Effect of the moldboard types on deflections of the plowing lines, power requirement and fuel consumption

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ABSTRACT

The moldboard plow is represented one of the most important implements used for the primary tillage in Iraq, and the moldboard is considered one of the important plow parts which works to slip the cut soil slice, break it up and turn it always towards the right side. For this reason, factorial experiment under randomized complete block design with three replication was conducted in field in collage of Agricultural Engineering Sciences – University of Baghdad in 2022, for aim of the study the effect of two types of moldboard slatted (which design and manufactured by researchers) and general purpose in deflections of plowing lines, estimate powers, energy requirements and fuel consumption under two depths of tillage 15 and 25 cm and two speeds of tractor 4.146 and 7.224 km.hr^{-1}. Depth of tillage 25 cm recorded least(best) vertical 2.859 % and lateral deflections 1.999%. Depth of tillage 15 cm got least power requirement 34.876 kw, energy requirement 79.967 kw. hr.ha^{-1} and fuel consumption 11.028 L.hr^{-1}. Speed of tractor 4.146 km.hr^{-1} got least vertical 3.003 %, lateral deflection 1.543%, power requirement 31.078 kw and fuel consumption 9.827 L.hr^{-1}. Slatted moldboard got least lateral deflection 2.112%, power requirement 38.658 kw, energy requirement 92.563 kw.hr.ha^{-1} and fuel consumption 12.220 L.hr^{-1}.

Keywords: Machines, Slats, tractor, Soil, Energy, Three- point hitch.
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INTRODUCTION

The moldboard plow is represented one of the most important implements used for the primary tillage in Iraq, and the moldboard is considered one of the important plow parts which works to slip the cut soil slice, break it up and turn it always towards the right side. The moldboard plow has historically been the most important and useful primary tillage implement in agricultural. There are several moldboard types that differ in their shape, size and purpose, and usually, the moldboard made of three layers, inner, middle and outer, or they are made from only one layer (16). Most researchers in Iraq and the world have taken in to account the importance of the fuel consumed amount in their studies, power and energy requirements during processes tillage and others, search to reduce it while keeping the productivity as much as possible. As a result of the continues increase in the fuel cost in the world, it has become imperative to be more efficient in fuel utilization in tillage operation. Choosing the tractor speed appropriate to the plowing depth, full tank tractor and operator skill increases the efficiency of the tillage process (1 and 12). The correlation between tillage depth and performance of tractor is non-linear because the mass of soil per cutting unit increases and a higher power is required to pull and operate the plow, in other words, bigger power amount requires with tillage depth increase (6, 15 and 26). The factors that affect fuel consumption, when using tillage implements are increase power requirement when increased each of the tractor speed, plow actual width, soil strength, soil moisture as well as tillage depth increase (20, 22 and24). Reaction arise represented by forces originating from the soil during cutting, breaking up, lifting, moving and flipping the section of the cut soil segment by the

moldboard plow, which leads to vertical and lateral deflection in the lines of tillage, depend on the type and plow design, weight, organization of the plow connection behind the tractor, tillage depth, tractor speed tractor, moisture and the soil texture (8). The deflection in the lines of tillage increasing with increase in the speed of the tractor and

should not exceed 10% under most operating conditions (23). The study of (7) Found that the vertical and lateral deflection in moldboard plow were 4.21% and 3.25% in respectively when tractor speed 4.5km.hr^{-1}. Energy requirement depend on power requirement and effective field capacity, it represented the power spent by engine of the tractor or the machine to complete the agricultural process. Found (5) the plowing depth 10 cm had significant superiority in comparison with plowing depth 20cm in recording lower value of unit energy power requirements of 158.596 kw.hr/ha. Found (21) lowest depth stability in moldboard plow when tiled at high speed of 9 km/hr, and increasing fuel consumption to 17.72 L/hr, and better depth stability when tilled at speed 5 km/hr. The aim of this experiment was reduce the fuel consumption, power requirement, energy requirement, vertical and lateral deflections while keeping the productivity as much as possible, knowing the field performance of the slatted and general purpose moldboard and comparing them, at different tillage depths and different range of tractor speeds.

MATERIAL AND METHODS

Field experiment

Field experiment was conducted in University of Baghdad - Collage of Agricultural Engineering Science in 2022. Soil moisture was 16 - 18 % when soil was tilled. Soils of samples were taken randomly from the field for analysis, table (1).

Table 1. Field soil properties.

Soil texture	Sandy Loam	
Sand	g. kg^{-1}	572
Silt		340
Clay		88
PH	5.86	
Bulk density g/cm^3	1.44	
Porosity %	45.66	

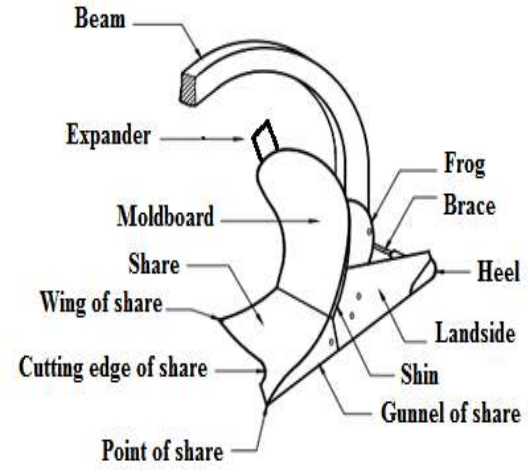
Experiment design

Factorial experiment under randomized complete block design with three replication using least significant design (LSD) 1 and 5 % was used to compare the mean of treatments. Statistical analysis system (SAS) was used (27). The experiment were done at two levels of tillage depth of 15 cm and 25 cm, two tractor speed at levels of 4.146 km. h^{-1} and 7.224 km. h^{-1}, and types of moldboard plow one of them designed and manufacture by researchers which slatted moldboard plow and the second was general purpose moldboard. The experiment included 8 treatments with three replication for each treatment (2×2×2×3= 24 Treatments).

