

PERFORMANCE CHARACTERISTICS OF A PTO-POWERED ONE-WAY DISK PLOW

M. H. RAOUFAT AND M. AZADBAKHT¹

Department of Farm Machinery, College of Agriculture, Shiraz University,
Shiraz, I.R. Iran.

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ABSTRACT

A PTO-powered one-way disk plow was developed to plow paddy fields with excessive soil compaction. The plow was operated in the rice fields after paddy harvest at peripheral disk velocity to ground speed ratios of 3.0, 2.2 and 1.7 at four soil depths. The factorial experiments were conducted as randomized complete block design in three replications. The performance of the powered disk plow was compared to that of the standard disk plow and pre-till soil conditions. The study indicated that the rotary plow markedly decreased aggregate size since the clod fineness was improved by an average of 29.5% compared to the standard disk plow. Smaller clod mean weight diameters (MWD) were obtained at low levels of velocity ratio (higher tractor speeds). The cross section of the soil tilled with the powered plow exceeded the standard disk by an average of 25% for the speed range studied. The disturbed cross-sectional area was larger at higher speeds. Average cone index reductions of 50 and 63 % were determined in depth ranges 10-15 and 15-20 cm, respectively. It was found that an increase in the tractor speed was associated with corresponding decrease in the soil cone index at 10-15 and 15-20 cm depth ranges. Therefore, for better penetration, the tractor speed should be kept at the

1. Assistant Professor and former Graduate Student, respectively.

fastest possible level. The maximum working depth was 16 cm for the standard disk plow but was 20 cm for the powered disk plow, i.e., a 25% increase. The study revealed that the powered disk plow resulted in a significant decrease in soil cone index and improvement of other factors as compared to pre-tillage conditions and the standard disk plow.

Key words: Paddy field, Powered disk plow, Soil pulverization.

تحقیقات کشاورزی ایران

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ویژگی های عملکرد مزرعه ای گاو آهن بشقابی یکطرفه موتور گرد

محمد حسین رئوفت و محسن آزاد بخت

به ترتیب استاد یار و دانشجوی سابق کارشناسی ارشد بخش ماشین های کشاورزی دانشکده کشاورزی دانشگاه شیراز - شیراز جمهوری اسلامی ایران.

چکیده

در مطالعه حاضر یک دستگاه گاو آهن بشقابی یکطرفه موتور گرد سه خیشه سوار به منظور انجام خاک ورزی در اراضی پس از برداشت شلتوک که با مشکل سختی بیش از حد خاک روبرو می باشند طراحی و ساخته شد. مشخصات تراکتور معمول در منطقه و چگونگی خاک ورزی مورد نیاز به منظور کشت گندم در این گونه اراضی در امرطراحی مورد توجه قرار گرفت ارزیابی گاو آهن مذکور در سه نسبت سرعت (سرعت پیرامونی بشقاب به سرعت پیش روی) و چهار محدوده عمق در قالب آزمایش های فاکتوریل در یک طرح بلوک کامل تصادفی در سه تکرار انجام گردید. نتایج حاصله از

عملکرد گاو آهن موتور گرد با نتایج حاصله از گاو آهن بشقابی معمولی و شرایط خاک قبل از خاک ورزی مورد مقایسه قرار گرفت. گاو آهن موتور گرد به طور چشمگیری اندازه کلوخه ها را کاهش داده و قطر متوسط کلوخه ها نسبت به گاو آهن معمولی ۲۹/۵ درصد کاهش یافته بود. ضمناً در نسبت های سرعت کمتر (سرعت بیشتر پیشروی) اندازه متوسط وزنی کلوخه ها کاهش یافته بود. خاک ورزی با دستگاه جدید افزایش سطح مقطع خاک ورزی شده را موجب گردید. ضمناً سطح مقطع خاک ورزی شده در سرعت های بالاتر افزایش یافت. گاو آهن موتور گرد به طور متوسط نمایه مخروطی را برای محدوده های ۱۵-۲۰ و ۲۰-۱۵ سانتی متری عمق خاک به ترتیب برابر ۵ و ۶۳٪ کاهش داد. همچنین افزایش سرعت پیشروی موجبات کاهش نمایه مخروطی برای دو محدوده یاد شده را موجب گردید. بدین ترتیب برای نفوذ بهتر دستگاه در خاک بایستی سرعت پیشروی تراکتور را در حد اکثر ممکن انتخاب نمود. حداکثر عمق خاک ورزی برای گاو آهن بشقابی معمولی ۱۶ و برای گاو آهن موتور گرد برابر ۲۰ سانتی متر بود. بدین ترتیب گاو آهن جدید افزایش عمق خاک ورزی، کاهش نمایه مخروطی خاک، و بهبود سایر ویژگی های مورد مطالعه را در مقایسه با گاو آهن بشقابی معمولی و شرایط خاک قبل از خاک ورزی موجب گردیده است.

