).

According to Huwe (2003), ploughing homogenizes and regulates water infiltration and the hydrological behavior of the soil is determined by its surface state. Figure 2 illustrates the infiltration behavior and shows that it is higher at the beginning of the cycle than at mid and end of cycle.

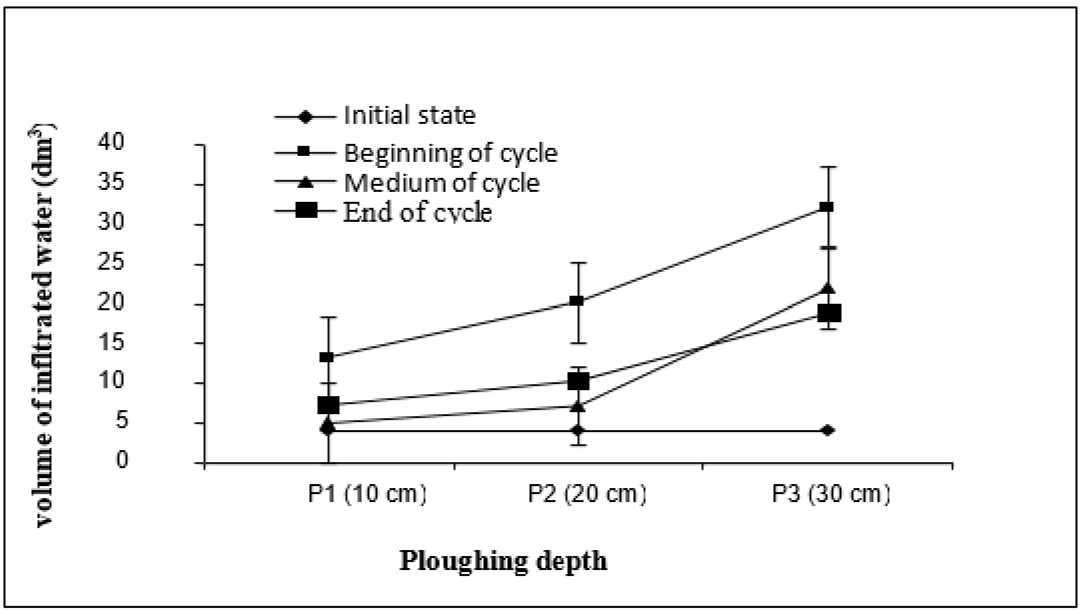

Figure 2:- Volume of infiltrated water by depth at three periods of cycle

Also, it grows from small depths to great depths of ploughing whatever the period of measurement. Compaction actions due to precipitation, trampling and others are responsible for the first observation by increasing the apparent bulk density of the soil during the cycle (Table 3, Figure 3).

However, at the same measurement period, differences are observed per ploughing depth. They are the logical consequence of variations in abundance. The medium and large depths by their high profusion are enriched in macro pores, which facilitates the circulation (superficial or by percolation) of the water. They are less prone to permanent stagnation, runoff and flooding. This substantially limits water erosion in some form.

Table 3:- Average values and standard deviations of soil density per plow depth during the cycle.

Ploughing depth	P1 (10 cm)	P2 (20 cm)	P3 (30 cm)
Initial state	1,28aA (0.08)	1,28aA (0.03)	1,29aA (0.02)
Beginning of cycle	1,18aA (0.01)	1,03aB (0.11)	1,04aB (0.13)
Medium of cycle	1,28aA (0.01)	1,21aAC (0.03)	1,23aAC (0.02)
End of cycle	1,21aA (0.02)	1,20aAB (0.01)	1,11aAB (0.05)

Each value is a mean with (standard deviation). For a same period (in the same line), values followed by a same miniscule letter are not significantly different (p>0.05) according to Newman and Keuls test. For a same depth (on the same column), values followed by a same capital letter are not significantly different (p>0.05) according to Newman and Keuls test.