Tractor and moldboard plow

New Holland tractor TD 80 with 75 hp was used in this experiment, four cylinder engine tractor and water cooling system, standard tires used as specified by the manufacturer with no damaged and all the tires pressures were adjusted. Operation tillage conducted with 2000 rpm engine tractor by put and control on lever fuel hand in tractor for all treatments in these experiment.

Moldboard plow contain three general purpose moldboard, each moldboard width 35 cm (total width 105 cm), maximum depth 27 cm and weight 316 kg (Fig.1- a and b).

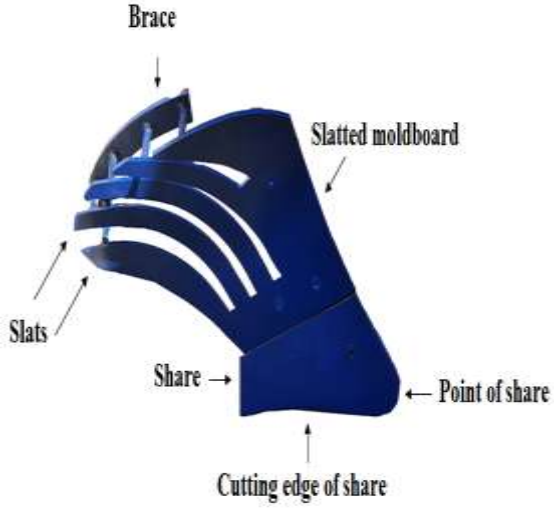


a

b

Fig.1 a- Schematic general purpose mold-board, b- Moldboard plow.

Slatted moldboard was designed and manufactured by researchers, it consist of five slats and behind brace, tied in the plow instead of the original moldboard which was general purpose moldboard during the field experiment according to experiment design (fig.2- a and b).



a

b

Fig.2. a- Slatted moldboard, b- plow with three Moldboard slats.

Performance parameters

Vertical deflection

The deflections percentage from the plow depth of tillage, which was organized and regulating the plow, this deflection is important in determining the serviceability of the plow and it is an important indicator of the occurrence of depreciation in the working parts of the plow, the vertical deflection for this study was calculated by using equations (10):

$$M_d = \sum D / N_d \quad (1)$$

$$\Delta_d = \sqrt{\Sigma (D - M_d)^2 / N_d} \quad (2)$$

$$\delta_d = (\Delta_d / M_d) \times 100 \quad (3)$$

Where M_d is mean of depth tillage (m), D is measure of depth (m), N_d is the number of replication, Δ_d is mean depth of deflection, δ_d is vertical deflection (percentage of irregular tillage depth %).

Lateral deflection

The percentage of deflection from the design width of the plow, and this deflection is evidence of a defect in the technical condition of the plow, calculated from the following equations (10):

$$M_w = \sum W / N_w \quad (4)$$

$$\Delta_w = \sqrt{\Sigma (W - M_W)^2 / N_w} \quad (5)$$

$$\delta_w = (\Delta_w / M_w) \times 100 \quad (6)$$

When M_w is mean of width (m), W is measure of width (m), N_w is the number of replication, Δ_w is mean width of deflection, δ_w

is lateral deflection (percentage of irregular tillage width %).

Fuel consumption

The amount of fuel consumption by the tractor during the plowing operation was measured by using the method of refilling the fuel tank tractor before and after every operation. This way involved filling of the tractor fuel tank to the brim before and after each operation test performed, using a 1000 ml graduated cylinder, from where the quantity of fuel used is measured per time of the operation, calculated the fuel consumption in unit L. h^{-1} by follow the equation (3, 9, 17 and 28):

$$Q_F = q_l \times 3600 \ / \ t \times 1000 \qquad (7)$$

Where Q_F is the quantity of fuel consumption ($L.h^{-1}$), q_l is the measure fuel quantity for tillage line treatment (ml), t is the time in (sec) to across one treatment, 3600 and 1000 were factors conversion.

The power requirement

The requirement engine estimate power was determined for each operation by using the following equation, (11, 14 and 25):

$$E_P = \frac{Q_F}{3600} \times \rho_f \times L.C.V \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36} \qquad (8)$$

Where E_P estimate power requirement in kw, ρ_f is density of fuel (0.85 kg/l for diesel of fuel), $L.C.V$ is Lower Calorific Value of fuel (1000 kcal/kg for diesel), 427 is thermo-mechanical equivalent in kg.m/kcal, η_{th} is thermal efficiency of the engine (40% for diesel engine) and η_m is mechanical efficiency of the engine (80% for diesel engine).

