International Journal of Agricultural Technology 2016 Vol. 12(5):851-858
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Determination and Comparison of Drill Seeder Draft in Different Engine Rotation Speed, Gear Ratio and Working Depth

Jahanbakhshi, A.[1], Tajari, B.[1], Razdareh, S. H.[1] and Kheiralipour, K.[2*]

[1]MSc. Student,Mechanical Engineering of Biosystems, Ilam University, Ilam, Iran.
[2]Assistant Professor, Mechanical Engineering of Biosystems, Ilam University, Ilam, Iran.

Jahanbakhshi, A., Tajari, B., Razdareh, S. H., Kheiralipour, K. (2016). Determination and comparison of drill seeder draft in different engine rotation speed, gear ratio and working depth. International Journal of Agricultural Technology 12(5):851-858.

Abstract Knowing the draft force is one of the primary necessities for designing, manufacturing and operating of agricultural implements. In this research, the effect of the tractor engine rotation speed (at three levels: 1000, 1500 and 2000 rpm) and gear ratio (at three levels: 1, 2 and 3 high) and implement working depth (at three levels: 4, 7 and 12 cm) on draft force of a drill seeder was investigated using a hydraulic dynamometer in a clay loam soil, Karaj, Alborz. Each treatment was considered in three replications, totally 27×3 experiments. The obtained data were analyzed as factorial test based on randomized complete design. The results showed that the effects of engine rotation speed, gear ratio, working depth and their interactions effects on draft were significant at 1 % probability level. The draft force was increased by increasing of engine rotation speed, gear ratio and working depth. The minimum draft was obtained in working depth of 4 cm, 1st high gear and engine speed of 1000 rpm and the maximum draft was in working depth of 12 cm, 3rd high gear and engine rotation speed of 2000 rpm with amount of 10.69 and 14.22 kN, respectively.

Keywords: Draft force, Drill seeder, Gear ratio, Engine rotation speed, Working depth, Massey Ferguson 399 Tractor.

Introduction

The information about implements' draft is essential for designing agricultural implements, calculating the required power in mechanized cultivations and required drawbar power to manage the agricultural operations.The characteristics of tractor and agricultural implement, working depth and soil type and its condition the main factors affecting the equipment draft force. The sandy soils have higher strength compared to the loamy soils. The working depth and width, tool shape, arrangement of devices and forward speed are the factors that will affect the strength. Increasing forward speed leads to increase the draft force of tillage and planting devices (Kepner, *et al*., 1978).

[*]**Corresponding author:** Jahanbakhshi, A.; **Email:** kamrankheiralipour@gmail.com

Janoub *et al*. (1998) determined the required draft force by the initial tillage tool implements on sandy loam soil and reported a significant increase for all devices with increasing depth. Taniguchi *et al*. (1999) investigated the effect of forward speed and different attachments of moldboard plow in Japan. Their results showed that the force increased with increase of forward speed. In a study, the effect of depth and speed on tensile strength of three types of primary tillage implements was investigated. With increasing of depth and forward speed, the results showed a significant increase in draft of all equipment (Naderloo et al, 2008). The relationship between working depth, tillage operation speed and draft force of disc plow was evaluated by Olatonji et al, 2009. Their results showed the draft force required to perform the tillage operations was increased with increasing of both operation parameters. Naghdian and Abdollahpoor (2014) obtained same results for moldboard plow.

The aim of this study was to investigate the effect of different working conditions on the draft force of drill seeder. For this purpose, the draft force of the seeder was determined and compared in different tractor engine rotation speeds, gear ratios and also working depths of the planter.

Materials and methods

The present research was conducted in the fields of Imam Khomeini Research Center of Karaj, Alborz. A farm with area of 50×50 m^2 with uniform topography after primary tillage was considered for experiments. Before starting the experiments, soil type of farm was determined by USDA soil texture triangle as clay loam (28% sand, 39.4% silt and 32.6% clay). The soil moisture content in depth of 15 cm was calculated by Eq. 1 (Srivastava *et al*., 2006).

$$W = \left(\frac{W_t - W_S}{W_S}\right) \times 100 \qquad (1)$$

Where W is dry basis moisture content (%) and W_t and W_s are the mass of wet sample and dried sample (g), respectively. By Eq. 1, the farm moisture content was calculated as 14% dry base.

