

Soil Properties after Plowing with Vertical and Horizontal Axis Rotavator

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Abstract—In this research, performance of rotavator with horizontal rotary axis and vertical rotary axis has been evaluated and compared. The mean weight diameter (MWD), cross-sectional area disturbed and cone index of soil investigated. Factorial experiments based on a randomized complete block with 18 treatments, three different velocities 2.2, 3.5, 6.1 km/h; three different depth of 5, 10, 15cm and with two rotary plows horizontal axis and vertical axis with three replications were used. Result showed that maximum MWD in 6.1 km/h and 15cm of depth were 55.6 and 52.5mm for horizontal axis rotavator, respectively. The minimum MWD in 2.2 km/h and 5cm of depth for vertical axis rotavator were 34.9 and 35.1mm, respectively. The values of cone index 1861.1 and 2339.5 kPa for vertical axis rotavator and horizontal axis rotavator were obtained, respectively, also the values of cross-sectional area disturbed 687 and 497.2cm² for vertical axis rotavator and horizontal axis rotavator were obtained, respectively.

Keywords—Horizontal rotary axis, vertical rotary axis, rotavator, MWD, cone index, cross-sectional area.

I. INTRODUCTION

THE agriculture of Iran is in a stage that moldboard tillers are replaced with rotary tillers. Horizontal axis tillers are more conventional among all rotary tillers. Vertical axis rotavator has been popular in recent years. Farmers claim different performances for horizontal and vertical axis rotavators but there are no scientific works which compare them. Some research has been done on comparison between rotavator and conventional plows. For example, [9] reported that by using rotavator soil which had been tillage before will be soft and mixed so the clods size will have a good distribution. In compare with active implement rotavator needs less pass in farm to reach the same soil quality [9]. Reference [18] compared the performance of conventional plows with horizontal axis rotavator and reported that soil specific weight and mean weight diameter were much less for rotavator. Reference [3] evaluated the type of blades shape performance. Also other researcher determined the performance of horizontal axis rotavators [5], [17], [6], [14].

The axis of rotavator may rotate in vertical or horizontal axle of rotor shaft (Fig. 1).

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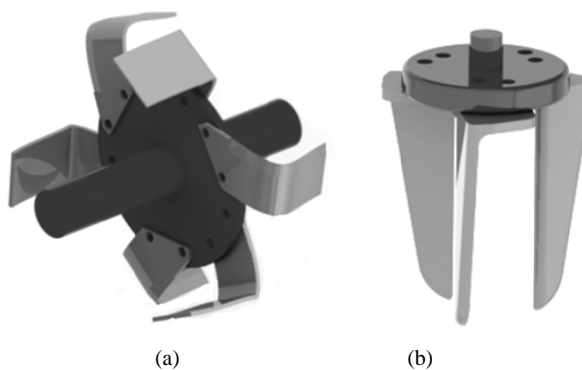


Fig. 1 Horizontal and vertical axis rotavators (a) Horizontal axis (b) Vertical axis

Soil texture after tillage with rotavator depends on soil conditions, blade cinematic and dynamic current of soil [12]. Dynamic current of soil depends on rotor axle direction and blade rotational direction. In rotor with horizontal axle, blades could be in down-cut or up-cut direction; while in vertical axle, the rotation direction could be clockwise or counter clockwise [7].

In this research, performance of rotavator with horizontal rotary axis and vertical rotary axis has been evaluated and compared. Therefore the mean weight diameter, cross-sectional area disturbed and cone index of soil investigated.

II. MATERIALS AND METHOD

A. Soil Textural Classification

The experiments were done in Rahmat Abad in Golestan province Iran. Textural classification of the soil was done by collecting adequate soil samples randomly from the designated experimental site. The textural classification of the soil at the experimental site was done using the UDSA soil classification system [16], [11]. Finally found that texture of soil was clay-silt.

B. Soil Moisture Content and Bulk Density Measurements

Soil moisture content was determined using the standard oven drying procedure [4], [15], [13], [10]. The soil sample for the determination of the moisture content collected immediately upon the completion of test-run. At least 12 soil samples were collected in metallic containers had a specified volume for each test-run from different located strata of the soil whose moisture content was to be determined. The mass of the collected moist soil samples was determined using a scale balance with an accuracy of 0.01g, and placed in a

constant temperature oven for drying at a temperature of about 105°C for a minimum drying period of 24 hours as described by [2]. Also by soil samples bulk density was determined. Finally found that moisture content and bulk density was 15.6% and 1.51g/cm³, respectively.

