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Effect of ballast and tire inflation pressure on wheel slip

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ABSTRACT : The experiments were conducted in sandy loam soil in stubble field. Tillage operations were performed using 55 hp tractor with two bottom mouldboard plough and disc plough for four combinations of rear and front ballast (*i.e.* no ballast, 90 daN front, 90 daN front and 200 daN rear, 200 daN rear) and four combinations of inflation pressure in front and rear tires (*i.e.* 90 kPa rear and 140 kPa front, 90 kPa rear and 200 kPa front, 130 kPa rear and 140 kPa front and 130 kPa rear and 200 kPa front tire) to study their effects on wheel slip of tractor for primary tillage operations. The test was conducted at recommended speed of operation 2.7 - 4 km/h. It was found that slip was decreased about 37.76 per cent with increase in ballast from no ballast to 200daN rear ballast condition for primary tillage operations at all inflation pressure.

KEY WORDS : Tractor, Ballast, Inflation pressure, Plough, Tractive efficiency, Sandy loam, Primary tillage

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Noway's most of the agricultural operations are carried out using tractor to improve pull and propulsion. A tractor is also intended to provide transport option with trailer for movement of materials and for field operations to power and propel agricultural heavy draft machines. For field work, the tractor is often used for tasks requiring high drawbar forces at lesser speeds (Alcock, 1986). Thus, the tractor must interface with the implement for providing the operating parameters necessary to meet the performance objectives for field work functions. It is well known that among many tractors, tractor ballast and inflation pressure individually and in combination affect the tractor performance in terms of tractive efficiency, drawbar force, slippage, field capacity etc. Increasing the ballast on pneumatic tires, up to a certain weight, improves the tractor performance as judged by its speed, fuel consumption and wheel slip. Coefficient of traction increases with increase in normal load up to certain value of slip beyond which it decreases with increase in normal load (Sharma and Pandey, 1997). An under ballast tractor experiences tire tread wear due to excessive wheel slip. The effective field capacity is reduced and the farmer spends more time and money in agricultural operations. Therefore the optimum ballasting is required to the minimum power lost during a tillage operation (Casady, 1997). Inflation pressure determines tire stiffness, which has a significant influence on the ground contact area of the tire and pressure distribution over the contact surface. Adjusting tire inflation pressure has been used as a means of reducing soil compaction and improving the tractive performance and drawbar characteristics of agricultural tractors. Effects of inflation pressure on ground contact pressure, pressure beneath the tire, drawbar characteristics as well as tractive efficiency have been considered by many researchers (Raper *et al.*, 1995; Jun *et al.*, 2004). The reduced tire inflation pressure of appropriate tire types can improve the drawbar characteristics and consequently fuel consumption (Smerda and Cupera, 2010).

Keeping this in view, the study was planned to find suitable combinations of tractor ballast and inflation pressure especially for heavy draft operations which require more energy to improve tractor performance. The outcome of the study will help the users and manufacturers to maximize the tractor implement performance thereby increasing the profits from agriculture. The specific objective of this study is to study the effect of ballast and tire inflation pressure on tractive efficiency for primary tillage operations using mouldboard plough and disc plough in sandy loam soil.

METHODOLOGY

The experiments using factorial RBD were conducted at Instructional Farm at College of Technology and Engineering, MPUAT, Udaipur, Rajasthan. The experiments were carried out in stubble field left after harvesting of maize crop. The soil parameters such as moisture content, soil cone index and bulk density were measured at the various locations before the experiments (Table A). These parameters were measured using digital cone penetrometer, digital soil moisture meter and core cutter. Tillage operations were performed using 55 hp (JD 5310)tractor with two bottom mouldboard plough and disc plough (Table B). The various combinations of rear and front ballast (*i.e.* no ballast, 90 daN at front, 90 daN at front and 200 daN at rear, 200 daN at rear) and inflation pressures in front and rear tires (*i.e.* 90 kPa rear and 140 kPa front, 90 kPa rear and 200 kPa front, 130 kPa rear and 140 kPa front, and 130 kPa rear and 200 kPa front tires) were considered for the experiments. These values were based on weight distribution of front and rear wheel for ballast and tractor manufacturer recommendations for inflation pressure. The tests were conducted at recommended speed of operation ranging between 2.7-4 km/h(Indian Standard: 9253, 2001).

Table A : Properties of experimental soil

Soil type	Sandy loam soil
Bulk density, g/cc	1.7
Soil moisture content, per cent (Dry basis)	15
Cone index , kPa	839.16
Previous crop	Maize

Table B : Specifications of primary tillage implements used for experiments

Implement	Width (mm)	Specifications
Mouldboard plough	700	General purpose type, one way plough, two bottoms in the frame each of width 350 mm
Disc plough	800	Two discs each of 630 mm diameter with tilt angle of21°, disc angle 44°

Field layout :

A 150 × 80 m size field was selected for the experiments. Field was divided into two parts of 150 × 40 m size as shown in Fig. A.