INTRODUCTION

Soil preparation for cropping after harvesting paddy rice is a difficult operation due to severe soil compaction. Penetration of conventional plowing tools such as moldboard or standard disk plows in such soils is almost impossible. The main reasons for increased soil compaction are the puddling operations prior to transplanting rice seedlings and the formation of hard-pan layers below the tillage depth. Power-driven soil tillage tools are needed to overcome the severe soil firmness in such fields. Getzloff and Soehney (2) studied forces and power requirements of freely rotating and driven disk plows

on hard clay loam soil found 30% reduction in draft forces with a peripheral disk velocity to ground speed (PDV/GS) ratio of 1.3. Soehney (6) observed more soil pulverization with a powered disk than a freely rotating disk. Young (8) found similar results with respect to draft and power requirements to those reported by Getzloff and Soehney (2). In addition, Young (8) found better pulverization and excellent penetration with a powered disk harrow. More recently, Singh *et al.* (5) developed a powered one-way plow and tested it in a paddy field having silty-clay loam soil with 30% moisture content. They operated the plow at ground speeds of 2.77, 4.31, 5.14 and 6.88 km h⁻¹ with PDV/GS ratios of 2.62, 1.90, 1.77 and 1.42, respectively. They obtained better pulverization with 43.5 mm clod mean weight diameter (MWD), more volume of soil tilled, higher depth of cut, less tractor drive wheel slip and less draft resulted with low PDV/GS ratio.

Rice, one of the major crops in the Fars province, Iran, is planted in fine-and medium-textured soils. The main crop rotation is rice-wheat. In contrast to rice cultivation, land prepared for wheat should be well-drained and with no blockage to water infiltration. After harvesting rice, the field is full of stubble and can not be prepared satisfactorily for wheat sowing with the conventional implements. The main objective of the present study was to evaluate the performance of a power take-off (PTO) driven disk plow by comparing it to standard disk plow.

MATERIALS AND METHODS

Considering the needs of farmers for a plow to till the compacted soil after paddy harvesting, it was decided to design and develop a powered one-way disk plow suitable for small size rice-farms in Fars province, Iran. The power source considered was a 53 kW Massey Ferguson tractor (MF-285) commonly used on local farms. The main components of the disk plow developed were a chassis, a rotating shaft incorporating five 610-mm diameter disk blades, spaced at 230 mm intervals and with a rear wheel to absorb side-force (Fig. 1).

Performance characteristics of a PTO-powered one-way disk plow

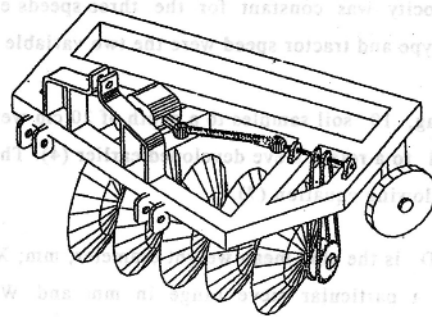


Fig. 1. Schematic diagram of the powered one-way disk plow developed.

The disk concavity and the plow working width were 100 and 1000 mm, respectively. The working and tilt angles of the new plow were 20° and 0°, respectively. The weight of the powered plow per disk blade was 95 kg.

