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Influence of Tillage Depth and Plough Speed on Performance of Primary Tillage Tools

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***Abstract* - In India near about 60% population is engaged in agriculture. Soil loosening is a primary method of cultivation before seeding. There are number of tillage tools used for primary cultivation i.e. cultivators, rotary tillers, moldboard plough and chisel plough, rotavators etc. During soil cultivation wear occurs due to interaction of tillage implement and soil particles, which in turn decreases tillage quality and increase draft forces and fuel consumption of tractor. Tool wear reduces farmer's efficiency, costing millions of dollars per year to Nation's economy. Knowledge of tillage depth and ploughing speed save the tillage time and improves tractor efficiency. In this study it is attempted to relate the influence of tillage depth and tractor speed on primary tillage tools.**
***Keywords*: Soil Loosening, Tillage Tools, Draft Forces, Chisel Plough, Tillage Depth**

I. INTRODUCTION

In India agriculture is the single largest sector, acts as a growth engine by ensuring food and nutritional security to the masses besides providing raw-materials to agro-based industries and also providing employment and thereby income to the rural folk of the State and Indian Economy. India had a large and diverse agricultural sector, accounting, on average, for about 15% of GDP and 11% of export earnings (U.S. Dept. of Agri., 2014). Preparation of land with tillage tools provides more reliable and enables the farmers to achieve his target at right time. Various tillage tools are used for primary cultivation. The main objective of primary tillage by different methods is to loosen the soil, weed control and to bury corps residue (Hakansson *et al.,* 1998).

During cultivation tillage tool rubs by soil particles, causes wear of implements. The wear rate on tillage tools is mostly affected by soil-tool pressure distribution. It becomes more serious as energy costs get higher because farm machinery contributes the major portion of the overall cost of crop production (Askari *et al.,* 2017). Tillage depth and tractor speed are most important operational parameters that influence the draught forces. Khushwaha and Linke (1996) reported that draught requirements of tillage implements as a function of operating speed is a significant criterion for evaluating tillage tools by field or laboratory. The enhancement of the operational efficiency of tractors has been a subject of considerable research. Chancellor and Thai (1984), Grogan *et al.*, (1987) and Smith (1993) states that up to 20% potential savings could be achieved by gear-up throttle-down method.

Another technique to enhance the operational efficiency is exact selection of tractor and tillage implement. Furthermore, Michel *et al.,* (1985) reported that proper selection of an efficient tool, such as chisel ploughshare rather than mouldboard plough, can cut down the tillage energy requirements up to 40%. Studies on influence of tractor speed and tillage depth were conducted by many researchers (ASAE., 1993; Khushwaha and Linke., 1996; Summers *et al.,* 1986). Furthermore, Al-Jonabi and Al-Suhaibani (1998) developed the general equation for primary tillage tools (Mouldboard plough, three chisel ploughs of different shanks, disc plough and an offset disc harrow). The researchers reported that tractor speed and tillage depth had significant linear effect on draught of all tillage tools. It is observed that due to increase in speed or tillage depth, draught forces increases linearly. The increase in draught forces reduces the tractor efficiency and increases more fuel penalties, which affect National economy badly.

II. FACTORS AFFECTING THE PERFORMANCE OF PRIMARY TILLAGE TOOLS

A. Effect of Tractor Forward Speed on Draught Requirement

Tractor forward speed is most prominent operational parameter that influences the draught forces, which directly affects the tillage quality and tractor fuel consumption. Draught requirements were changed due to increase or decrease with forward speed and type of implement used same order of magnitude has been found by Molari *et al.*, (2017). The researchers found that with increase in speed at an optimum level (4.2 Km/h) the soil pressure increases linearly, after that decrease with increase in speed.

Furthermore, Taniguchi *et al.*, (1999) observed the effect of forward speed and optimal plow attachments on draft forces and soil manipulation. This research was conducted in summer 1997 and forward speeds ranging from 1.0 to 4.0 m/s with an interval of 0.5 m/s. Fig. 1 shows the speed-force relationship of moldboard plough. The linear relationship were observed in Fig.1, same results were found by other researches (Al-Jonabi & Al-Suhaibani.,1998; Molari *et al.*, 2017; Al-suhaibani *et al.*, 2006; Aykas *et al.*, 2004; Stafford., 1979; Simens *et al.*, 1965). Author reported that this kind of speed-draft relationship results mainly from the forces required to accelerate the soil blocks and to prevail over the shear resistance.