In this study, a conventional six-row tractor mounted drill seeder (Modeel: FK2.5-15/3, Hamadan Machine Barzegar Co., Hamedan, Iran) with 2.70 m working width was considered. The maximum working depth of the drill is 15 cm that can be adjusted according to different seeds.

Figure 1. The studied drill seeder.

The planter was equipped by shovel furrow openers and iron covering devices. To operate the drill, it was connected to a 3140 John Deer tractor and pulled by a MF 399 tractor (Table 1).

Table 1. Technical specifications of used tractors.

Tractor Model	Manufacturer	Number of gears	Number of cylinders	Mass (Kg)	Power (hp)
MF399	Iran Tractor Manufacturing	12f, 4r	6	3586	110
JD3140	John Deere	16f, 8r	6	3991	97

The tests were conducted as factorial experiments in a completely randomized design with three replications. Examined factors in this research were engine rotation speed (1000, 1500 and 2000 rpm), gear ratio (1, 2 and 3 high) and working depth (4, 7 and 12 cm).

For measuring the draft force required for pulling the implements different type of dynamometers can be used (Kirisci *et al*. 1993; Chen *et al*., 2007). To determine the draft force in the present study, the hydraulic dynamometer and the two tractors were used (Naderloo *et al*., 2008; Ataee, 2004; Naghdian and Abdollahpoor, 2013) as shown in Fig. 2.

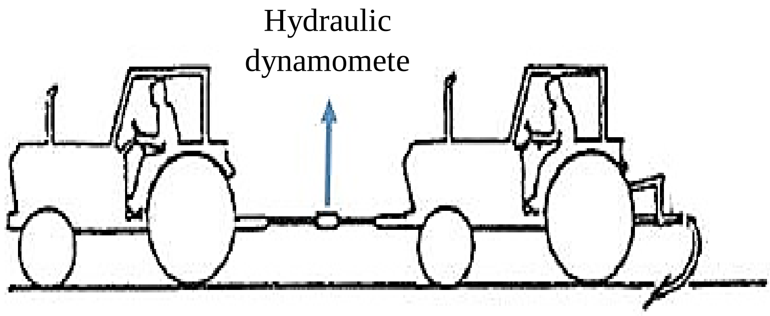

Figure 2. The connected hydraulic dynamometer between two tractors.

Using hydraulic dynamometer, test tractor should be used as pulling tractor and the tractor attached to it must be used as carrier tractor. Force applied by pulling tractor is gross draft force, because it includes the rolling resistance of the pulling tractor and net draft force of the implement. To calculate the net draft force, the rolling resistance of the carrier tractor must be mines from the gross drat force. In this regard, to calculate the rolling resistance of the carrier tractor, the mentioned tractor must be pulled by pulling tractor and the force required to pull it must be recorded by the dynamometer.

In this study, to determine the draft force, a hydraulic dynamometer with a capacity of 10 tons was used. The drill seeder was attached to John Deere tractor (carrier) and Massey Ferguson tractor (pulling tractor) was used to pull the carrier tractor. The dynamometer was attached between the two tractors (Fig. 3.). To determine the draft force in each engine rotation speed and gear ratio, firstly the drill was put higher than soil surface using the hydraulic arms of carrier tractor and then the draft force was determined as rolling resistance of carrier tractor (John Deere). Then the drill was operated in a specific working depth and the gross draft force was determined. The difference of recorded grass forces and rolling resistance was obtained as net draft force of drill seeder.

Figure 3. The pulling (left) and carrier (right) tractor.

The recorded data by the dynamometer was based on Lb/in^2. This data was converted to N/m^2. Then, the obtained data was multiplied by the cross section area of the dynamometer piston (0.010048 m^2) to calculate the draft force (N). To analyze the draft forces in different operation conditions, Excel 2013 and SAS 9.1 Software were used.