C. Experimental Layout

Factorial experiments based on a randomized complete block with 18 treatments, three different velocities 2.2, 3.5, 6.1 km/h; three different depth of 5, 10, 15cm and with two rotary plows horizontal axis and vertical axis were used. All experiments have been done in three replications. MF399 tractor was used in all experiments. To calculate forward velocity we used a chronometer to found time in 100 m tractor move and then determined velocity.

For each experiment plows were mounted on tractor and their power was provided through PTO shaft of tractor. Determining mean weight diameter (MWD), cone index and cross-sectional area disturbed of soil were done after plowing. By MWD, cone index and cross-sectional area disturbed, soil pulverization, soil loosening and soil disturbed respectively were found.

D. Mean Weight Diameter (MWD) Measurements

To measure soil fragmentation in different depth and velocity with two plows, rotary sieve was used. Basic of this instrument was like the instrument which had been used by [8]. This instrument has six cylindrical sieves with different diameters which have mounted on each other by bolts (Fig. 2).

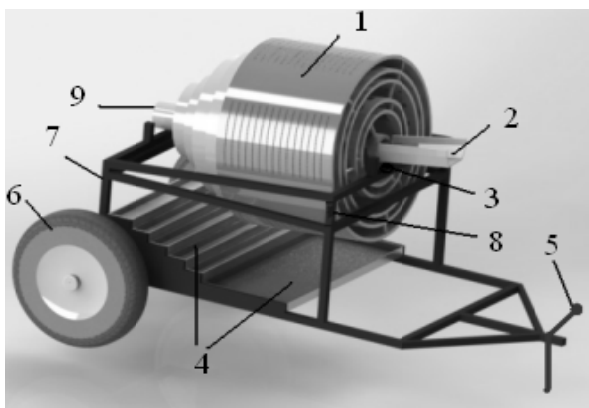


Fig. 2 A schematic of rotary sieve 1. Set of sieves 2. entry 3. rubber wheel 4. metal utensil 5. jack 6. carrying wheel 7. frame 8. tilt adjustment screw 9. sieve rotary axle

To find MWD, (1) was used which introduced by [1].

$$MWD = \sum X_i \cdot W_i \quad (1)$$

where, MWD: mean weight diameter (mm), X_i : mean soil particles in each area (mm),

W_i : Soil particles weight as a percentage of the total weight of the soil (kg).

E. Soil Cone Index Measurements

The cone penetrometer (SP1000 made by Findly Irvine) was used to measure soil cone index in different depths. This device consists of three main parts a microprocessor, converter and penetration rod (Fig. 3). Data were collected in farm and then transferred to the computer.

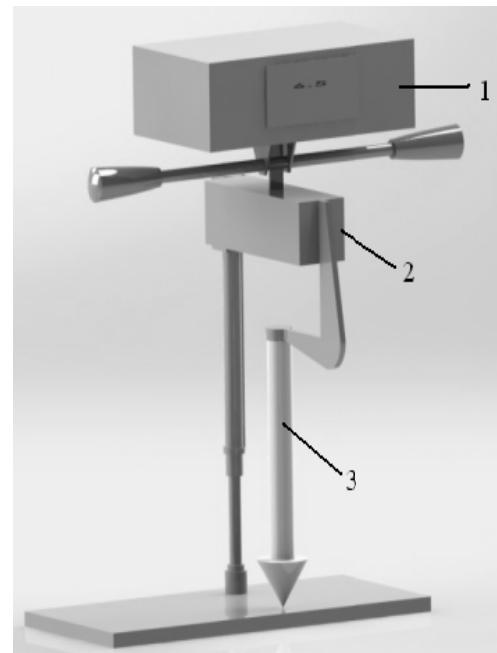


Fig. 3 Cone penetrometer 1. Microprocessor 2. Converter 3. Penetration rod

F. Soil Disturbed Determination

The plowed soil profile was dug in order to find the state and amount of soil cross sectional area during vertical axis rotary and horizontal axis rotary. This parameter shows soil disturbed differences with horizontal axis rotary and vertical axis rotator. At any point of each plot a cross section perpendicular to plow movement to determine soil disturbed profile were created. The depth and width of profile was as size of working depth of plow which was 10cm depth and 1m width. A long wooden ruler which had mark in every 10cm and placed horizontally on edge of profile was used in order to found cross section of profiles. To do this the most distal point of soil profile was recorded at 10cm intervals. Finally trapezoid shapes which were created by putting these 10cm intervals records together so the overall shape were drawn and total area were calculated.

