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The Influence of Inflation Pressure in Tires and Forward Speed on Tractor Performance

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Abstract

This study was conducted at the Faculty of Agriculture, University of The Nile Valley, during the 2018 and 2019 winter season to evaluate the effects of forward speed and tire inflation pressure on tractor performance. Tillage operations were carried out using an 83-hp tractor equipped with a three-bottom disc plow. Three levels of tire inflation pressure and three forward speeds were tested. The evaluated indicators included wheel slip, fuel consumption, and field capacity. The results showed that both forward speed and tire inflation pressure significantly affected all studied parameters. Wheel slip and fuel consumption increased with increasing forward speed and tire inflation pressure, whereas field capacity improved with higher forward speeds and appropriate tire pressure levels. A significant interaction between forward speed and tire inflation pressure was observed for wheel slip and fuel consumption, while no significant interaction was found in field capacity. These findings highlight the importance of proper adjustment of operating speed and tire inflation pressure to improve tractor performance and reduce traction losses and fuel consumption.

Keywords: Tire inflation pressure, forward speed, slip, fuel consumption, field capacity

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تأثير ضغط النفخ في الإطارات والسرعة الأمامية على أداء الجرار

المستخلص: أُجريت هذه الدراسة بكلية الزراعة، جامعة وادي النيل، خلال الموسم الشتوي 2019/2018، بهدف تقييم تأثير السرعة الأمامية وضغط نفخ الإطارات على بعض مؤشرات أداء الجرار الزراعي. نُفذت عمليات الحراثة باستخدام جرار بقدرة 83 حصانًا مزود بمحراث قرصي ثلاثي، حيث تم اختبار ثلاث مستويات من ضغط نفخ الإطارات وثلاث سرعات أمامية مختلفة. شملت المؤشرات المدروسة نسبة الانزلاق، استهلاك الوقود، والسعة الحقلية. أظهرت النتائج أن السرعة الأمامية وضغط الإطارات أثّرا تأثيرًا معنويًا على جميع المتغيرات المدروسة. فقد ازداد الانزلاق واستهلاك الوقود بزيادة السرعة وضغط الإطارات، في حين تحسنت السعة الحقلية مع زيادة السرعة وضبط ضغط الإطارات. كما أظهر تحليل التباين الثنائي وجود تفاعل معنوي بين السرعة وضغط الإطارات في حالتي الانزلاق واستهلاك الوقود، بينما لم يكن التفاعل معنويًا بالنسبة للسعة الحقلية. وتؤكد النتائج أهمية الضبط المتكامل للسرعة الأمامية وضغط نفخ الإطارات لتحسين الأداء التشغيلي وتقليل الفاقد في الجر واستهلاك الوقود.

الكلمات المفتاحية :ضغط نفخ الإطارات، السرعة امية، الانزلاق، استهلاك الوقود، السعة **الحقلية**

INTRODUCTION

Recent studies have increasingly focused on the effects of tire inflation pressure and forward speed on agricultural tractor performance, due to their significant influence on tractive efficiency, wheel slip, fuel consumption, and soil preservation. Wheel slip is a critical indicator of tire–soil interaction, as excessive wheel slip leads to power losses and higher energy consumption. Contemporary research confirms that slip is not governed solely by vertical wheel load, but is strongly affected by tire inflation pressure and operating speed.

Experimental evidence indicates that reducing tire inflation pressure enhances the tire–soil contact area, resulting in improved traction and reduced slip, particularly at low to moderate forward speeds. Franceschetti et al. (2025) reported that lower inflation pressures significantly improved drawbar pull and tractive efficiency, although these benefits diminished at higher speeds due to increased rolling resistance and dynamic losses. Similarly, Li et al. (2024) demonstrated that increased contact length under low inflation pressure leads to more uniform stress distribution and reduced relative slip.