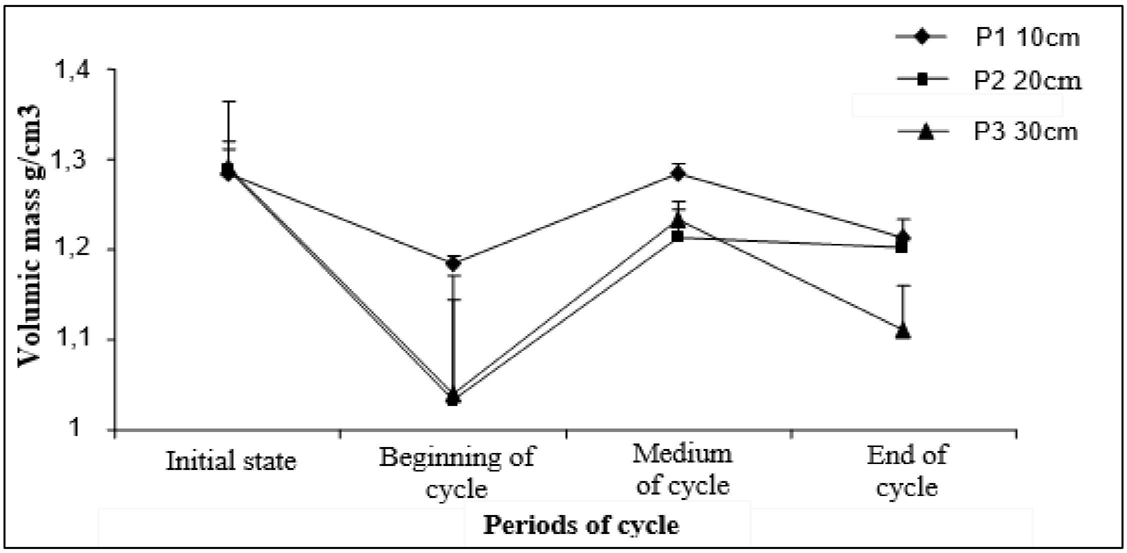

Figure 3:- Variation of volumic mass by ploughing depth

The density data partly explain the above-mentioned water phenomena. Indeed, even if the statistical analysis (Table 3) does not show a significant effect of the depth of ploughing factor on soil density, the observation of the graphs in diagram 3 reveals decreasing and increasing densities during the cycle for the three treatments. Thus, within the same depth, Table 3 reveals that soil conditions before and just after ploughing differ significantly at the 5% threshold for P2 and P3. Also, these two depths differ significantly at mid-cycle. Thus, between 5 and 10 cm deep, the three treatments presented the same characteristic for this parameter. This is justified insofar as the shallowest depth tested is at least equal to 10 cm and the whole device was exposed to the same environmental and meteorological factors. In ploughing the soil is freshly loosened, the voids and pores are high, which justifies the low values recorded for the density. In the course of the cycle, the phenomena of settlement (passage of gear and trampling), fragmentation (by climate, fauna) and aggregation (by moderate compaction or by climate and / or fauna) Balances a higher density than previously. At the end of the cycle, the density is improved because of the ploughing-butting done earlier.

Growth and Yield:-

The effects of the same tillage technique, for example ploughing with the plow, can be very variable. The links between tillage and production are therefore complex and indirect (Chopart, 1994). Soil density, infiltration and soil moisture are parameters that greatly influence crop growth and development. Observations show that the number of germinated grains increases from the first to the fourth day of survey, when it is nearly 100% for both varieties; this is naturally explained by the physiology of the seeds. However, the study also shows that for the same survey day, the number of shoots counted generally decreases from depth 10 cm to depth 30 cm.

This delayed effect is due to the deep depths associated with the high depths and the manual sowing. It also affects the height and number of leaves of both maize varieties at 10 days after sowing (Figure 4 and Figure 5). The height and the number of leaves decrease from small to great depth in the order of 3 to 4 leaves.

