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Work Rate, Wheel Slippage and Some Soil Properties as Affected By A Staggered Reciprocating Sub-Soiler and Tractor Forward Speed

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ABSTRACT:

A staggered reciprocating, tractor mounted vibrating subsoiler was developed by Agricultural Mechanization Engineering, Department - China Agricultural University to break soil hardpan which is common in corn fields due to the traffic of tractors during cultivation and trucks after crop harvesting. Field experiments were conducted to determine the influence of subsoiler shanks working mode under different forward speeds on the field capacity, Wheel Slippage, soil bulk density and soil moisture content. Field tests were conducted at the Demonstration Farm of the Guan Jingquan Jixie tanhuang Factory - Gu An city in He bei province, China in 2013.

A significance increase in effective field capacity was found to be greater for vibrating (VS) compared to non-vibrating subsoiler shanks (NVS) at different forward speeds. Wheel slippage was found significantly ($P<0.05$) better in Vibrating mode than non-vibrated mode However, a significant difference between speed 1 and speed three was observed, while, no significant difference observed between speed 2 and speed 3. A significant difference was found between non-vibrated shank and vibrating shank at different depths in term of bulk density, while, statistically it was not affected by different tractor forward speeds . The soil moisture content in no-vibrating shank and the vibrated shank was found to be similar at all depth layers of the plowed soil, and there is no siginficant difference between them ($P<0.05$), also statistically, it was not affected by different forward speeds. It was concluded that, the vibrating subsoiler reduces wheel slippage and soil compaction, while, it increases the effective field capacity.

Keywords: *Vibration subsoiler, effective field capacity; Soil bulk density; wheel slippage; reciprocating.*

INTRODUCTION

The use of heavy agricultural equipment and tractors and the continuous plowing of agricultural soil at the same depth create plow sole or hardpan immediately below the normal plowing depth. The hardpan forms a barrier which hinders the penetration and circulation of water into the ground and prevents tap roots of plants to grow downwardly into the soil where they can utilize the subsoil nutrients and moisture.

Soil compaction is main form of soil degradation which affects 11% of the land area (Ahmed eta al., 2007). It can have adverse effects of upon plants by increasing field saturated hydraulic conductivity (Iqbal et al., 2005; Solhjou and Niazi Ardekani, 2001). To minimize soil compaction, numerous techniques have been developed. The use of vibrating or oscillating subsoiler is one technique that can reduce the draft force when the maximum velocity of oscillation is greater than the velocity of the tool carrier (Yow and Smith, 1976). The reduction of draft was most important performance indicator of subsoiler (Sakai et al., 1988). To maintain soil quality, reduce costs and environmental effects, tillage should be carried out under favorable soil conditions with as little energy input as possible. The objectives of the present study was to compare between two shank working modes of a staggered reciprocating subsoiler under different forward speeds and their influence on implement work rate, wheel slippage and soil properties such as bulk density and moisture content in the silt-loamy soil.

MATERIALS AND METHODS

Experimental Site

The study was carried out at Gu An city in He bei province (116°17′E, 39°19′N) southern of Beijing. Where it has a flat terrain with ratio of slope is below 5° and 500-600 mm average rainfall.

The experiments were conducted at 2013. Soil texture was found to be silt clay soil (Li xia and Zhang dong 2011).

Experimental Design and Treatment Applications

The layout of the experiment was a split-plot design, with a factorial arrangement of treatments consisting of two shanks working modes (VS) and (NVS) as main plot and three tractor forward speeds (Sp1, Sp2 and Sp3) as sub-plot with three replications giving a total of eighteen plots.

The treatments were randomly distributed in the main and sub-plots. Sub-plot area was 108 m^2 (30 m x 3.6 m) were separated by a distance of 1.0 m and by distance 5.0 m at the end of sub-plot. A mounted staggered reciprocating subsoiler (Fig. 1) which was developed by China Agricultural University was used for all the tests. The shanks of this implement can operate under two different situations:

1 – VS is Vibrating status it was obtained through operated the implement with the tractor power-take-off (PTO)

2 – NVS is Non vibrating status this situation could be obtained by turn off the PTO of the tractor. The implement had four vibrated shanks arranged as a semi V shape in two rows with distance 60 cm between shanks.