III. RESULTS AND DISCUSSION

A. Soil Mean Weight Diameter Determination

The effects of two different rotavator with vertical and horizontal axis in different depths and velocities on MWD have been analyzed in this experiment. Table I shows analysis of variance for MWD.

TABLE I
ANALYSIS OF VARIANCE RESULTS FOR EFFECTS OF VELOCITY, DEPTH AND KIND OF PLOWS BY CONSIDERING MWD

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Speed (km/h)	2	219.9	109.9	279.21**
Depth (cm)	2	26.3	13.15	33.4**
Plow	1	3193.5	3193.5	8110.6**
Speed × Depth	4	1.09	0.27	0.7 ^{ns}
Speed × Plow	2	161.6	80.9	205.17**
Depth × Plow	2	29.9	14.9	38.05**
Depth × Plow × Speed	4	1.8	0.4	1.18**

** Significant in statistic level of 1 %, and ns not significant.

According to Table I interactions between velocity and plow were meaningful so comparison tests of different levels effects of each factor were done for MWD and results are shown in Table II.

TABLE II
COMPARISON TESTS OF DIFFERENT LEVELS OF VELOCITY AND TYPE OF PLOW ON MWD

Speed(km/h)	Plows	
	1	2
2.2	34.9 ^{Ba}	46.6 ^{Ac}
3.5	35.2 ^{Ba}	49.6 ^{Ab}
6.1	35.6 ^{Ba}	55.6 ^{Aa}

* Same capital letters in each row and same small letters in each column show not significant different (LSD1%).

According to Table II in each velocity the effects of plow type is meaningful but in plow 1 (vertical axis rotavator) different velocity levels have no effect on MWD, but in plow 2 (horizontal axis rotavator) different levels of velocity is effective on MWD. This is because soil is picked up as a whole piece and create hunk in horizontal axis rotavator. This kind of tiller in lower velocity has much time to cut down the hunks. Vertical axis rotavator never creates hunk and mixes soil, therefor velocity has no effects on it. Also it was observed that maximum MWD in 6.1 km/h and horizontal axis rotavator was 55.6mm. Minimum MWD in 2.2 km/h and vertical axis rotavator was 34.9mm.

Fig. 4 shows velocity changes with MWD in two different plows.

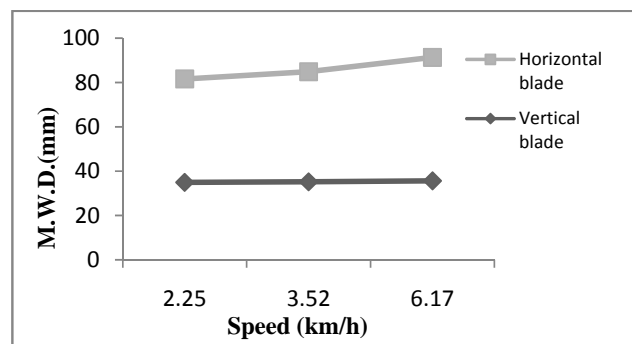


Fig. 4 Comparison of MWD changes because of effects of tillage with two different type rotavator (horizontal and vertical axis) in different velocity

According to Fig. 4 in vertical axis rotavator by increase in velocity the MWD remain almost fixed but in horizontal axis rotavator MWD increases with increase in velocity. Also in each velocity MWD for vertical type is less than horizontal one.

As it is shown in Table I the interactions of depth and plow is significant so results are shown in Table III.

TABLE III
COMPARISON TESTS OF DIFFERENT LEVELS OF DEPTH AND PLOW TYPE ON MWD

Depth(cm)	Plows	
	1	2
5	35.1 ^{Ba}	49.0 ^{Aa}
10	35.1 ^{Ba}	50.4 ^{Ab}
15	35.2 ^{Ba}	52.5 ^{Aa}

* Same capital letters in each row and same small letters in each column show not significant different (LSD1%).

