Effects of tractor forward speeds on mulching depths during oil palm frond pulverization

B. G. Jahun[1], D. D. Usman[1*], H. A. Saeed[1], D. Ahmad[2], M. R. Mahdi[2], S. Sulaiman[3]

(1. Department of Agricultural and Bioresource Engineering Abubakar Tafawa Balewa University, PMB 0248, Bauchi State Nigeria;
(2. Department of Biological and Agricultural Engineering Universiti Putra Malaysia 43400 Serdang, Selangor/Darul Ehsan Malaysia;
(3. Department of Mechanical and Manufacturing Engineering Universiti Putra Malaysia 43400 Serdang, Selangor/Darul Ehsan Malaysia)

Abstract: The study investigates the influence of tractor forward speeds in predicting the reasonableness of the hypothesis on depth of mulching of oil palm fronds. In the oil palm industry, only 10% palm oil is produced and the remaining in the form of wastes, estimated at 80 million dry tonnes annually in Malaysia. To mulch this amount of wastes to the required depth, an optimum tractor forward speed is needed. Four blades with different lifting angles, two tractor PTO speeds and three tractor forward speeds were assessed using parametric test at Universiti Putra Malaysia oil palm plantation. The result shows that the best-fit regression equation was a quadratic regression with high coefficient of determination. It indicates that change on tractor forward speeds interaction has significant effect using Tukey's Studentized mean comparison when predicting the depth of mulching. Ninety-seven percent of the depth of mulching variance is explained by three factors interaction. Since tractor forward speed was a major predictor of depth of mulching, the implication of this result is that change in tractor forward speeds predicts the depth of mulching in an oil palm plantation significantly. Additionally, the predicted model can further be used to predict depth of mulching during field operation, replanting and access operation for mulching of oil palm fronds. Conclusively, blades with 120° gave the best mulching depth and a tractor forward speed of 0.57 km h^{-1} as the recommended speed.

Keywords: oil palm fronds, mulcher blades, mulching, mulching depth, tractor forward speeds

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1 Introduction

The oil palm *(Elaeis guineensis)* is a tropical tree of western and central African origin, known as the African oil palm, and is one of the oil palm types in the *Arecaceae* or palm family (Singh et al., 2013). Malaysia's present farmstead covers 5 million hectares as a significant exporter and producer of palm oil in the world, which is about 73 percent of the agricultural area (Smith et al., 2018). Ten percent of Palm oil is generated in the sector, while 90% is generated in the form of waste, which generates the largest amount of biomass, which is expected at 80 million tonnes per year (Aljuboori, 2013).

Oil palm fronds were stacked while trimming and replanting. The availability of fronds was calculated at the pruning process using an approximation of 10.4 tonnes ha^{-1}, which presently gives an annual average of 6.97 million tonnes Sung, 2016). Meanwhile, an average of 54.43 million tons of oil palm fronds per year would be available during replanting in the years 2007 – 2020 as evaluated by Haafiz et al. (2014).

Currently, palm fronds and stems are underused, and the presence of these oil palm wastes has created a

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***Corresponding author: D. D. Usman,** lecture, Ph.D., Department of Agricultural and Bioresource Engineering Abubakar Tafawa Balewa University, PMB 0248, Bauchi State Nigeria. Tel: +2347036689063. Email: ddusman@atbu.edu.ng.

significant problem of discarding in the plantation industry. It serves as a resident for insects, rodents and diseases which destroy young seedlings, decrease yields and cause crop losses of 40% and 92% respectively as reported by Sung (2016). Mulching is a technological practice that mulches and buries crushed oil palm residues and shredded trees in the soil. It is primarily used to crush and pulverize residues of oil palm fronds and shredded trunks to destroy insect and rodent residents, diseases, reduce soil erosion and boost nutrients (Onoja et al., 2019). Mulching is used in arable land to crush plant residues (Čedík et al., 2016).