Energy requirement

The power spent by engine of the tractor or the machine to complete the agricultural process multiplied by the time and divided by the unit area. It affected by the type of agricultural operation, texture , moisture and density soil, design and width plow, speed of tractor and depth tillage. Calculated by the following the equations (11 and 5):

$$E_r = E_p \ / \ E_{FC} \qquad (9)$$

Where E_r was Machinery unit energy requirement in (kw.hr. $hectare^{-1}$) and E_{FC} is Effective Field Capacity ($ha.hr^{-1}$).

$$EFC = 0.1 \times Va \times Wp \times FT - - - -(10)$$

When EFC was Effective Field Capacity in ha. hr^{-1}, Va was actual velocity in km/hr, Wp was working actual width plow in m, ft coefficient estimate time for primary tillage 0.75-0.85 and used 0.80 in that experiment (18) and 0.1 was factor conversion.

RESULT AND DISCUSSION

Vertical deflection

Result showed significant effects in the depth of tillage on vertical deflection, depth 25 cm recorded lower vertical deflection of 2.859 %, while depth of tillage 15 cm was 4.186 %, because of increasing the depth of plowing leads to an increase in the section of the soil facing the plow share due to the increased cutting and thus leads to the relative stability of the plow, these results are in agreement with the results obtained (7). Result show significant effects in the speed of tractor, speed 4.146 km. hr^{-1} recorded lower value was 3.003 %, while the high speed 7.224 km. hr^{-1} recorded 4.042 %, and that because of increasing the speed reduce the stability of the depth due to the increase of the resistance compounds by increasing the acceleration, in addition to the sum of the soil forces remains at a lower angle against the plow. No significant between the treatments in the types of moldboard. Interaction depth of tillage with speed of tractor showed significant effect, Interaction depth 25 cm and speed 4.146 km. hr^{-1} was lower value 2.157 %, while interaction 15 cm with 7.224 $km.hr^{-1}$ was 4.523 % fig.3. Interaction depth of tillage with moldboard types showed significant effect, interaction depth 25 cm with slatted moldboard recorded lower value was 2.857 % while interaction depth 15 cm with general purpose moldboard was 4.1884 %. Interaction speed of tractor with moldboard types showed significant effect, interaction speed 4.146 $km.hr^{-1}$ with slatted moldboard recorded lower value 3.002%, while speed 7.224 $km.hr^{-1}$ with general moldboard was 4.045%. Interaction depth of tillage, speed of tractor and moldboard types showed significant effect, interaction depth 25 cm, speed 4.146 km. hr^{-1} and slatted moldboard recorded lower value

2.156 %, while interaction depth 15 cm, speed 7.224 km. hr^{-1} and general moldboard recorded higher value 4.526 % fig.4.

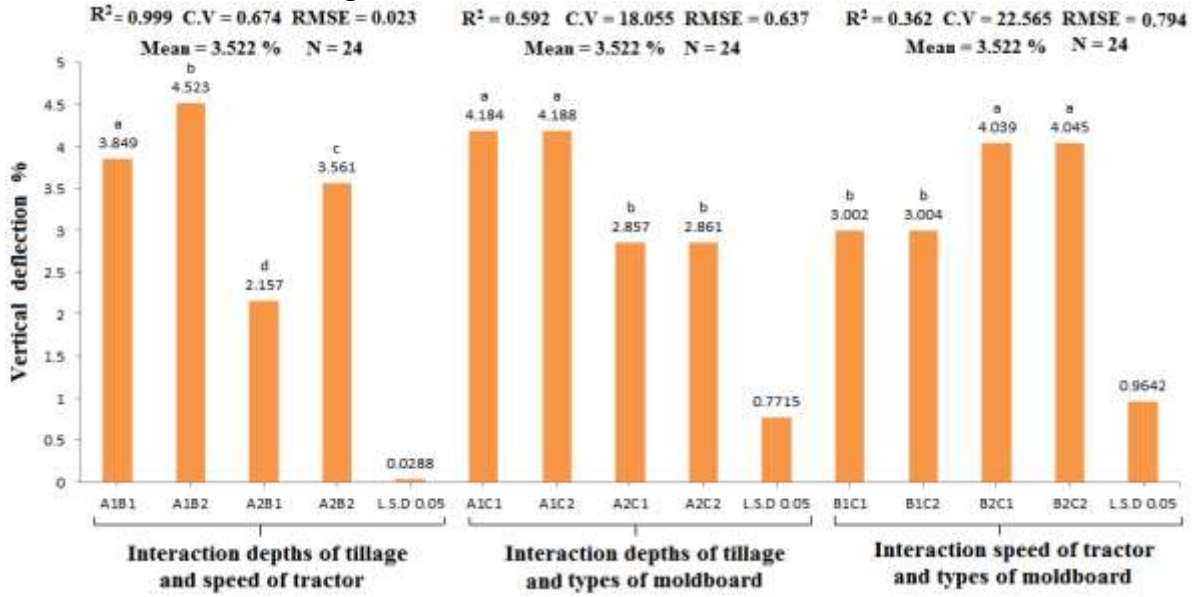


Fig.3 Binary interaction depths of tillage, speeds and types of moldboard on vertical deflection.
A1=15cm A2=25cm B1= 4.146 km.h^{-1} B2= 7.224 km.h^{-1} C1= Slatted moldboard C2= General purpose moldboard. (Means with the same letter are not significantly different).