According to Table III in each depth level the effects of plow type is significant, but type of plow on different depth levels have no effect on MWD. It means that in same depth, vertical axis rotavator cut down soil more than horizontal one but in both of them the amount of soil pulverization in different depth is the same. Because in horizontal axis soil picks up as a whole piece and create hunk and these hunks are thrown back during axis rotation and on impact with the back plate may not shatter, but in vertical axis rotavator soil is mixed and uniformly cut down. Also it was observed that maximum MWD in 15cm and horizontal axis rotavator was 52.5mm. Minimum MWD in 5cm and vertical axis rotavator was 35.1mm.

In Fig. 5 depth changes effects on MWD in two different plow is plotted.

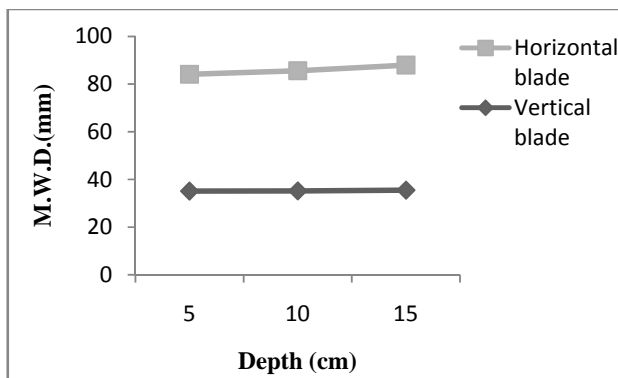


Fig. 5 Comparison of MWD changes because of tillage with two different rotavator in different depth

According to Fig. 5 in vertical axis rotavator MWD remain almost fixed with increases of depth but in horizontal one MWD increases with increases in depth. Also in each level of depth the MWD for vertical axis was much less than horizontal one.

B. Cone Index Measurement

In this test the effects of two different type rotavator in

different velocity and depth on soil cone index were statistically analyzed. Variance analysis for cone index is presented in Table IV.

TABLE IV
VARIANCE ANALYSIS RESULTS OF VELOCITY, DEPTH AND PLOW TYPE
EFFECTS ON SOIL RESISTANCE

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Speed(km/h)	2	81102.4	40551.2	0.09 ^{ns}
Depth(cm)	2	55640608.3	27820304.2	59.39**
Plow	1	3089722.5	3089722.5	6.6*
Speed × Depth	4	1510221.87	377555.5	0.81 ^{ns}
Speed × Plow	2	1037243.1	518621.52	1.11 ^{ns}
Depth × Plow	2	1231644.4	6158221.2	1.31 ^{ns}
Depth × Plow × Speed	4	1579625.6	394906.4	0.84 ^{ns}

** and *Significant in statistic level of 1 and 5%, and ns not significant.

As Table IV shows the effects of depth and plow type on soil resistance in 1 and 5% level is significant respectively, but none of the factors have no significant. The effects of depth and plow type on soil resistance in all experiment are shown in Figs. 6 and 7 separately.

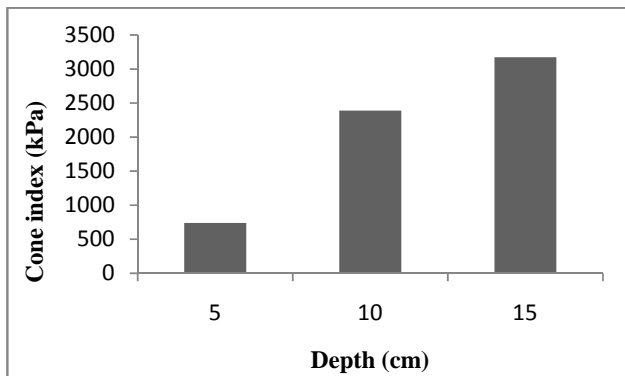


Fig. 6 Comparison of soil cone index according to depth because of tillage with two different rotavator

As it clear in Fig. 6, cone index increases with increase in depth. This is because that, according to Table III MWD increases with depth in both plows so in deeper depth more force is needed. Values of 738.1, 2389 and 3173 kPa for 5, 10 and 15cm are shown, respectively. According to Fig. 7 soil resistance in vertical axis rotavator is less than horizontal axis rotavator. This is because that, according to Fig. 5 the result is that MWD of horizontal axis rotavator is much more than vertical one, so tillage with this plow creates more resistant soil. Values of 1861.1 and 2339.5 kPa for vertical axis rotavator and horizontal axis rotavator are shown, respectively.