The interaction between forward speed and tire inflation pressure has also been shown to play a decisive role in tractor performance. According to Akhmetov et al. (2024), low inflation pressure combined with moderate speed reduces soil stress and improves tractor stability, whereas higher pressures increase wheel slip, especially in soils with higher moisture content. Moreover, recent modeling studies by Kumar et al. (2025) emphasized that integrated optimization of tire pressure and forward speed yields superior overall performance compared with independent parameter adjustment. Overall, the literature highlights that appropriate matching of tire inflation pressure and forward speed is essential for optimizing tractor performance, minimizing energy losses, and preserving soil physical properties. However, further field-based investigations are required to quantify their combined effects under varying operating conditions, which provide the basis for the present study.

MATERIALS AND METHODS

The experiment was conducted at the Faculty of Agriculture, University of The Nile Valley, Sudan, during the winter season of 2018/2019. An 83 hp Landin 8860 tractor equipped with a three-bottom disc plow was used for tillage operations (Tables 1 and 2). Three levels of tire inflation pressure (10, 20, and 30 kPa) and three forward speeds were evaluated. Wheel slip, fuel consumption, and field capacity were measured during the experiment. Each treatment was replicated three times. The collected data were statistically analyzed using two-way analysis of variance (ANOVA) to determine the effects of forward speed, tire inflation pressure, and their interaction on the studied parameters

Table:(1). Specifications of Landin 8860-wheel tractor

SPECIFICATIONS	Super 8860 ROPS
Tractor Power (hp)	83.6
Engine	Perkins 4cyl
Transmission Speeds	12
Front Tires	12.4R24
Rear Tires	18.4R30
Engine Capacity (L)	4.4L
Ground Speed PTO	Standard
Weight 4WD (without ballast) (kg)	3147

Table:(2). Specifications of Disc plow

Specifications	Disc plow
Mark	Super - AF
Make	Brazil
Width of cut	97cm
Number of units	3
Hitching	3point linkage
Tractor power	50 kw

Results and Discussion

Effect of Forward Speed and Tire Inflation Pressure on Slip:A two-way analysis of variance (ANOVA) was conducted to evaluate the effects of forward speed (S) and tire inflation pressure (P) on wheel slip at a significance level of $\alpha = 0.05$. The statistical results are presented in Table 3, while the interaction effect is illustrated in Figure 1.

As shown in Table 3, forward speed exerted a highly significant effect on slip, with slip increasing markedly as speed increased. This behavior can be attributed to the intensification of dynamic forces at the tire–surface interface, which leads to reduced effective traction. This trend is consistent with classical vehicle dynamics theory, where higher operating speeds are associated with increased slip ratios and reduced friction utilization (Gillespie, 1992; Wong, 2010).

Tire inflation pressure also had a significant influence on slip. Variations in inflation pressure modify the tire–soil contact area and stress distribution, thereby directly affecting traction performance. This effect has been widely documented in tire mechanics studies, where tire inflation pressure is considered a governing factor in contact behavior and energy dissipation (Pacejka, 2006). Furthermore, improper inflation pressure has been shown to cause non-uniform stress distribution and increased energy losses at the tire–ground interface (Besselink et al., 2010).

Moreover, a statistically significant interaction between forward speed and tire inflation pressure was observed, indicating that the effect of tire pressure on slip depends on the operating speed. As illustrated in Figure 1, the non-parallel response curves confirm that pressure variations have a more pronounced impact on slip at higher speeds. This finding agrees with Li et al. (2018), who emphasized that independent control of speed or tire pressure is insufficient under high-speed conditions, and that integrated operational strategies are required to effectively minimize slip.