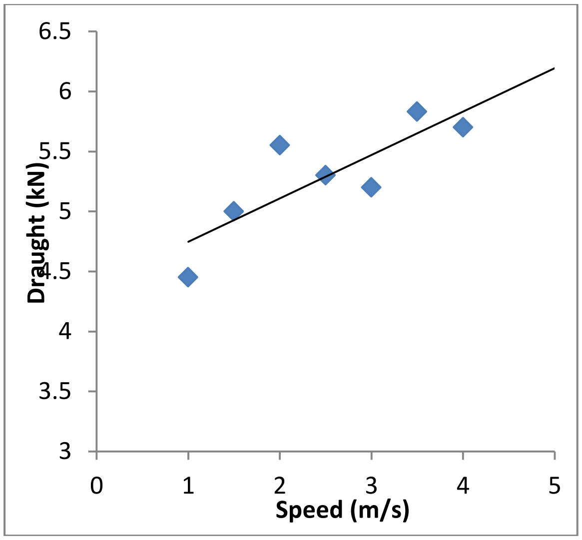

Fig. 1 Relationship between travel speed and draft force (Taniguchi *et al.*, 1999)

Al-Suhaibani & Al-Jonabi.,(1997) examined the effect of tillage speed and depth on draught of chisel plough, moldboard plough, disc harrow and an offset disc harrow at two different sites. From Figures 2-4 shows the variation of draught forces acting on different implements at depth of 100, 150 and 200 mm. It is observed that for the same depth and range of speed, draught force acting on moldboard and disk ploughs were higher than the chisel plough and offset disk harrow. This could be due to the change in shape and size of the implement. The remarkable increase in draught was reported for all the implements due to change in speed and depth of tillage tools.

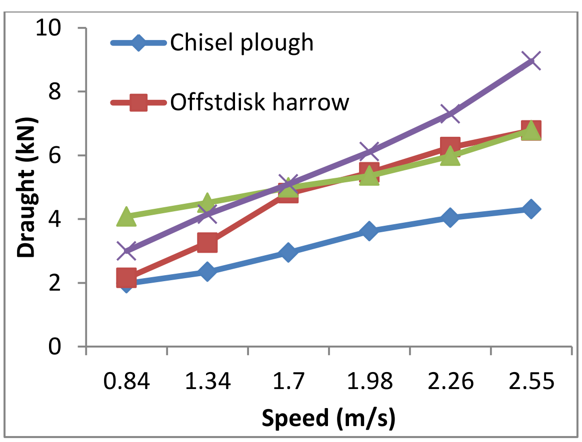

Fig. 2 Variation of specific draught of the four implements at depth of 100 mm (Al-Suhaibani & Al-Jonabi.,1997)

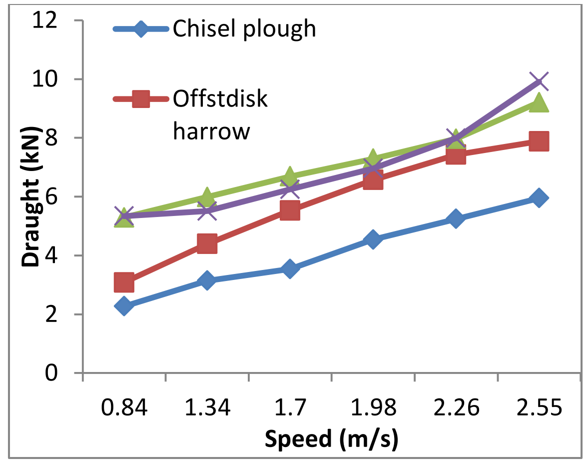

Fig. 3 Variation of specific draught of the four implements at depth of 150 mm (Al-Suhaibani & Al-Jonabi.,1997)