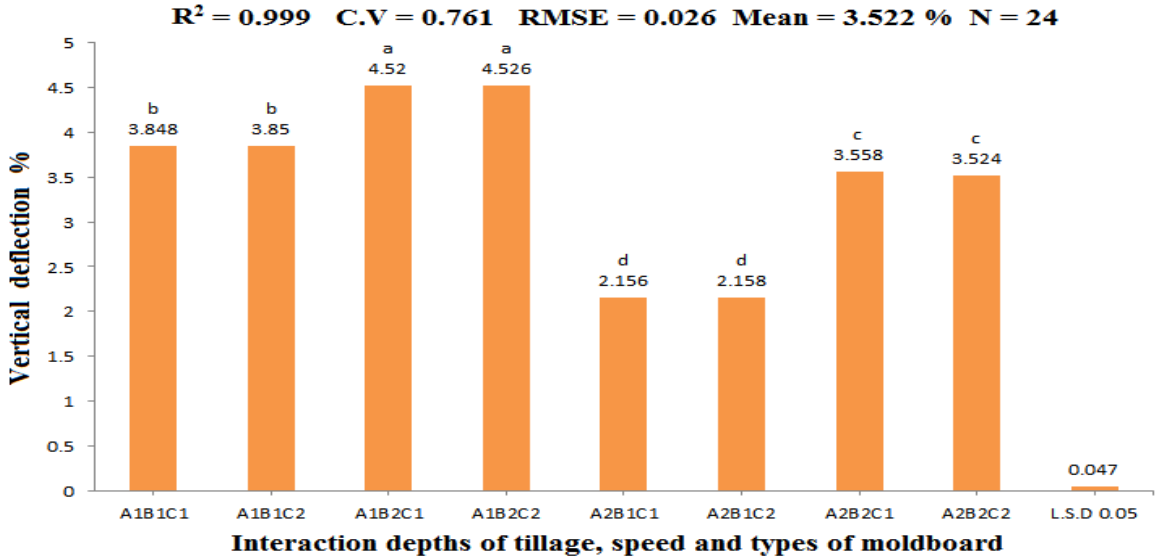


Fig. 4 Triple interaction of depth of tillage, speed of tractor and moldboard types on vertical deflection.

Lateral deflection

Result showed significant effects in the depth of tillage, depth 25 cm recorded lower lateral deflection of 1.999 %, while depth of tillage 15 cm was 2.257 %, and that because of the plow become more stability with increasing depth, these results are in agreement with the results obtained (7). Result show significant effects in the speed of tractor, speed 4.146 km.hr^{-1} recorded lower value of 1.543 %, while the high speed 7.224 km.hr^{-1} recorded of 2.713 %, and that because of increasing the speed reduce the stability and increase soil resistance strength. Result showed slight deference value between slatted and general moldboard were 2.112 % and 2.144 % respectively. Interaction depth of tillage with speed of tractor showed significant effect, Interaction depth 25 cm and speed 4.146 km. hr^{-1} was lower value 1.231 %, while interaction 15 cm with 7.224 km.hr^{-1} was 2.767 % fig.5. Interaction depth of tillage with

moldboard types was no significant. Interaction speed of tractor with moldboard types showed significant effect, interaction speed 4.146 km. hr^{-1} with slatted moldboard recorded 1.536 %, while speed 7.224 $km.hr^{-1}$ with general moldboard recorded 2.738%. Interaction depth of tillage, speed of tractor and moldboard types showed significant effect, interaction depth 25 cm, speed 4.146 $km.hr^{-1}$ and slatted moldboard recorded lower value 1.228 %, while interaction depth 25 cm, speed 7.224 km. hr^{-1} and general moldboard recorded higher value 2.775 % fig. 6.

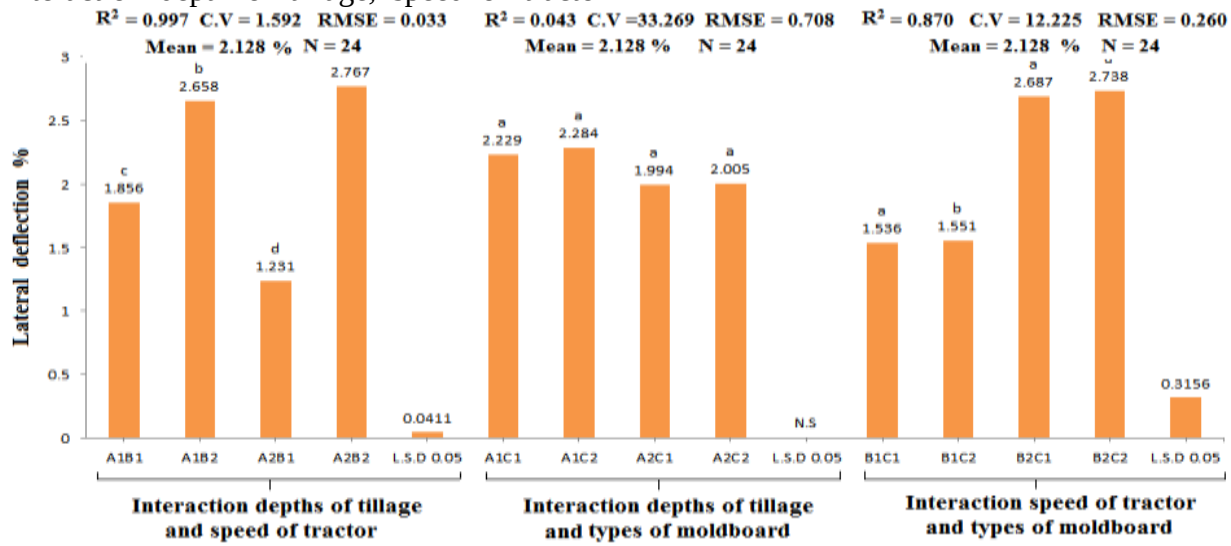


Fig.5 Binary interaction depths of tillage, speeds and types of moldboard on lateral deflection.