Results and discussion

The results of the present research have been listed in Table 2. In this table, GR is gear ratio, WD is working depth and ERS is engine rotation speed factor.

Table 2. The effect of different factors and their interactions on draft force of drill seeder.

Factor	df	Sum Squares	Mean Squares
ERS	2	13.041	6.520*
GR	2	4.788	2.394*
WD	2	37.175	18.587*
ERS×GR	4	0.811	0.202*
ERS×WD	4	0.286	0.071*
GR×WD	4	0.510	0.127*
ERS×GR×WD	8	0.551	0.068*
Error	54	0.433	0.00802
Total	80	57.599	-

*significant at 1% probability level.

According to Table 1, the effect of engine rotation speed and gear ratio of MF 399 tractor, working depth of the drill and their interactions on the daft force of the drill was significant at level of 1% probability. With 99% certainty, one can say that there is a significant difference between the averages of draft force in different operating conditions. The average draft forces in the engine rotation speed of 1000 rpm have been shown Fig. 4.

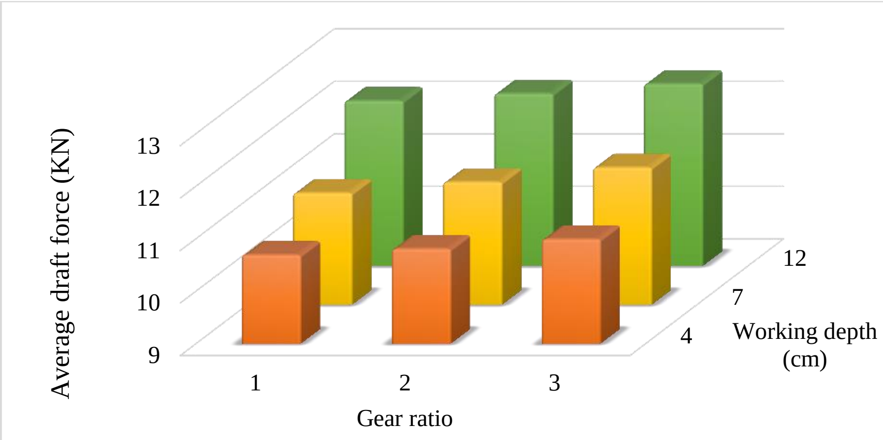

Figure 4. The averages draft forces in engine rotation speed of 1000 rpm.

As seen in Fig. 4, the draft force was increased with increasing of working depth and gear ratio. Increasing the working depth shows greater changes in draft force compared to different gear ratios. This is due to increase of soil resistance by increasing of the shovel working depth. The highest and lowest draft force was obtained in 3rd gear and depth of 12 cm and 1st gear and depth of 4 cm which were equal to 12.46 and 10.69 kN. This result is similar to the findings of Naderloo *et al.* (2008).

The average draft force in engine rotation speed of 1500 rpm and in different depths and gear ratios have been shown in Fig. 5.

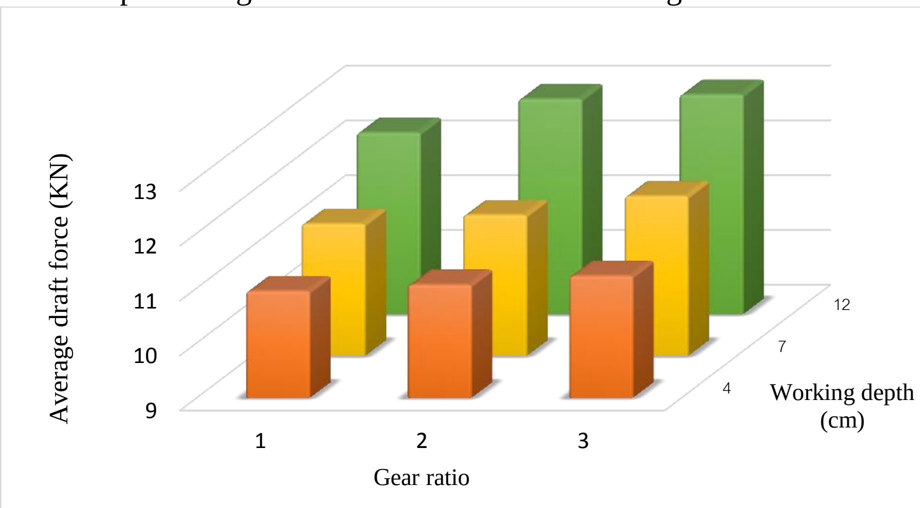

Figure 5. The changes of draft force in engine rotation speed of 1500 rpm.