The potential of mulching tool to sustain surface biomass mulching is mainly relied on the implement blades lifting angle and geometry. Zeng (2019) equated two types of cultivation tool to ascertain their capability to sustain grain sorghum surface biomass handling when working at two different mulching depths for summer and winter cultivation. Chisel-type tool, were found to mulch substantively less crop residue than disk-type implements (Wallace et al., 2017). Disk-type tool tends to bury increased amounts of crop residue when working at deeper mulching depths and this utilizes more energy and discourage farmers (Makange and Tiwari, 2015).

Mulching operation needs optimal depth and forward tractor speeds spent on farms. Therefore, requirements for depth and tractor forward speeds are essential in order to determine the blade lifting angle and geometry that could be used in mulching oil palm fronds for tractor mounted mulcher (Islam et al., 2019). The depth needed for mulcher implement will also be influenced by soil conditions and mulcher blade geometry (Jahun et al., 2016).

It is easy to adjust the Mulcher mulching depths and tractor forward speeds. The rotational blades shredded the oil palm fronds and mixed oil palm debris evenly throughout the implementation of mulching depth (Mandal et al., 2013).

A mulching tool, most notably the blade system, must mulch the soil and integrate it well to the required degree with the oil palm residue and adequately manipulate the soil (Osman, 2018). Mulching blades must make efficient use of the energy supplied to the soil by integrating the oil palm fronds into the soil. As noted by Beach et al. (2018), the capability of the mulching blade system must be high. The soil parameters used to determine mulching blade efficiency are disturbed by soil quantity, blade penetration depth, and soil condition.

Conventional method for determining tractor forward speed requiring a measuring tape or wheel and a stop watch was commonly used to determine average field tractor forward speed per row length (Ranjbarian et al., 2017). Although this method precision value that is acceptable in determining average field speed, the sensing of speed variation during the experiment is lacking (Campbell and Stanley, 2015). It also takes extra time to measure the distance that was frequently handled by two field personnel.

Variation in soil strength improves the mulcher implement penetration rate. When the soil is very difficult or compact, the implement penetration capacity reduces considerably, forcing the entire implement frame to be lifted (Roozbeh, 2020). Singh (2016) indicated that, by using scrapers, disks can cut, rolls over roots and other obstructions through crop residues and can function in non-scouring soil. They do not provide complete trash coverage, and cannot be used in a plantation farm. The aim of this article is to compare the efficiency of four tractor-mounted mulcher blades on mulching depths and tractor forward speeds.

2 Materials and methods

2.1 Experimental design and data collection

Experiments were performed at Universiti Putra Malaysia plantation farm to study the impacts of tractor forward speeds on the mulching depth efficiency of four mulching blades. Soil profiles of the farm are classified as textures of sandy clay loam. For this research, three influencing factors were selected: blade lifting angle at 4 levels (0°, 60°, 120° and 150°) as shown in Figure 1, three tractor forward speeds (1, 3 and 5 km h^{-1}) and two PTO speeds (540 and 1000 rpm) as independent variables were interacted and monitored the dependent variable. This was regarded to be a factorial idea fitted in a completely randomized block design (CRBD). Each experimental trial was performed in three replications, which gave 72 experimental designs. In the study, a 1.4 m working width of tractor and Howard Mulcher HM 50 implement was used, for a run length of 5 m and a plot size of 7 m^2. As such, a total of 72 plots in 504 m^2 experimental area were conducted for this research. A 0.5 m wide swath was left on each plot side for wheel path as shown in Table 2. To analyze the amount of significant and non-significant variance assessment (ANOVA) was used on the treatment and Tukey's Studentized technique of (α < 0.05) was used to determine significant differences between treatment means using statistical analysis systems (SAS 9.2) 2010 software. The ground speed of the tractor was evaluated using a concept of range and time. In all forward speeds, three gear levels called first, second and third were used. The depth was evaluated after the mulching using a unique graduation meter rule. Mulching depth was determined by means of steel ruler and undisturbed soil top as reference as shown in Figure 3. The steel meter ruler consists of a vertical scale, 10 cm high, which is divided in cm and fitted in an aluminum frame. While the area is mulched, the mulching depth was measured in about 10 places by means of a steel ruler and averaged. As shown in Figure 4, a Mulcher implement (1.4 m) and a New Holland tractor (G240) were used.