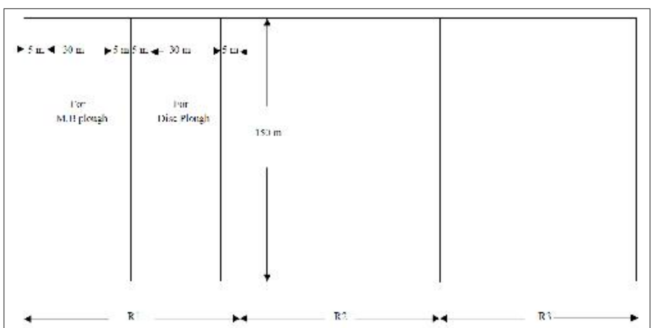

Fig. A : Field layout for experiments

Measurement of different parameters during experiment :

Experiments were conducted to study the effect of different combinations of ballast and inflation pressure on tractive efficiency for two primary tillage implements. Procedure for measurement of different parameters during experiments is given as under.

Speed of travel :

The speed of operation was measured in field by fixing two poles in the test plot 30 m apart. Time required to cover the 30 m distance was measured with the help of stopwatch and speed of operation in km/h was calculated from an average of 5 readings. The forward speed during the experiments usually ranged between 2.7-4 km/h.

Slip calculation :

Time required to cover 30 m distance on zero condition (smooth tar road) was measured and theoretical speed of operation was calculated from an average of 5 readings. The actual speed of operation was calculated as described above. The slip was calculated as:

$$S = \frac{Vt - Va}{Vt}$$

where,

S = slip, (decimal)

Va = Speed of tractor in a field, m/s and

Vt = Speed of tractor on hard surface, m/s

RESULTS AND DISCUSSION

The various tests were conducted in stubble field condition after harvesting of maize crop to study the effect of ballast and tire inflation pressure on the wheel slip of the tractor for primary tillage operations. The performance of agricultural tractor was tested using the primary tillage implements (mouldboard plough and disc plough) at four different ballast conditions *viz*., no ballast, 90 daN at front, 90 daN at front and 200 daN at rear and 200 daN at rear axle and four different inflation pressure combinations 90 -140 kPa, 90 – 200 kPa, 130 – 140 kPa and 130 – 200 kPa at rear tire and front tire, respectively with a operating speed 2.8 km/h. Based on results, the analysis of variance was carried out using factorial RBD to find out the significant difference between various treatments.

Effect of ballast on slip for M B plough :

The analysis of variance shows that the main and their interaction effects of plough, ballast and inflation pressure were highly significant on per cent wheel slip (Table 1). The relationship between ballast and slip for M B plough at different inflation pressure is shown in Fig 1. The curves reveal that slip decreased with increase in ballast conditions at all inflation pressures for M B plough. This may due to increase in contact area of tyre because of increase in ballast load on tyre there by generating more net traction at lower slip values.

The Table 2 shows that the average reduction in slip was 39.72 per cent with increase in ballast from no ballast condition to 200 daN rear ballast condition for M B plough at all inflation pressure. This may due to increase in contact area of tyre with soil surface due to increased load on tyre. These results are similar to findings of Lohan and Aggarwal (2001).

Effect of ballast on slip for disc plough :

The relationship between ballast and slip for disc plough at different inflation pressure combinations is shown in Fig 2. The curves reveal that slip decreased with increase in ballast at all inflation pressure combinations for disc plough. This may be due to the same reasons as postulated for M B plough. Table 2 shows that the average reduction in slip was 35.80 per cent with increase in ballast from no ballast condition to 200 daN rear ballast condition for disc plough at all inflation pressures. This may be due to the same reasons as postulated for M B plough.

Effect of inflation pressure on slip for M B plough :

The analysis of variance shows that the main and their interaction effects of plough, ballast and inflation pressure are highly significant on per cent wheel slip (Table 1). The relationship between inflation pressure and slip for M B plough at different ballast conditions is shown in Fig 2.