Two tractors were used in this experiment, one for testing and the other as auxiliary for pulling. The soil bulk density, soil moisture content and soil penetration resistance of the 0-10, 10-20 and 20-30cm of the experimental site are shown in Table 1. The experimental site was cropped with corn (zea maize) in previous year. For all treatments the engines speed of the tractor adjusted by using a fuel hand accelerator lever to maintain steady engine rpm on the dashboard. The tillage depth was adjusted to 30 cm.

Table 1: Some soil properties of the experimental site before test:

Depth (cm)	Bulk density (gm/cm3)	Moisture content (%)
0 – 10	1.57	9.21
10 – 20	1.63	9.19
20 – 30	1.68	12.1

Fig. 1 Photographic view of new developed chisel plow.

Measurements

Effective field capacity (EFC)

The time lost in every event such as turning, adjustment and change of gear was recorded and time lost for real work was used. The field capacity was calculated by using the equation given below.

$$Total\ time(h/ha) = \frac{(Pt+Tt+Lt)\times 10000}{Plot\ area \times 3600}$$

Where, *EFC* = effective field capacity, ha/h; *A* = Area tilled, ha; *Tp* = productive time, h; *Tt* = non- productive time, h.

Rear wheel slippage (%)

The tractor rear wheel slippage is the travel reduction of the tiller during operation in the field and usually expressed as percentage can be determined by the following equation:

$$S = \left(\frac{d_l - d_w}{d_l}\right) \times 100\%$$

S = wheel slippage (%), d_l = distance traveled with load and d_w = distance traveled without load

Bulk density

Five undisturbed soil samples per 4 replicates treatments were randomly collected from the layers of (0 - 10, 10 - 20 and 20 - 30 cm) of the soil for laboratory determination, using 50 × 54 mm cylindrical cores then it was dried at 105 °C for 24 hour after the tillage. The samples were collected a day after the treatments were applied. Soil bulk density was calculated by using the following equation:

$$BD = \frac{W_{dry}}{V}$$

Where:
BD = dry bulk density (g cm^{-3})
W_{dry} = weight of the dried soil sample (g)
V = total volume of the soil sample (cm^3)

Moisture content:

Soil moisture content was measured before starting and after the plowing operation at three depth ranges of 0-10, 10-20 and 20-30 cm, five samples at every tillage passes of test implements were taken after the field was plowed for data analysis. The traditional method of measurement consists of removing a sample by soil auger and place the sample in an oven at 1050C for 24 hours (ASAE Standards, 2002. EP419.1; Hillel, 1980; Dirksen, 1999). The water content in dry weight basis can be calculated using the following formula:

$$MC\,(w.b) = \frac{W_w - W_d}{W_d}$$

Where:
MC = soil moisture content, W% .
Ww = wet soil mass, g.
Wd = dry soil mass, g.

Statistics analysis

Data were compiled and subjected to mean calculation and analysis of variance using STATISTIX 8 and Microsoft Excel software. Treatment means were also compared using the Duncan's multiple range tests was used to identify significantly different means among all the treatments. The level of probability value was set at 0.05 for all comparisons.

Effect of two shanks working mode and forward speed of a staggered reciprocating subsoiler on Implement EFC:

The average of effective field capacity (EFC) of the two shanks working mode (NVS) and (VS) and the average of (EFC) for the three different forward speeds (Sp1, Sp2 and Sp3) of a staggered reciprocating subsoiler and their analysis variance at the experiment site were comprised in (Table 2 and Fig.2) respectively.

Over the course of the study, two shanks working style of a staggered reciprocating subsoiler significantly different ($P<0.05$) affect effective field capacity (Table 2). The average effective field capacity overall treatments of vibration shank and Non vibration shank was 0.55 ha/hr and 0.48 ha/hr respectively.