Table:(3). Two-way ANOVA results for slip

Source of variation	df	Sum of Squares (SS)	F-value	p-value
Speed (S)	2	120.86	433.94	< 0.001
Tire pressure (P)	2	44.99	161.52	< 0.001
S × P interaction	4	3.33	5.98	0.003
Error	18	2.51	—	—
Total	26	171.69	—	—

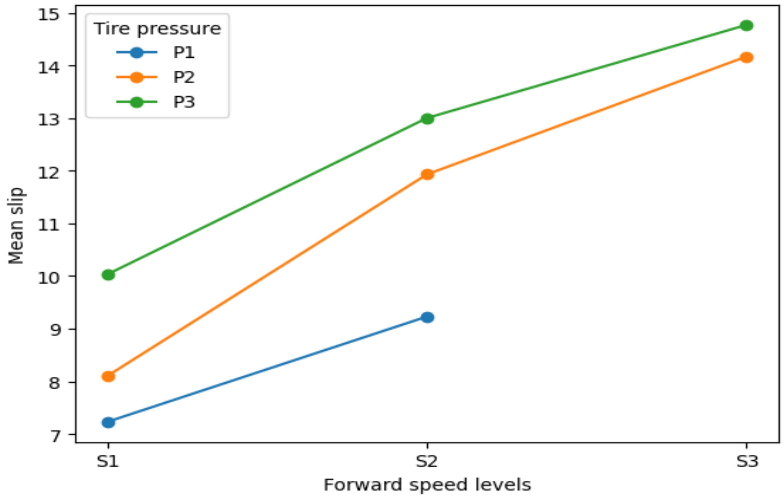

Figure: (1). Interaction plot showing the combined effect of forward speed and tire inflation pressure on slip.

Effect of Forward Speed and Tire Inflation Pressure on Field Capacity: The effects of forward speed and tire inflation pressure on field capacity were analyzed using a two-way ANOVA. The statistical outcomes are summarized in Table 4, and the interaction pattern is shown in Figure 2.

According to Table 4, both forward speed and tire inflation pressure significantly affected field capacity. The increase in field capacity with forward speed is primarily attributed to the greater area covered per unit time, which is consistent with fundamental principles of agricultural mechanization (Hunt, 2001; Srivastava et al., 2006). Tire inflation pressure also contributed significantly to improvements in field capacity. Higher pressure levels reduce rolling resistance and improve power transfer efficiency, resulting in enhanced operational performance. Similar observations were reported by Grisso et al. (2014), who highlighted the importance of proper tire pressure management for improving the overall efficiency of agricultural machinery. In contrast, the interaction between speed and tire pressure was not statistically significant, indicating that their effects on field capacity act largely independently, as illustrated in Figure 2.

Table:(4). Two-way ANOVA results for field capacity

Source of variation	**SS**	**df**	**MS**	**F**	**p-value**
Speed (S)	0.1267	2	0.0634	12.33	0.00042
Tire pressure (P)	1.0807	2	0.5403	105.18	< 0.0001
S × P interaction	0.0156	4	0.0039	0.76	0.566
Error	0.0925	18	0.0051	—	—
Total	1.3154	26	—	—	—

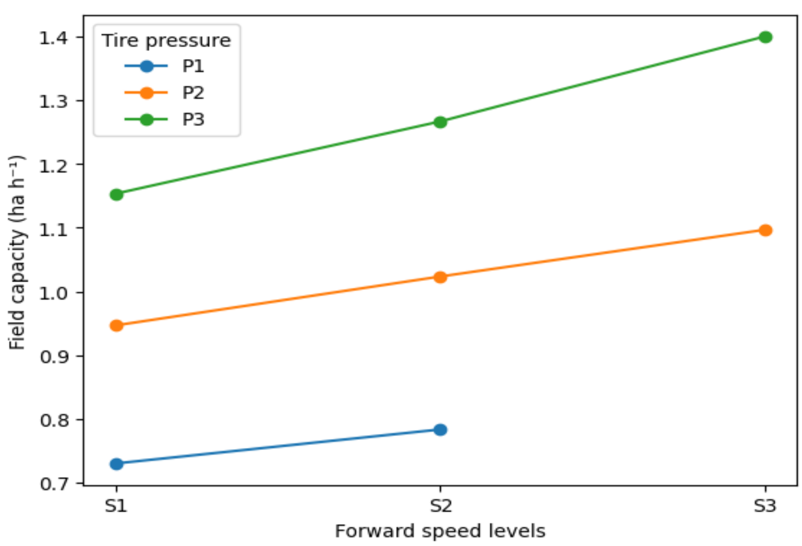

Figure: (2). Interaction plot showing the combined effect of forward speed and tire inflation pressure on field capacity (ha h^{-1}).