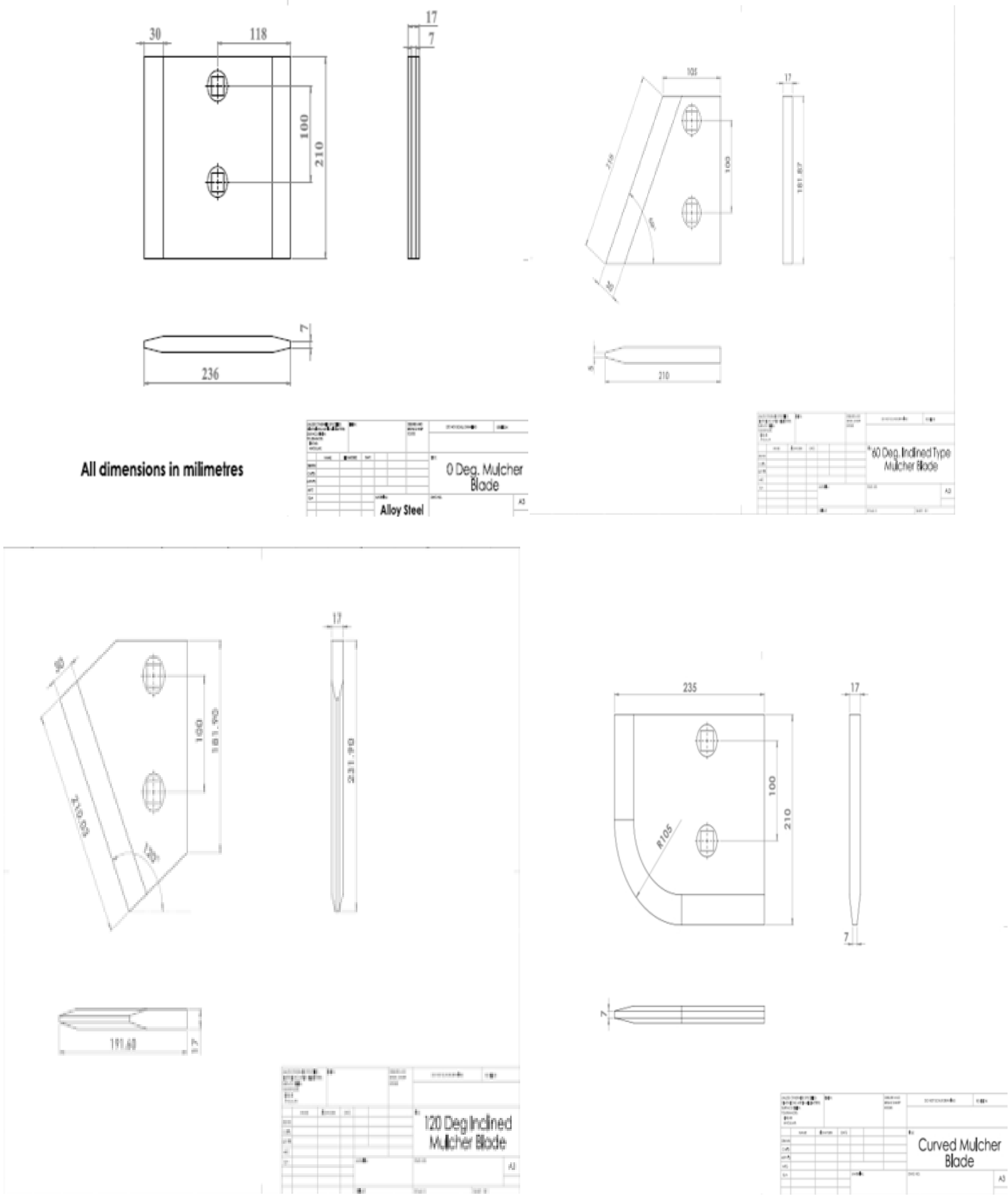

Figure 1 Orthographic model mulcher blades with 0°, 60°, 120° and 150° lifting angles