The curves reveal that in general slip decreased with increase in inflation pressure at all ballast conditions for M B plough. It is also evident that at 0 and 90 daN at front ballast

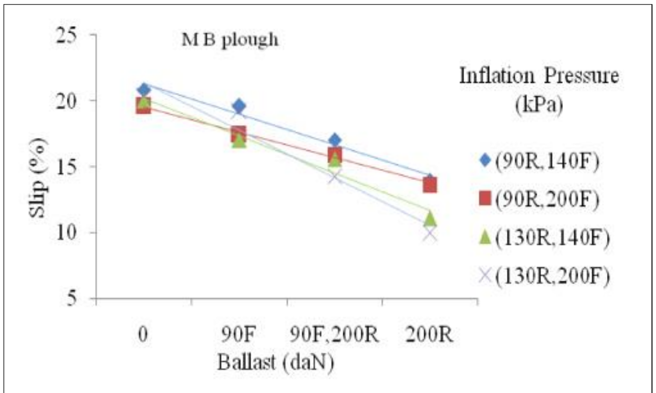

Fig. 1 : **Relationship between ballast and slip for M B plough at different inflation pressure combinations**

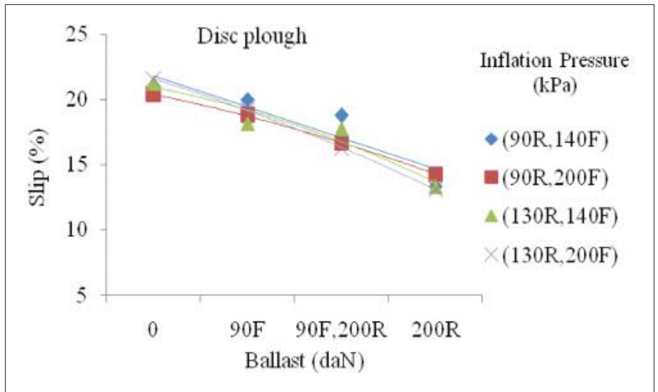

Fig. 2 : **Relationship between ballast and slip for Disc plough at different inflation pressure combinations**

Table 1 : Analysis of variance for plough, ballast and inflation pressure on per cent slip

Sr. No.	Source	DF	SS	MS	F	SE	CD
1.	Plough	1	31.16	31.1679	06750.944**	0.010	0.037
2.	Ballast	3	797.9	265.972	57609.283**	0.014	0.052
3.	Inflation pressure	3	26.26	8.75482	1896.2870**	0.014	0.052
4.	Plough x Ballast	3	3.502	1.16755	252.89100**	0.020	0.074
5.	Plough x Inflation pressure	3	6.776	2.25882	489.25900**	0.020	0.074
6.	Ballast x Inflation pressure	9	39.98	4.44311	962.37300**	0.028	0.104
7.	Plough x Ballast x Inflation pressure	9	10.38	1.15381	249.91400**	0.039	0.147
8.	Error	62	0.286	0.004616			

** indicates significance of value at P=0.01, GM = 17.160, CV = 0.396

Table 2 : Mean values showing the two variable interaction effect of plough and ballast on per cent slip

Plough	Ballast, daN				Mean
	0	90 F	90 F + 200 R	200 R	
M.B plough	20.204	18.284	15.694	12.177	16.590
Disc plough	21.027	19.022	17.371	13.498	17.729
Mean	20.615	18.653	16.533	12.837	17.160

CV = 0.396, CD = 0.074

the slip decreased up to certain level and then it increased with inflation pressure. This may due to increase in contact area of tyre because of increase in ballast load on tyre there by generating more net traction at lower slip values. Whereas at lower ballast values increase in inflation pressure might have decreased tyre deflection thereby decreasing contact area and finally increasing slip values.

The two variable interaction effect for M B plough (Table 3) shows that there was a no significant difference in per cent slip at 130 kPa rear, 140 kPa front and 130 kPa rear, 200 kPa front tyre inflation pressure combinations. Table 3 shows that the average reduction in per cent slip was 10.53 per cent with increase in inflation pressure from 90 kPa rear, 200 kPa front to 130 kPa rear, 200 kPa front inflation pressure for M B plough at all ballast conditions.

It is clear from Table 4 that for M B plough there was no significant difference in slip at 90 kPa rear, 200 kPa front and 130 kPa rear, 140 kPa front inflation pressure 90 daN front ballast condition. Similarly no significant difference was observed at 90 kPa rear, 200 kPa front and 130 kPa rear, 140 kPa front inflation pressure for 90 daN front and 200 daN rear ballast condition. Similarly no significant difference was observed at 90 kPa rear, 140 kPa front and 90 kPa rear, 200 kPa front inflation pressure for 200 daN rear ballast condition. This may due to the increased in contact area of tyre with soil surface due to increased the load on tyre and effect of tyre inflation pressure on contact area. These results are similar to findings of Lohan and Aggarwal (2001).