With increasing of working depth and gear ratio, the draft force was increased in Fig. 5. As can be seen in this figure, at working depth of 12 cm and 1st gear, the average draft force was lower than the corresponding values in 2nd and it was lower than that of 3rd gear.

The draft forces in engine rotation speed of 2000 rpm and in different depths and gear ratios have been shown in Fig. 6.

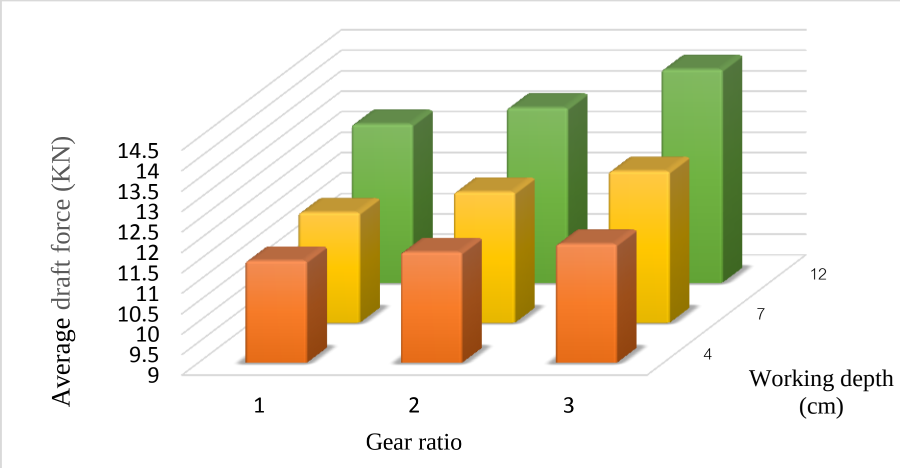

Figure 6. The various draft forces in engine rotation speed of 2000 rpm.

As indicated in Fig. 6, with increasing of working depth and gear ratio at engine rotation speed of 2000 rpm the draft force was increased same as other engine rotation speed. Also according to Fig. 4-6, the draft forces in all conditions increased with increasing of engine rotation speed.

This result is due to increasing of acceleration exerted to soil that is proportional to the squared forward speed of the implement. Increasing the soil acceleration increases the draft force for at least two reasons. Firstly, due to increasing of normal loads exerted to the involved tools by soil and thereby increasing of the frictional resistance and secondly due to the kinetic energy applied to the soil. This result is similar to that of Kapner *et al* in (1987) and Rashad Sadaghi and Laghvi (2009).

In order to increase mechanization level and degree and also to reach sustainable agriculture, the quantity and quality of agricultural machinery must be reached to an optimum level (Asadi *et al.*, 2010). So, the results of this research can be useful for choosing the proper implements for a specific region and consequently the proper distribution of tractors and agricultural machinery and supplementary parts, establishing the operation conditions, managing the fuel consumption and finally to improve the mechanization level and degree. Also, the obtained data can be utilized to model the draft force of the seeders in different operation and planting conditions.

Conclusion

The draft force of drill a seeder was determined and compared in different levels of gear ratio, engine rotation speed and working depth in clay loamy-soil. After data analysis, the obtained results showed that draft force were significantly different in different treatments. By increasing each factor, the draft force was increased. The highest draft force (14.22 kN) was in 12 cm working depth, 3rd gear and 2000 rpm engine rotation speed and the minimum value (10.69 kN) was observed in working depth of 4 cm, 1st gear and engine rotation speed of 1000 rpm.

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(Received: 9 November 2015, accepted: 5 September 2016)