Table 1 **Field Layout for Performance of Mulcher Blade Designs**

	8.5m				
	60°	90°	150°	120°	
V1	B1V1P1	B2V1P1	B3V1P1	B4V1P1	R1
	B1V1P1	B2V1P1	B3V1P1	B4V1P1	R2
	B1V1P1	B2V1P1	B3V1P1	B4V1P1	R3
	B1V1P2	B2V1P2	B3V1P2	B4V1P2	R1
	B1V1P2	B2V1P2	B3V1P2	B4V1P2	R2
	B1V1P2	B2V1P2	B3V1P2	B4V1P2	R3
V2	B1V2P1	B2V2P1	B3V2P1	B4V2P1	R1
	B1V2P1	B2V2P1	B3V2P1	B4V2P1	R2
	B1V2P1	B2V2P1	B3V2P1	B4V2P1	R3
	B1V2P2	B2V2P2	B3V2P2	B4V2P2	R1
	B1V2P2	B2V2P2	B3V2P2	B4V2P2	R2
	B1V2P2	B2V2P2	B3V2P2	B4V2P2	R3
V3	B1V3P1	B2V3P1	B3V3P1	B4V3P1	R1
	B1V3P1	B2V3P1	B3V3P1	B4V3P1	R2
	B1V3P1	B2V3P1	B3V3P1	B4V3P1	R3
	B1V3P2	B2V3P2	B3V3P2	B4V3P2	R1
	B1V3P2	B2V3P2	B3V3P2	B4V3P2	R2
	B1V3P2	B2V3P2	B3V3P2	B4V3P2	R3

Note: Bi = ith blade angle; i = 1, 2, 3 and 4. Vi = ith tractor forward speed; i = 1, 2 and 3. Pi = ith PTO speed; i = 1 and 2

The tractor operation forward speeds were assessed by noting the machine working or operating distance and the time taken to cover the distance shown in Equation 1. Therefore, the operating speed was evaluated from the reported expression (Aremu and Ogunlade, 2016);

$$SW = \frac{Dw}{Tt} \qquad (1)$$

Where,

SW = Working speed, km h^{-1}, DW= Working speed, km, T_t=Total working time, hr.

2.2 Field experimental procedure

The tractor forward speeds used for mulching operations were 1, 3, and 5 km h^{-1}. These forward speeds were attained by regulating engine throttle at minimum engine speed and at three different tractor forward speeds settings as reported by Raghavendra and Yadahalli (2018). The tractor forward speeds were determined by placing the front tyres of the tractor at the beginning of 5 × 1.4 m of each plots. A stop watch is recording the time the tractor arrived at the end of each plot. A scale tape was used to measure the distance of tractor forward travel. The time and distance travel are recorded and applied in Equation 1 to obtain the tractor forward speeds as shown in Figure 4. In the case of mulching operation during replanting period, the tractor PTO gear is generally changed in the first or second gear (540 or 1000 rpm). Tractor operator would adjust the mulching pitch of tractor mounted mulcher by controlling the tractor forward speed precisely to satisfy needs for mulching and field performance evaluation (Jahun, 2018). To increase mulching efficiency while satisfying mulching field performance evaluation, it is recommended to adjust the PTO rotational speed continuously. The aim is to explore the advantage of the variable rotational speed of the tractor's PTO shaft. These target speed were obtained by operating the tractor at a PTO speeds of 540 and 1000 rpm, and adjusting the gearbox position. The mulcher blades were changed at every set of operations.

3 Results and discussion

The ANOVA results obtained for effects of mulching depth and tractor forward speeds and different mulcher blades performance are shown in Tables 2 and 3.