The average effective field capacity for (VS) was found to be greater than that of NVS by 13% at Sp1, by 11.3% in Sp2 and by 10.8% for Sp3 (Fig. 2). Observed from the field expierment the width cuting of each shanks in vibrating position found to be wider than that in the non-vibrating, this may be due to that vibrating shanks create more shake and break of soil clods at two sides of each shank resulted in more width for one shanks which is causes increase in total width and the field capcity. Moreever, could be due to that fact that vibration decreased the slipage and led to decreasing losses in speeds resulted in increasing effective field capacity, this result agrees with Hunt (1995) who stated that effective field capacity is mainly affected by draft, speed and width of machine. Furthermore, with an increase in the draft and slippage of an implement leads to decrease an implement speed thus decreased effective field capacity. Aziz (1995) reported that, a reduction in wheel slippage resulted in increased implements speed, while a reduction of ploughing draft reduces the slippage.

Fig. (2) Show, the average effective field capacity for the two shanks position under the three different forward speeds (Sp1, Sp2 and Sp3) at experiment site. A statistically high significant difference (P<0.01) was observed in effective field capacity between three different speeds (Table. 2).

As the speed was increased from speed one to speed three the average effective field capacity was increased by 29.2 % in vibration mode and by 31.03 in non-vibration (Fig. 2). This result may be due to that fact, field capacity is mainly affected by speed travels in field, time losses and width of the machine and this agrees with (Kepner et al., 1982). The interaction between the two shank working style and foorward speeds showed no significant difference (P > 0.05), Table (2).

Table 2 Statistical description of variation for the Effective Field Capacity affected by tow shanks working style and different forward speed

source	S.S	M.S	Prob.	F
Shanks	0.01869	0.01869	0.0357*	26.49
Speed	0.10501	0.05251	0.0000**	90.44
Shanks×Speed	0.00008	0.00004	0.9357^{ns}	0.07

S.S=Sum of squire, M.S = Mean of squire, Prob. =probability,* = significant, ** = highly significant and ns = no significant.