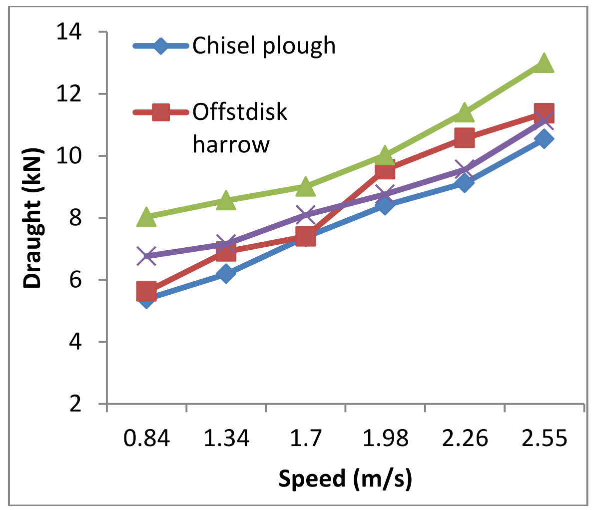

Fig. 4 Variation of specific draught of the four implements at depth of 200 mm (Al-Suhaibani & Al-Jonabi.,1997)

B. Effect of Tillage Tool Depth on Draught Requirement

Another factor influencing the performance of primary tillage tools is ploughing depth of implements, which affects the energy requirements, tillage time and cost. Arvidsosn *et al.*, (2004) studied the effect of moisture content on specific draft forces of chisel plough, moldboard plough and disc harrow. The author found that with decrease in moisture content, the cohesion strength of different soils increases simultaneously and vice-versa. So, here it is observed that moisture content in soil also affects the draught forces. Hakansson *et al.*, (1998) studied the optimal ploughing depth of moldboard plough under various conditions in Sweden. Author used 19 sites in Sweden with ploughing depth about 15, 22 and 28 cm. It is concluded that for sandy soils, relatively deep tillage upto 30 cm is required for physical reasons. Shallow ploughing should be chosen for soils with high content of fine slit. Again for clay soil and clay loam soil deep ploughing is preferred, but due to higher energy requirements and high cost of ploughing, it is not recommended more than 22-25 cm.

Raper (2002) conducted the study on implement type and tillage depth. In this research author conducted study in fall and spring season on disk plough and chisel plough with depth of 7.6 and 15.2 cm. Fig. 5 shows that draught force was considerably higher in spring and fall seasons for deep chisel plough, more than twice than disk plough in every season. Linear characteristics were observed between draught force and tillage depth for chisel and disk plough. The minimum draught force was required by disk-shallow treatment. Draught force increases with increase in tillage depth.

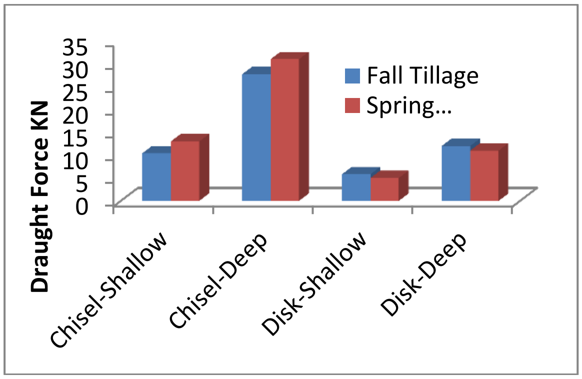

Fig. 5 Relationship between draught force and tillage depth (Raper 2002)

Similar results were also found by others (Owen 1989; Collins & Fowler 1996). Grisso *et al.,* (1996) observed the effect of speed and tillage depth on operating forces on different tillage implements in silty clay loam soil. The effect of tillage depth on draught of chisel plough, tandem disk and field cultivators were found to have more influence than travel speed.

The effect of tillage depth (50, 100 and 150 mm) and tillage speed (0.57 and 1.4 m/s) on soil cutting forces was studied on different implements by Rahman & Chen., (2001). For all tillage implements and tillage speeds, tillage depth is more critical than speed of tillage tool, in terms of influence of draft forces. Draft force behaves linear with working depth. At the same tillage depth, sweep tool requires more draft forces than the disc type tool. Godwin *et al.,* (2007) studied the mathematical model for prediction of draught forces on moldboard plough incorporating the effect of soil properties and ploughing speed. From Figures 6 and 7 it is observed that the linear relationship shows between depth-force and speed-force same results were found by other researches (Kalantari *et al.,* 2014; Naderloo *et al.,* 2009; Sahu & Rehman, 2006; Manuwa, 2009). However, the increase in draught forces is much greater for increase in depth than for increase in speed over typical practical ranges.