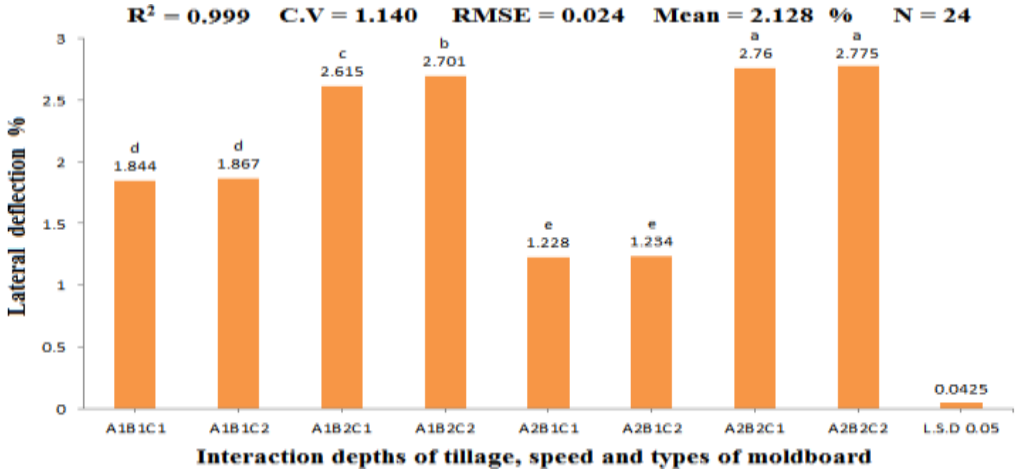


Fig. 6 Triple interaction of depth of tillage, speed of tractor and moldboard types on vertical deflection.

Fuel consumption

Result showed significant effects in the depth of tillage on fuel consumption, depth 15 cm recorded lower (best) fuel consumption of 11.028 $L.hr^{-1}$, while depth of tillage 25 cm was 13.702 $L.hr^{-1}$, and that because of increasing the depth of plowing leads to an increase in the volume of disturbed soil, and then the need for more energy and fuel to accomplish the plowing process, these results are in agreement with the results obtained (2 and 19). Result show significant effects in the speed of tractor, speed 4.146 $km.hr^{-1}$ recorded lower value was 9.827 $L.hr^{-1}$, while the high speed 7.224 $km.hr^{-1}$ was 14.903 $L.hr^{-1}$, and that because fuel consumption is directly proportional to the speed of the tractor on the basis of the unit of measurement liter / hour, these results are in agreement with the results obtained (4, 12, 21 and 29). Result showed significant effect on moldboard types, slatted recorded lower value of 12.220 $L.hr^{-1}$, while general moldboard recorded of 12.510 $L.hr^{-1}$, and that because of slatted moldboard make to

break up the slice of soil cut by the plow share during its transmission on the slatted moldboard, so the resistance and friction of the soil with slatted moldboard is less compared to the general purpose moldboard, on the other hand, the percentage of slippage when using the slatted moldboard is less, therefore the fuel consumption is less. Interaction depth of tillage with speed of tractor showed significant effect, Interaction depth 15 cm and speed 4.146 km.hr^{-1} was lower value 8.658 L.hr^{-1}, while interaction 25 cm with 7.224 km.hr^{-1} was 16.408 fig.7. Interaction depth of tillage with moldboard types was no significant. Interaction speed of tractor with moldboard types was significant, interaction speed 4.146 km.hr^{-1} and slatted moldboard recorded lower value was 9.629 L.hr^{-1}, while speed 7.224 km.hr^{-1} with general moldboard record higher value 14.995 L.hr^{-1}. Interaction depth of tillage, speed of tractor and moldboard types showed significant effect, interaction depth 15 cm, speed 4.146 km.hr^{-1} and slatted recorded lower value 8.493 L.hr^{-1}, while interaction depth 25 cm, speed 7.224 km.hr^{-1} and general moldboard recorded higher value 16.477 L.hr^{-1}, fig. 8.