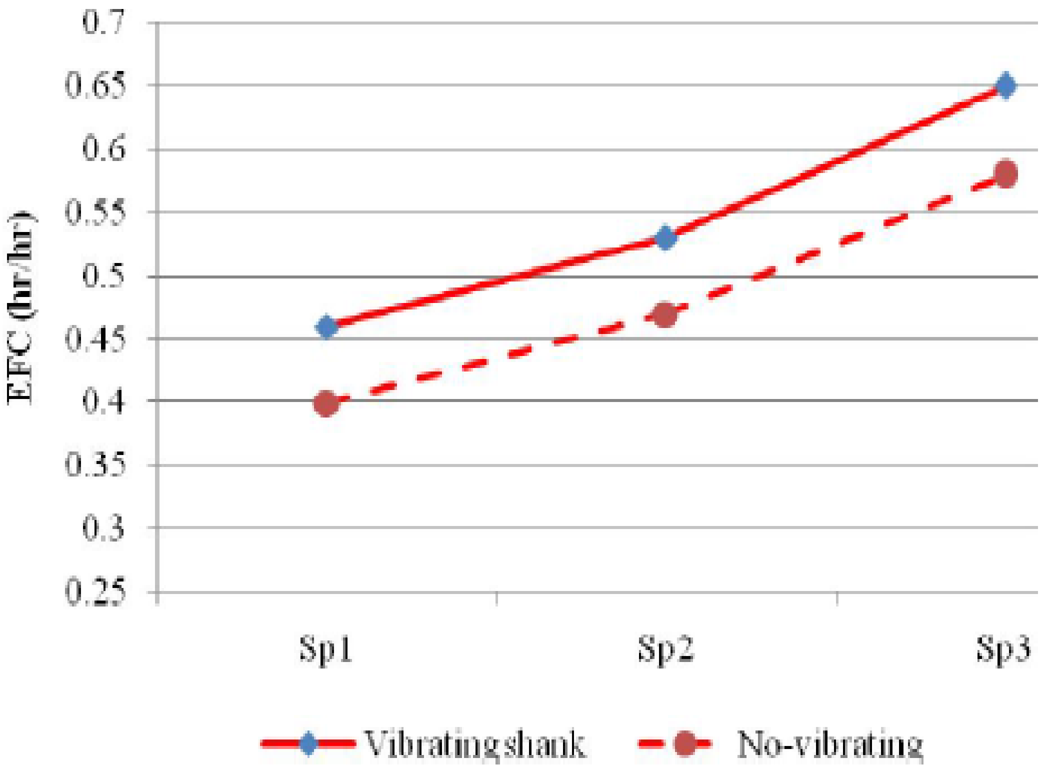

Fig. 2 Changes of shanks average effective field capacity versus different forward speed.

Effect of two shanks working mode and forward speed of a staggered reciprocating subsoiler on wheel slippage:

The influence of shanks working mode on wheel slippage in different treatment is shown in Fig. 3. The statistical analysis displayed in Table (3) which is shows that there are significant differences (P>0.05) in wheel slippage between two shanks working style.

Table **Error! No text of specified style in document.**1 Statistical description of variation for the Wheel slippage affected by tow shanks working style and different forward speed

source	S.S	M.S	Prob.	F. value
shanks	41.8918	41.8918	0.0235*	41.02*
speed	21.1732	10.5866	0.0394*	4.98*
shanks×speed	1.6046	0.8023	0.6972^{ns}	0.38^{ns}

S.S=Sum of squire, M.S = Mean of squire, Prob. =probability,* = significant and ns = no significant.

Fig. 3 shows the average slippage of the two shanks working style of a staggered reciprocating subsoiler at the experiment site. The average slippage for (NVS) was found to be higher than that of (VS) at different forward speed. This may be due to the higher draft forces exerted by the weight of the implement. The percentage of wheel slippage increased with increasing the amount of implement draft, this results agreement with findings of Barger et al. (1967), also this results agrees with Albana (1990) who observed that, increase in machine draft was accompanied by increase in wheel slippage.

The Duncan's multiple range test for slippage show significant difference among the two working mode and between speed 1 and three, while no significant differents between speed 2 and speed 3 (Fig. 3).

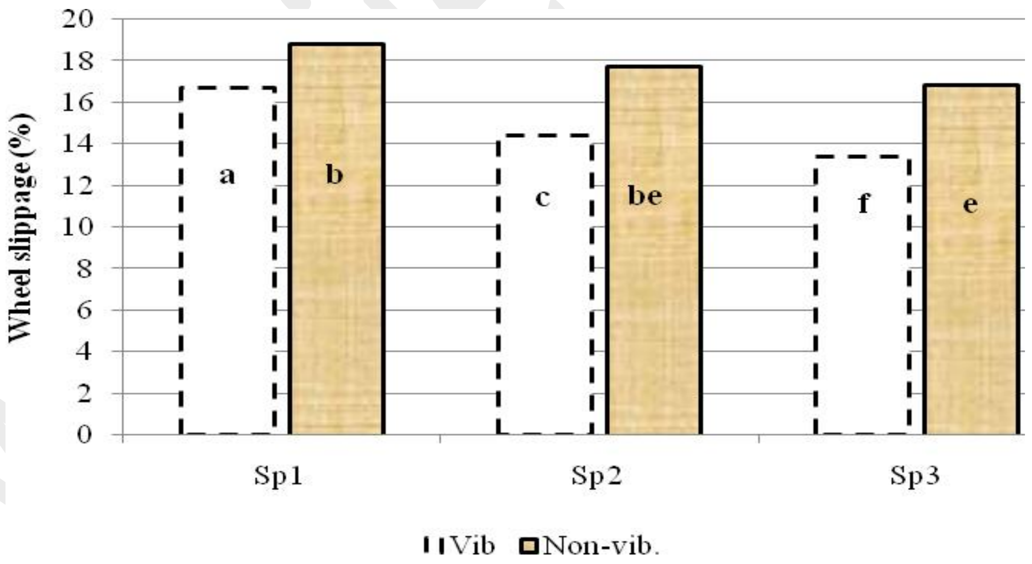

Fig. 3 Duncan's multiple range test for the averrage of wheel slippage (%) affected by two shanks working position under different forward speed.