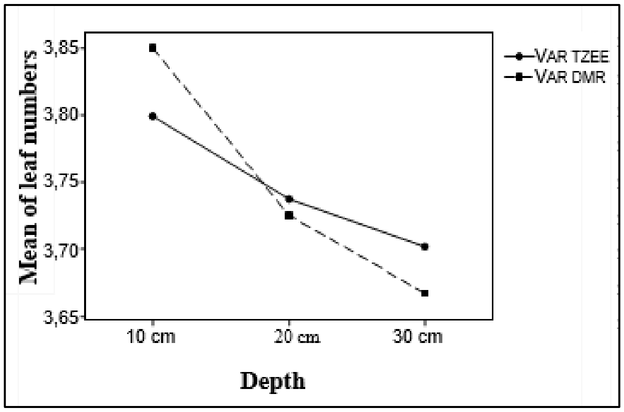

Figure 4:- Variation of mean nomber of maize leaves ten (10) days after sowing

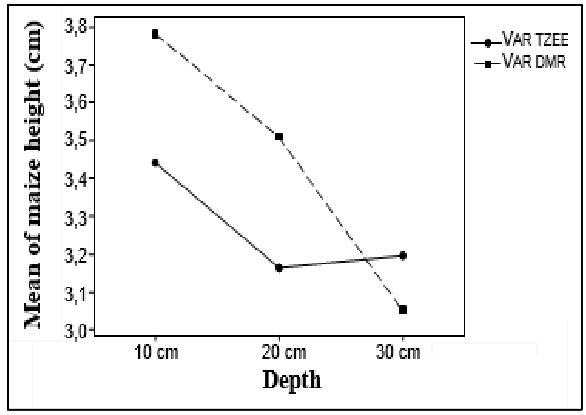

Figure 5:- Variation of mean height

Specifically, Tables 4 and 5 respectively contain the average leaf number and corn leg height at 10 days after sowing and 15 days after NPK fertilization. At 10 days, the two varieties count on average the same number of leaves except the depths 20 cm and 30 cm of the V2 variety which are statistically lower.

Table 4:- Mean values and standard deviations of the number of leaves during the cycle.

	Varieties	P1 (10 cm)	P2 (20 cm)	P3 (30 cm)
10 days after sowing	V1	3,80aA (0,43)	3,74aA (0,50)	3,70aA (0,57)
	V2	3,85aA (0,42)	3,73bA (0,49)	3,66bA (0,60)
60 days after sowing	V1	10,27aA (1,16)	10,41aA (1,30)	10,42aA (1,32)
	V2	10,78aB (1,08)	11,44bB (1,15)	11,14bB (1,45)

Each value is a mean with (standard deviation). For a same period (in the same line), values followed by a same miniscule letter are not significantly different (p>0.05) according to Newman and Keuls test. For a same depth (on the same column), values followed by a same capital letter are not significantly different (p>0.05) according to Newman and Keuls test.

Table 5:- Mean values and standard deviations of corn height during the variety cycle.

	Varieties	P1 (10 cm)	P2 (20 cm)	P3 (30 cm)
10 days after sowing	V1	3,45aA (1,21)	3,17bA (0,99)	3,19abA (1,11)
	V2	3,77aB (1,04)	3,51bB (0,99)	3,05cB (0,91
60 days after sowing	V1	84,69aA (18,30)	90,85abA (14,88)	95,47bA (25,86)
	V2	89,44aA (19,26)	118,56bB (22,57)	114,75bB (24,40)

Each value is a mean with (standard deviation). For a same period (in the same line), values followed by a same miniscule letter are not significantly differents (p>0.05) according to Newman and Keuls test. For a same depth (on the same column), values followed by a same capital letter are not significantly different (p>0.05) according to Newman and Keuls test.

The mean number of sheets is 10 and 11 respectively for TZEE and DMR. It is significantly more important for medium and large depths than for the small depth especially for the DMR variety. With regard to height, significant differences are also noted; The greatest heights are also recorded for medium and large depths (95.47 cm for TZEE in P3 and 118.56 cm for DMR in P2).