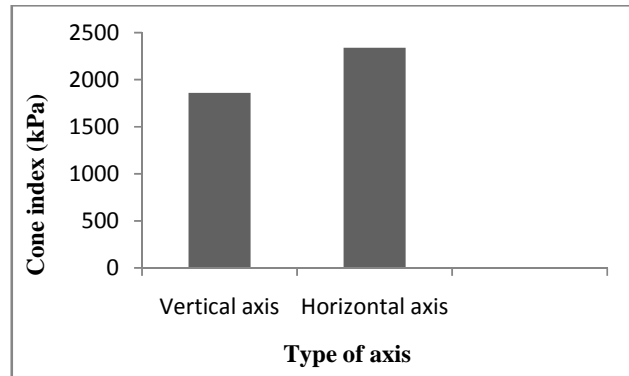


Fig. 7 Comparison of soil cone indexes according to rotavator type

C. Soil disturbed determination

In this experiment the effects of two different rotavator (horizontal and vertical axis) on soil disturbed in different velocity and depth were statistically analyzed. Table V shows analysis of variance for MWD.

TABLE V
VARIANCE ANALYSIS RESULTS OF VELOCITY AND PLOW TYPE EFFECTS ON
SOIL DISTURBED

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Speed(km/h)	2	198794.8	99397.4	10.2**
Plow	1	162070.2	162070.2	16.7**
Speed × Plow	2	56307.4	28153.7	2.89 ^{ns}

** Significant in statistic level of 1 %, and ns not significant.

As Table V shows effects of velocity and plow on soil disturbed in 1% level is significant but their interaction is not significant. Figs. 8 and 9 shows velocity and type of plow effect on soil disturbed in all experiment.

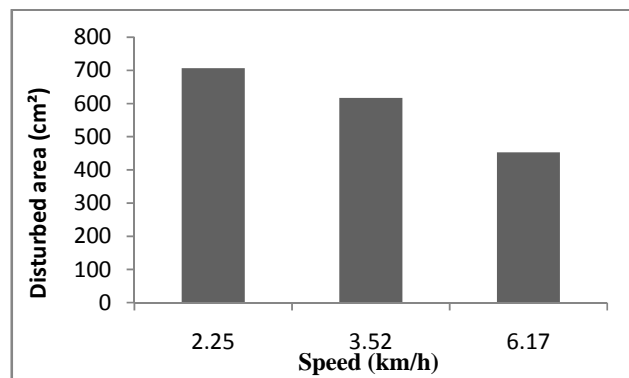


Fig. 8 Comparison of soil disturbed for tillage with two different plow (horizontal and vertical axis) in different velocity

According to Fig. 8 soil disturbed decreases with increase in velocity. This is because at lower speeds the blades are in real depth and create uniformity in plow depth. Values of 706.6, 616.8 and 452.8 cm² for 2.2, 3.5 and 6.1 km/h are shown, respectively. As Fig. 9 show soil disturbed in vertical axis rotavator is much more than horizontal one. This is mostly due to the higher working depth. Values of 687 and 497.2 cm² for

vertical axis rotavator and horizontal axis rotavator are shown, respectively.

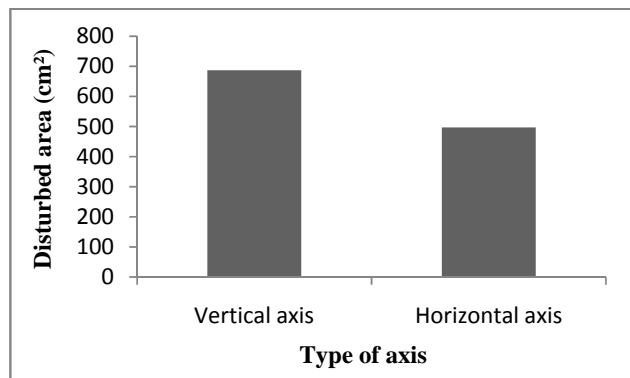


Fig. 9 Soil disturbed comparison with two different axis rotary plow (horizontal and vertical)

IV. CONCLUSION

Considering the speed increase will lead to increased farm efficiency, in rotavator with vertical axis increasing farm efficiency and more pulverization are simultaneously. While in rotavator with horizontal axis increasing farm efficiency leads to less pulverization. There is plowing depth uniformity in both types of rotavator, while in rotavator with vertical axis most hunks are crushed at different depths. Also, soil resistance in vertical axis rotavator is less than horizontal axis rotavator and soil disturbed in vertical axis rotavator is much more than horizontal one. Thus, regardless of other factors and according to the results, use of rotavator with vertical blade more appropriate than rotavator with horizontal blades.