Effect of two shanks working mode and forward speed of a staggered reciprocating subsoiler on bulk density:

In order to determine the effect of shank working mode and operating speeds of a new developed vibratory chisel plow on bulk density after the tillage, the variance analysis was done for each depth and the results are presented in Table 4. Bulk density for tow shanks working mode before and after the tillage, and Duncan's multiple range test estimates of the average bulk density values are shown in Fig 4. A significant difference was found between non-vibrated shank (NVS) and vibrating shank (VS) at the different depth (Table 4). It is clear that the values of soil bulk density were decreased after all tillage treatments compared with those before tillage, also it significantly observed less in (VS) than (NVS) in different depth (Table 4), where it found, it was reduced by 7.3% for the first depth, 14.59% for the second depth and by 7.69% for last depth. In general at (NVS) the average of the bulk density in all depth was found to be greater than (VS). Shank shaking lead to more shake and break of soil clods resulted in more aggregate which is causes decrease in the bulk density.Brady (1984) reported that the bulk densities of clay, clay loam, and silt loam surface soils normally range from 1 to 1.6 Mg m^{-3} depending on their condition. Kar et al. (1976) reported that a bulk density greater than 1.6 Mg.m^{-3} for loam soil adversely affected the root growth. At the depth of 0-20 cm in all treatments, the lowest bulk density was 1.017 Mg m^{-3} and the highest bulk density was 1.173 Mg m^{-3}.

Bulk density reflects the soil condition disturbed. An increasing trend was observed in bulk density over depth for all treatments as the soil gradually got compacted under the influence of particle resettlement, (Fig 4).

Bulk density of the soil at different depths for different levels of speed designated as Sp1, Sp2 and Sp3 are shown in Fig.5.

Bulk density generally increased with depth but decreased with speed of tillage operation within the all layers of depth. The effect of operating speed on bulk density was statistically no significant at all depth. Thereafter, increased speed did not have much impact on bulk density reduction, as the speed was increased from speed one to speed three the average bulk density was slighty decreased by 1.6%, 3.1% and 3.5% for depth one, depth 2 and depth three resepctivelly. This is attributable to the fact that at higher speeds of operation, the tractor tractive efficiency became very low leading to skidding. The ultimate effect was the pulverization of the soil top layer by the tillage tool while compacting the lower horizons. These results generally agree with earlier findings elsewhere under varying soil conditions (Soane et al., 1981; Thakur et al., 1988 and Rautaray et al., 1997).

The interaction effect of average shanks working mode and forward speeds was observed no siginficant ($P<0.05$) for overall depth Table 4.

Table 4 Analysis variances for the Bulk density as affected by tow shanks working mode and different forward speed of a new developed vibratory chisel plow

depth	Source	Shanks	Speed	shanks×speed
0 - 10	Prob	0.0232*	0.14^{ns}	0.5277^{ns}
	F	41.55	2.53	0.69
10 - 20	Prob	0.0017**	0.1515^{ns}	0.2167^{ns}
	F	587.53	2.41	1.86
20 - 30	Prob	0.0626*	0.157^{ns}	0.2787^{ns}
	F	14.5	2.36	1.5

S.S=Sum of squire, M.S = Mean of squire, Prob. =probability,* = significant and ns = no significant.