The height table reveals that TZEE is significantly different from DMR for the three 10-day tillage depths. Within each variety, significant differences are also noted. At 15 days after NPK fertilization, the DMR variety showed greater height and foliage than TZEE (Figure 6 and Figure 7).

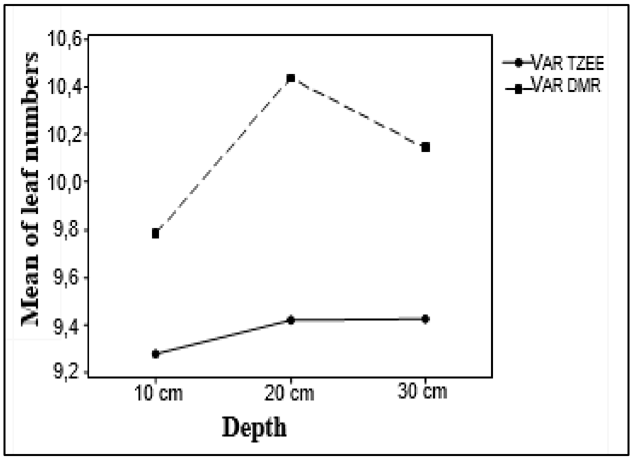

Figure 6:- Variation mean number of leaves 60 days after sowing

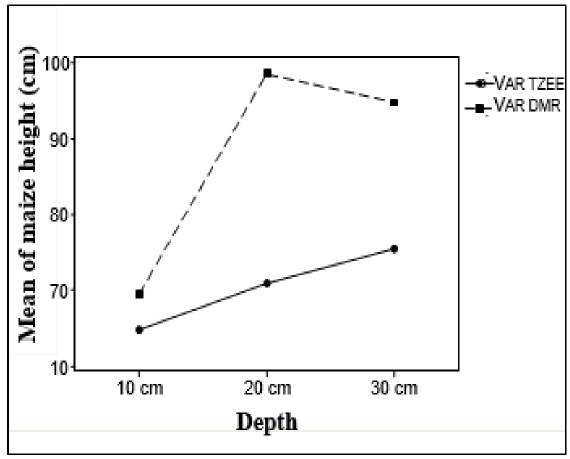

Figure 7:- Variation of maize height 60 days after sowing

In summary, deep tillage improves surface soil permeability, soil water use and growth, and water efficiency (Chopart, 1994). More importantly, the links between tillage and production depend in particular on the water supply conditions of the crops (Chopart, 1994) and the results obtained for grain yield in the context of our study are the positive consequence. Indeed, the best yields are recorded for the 20 cm depth for the two varieties (3.3 t / ha for TZEE and 3.75 t / ha for DMR, Table 6 and Figure 8).

Table 6:- Influence of three types of plow on the yields of two maize varieties (mean and standard deviations in brackets

	Varieties	P1 (10 cm)	P2 (20 cm)	P3 (30 cm)
Yield (t/ha)	V1	2,58 (0,28)	3,33 (0,30)	2,89 (0,58)
	V2	3,70 (0,19)	3,75 (0,37)	3,51 (0,51)