3.1 Effects of blade lifting angles, tractor forward speeds, and tractor PTO speeds on mulching depth using ANOVA

ANOVA was performed to determine whether there were significant impacts on mulching depth of blade lifting angles, tractor forward speeds and tractor PTO speeds as shown in Table 1. ANOVA results effect indicated that the blade-lifting angle (F=44.02, *p* = 0.0001 $p<0.05$) had a very significant effect on the mulching depth, indicating that the difference in the geometry of blade-lifting angles had a significant impact on the depth produced as a consequence of mulching, and mean depths were not equal between blade-lifting angles. Tractor forward speed levels also showed a highly significant impact on the mulching depth (F=28.03, *p* =0.0001 $p<0.05$), which showed that the greater the speed level, the deeper the mulch. The power take-off speed for mulching had a significant effect on the mulching depth (F=7.33, *p* =0.0095 $p<0.05$). The mean depth of mulching differentiated with PTO tractor speeds, which also showed a significant impact between blocks (F=0.02, *p* =0.044 $p<0.05$). This may be due to the oil palm plantation undulated nature. The interactions of blade lifting angles with tractor forward speeds, blade lifting angles with tractor PTO speeds as well as the combination of tractor forward speeds with tractor PTO mulching operation speeds all led significantly to the mulching depth with significance levels (F=9.13, *p* =0.0001 $p<0.05$), (F=5.24, *p* =0.0034 $p<0.05$), and (F=28.48, *p* = 0.0001 $p<0.05$). The two-way combination treatments had highly significant impacts on the mean of oil palm frond mulching depth. Interaction impact shows that the correlation between blade lifting angles, tractor PTO speeds, and tractor forward speeds with mulching depth depends on blade lifting angles, tractor PTO speeds, and tractor forward mulching speeds. Treatment of three-way blade lifting angle interaction, tractor forward speeds, and tractor PTO speeds also shows significant impacts on the mulching depth (F=28.48, *p* =0.0001 $p<0.05$). For combinations of blade lifting angles, tractor forward speeds, and tractor PTO speeds, at least one of the mean mulching depths is considerably distinct. We can conclude that in the mean mulching depth there was an interaction between blade lifting angles, tractor forward speeds, and tractor PTO speeds. Variance analysis showing significance in primary treatment and interaction treatment will not be enough to conclude the significance level. Therefore, determining where the difference lies is necessary. The level and variety of the meaning level can be solved only by means of a mean comparison.

Table 2 Effects of blade lifting angles, tractor forward speeds, and tractor PTO Speeds on mulching depth using ANOVA

Source	DF	Mean Square	F Value
Model	25	26.68	16.84**
Blade Lifting Angles	3	69.73	44.02**
Tractor Forward Speeds	2	44.41	28.03**
Tractor PTO Speeds	1	11.61	7.33*
Block	2	0.02	0.02*
Blade Lifting Angles*Tractor Forward Speeds	6	14.47	9.13**
Blade Lifting Angles*Tractor PTO Speeds	3	8.29	5.24*
Tractor Forward Speed*Tractor PTO Speeds	2	45.12	28.48**
Blade Lifting Angles*Tractor Forward Speeds*Tractor PTO Speeds	6	25.91	16.35**
Error	46	1.58	
Corrected Total	71		

Note: **highly significant *significant

3.2 Effects of blade lifting angles on mulching depth

The medium for main impacts and interaction effects of blade lifting angles, tractor forward speed and tractor PTO speed on the mulching depth were compared for treatment means. Figure 6 shows means comparison using the Tukey means comparison for the impacts on the mulching depth of blade lifting angles. The separating means showed that means are not significantly distinct with the same letters. Mulching depth estimates were insignificantly distinct with mean mulching depths of 17.89 and 17.51 cm respectively for blades with 60^o and 120^o lifting angles. Similarly, for blades with 0^o and 150^o lifting angles, mulching depths of 21.27 and 20.91 cm were not significantly distinct. The variation in the mean mulching depth would also assist to conclude that 0^o and 60^o lifting angles had significantly differed between blades. Similarly, blades with 120^o and 150^o differed significantly. Mulching depth with blade with lifting angle of 150^o generally provided the highest mulching depth, while blade with lifting angle of 120^o provided the smallest mulching depth. We may say that it is suggested for mulching to use the blade with 120^o

lifting angle. The findings were in agreement with the results of Ghimire et al. (2017) results.