Effect of Forward Speed and Tire Inflation Pressure on Fuel Consumption:The combined effects of forward speed and tire inflation pressure on fuel consumption (L h -1)were evaluated using a two-way ANOVA at a significance level of $\alpha = 0.05$. The statistical results are summarized in Table 5, while the interaction trends are illustrated in Figure 3.

As shown in Figure 3, fuel consumption increased consistently with increasing tire inflation pressure across all forward speed levels. This behavior can be attributed to increased rolling resistance caused by changes in tire deformation and contact characteristics, which directly increase energy losses during operation. Similar findings were reported by Taylor et al. (2006), who identified improper tire inflation pressure as a major contributor to increased fuel consumption, particularly under heavy operating loads.

In addition, fuel consumption increased with forward speed at any given pressure level due to higher power demand associated with elevated operating speeds. This observation is consistent with established vehicle dynamics principles (Gillespie, 1992; Wong, 2010). The analysis further revealed a significant interaction between forward speed and tire inflation pressure, indicating that the effect of tire pressure on fuel consumption depends on the operating speed. As reported by Taghavifar and Mardani (2015), the adverse impact of high tire pressure on fuel efficiency becomes more pronounced at higher speeds, which explains the steeper increase in fuel consumption observed in Figure 3.

Overall, these findings demonstrate that slip, field capacity, and fuel consumption are governed by the combined effects of forward speed and tire inflation pressure rather than by either factor alone. Therefore, optimizing machine performance and fuel efficiency requires integrated management of operating speed and tire inflation pressure, particularly under high-speed operating conditions

Table:(5). Two-way ANOVA results for fuel consumption

Source of variation	df	Sum of Squares (SS)	Mean Square (MS)	F-value	p-value
Speed (S)	2	4.127	2.063	92.85	< 0.001
Tire pressure (P)	2	16.296	8.148	366.65	< 0.001
S × P interaction	4	0.444	0.111	5.00	< 0.01
Error	18	0.400	0.022	—	—
Total	**26**	**21.267**	—	—	—

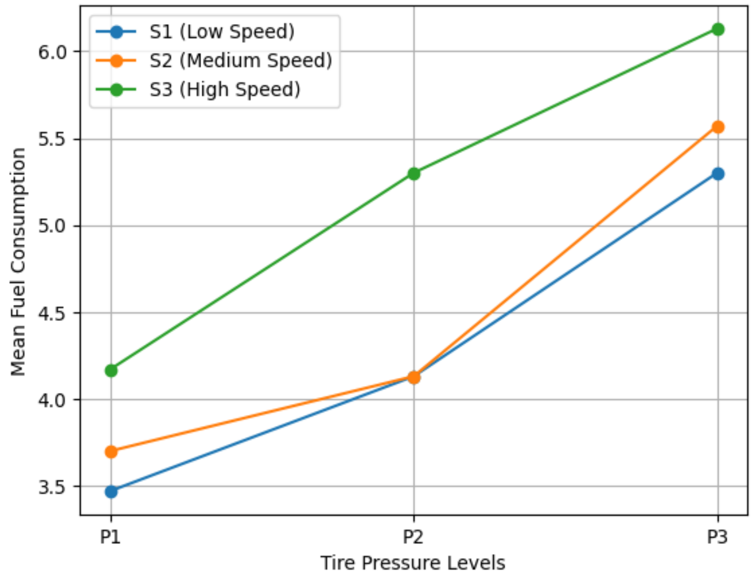

Figure: (3). Interaction plot showing the combined effect of forward speed and tire inflation pressure on fuel consumption (Lh^{-1}).