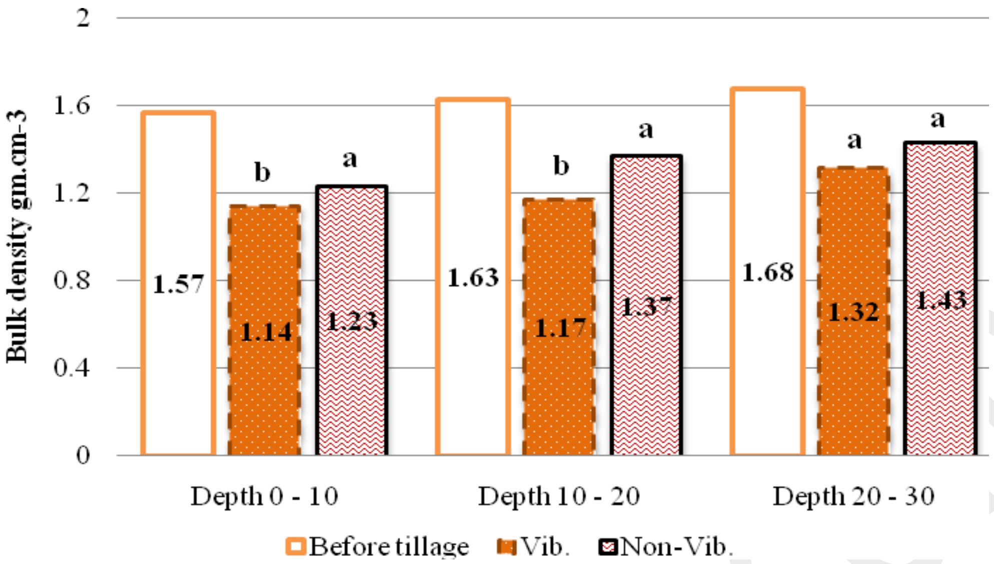

Fig. *Error! No text of specified style in document.* ***Soil bulk density as affected by tow type of shanks working style immediately after tillage under different depths. (Mean followed by the different letter differ significantly according to Duncan's test P < 0.05).***

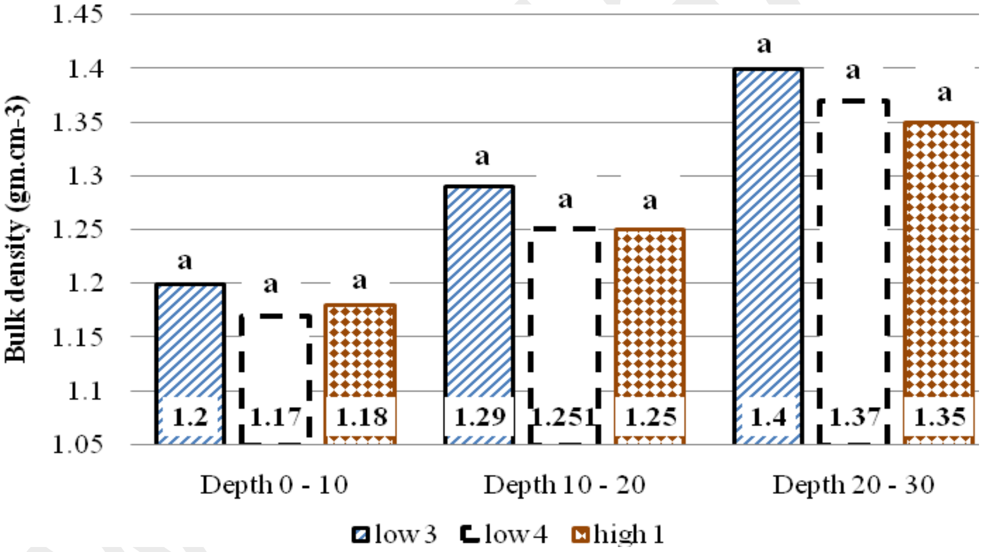

Fig. 5 Soil bulk density affected by different forward speeds immidiatly after (3hrs) tillage. Data followed by different letters indicates the significant at the level of P < 0.05.