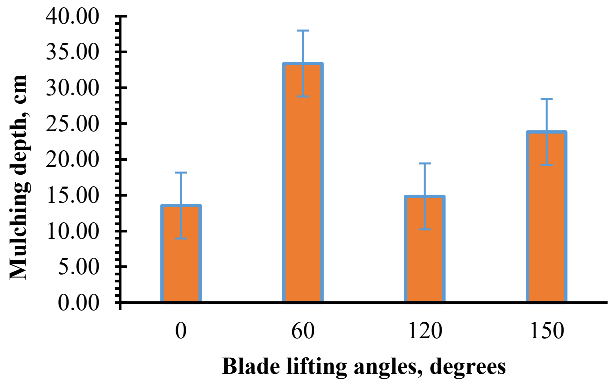

Figure 2 Effects of different types of blades on depth of mulching

3.3 Effects of tractor forward speeds on mulching depth

ANOVA as shown in Table 1 shows that tractor forward speed had a significant impact on the depth of mulching. This implies that the mean between the speed rate was not the same. Figure 3 shows the Tukey means comparison technique for the impacts on the mulching depth of tractor forward speeds (1, 3, and 5 km h^{-1}). Mulching depths implies that they are not substantially distinct with the same letters. It shows that mulching depths with tractor forward speeds of 1 and 3 km h^{-1} were not significantly different with 18.75 and 18.48 cm, while mulching depth at 5 km h^{-1} differs significantly from mulching depth at 1 and 3 km h^{-1} tractor forward speeds. This implies that the highest level of mulching speed, the greater the mulching depth than the reduced and mid-speed levels, and therefore we can also conclude that by raising the tractor forward speed while mulching the oil palm fronds with soil also improved the depth of mulching. Makange and Tiwari (2015) recorded the same trend in the impact of mulching depth on soil modification.

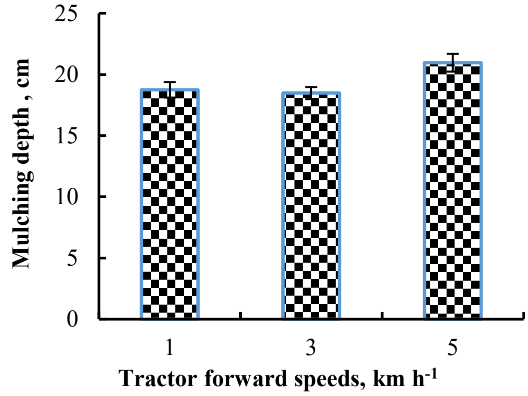

Figure 3 Effects of tractor forward speeds on mulching depth

3.4 Effects of blade lifting angles and tractor forward speeds on mulching depth

The impacts on mulching depth of blade lifting angles and tractor forward speeds had shown that at least one of the mulching depth means is significantly distinct. Figure 4 shows that the blade with 0° lifting angle did not show a substantial difference in tractor forward speed because the mean depth of the mulching was considerably the same with a mean depth of 21.57, 20.68, and 21.55 cm respectively. Similarly, there was no important difference in the blade with a lifting angle of 60°. We can see that tractor forward speeds of 1, 3 or 5 km h^{-1} had no significant impact on the mulching depth with average depths of 18.09, 17.42 and 18.16 cm. Becker et al. (2019) endorsed this in a research that the faster the blade action, the more the tractor forward speeds.