After completion of preliminary tests and settings, field trials were conducted to evaluate the performance of the plow and assess the changes in the soil physical properties compared to pretilled and standard disk plowed soil conditions. The experiments were conducted in Kooshkak Research Farm of Shiraz University located in North-West of Shiraz, Iran. The tests were carried out after paddy harvest in fall 1998; the soil was silty-clay, firm, and covered with heavy paddy residues. The standard disk plow had three disk blades, 700 mm dia. with a total working width of 1000 mm. The disk and tilt angles of this plow were 45° and 25°, respectively. The weight of the standard disk plow per disk blade was 127 kg. The two plows were operated at three tractor forward speeds of 3.75, 5.0 and 6.25 km h⁻¹ along the experimental plots. The factorial experiments were conducted as randomized complete block design with three replications. The size of each plot was 70×3 m in which soil cone index, clod MWD and cross-sectional area of the soil disturbed were measured and recorded. Considering the constant rotational velocity of the plow disks, the ratios of peripheral disk velocity to tractor forward speed were calculated as 3.0, 2.2 and 1.7 for the forward speeds of 3.75, 5.0 and 6.25 km h⁻¹, respectively. Since the

peripheral disk velocity was constant for the three speeds envisaged for this research, the plow type and tractor speed were the two variable effects of which were investigated.

After plowing, 10 soil samples to a depth of 20 cm were collected from each plot and fed to a rotary sieve developed earlier (4). The clod MWD was calculated by the following equation (7).

$$MWD = \sum X_i \cdot W_i \quad [1]$$

where: MWD is the clod mean weight diameter, mm; X_i is average clod diameter in a particular sieve range in mm and W_i is the weight of aggregates in the size range i , as a fraction of total dry weight of sample analyzed.

After completion of the plowing operation in each plot, a soil profile-meter was used to measure the tilled depths across the plowing width in 10 locations selected randomly. The data were used to calculate the cross-sectional area of the disturbed soil.

An SP-1000 Bush soil recording penetrometer was used to measure the soil cone index in each plot, 12 insertions per each depth range were accomplished; the sampling spots were randomly selected. Penetrometer readings were taken at four depth ranges of 0-5, 5-10, 10-15 and 15-20 cm, both before and after tillage operations. The average soil moisture content of experimental plots was 14% db at the 0-20 cm depth range. Comparison of mean values of the MWD of the soil sampled to a depth of 20 cm was performed by Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

1. Effects of Plow Type and Forward Velocity on Soil Pulverization

The analysis of variance on soil MWD data indicated that, plow type and forward velocity had significant effects on the soil pulverization, however there was no significant interaction between plow type and forward velocity. The comparison of mean values indicated that soil tilled with the powered plow had significantly lowered MWD compared to that tilled by the standard disk plow

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(Table 1). The results are similar to those obtained by Soehney (6) who observed more soil pulverization with powered disk whereas large clods resulted in freely rolling disk. Young (8) also found better pulverization and excellent penetration with powered disk harrow. Table 1 also shows that the clod MWD decreased from 159.7 mm to 82.5 mm as the PDV/GS ratio of the powered plow decreased from 3 to 1.7. Sing *et al.* (5) observed that clod MWD decreased from 54.0 mm to 43.5 mm as PDV/GS ratio decreased from 2.62 to 1.4. A similar trend was observed for the plots tilled by the standard disk plow. Comparison of the two sets of data reported in Table 1 indicates that soil tillage by the powered plow reduced the clod fineness by an average of 29.5% as compared to the standard disk plow. In general the clod MWD was the lowest for the soil tilled by the powered plow at the highest tractor forward speed mainly due to frequent collision of the soil clods with each other and the disk blades. Similarly, Gupta and Pandey (3) reported that the improved quality of soil puddle with an increase in rotor speed was presumably due to decrease in bite length and increase in throwing velocity of the soil mass.

Table 1. Comparison of mean values of soil mean weight diameter (MWD) as influenced by plow type and PDV/GS ratio at 0-20 cm depth range.

Plow type	PDV/GS			Average
	3	2.2	1.7	
SDP ¹	225.3Aa [†]	164.3Ba	104.4Ca	164.7a
RDP ²	159.7Ab	106.1Bb	82.5Ca	116.1b
Average	192.5A	135.2B	93.4C	

†. Means within each row (with small letters) or column (with capital letters) followed by the same letter are not significantly different at P<0.01.

1. SDP: Standard disk plow. 2. RDP: Powered one-way disk plow.
 PVD: peripheral disk velocity. GS: Ground speed.

2. Effects of Plow Type and Forward Velocity on Soil Disturbance

Only the plow type had significant effects on this measurement. The cross section of the soil tilled by the powered plow was larger compared to that tilled by the standard disk plow for all the speed ranges considered (Table 2)

Furthermore, the cross-sectional area disturbed was generally larger at lower forward speeds for both plow types.