Effect of two shanks working mode and forward speed of a staggered reciprocating subsoiler on soil moisture content:

Table 5 present the variance analysis for the soil moisture content which was influenced by the treatments at different depth. Soil moisture was determined prior to tillage at different three layers and that was shown in (Table 6), also Table (6) offer the effect of the shank working mode and Duncan's multiple range test estimates of the moisture content of a new developed vibratory chisel plow. Statistacly the two shanks working mode vibrated shank (VS) and No-vibrating shank (NVS) shows there is no siginficant different (P<0.05) at the different depth Table 5. The Duncan`s multiple range test for soil moisture content showed no siginificant difference among the shank working style (Table 6).

Soil moisture content as affected by different forward speeds (Sp1, Sp2 and Sp3) at different depths, respectively are displayed in Fig.6. The mean of moisture content influenced by different forward speeds was found there is no significant different ($P<0.05$) at different depth Table 5. In this experiment there was no definite trend of moisture variation with speed. This may be attributed to the fact that all measurements were taken the same day within the same weather condition, this results was agree with that found by I.E. Ahaneku and Ogunjirin., 2005.

The interaction effect of average shanks working mode and forward speeds was observed no siginficant ($P<0.05$) overall depth Table 5.

Table 5 Analysis variansis for the moisture content as affected by tow shanks working mode and different forward speed of a new developed vibratory chisel plow

depth	Source	Shanks	Speed	shanks×speed
0 - 10	Prob	0.5866^{ns}	0.7957^{ns}	0.668^{ns}
	F	0.41	0.24	0.42
10 - 20	Prob	0.4618^{ns}	0.8235^{ns}	0.9575^{ns}
	F	0.82	0.20	0.04
20 - 30	Prob	0.2561^{ns}	0.6127^{ns}	0.9607^{ns}
	F	2.48	0.52	0.04

S.S=Sum of squire, M.S = Mean of squire, Prob. =probability and ns = no significant.

Table 6 The soil moisture content affected by two shanks working mode at different depth (%)

Source	Depth1	Depth2	Depth3
Vibrating shank	8.64^{a}	8.80^{a}	11.25^{a}
No-vibrating	8.83^{a}	8.91^{a}	11.53^{a}
Before tillage	9.21	9.19	12.1

(Mean followed by the different letter differ significantly according to Duncan's test $P<0.05$)

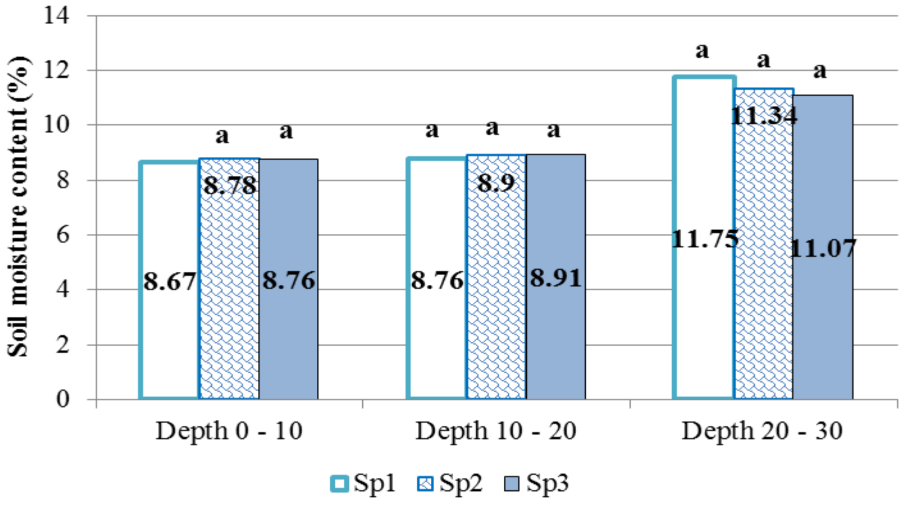

Fig. 6 Soil moisture content as affected by different forward speeds. Data with the following same letters indicates the no-significant at the level of $P < 0.05$.

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