C. Effect of Tillage Speed, Depth and Draught Forces on Fuel Consumption

Efficiency of tractor (Fuel consumption) is more important in tillage system. There are many types of primary tillage tools used for soil loosening, requires energy according to the type of tillage tool. According to Natsis *et al.,* (1999) in sandy soils wear of tillage tools increases with increase in moisture content and inversely proportional for loam and clay soils. This increase in wear leads to increase in draught forces of moldboard plough. Author found that with increase in tool edge thickness from 1 to 6 mm, draught forces increased by 62% and fuel consumption increased by 41% and rate of work decreased by 30%.

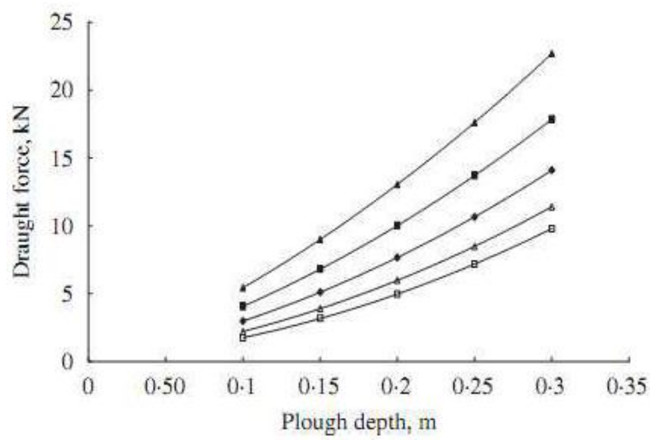

Fig. 6 Effect of depth on predicted draught force for plough for a range of forward speeds □ 1m/s; Δ 2m/s; ♦ 3 m/s; ■ 4 m/s; ▲ 5m/s forward speed (Godwin *et al.,* 2007)

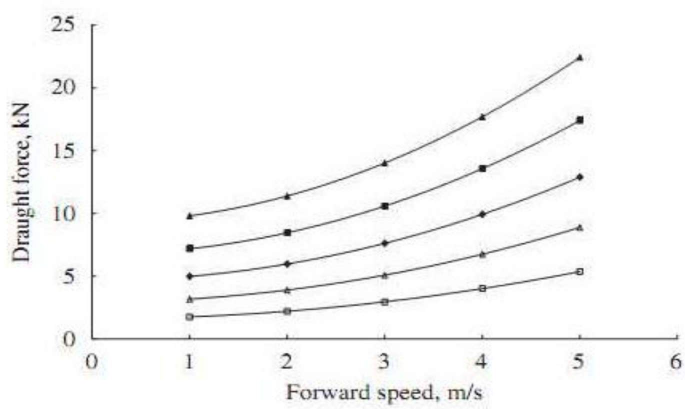

Fig. 7 Effect of tillage speed on predicted draught force for plough for a range of depths □ 0.1m; Δ 0.15m; ♦ 0.2 m; ■ 0.25 m; ▲ 3 m tillage depth (Godwin *et al.,* 2007)

Askari *et al.,* (2017) measured the performance of tractor and tillage implements. Three tillage tools i.e. moldboard plough, disk plough and chisel plough were examined at different forward speeds (1.5, 2.3, 3 and 4 km/h) at 23 cm tillage depth. They found that increase of forward speed results increase in draught forces, causes increase in fuel consumption. Similar results of increase in fuel consumption have also been reported by Kichler *et al.,* (2011) and Kheiralla *et al.,* (2004). These increase in draught forces influence the energy requirements. Fig. 8 shows the influence of speed and implements type on fuel consumption.