Table 2 shows the relationship between PDV/GS ratio and the cross-sectional area of the disturbed soil for both plows. The higher the ratio, the larger the soil disturbance. Data on soil disturbance due to tilling with powered plow has not been reported previously. Singh *et al.* (5) measured volume of soil worked by the powered plow at four PDV/GS ratios. The volume of the soil worked increased from 41.27 m³ to 43.95 m³ as the PDV/GS ratio decreased from 2.62 to 1.40. In the present work, the volume of the soil worked was not measured, but the results show that cross-section of the disturbed soil increased as the PDV/GS ratio increased; the same trend was noticed for the standard disk plow. Table 2 also shows that as the speed ratio increased, the powered plow disturbed the soil more aggressively compared to the standard disk plow.

Table 2. Comparison of mean values of disturbed soil cross-sectional area as influenced by plow type and PDV/GS ratio at 0-20cm depth.

Plow type	PDV/GS			Average
	3	2.2	1.7	
SDP ¹	1690Aa [†]	1310Aa	1198Ba	1399a
RDP ²	1849Ab	1542Ab	1239Ba	1543b
Average	1769A	1426A	1218B	

†. Means within each row (with small letters) or column (with capital letters) followed by the same letter are not significantly different at P<0.01.

1. SDP: Standard disk plow. 2. RDP: Powered one-way disk plow.
 PVD: Peripheral disk velocity. GS: Ground speed.

The maximum working depth was 16 cm for the standard disk plow but was 20 cm for the powered disk plow, i.e, a 25% increase (Fig. 2). Therefore, it can be concluded that the powered plow disturbed the soil to a greater depth than the standard disk plow. Also the powered plow cut a much larger cross-section than the standard disk plow.

3. Effects of Plow Type and Forward Velocity on Soil Cone Index:

The plow type and working depth had a significant effect on the soil cone index, whereas the forward velocity did not. A significant V×P interaction was observed.

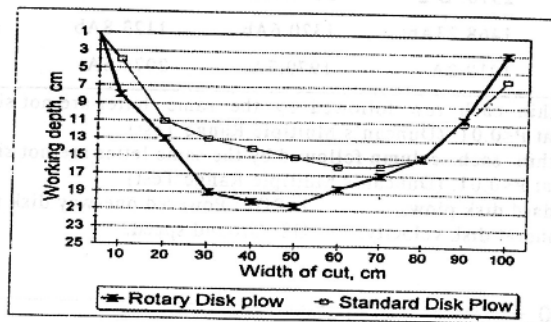


Fig. 2. Soil profiles tilled by the standard and powered one-way disk plows at tractor forward speed of 6.25 km h^{-1} .

Data presented in Fig. 3 compares the mean soil cone indices in the four plowing depth ranges in plots tilled with both plows at three speed ratios. The soil tilled with the powered plow had a lower cone index than the standard disk plow. At increased soil depths, plowing with the powered plow was more effective in reducing soil strength (Fig. 3). For example, at a speed of 6.25 km h^{-1} , the cone indices for the soil (at 14% mc db) tilled with the standard disk plow at PDV/GS ratio of 1.7 were 1501 and 3025 kPa for depth ranges 10-15 and 15-20 cm, respectively, whereas the corresponding values for the powered disk plow were 755 and 1123 kPa, respectively. The average reduction of the cone indices was 50% and 63% at 10-15 and 15-20 cm, respectively. A similar trend was not observed for the other two depths studied. The mean values of the soil cone index as affected by the plow type and speed ratio are presented in Table 3. The graph emphasizes the significant decrease in cone index when tilling by the powered disk plow as compared to the standard disk plow.