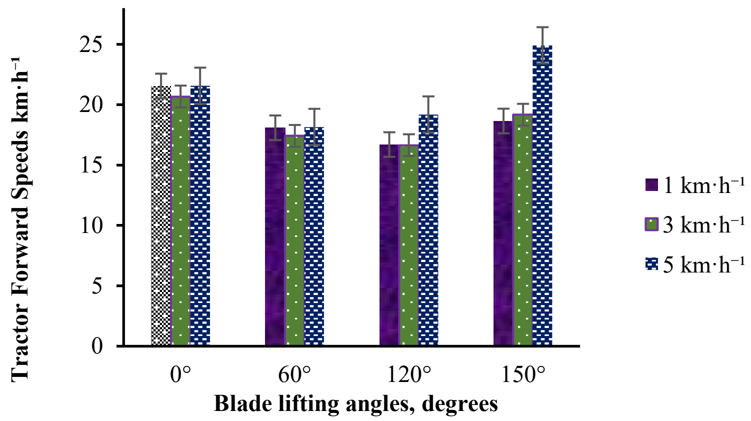

Figure 4 Effects of blade lifting angles and tractor forward speeds on mulching depth

3.5 ANOVA on effects of blade lifting angles, tractor forward speeds, and tractor PTO speeds on actual tractor forward speeds

ANOVA was conducted to explore the source of variation in blade lifting angles, tractor forward speeds and tractor PTO speeds on tractor forward speeds. The findings in Table 2 show that the blade lifting angles (F = 67.78, p <0.0001 with ($p<0.05$) have an extremely important effect on the actual tractor forward speeds. It obviously demonstrates that the angles of the blade lift had significant impacts on the actual forward speed of the tractor. The trend shows that, among the blade lifting angles, the means of actual tractor forward speeds were not equivalent. The tractor forward speeds had a very significant impact on the actual tractor forward speeds (F = 35.23, p <0.0001 with ($p<0.05$). It revealed that the greater the speed, the greater the actual forward speed of the tractor. Conclusively, there were considerably different tractor forward speeds. The tractor PTO speeds from the ANOVA had extremely important impact on the actual tractor forward speeds (F =107.24, p <0.0001 with ($p<0.05$). The tractor PTO velocities had an invariably significant impact on the actual tractor forward speeds. The average actual forward tractor speeds varied with PTO tractor speeds that showed no important impact between blocking (F value 0.05, p <0.9534 with ($p<0.05$). This could be due to the tractor's adverse draft forward speeds during the mulching of oil palm fronds on normal tractor forward speeds.

The treatment of blade lifting angles and tractor forward speeds had a major effect on the real tractor forward speeds (F = 3.93, p <0.0030 with ($p<0.05$). Similarly, interaction between blade lifting angles and tractor PTO speeds indicates a non-significant impact on actual tractor forward speeds with (F = 0.57, p <0.6395 with ($p<0.05$), meaning that at all distinct lifting angles and tractor PTO speed levels there would be no meaning based on their interaction. The interaction of tractor forward speeds and tractor PTO speeds has extremely significant impact on actual tractor forward speeds (F= 76.58, p < 0.0001 with ($p<0.05$). We can conclude that the interaction between tractor forward speeds and tractor PTO speeds is extremely dependent on blade geometry and lifting angles, tractor forward speeds and tractor PTO speeds on actual tractor forward speeds. The interaction between three variables researched characteristics that are blade lifting angles, tractor forward speeds and tractor PTO speeds revealed extremely important impact on the actual tractor forward speeds (F = 101.89, p < 0.0001 with ($p<0.05$). It is obviously shown that there is a significant shift in one of the average actual tractor forward speeds for the relationship of blade lifting angles, tractor forward speeds, and tractor PTO speeds. Since the test of significance using ANOVA cannot be concluded, further assessment using means comparison is suggested.