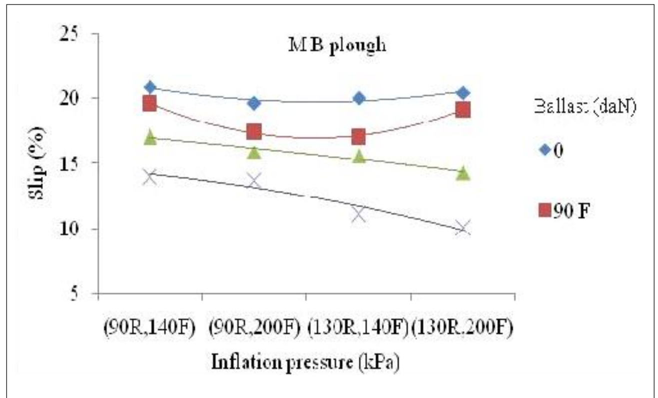

Fig. 3 : Relationship between inflation pressure and slip for M B plough at different ballast conditions

Effect of inflation pressure on slip for disc plough:

The relationship between inflation pressure and slip for disc plough at different ballast conditions is shown in Fig. 4. The curves reveal that slip decreased with increase in inflation pressure at all ballast conditions for Disc plough. Similarly like M B plough at low ballast condition and high inflation pressure conditions slip increased. The reasons may be same as given for M B plough. The two variable interaction effect for disc plough (Table 3) shows that there was a no significant difference in per cent slip at 90 kPa rear, 200 kPa front and 130 kPa rear, 200 kPa front tyre inflation pressure combinations.

Table 3 shows that the average reduction in per cent slip was 3.92 per cent with increase in tyre inflation pressure from 90 kPa rear, 140 kPa front to 130 kPa rear, 200 kPa front tyre inflation pressure for disc plough at all ballast conditions. It is clear from Table 4 that for disc plough there

Table 3 : Mean values showing two variable interaction effect of plough and inflation pressure on per cent slip

Plough	Inflation pressure, kPa				Mean
	90 R,140 F	90 R, 200 F	130 R, 140 F	130 R, 200 F	
M.B plough	17.844	16.628	15.923	15.964	16.590
Disc plough	18.229	17.532	17.643	17.513	17.729
Mean	18.037	17.080	16.783	16.739	17.160

CV = 0.396, CD = 0.074

Table 4 : Mean values showing the three variable interaction effect of plough, ballast and tyre inflation pressure on per cent slip

Plough	Ballast (daN)	Inflation pressure (kPa)			
		90 R,140 F	90 R,200 F	130 R,140 F	130 R,200 F
M B plough	0	20.83	19.57	20.00	20.41
	90F	19.57	17.39	17.02	19.15
	90F,200R	17.02	15.91	15.56	14.29
	200R	13.95	13.64	11.11	10.00
Disc plough	0	20.83	20.41	21.28	21.57
	90F	20.00	18.75	18.18	19.15
	90F,200R	18.75	16.67	17.78	16.28
	200R	13.33	14.29	13.33	13.04

CD = 0.147

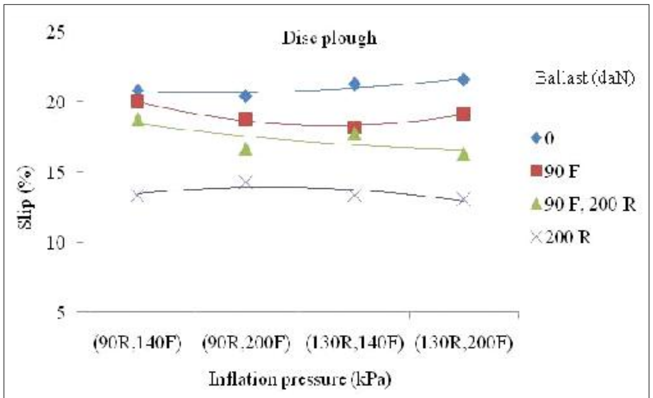

Fig. 4 : Relationship between inflation pressure and slip for disc plough at different ballast conditions

was no significant difference in slip at 130 kPa at rear, 140 kPa at front and 130 kPa at rear, 200 kPa at front inflation pressure for no ballast condition. Similarly no significant difference was observed at 90 kPa at rear, 200 kPa at front and 130 kPa at rear, 200 kPa at front inflation pressure for at 90 daN at front and 200 daN at rear ballast condition. Similarly no significant difference was observed at 90 kPa at rear, 140 kPa at front and 130 kPa at rear, 140 kPa at front inflation pressure for at 200 daN at rear ballast condition. This may due to the increased in contact area of tyre with soil surface due to increased the load on tyre and effect of tyre inflation pressure on contact area. These results are similar to findings of Lohan and Aggarwal (2001).

Conclusion:

From the experiments followings conclusions were drawn:

– Slip was decreased about 37.76 per cent with increase in ballast from no ballast to 200daN rear ballast condition for primary tillage operations at all inflation pressure.

– At low ballast condition and high inflation pressure wheel slip was increased.

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