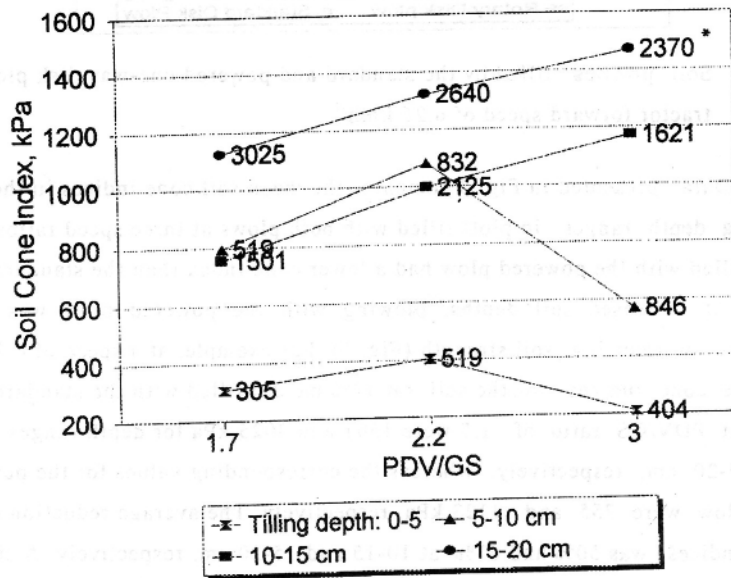
Table 3 Comparison of mean values of soil cone index as influenced by plow type and PDV/GS ratio at 6-20cm depth.

Plow type	PDV/GS			Average
	3	2.2	1.7	
SDP ¹	2370. B [†] a*	2640.7Aa	3025.3Aa	2678.7a
RDP ²	1468.23Ab	1320.6Ab	1123.8Ab	1304.2b
Average	1919.2A	1970.7A	2074.6A	

†. Means within each row followed by the same letter are not significantly different at P<0.01. (Duncan's Multiple Range Test).

*. Means within each column followed by the same letter are not significantly different at P<0.01. (Duncan's Multiple Range Test).

1. SDP: Standard disk plow. 2. RDP: Powered one-way disk plow.
 PVD: Peripheral disk velocity. GS: Ground speed.



* Cone index of the soil tilled by standard disk plow corresponding to each data point

Fig. 3. Relationship between soil cone index and PDV/GS ratio for the soil tilled by the powered one-way disk plow.

The effects of plowing with the powered and standard disk plows on the soil cone index at four depth ranges, three tractor forward speeds and the pre-till soil cone indices for the given depth ranges are shown in Fig 4. The graph suggests that to obtain more tool penetration into the soil the tractor forward speed should be kept at the highest possible (lowest PDV/GS ratio). This is especially true for the two depth ranges 10-15 and 15-20 cm. The results are in good agreement with those reported by Singh *et al.* (5) who observed that bulk density was decreased from 1.26 to 1.18 g cm⁻³ as PDV/GS-ratio decreased from 1.62 to 1.42. The soil cone index significantly decreased due to plowing relative to soil conditions before tillage (Fig. 4). This may be due to the decrease in bite length of the soil tilled at high velocity ratios.

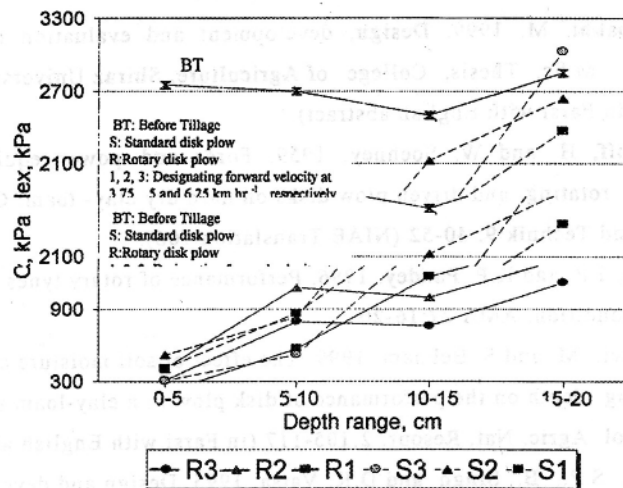


Fig. 4. Soil cone index after tillage by powered one-way and standard disk plows at four soil depth ranges and three speeds compared to soil conditions before tillage.

CONCLUSIONS

Based on the experimental results, the following conclusions are drawn:

1. To obtain finest soil clod size, the powered plow should be used with the lowest PDV/GS ratio possible.

2. Larger cross-section at increased depth is another advantage of the powered plow compared to the standard disk plow. For better results the plow should be operated at the highest PDV/GS ratio.
3. Desirable tool penetration can be obtained at the highest tractor forward speed possible.
4. The new plow can successfully loose the soil to a depth suitable for wheat production after rice in rice-tract.
5. The new plow can markedly improve the soil physical conditions. Reduced power requirement and wheel slip reported elsewhere (2, 5, 8) are other advantages of the powered plow.

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