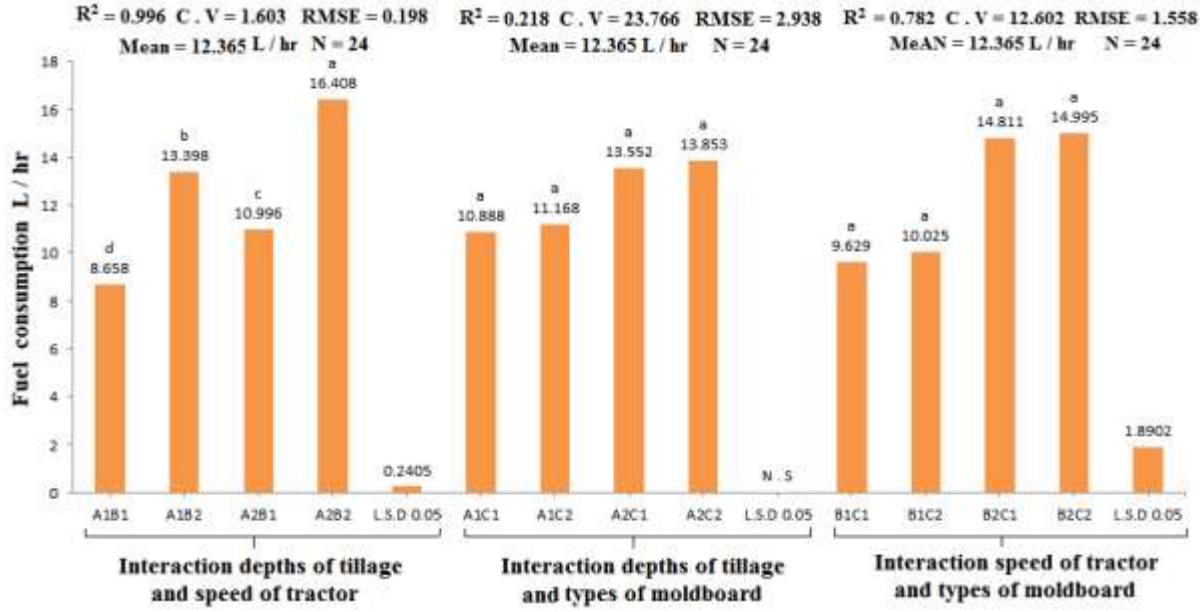


Fig.7 Binary interaction depths of tillage, speeds and types of moldboard on fuel consumption.

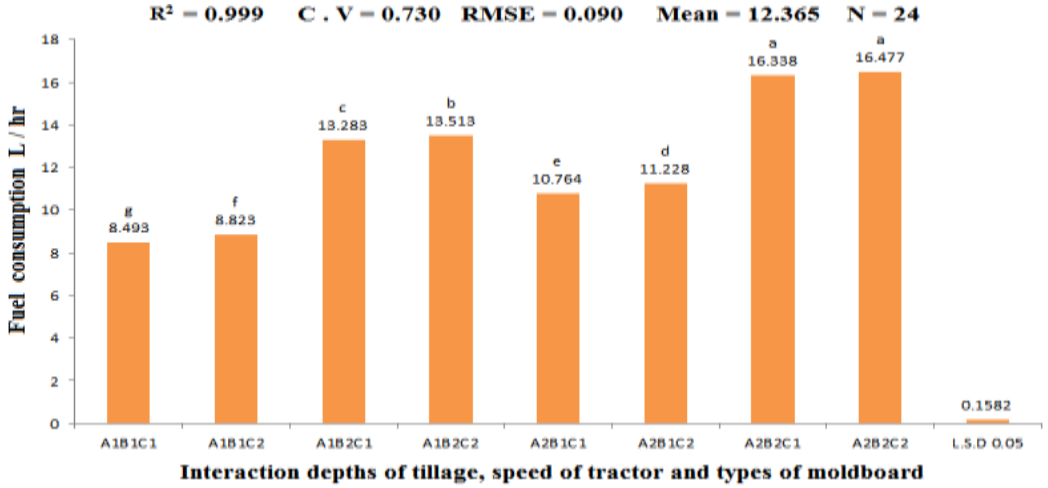


Fig. 8 Triple interaction of depth of tillage, speed of tractor and moldboard types on fuel consumption.

Power requirement

Result showed significant effects in the depth of tillage on power requirement, depth 15 cm recorded lower power requirement was 34.876 Kw, while depth of tillage 25 cm was 43.912 Kw, and that because of increase in

fuel consumption when the plowing depth increases, which is one of the factors affecting the formula for calculating the power requirements. Result show significant effects in the speed of tractor, speed 4.146 km.hr-1 recorded lower value was 31.078 Kw, while the high speed 7.224 km.hr^{-1} was 47.145 Kw, and that because of increase in fuel consumption when speed of tractor increases, and strength of the soil against the penetration of the shares of plow increase with the increase in the speed of the tractor, so still need a greater power requirement to overcome the resistances of the soil. Result showed significant effect on moldboard types, slatted moldboard recorded lower value 38.658 Kw, while general moldboard recorded 39.564 Kw, and that because of the difference in fuel consumption in both of them when used in the soil tilled. Interaction depth of tillage with speed of tractor showed significant effect, Interaction depth 15 cm and speed 4.146 km. hr^{-1} was lower value 27.375 Kw, while interaction 25 cm with 7.224 km. hr^{-1} was 51.912 Kw fig.9. Interaction depth of tillage with moldboard types was no significant. Interaction speed of tractor with moldboard types was significant, interaction speed 4.146 km. hr^{-1} and slatted moldboard recorded lower value was 30.456 Kw, while speed 7.224 km. hr^{-1} with general moldboard recorded higher value 47.429 Kw. Interaction depth of tillage, speed of tractor and moldboard types showed significant effect, interaction depth 15 cm, speed 4.146 km. hr^{-1} and slatted moldboard recorded lower value 26.863 Kw, while interaction depth 25 cm, speed 7.224 km. hr^{-1} and general purpose moldboard recorded higher power requirement value 52.117 Kw, fig. 10.