Overall, the results demonstrate that slip, field capacity, and fuel consumption are governed by the combined effects of forward speed and tire inflation pressure rather than by either factor alone. While field capacity is primarily influenced by the independent contributions of speed and pressure, slip and fuel consumption are strongly affected by their interaction, particularly at higher speeds. Therefore, optimizing machine performance, traction efficiency, and fuel economy requires an integrated management strategy that simultaneously considers both operating speed and tire inflation pressure

Conclusion

The study demonstrated that tractor performance is strongly influenced by forward speed and tire inflation pressure. Increasing forward speed resulted in higher wheel slip and fuel consumption, while improving field capacity. Tire inflation pressure played a critical role in controlling traction efficiency and fuel use, particularly at higher speeds. Therefore, proper and combined adjustment of forward speed and tire inflation pressure is recommended to improve tractor performance, reduce traction losses, and enhance fuel efficiency under field conditions.

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Duality of interest: The authors declare that they have none.

Author contributions: Contribution is equal between authors.

REFERENCES

Akhmetov, A., Akhmedov, B., & Ishchanov, J. (2024). Effect of forward speed and tire inflation pressure on soil–tire interaction and tractor performance. *Vehicles*, *6*(3), 121. https://doi.org/10.3390/vehicles6030121

Besselink, I. J. M., Schmeitz, A. J. C., & Pacejka, H. B. (2010). An improved tire model for the simulation of tire–road interaction. *Vehicle System Dynamics, 48*(1), 1–23.

Franceschetti, B., Diserens, E., & Schreiber, M. (2025). Influence of tire inflation pressure and forward speed on tractive performance of agricultural tractors. *Vehicles*, *7*(4), 109. https://doi.org/10.3390/vehicles7040109

Gillespie, T. D. (1992). *Fundamentals of vehicle dynamics*. SAE International.

Grisso, R. D., Pitman, R., Perumpral, J. V., & Kocher, M. F. (2014). *Tractor performance and fuel economy*. ASABE Publications.

Hunt, D. (2001). *Farm power and machinery management* (10th ed.). Iowa State University Press.

Kumar, R., Singh, S., & Patel, A. (2025). Development of software for performance analysis of wheeled agricultural tractors. *Journal of Terramechanics, 107*, 45–56. https://doi.org/10.1016/j.jterra.2024.12.004

Li, Y., Zhang, H., & Wong, J. Y. (2018). Modeling of tractor tire slip considering tire inflation pressure and operating speed. *Journal of Terramechanics, 78*, 45–54.

Li, Y., Zhang, H., & Wong, J. Y. (2024). Effect of contact length of bias-ply tractor tire on tractive performance. *Journal of Terramechanics, 104*, 1–10. https://doi.org/10. 1016/j.jterra. 2023.11.001

Pacejka, H. B. (2006). *Tire and vehicle dynamics* (2nd ed.). Butterworth-Heinemann.

Srivastava, A. K., Goering, C. E., Rohrbach, R. P., & Buckmaster, D. R. (2006). *Engineering principles of agricultural machines* (2nd ed.). ASABE.

Taghavifar, H., & Mardani, A. (2015). Investigating the effect of tire inflation pressure on fuel consumption and tractive performance. *Energy*, *80*, 256–263. https://doi.org/10.1016/j. energy.2014.11.070

Taylor, R. K., Way, T. R., & Bashford, L. L. (2006). Tractor fuel consumption and performance as affected by tire inflation pressure. *Applied Engineering in Agriculture, 22*(4), 517–524.

Wong, J. Y. (2010). *Terramechanics and off-road vehicle engineering* (2nd ed.). Butterworth-Heinemann