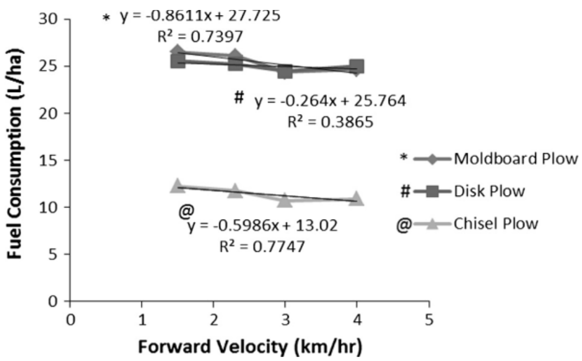

Fig. 8 Relationship between tractor speed, fuel consumption and implement type (Askari *et al.*, 2017)

It is observed from Fig. 8, with increase in tractor forward speed from 1.5 to 3 Km/h, fuel consumption of the tractor decreased. Fuel consumption of tractor further increases with speed increase in speed from 3 to 4 Km/h. Higher fuel consumption was measured for moldboard plough and lowest for chisel plough. Moitzi *et al.*, (2013) studied the influence of working width of moldboard plough (3, 5 and 7 tines) at depth of 25 cm and T-trailed cultivator with working depth of 15 and 25 cm. Fig. 9 shows that performance of tractor increases with the working width of ploughs. Area ploughed by three tine (2*3) moldboard plough is 0.5 ha/h, 1.9 ha/h for five tine (2*5) and 2.3 ha/h for seven tine (2*7). For cultivators at depth of 25 cm is 2.58 ha/h and at depth of 15 cm is 3.7 ha/h.

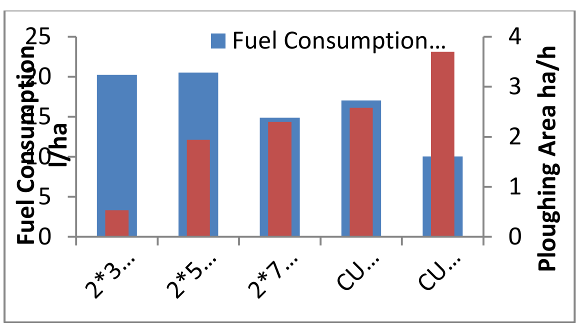

Fig. 9 Shows relationship between plough width, depth, plough type, ploughing area and fuel consumption

Here, from Fig. 9 it is also noticed that with decrease in cultivator depth from 25 to 15 cm, performance of tractor increased. With increase in working depth of the cultivators, the fuel consumption of tractor increases by 70%. Furthermore, effect of tillage depth on tractor fuel consumption was studied by Fathollahzadeh *et al.*, (2010). A moldboard plough was used in this study at 0.15, 0.25 and 0.35 meter depth. In Fig. 10, results showed that tractor with moldboard plough consumes fuel 27.44, 30.09 and 34.06 l/ha for the depth of 0.15, 0.25 and 0.35 m respectively. Fuel consumption of tractor increased 9.66% and 24.10 % when depth of plough increased 0.15 to 0.25 m and 0.15 to 0.35 m respectively. For working depth 0.20 to 0.25 m average fuel consumption 30 l/ha was measured.

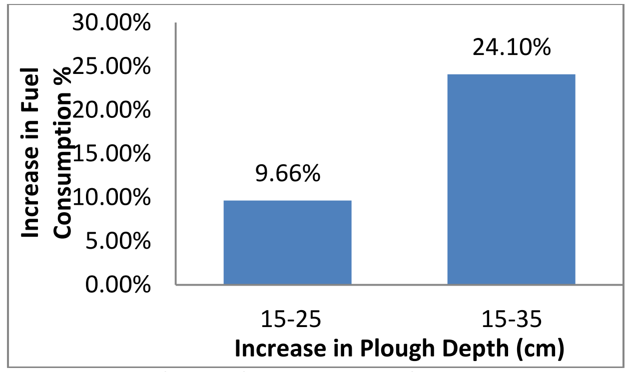

Fig. 10 Influence of working depth on fuel consumption

III. CONCLUSION

1. With increase in tillage depth and speed of tractor, the draught force increases. However, the tillage depth has more significant impact the draught forces as compare to the tractor speed.
2. Tractor speed and working depth of implements influences the draught forces, which in terms influences the fuel consumption.
3. Width of tillage tool is also an important factor which affects the draught forces and fuel consumption, but overall efficiency increased with the increase in width of tillage tool.

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