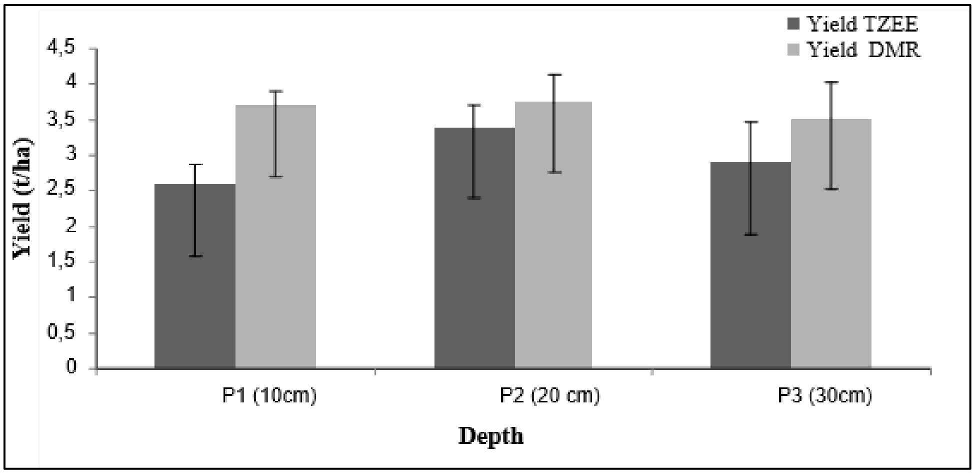

Figure 8:- Effect of ploughing depth on the yield.

In the spirit of this study, and in the light of the previous results, these yields are the result of a medium crumbling, a proliferation favorable to a solid rooting of the feet, a good availability of water and a Good nutrition.

Keeping in mind that variability depends on species, soil and quality of work, this study proposes an optimum ploughing per variety. It is determined by the surface response method; Thus, for the TZEE variety, the optimal depth is 21.06 cm and that of the DMR variety is 16.23 cm.

Conclusion:-

At the end of this work, the aim is to contribute to the determination of an optimum ploughing depth by studying the structural changes in the soil related to the depth of ploughing and their influence on the yield of a maize crop. That there is an obvious relationship between the ploughing depth and certain physical parameters of the worked horizons. Indeed, the cultural operations, as they were practiced, allowed remarkable structural modifications. The impact of the depths of ploughing was of great importance on the crumbling of the soil, the profusion above all the infiltration of water; the density which did not show any significance was also to some extent affected. This led in the case of an average working depth to a better structural condition of the soil. As a result, maize cultivation showed the best vegetative development and grain yield. The tillage optimizations derived from this study are 21.06 cm and 16.23 cm respectively for the TZEE-W-SR and DMR-ESR-W varieties.

References:-

1. Azontondé, H. A. (1991): Propriétés physiques et hydrauliques des sols au Bénin. Soil Water Balance in the Sudano Sahelian Zone. IAHS Publ. no. 199, 1991.
2. Azouma, O. Y. (1999) : Protection des sols en culture mécanisée ; document synthèse. Cahiers d'agricultures 1999 ; 8 :189-95.
3. CEEMAT, (1977) : Manuel de motorisation des cultures tropicales. Techniques rurales en Afrique, tome1, Paris : ministère français de la coopération, 661p.
4. Chopart, J. et W. Hoogmoed, (1994) : Système racinaire des cultures annuelles tropicales : effets du travail du sol sur les racines, FAO, cours de formation, 4-13 juillet 1994.
5. De Blic Ph. (1995) : L'organisation macrostructurale du sol : Méthode d'étude, Cah. ORSTOM, sér, Pédol., 37-40.
6. ESTER (2003) : Guide d'essais de terrain, et matériels de travail du sol. Coordination nationale des essais de terrain de matériel agricole ; version n°1.91p
7. Huwe, B. (2003): The role of soil tillage for soil structure, p. 27-50, In A. El Titi, ed. Soil Tillage in Agroecosystems. CRC Press LLC, Boca Raton.
8. Seguy L. (1994) : Contribution à l'étude et à la mise au point des systèmes de culture en milieu réel : petit guide d'initiation à la méthode de « création-diffusion » des technologies en milieu réel – résumés de quelques exemples significatifs d'application. Montpellier : CIRAD-CA ; 191p.
9. Vitlox, O. (1994) : Compaction des sols. Etat de l'environnement wallon, Volume 1. Ministère de la région wallonne. Direction générale des ressources naturelles et de l'environnement, 65-67.
10. Yoro, G. et G. Godo, (1990) : Les méthodes de mesure de la densité apparente : analyse de la dispersion des résultats dans un horizon donné, cah. ORSTOM, sér. Pédol., vol.XXV, n°4, 423-429.