REFERENCES

- [1] M. Azadbakht, Design, Development and Evaluation of Rotary Plow. M. Sc. Thesis, College of Agriculture, Shiraz University, Shiraz, Iran (in Farsi with English abstract). 1999.
- [2] ASAE Standards, ASAE EP291.2 DEC98. Terminology and Definitions for Soil Tillage and Soil-Tool Relationships. American Society of Agricultural Engineers. St. Joseph, Mich. USA. 2000.
- [3] J. M. Baloch, S. B. Bukhari, J. Kilgour, and A. Q. A. Mughal, Performance of Power Tiller Blades. *Agricultural Mechanization in Asia, Africa and Latin America*. 17: 22-26. 1986.
- [4] J. Bardet, *Experimental Soil Mechanics*. Prentice Hall. ISBN: 0133749355. 1997.
- [5] J. M. Beeny and D. J. Greig, The Efficiency of a Rotary Cultivator. *Journal of Agricultural Engineering research*. 10: 5-12. 1965.
- [6] J. N. Beeny, and D.C.P. Khoo, Preliminary Investigation into the Performance of Different Shaped Blades for Rotary Tillage of Wet Rice Soil. *Journal of Agricultural Engineering Research*. 15: 27-33. 1970.
- [7] K. H. Bukhari, S. Bukhari, M. M. Leghari, and M. S. Memon, The Effect of Speed and Rear Shield on the Performance of Rotary Tiller. *Agricultural Mechanization in Asia, Africa and Latin America*. 27, 9-14. 1996.
- [8] W. S. Chepil, A Compact Rotary Sieve and the Importance of Dry Sieving in Physical Soil Analysis. *Soil Science Society of America Proceedings*. 26, 4-6. 1962.
- [9] M. F. Destan, and K. Houmy, Effects of Design and Kinematic Parameters of Rotary Cultivators on Soil Structure. *Soil & Tillage Research*. 17, 291-301. 1990.
- [10] W. H. Gardner, Water Content. In *Methods of Soil Analysis, Part I. Physical and Mineralogical Methods*, 2nd Ed., ed. A Klute, 493-544. Madison, Wis.: American Society of Agronomy. 1986.
- [11] W. R. Gill, and G. E. Vanden Berg, *Soil Dynamics in Tillage and Traction*. Agricultural Handbook No. 316. Washington D.C., US GPO. 1967.
- [12] G. L. Kinzel, R. Holmes and S. Huber, *Computer Graphics Analysis of Rotary Tillers*. Transactions of the ASAE, 1392-1395 & 1399. 1981.
- [13] T. W. Lambe, *Soil Testing for Civil Engineers*. John Wiley & Sons. ISBN 0-471-511833-8. 1951.
- [14] K. S. Lee, S. H. Park, W. Y. Park and C. S. Lee, Strip Tillage Characteristics of Rotary Tiller Blades for Use in a Dryland Direct Rice Seeder. *Soil & Tillage Research*. 71, 25-32. 2003.
- [15] J. N. Mandal, and D. G. Divshikar, *Soil Testing in Civil Engineering*. India Book House Limited. ISBN: 8120409035. 1994.
- [16] E. McKyes, *Agricultural Engineering Soil Mechanics*. Developments in Agricultural Engineering 10. Elsevier Publishing Co. 1989.
- [17] M. Misczak, A Torque Evaluation for a Rotary Subsoiler. *Soil & Tillage Research*. 84, 178-183. 2005.
- [18] J. Prasad, A Comparison between a Rotavator and Conventional Tillage Equipment for Wheat-Soybean Rotations on Vertisol in Central India. *Soil & Tillage Research*. 37, 191-199. 1996.