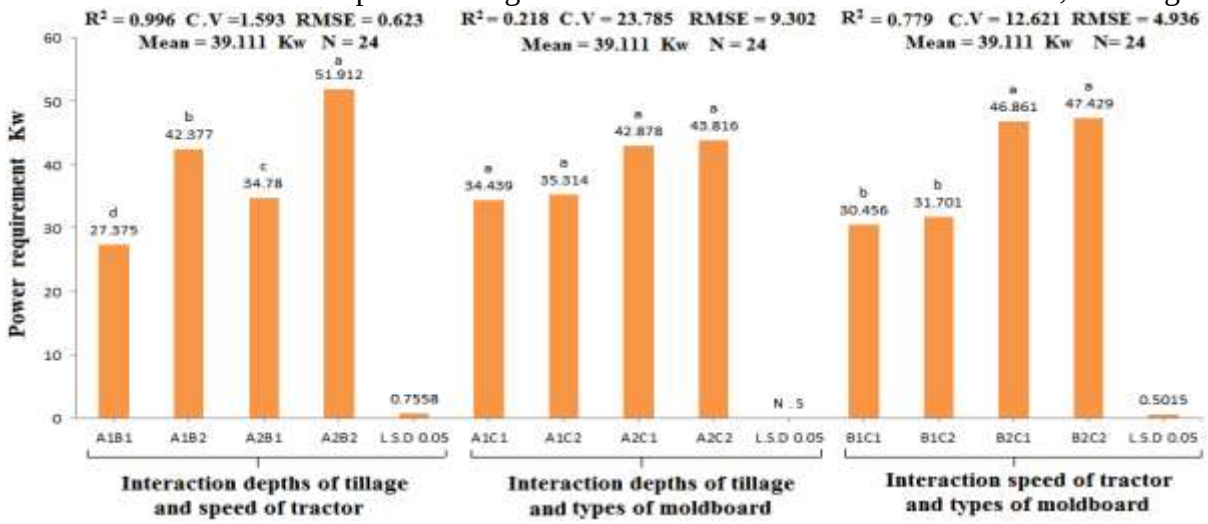


Fig.9 Binary interaction depths of tillage, speeds and types of moldboard on power requirement.

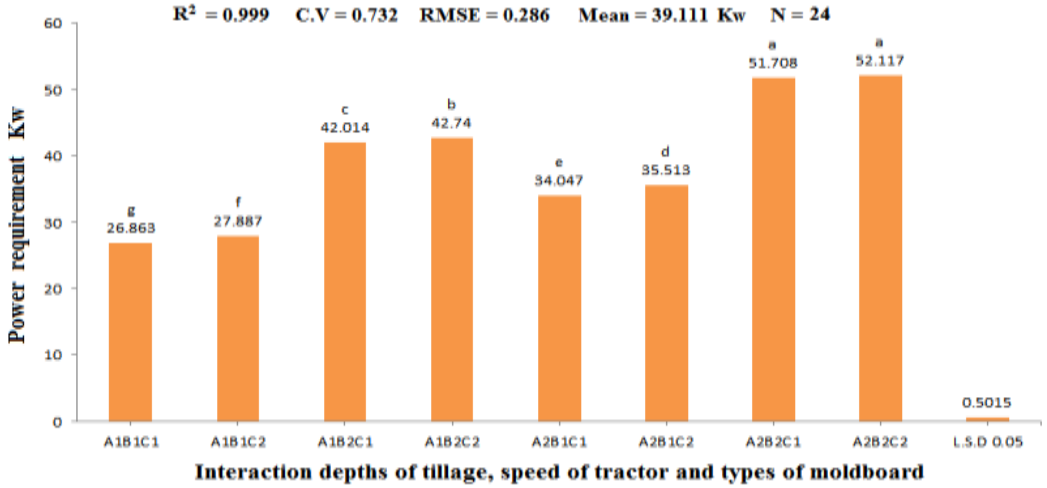


Fig. 10 Triple interaction of depth of tillage, speed of tractor and moldboard types on power requirement.

Energy requirement

Result showed significant effects in the depth of tillage on energy requirement, depth 15 cm recorded lower power requirement was 79.967 Kw.hr.ha^{-1}, while depth of tillage 25 cm was 108.513 Kw.hr.ha^{-1}, because of the increase in the volume of soil cut by the plow share when the plowing depth increases, and the difference in the power requirement and actual field capacity at different plowing depths, which affect the equation for calculating energy requirements (according to equation 9). Result show significant effects in the speed of tractor, speed 7.224 km.hr^{-1} recorded lower value was 90.513 Kw.hr.ha^{-1}, while the speed 4.146 km. hr^{-1} was 98.086 Kw.hr.ha^{-1}, and that because increasing the speed of tractor leads to increase in the plowed area and reduces the time required to complete the plowing process, and thus the energy requirement decreases (4 and 11). Result showed significant effect on moldboard types, slatted moldboard recorded lower value of 92.563 Kw.hr.ha^{-1}, while general purpose moldboard recorded of 96.036 Kw.hr.ha^{-1}, and that because of general purpose moldboard was needed power requirement more than slatted moldboard, and difference in actual field capacity between both of them. Interaction depth of tillage with speed of tractor showed significant effect, Interaction depth 15 cm and speed 7.224 km.hr^{-1} was lower value of 76.916 Kw.hr.ha^{-1}, while interaction 25 cm with 4.146 km.hr^{-1} was 113.154 Kw.hr.ha^{-1} fig. 11. Interaction depth of tillage with moldboard types was significant, interaction depth 15 cm with slatted recorded of 78.351 Kw.hr.ha^{-1} while interaction depth 25 cm with general moldboard was 110.490 Kw.hr.ha^{-1}. Interaction speed of tractor with moldboard types was no significant. Interaction depth of tillage, speed of tractor and moldboard types showed significant effect, interaction depth 15 cm, speed 7.224 km.hr^{-1} and slatted moldboard recorded lower value 75.576 Kw.hr/ha, while interaction depth 25 cm, speed 4.146 km.hr^{-1} and general purpose moldboard recorded higher energy requirement value 115.981 Kw.hr.ha^{-1} fig. 12.

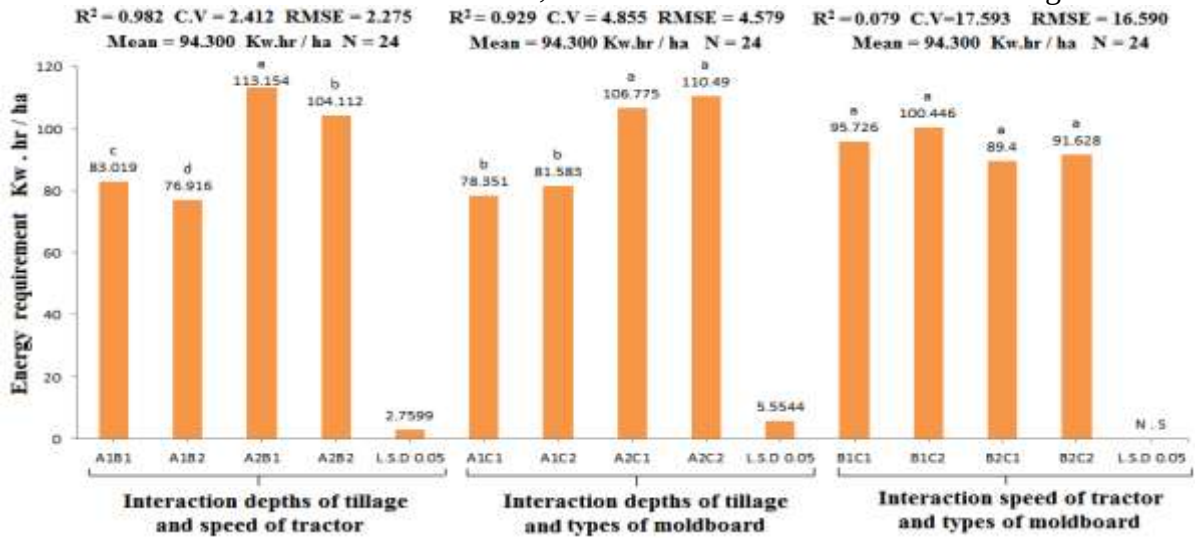


Fig.11 Binary interaction depths of tillage, speeds and types of moldboard on energy requirement.

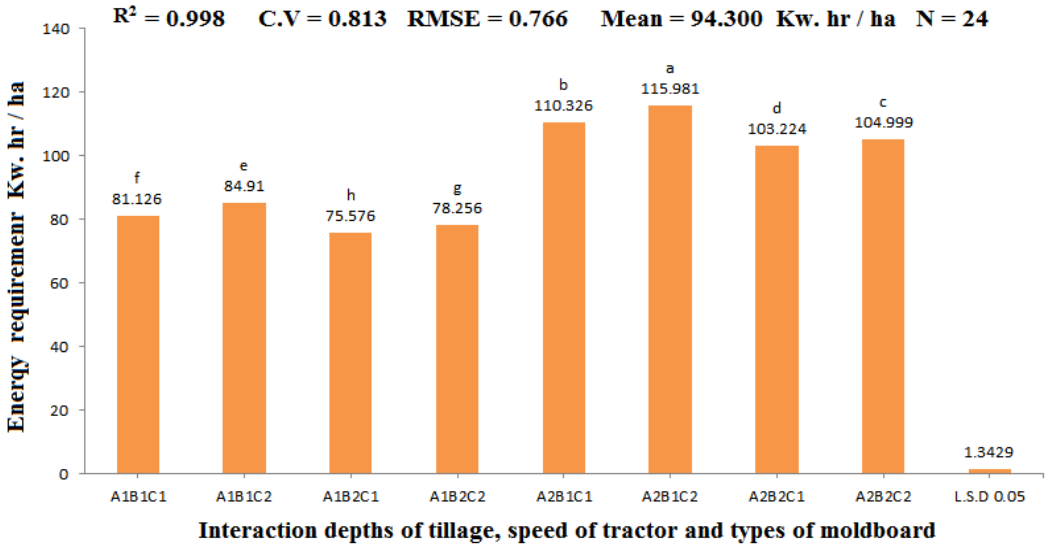


Fig. 12 Triple interaction of depth of tillage, speed of tractor and moldboard types on energy requirement Kw.hr.ha^{-1}.

CONCLUSION

Depth of tillage and speed of the tractor are the key parameters that affect performance, deflections in lines of tillage, fuel consumption, power estimate and energy requirement and this suggests that by observing and collecting data on the variables will aid optimal tillage. The slatted moldboard achieved the best (minimum) values of vertical and lateral deflections, fuel consumption, power requirement and energy requirement comparative with general purpose moldboard. Increasing the depth of tillage was reducing vertical and lateral deflections, while fuel consumption, power and energy requirement increased. Increasing the speed of the tractor was increased the deflections in plowing lines, power requirement and fuel consumption in unit L. hr^{-1}, while energy requirement was reduced.

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