Table 3 ANOVA on effects of blade lifting angles, tractor forward speeds, and tractor PTO speeds on actual tractor forward speeds

Source	DF	Mean Square	F Value
Model	25	0.14	46.84**
Blade Lifting Angles	3	0.20	67.78**
Tractor Forward Speeds	2	0.10	35.23**
Tractor PTO Speeds	1	0.31	107.24**
Block	2	0.0001	0.05^{ns}
Blade Lifting Angles*Tractor Forward Speeds	6	0.01	3.93*
Blade Lifting Angles*Tractor PTO Speeds	3	0.002	0.57^{ns}
Tractor Forward Speeds*Tractor PTO Speeds	2	0.22	76.58**
Blade Lifting Angles*Tractor Forward Speeds*Tractor PTO Speeds	6	0.30	101.89**
Error	46	0.003	
Corrected Total	71		

Note: **highly significant *significant ns =not significant

3.6 Effects of blade lifting angles on actual tractor forward speed

The treatment implies relationship was studied on the main impacts on the actual forward speeds of the tractor. Figure 5 shows comparison by means of Tukey's separation for the impacts of blade lifting angles on tractor forward speeds. The means of comparison shows that the averages are not substantially different with the same letters. With averages of 0.57 and 0.60 km h^{-1}, the mean of real tractor forward speeds for 0° and 60° lifting angles were not considerably altered. Also, blades with lifting angles of 120° and 150° with mean forward speeds of 0.77 and 0.77 km h^{-1} on the actual tractor show no important distinction. The shift in means shows that there were significant variations between lifting angles of 0° and 60° blades and lifting angles of 120° and 150° blades.

The blade with a lifting angle of 0° generally gave the smallest actual tractor forward speeds and the highest was achieved by the blades with lifting angles of 120° and 150°. Conclusively, for actual tractor forward speeds for mulching of oil palm fronds, blade with 0° lifting angle may be recommended as suggested by Chandio (2013).

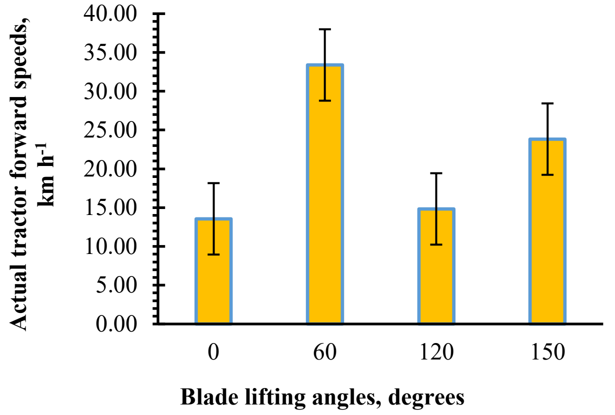

Figure 5 Effects of different types of blades on the actual tractor forward speeds

3.7 Effects of tractor forward speeds on actual tractor forward speeds for mulching oil palm fronds

Table 2 demonstrates the outcomes of the ANOVA that show tractor forward speeds exceeded the actual tractor forward speeds. This invariably implies that they were not equivalent among the average values of actual tractor forward speeds.

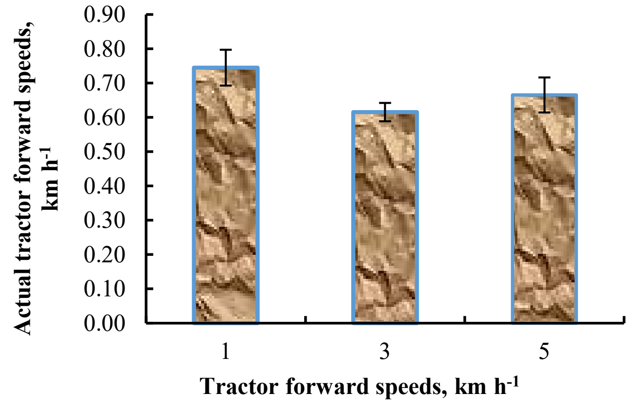

Figure 6 Effects of tractor forward speeds on actual tractor forward speeds

Figure 6 also illustrates the Tukey's technique of separation of means, which evidently indicates that mean with the same letters is not substantially different. It shows that with the mean average of 0.75, 0.62 and 0.67 km h^{-1}, and all tractor forward speeds (1, 3 and 5 km h^{-1}) appeared considerably different. It shows that the highest actual tractor forward speed is 1 km h^{-1} and the lowest for oil palm fronds is 3 km h^{-1}. It can be concluded that 3 km h^{-1} tractor forward speed gave 0.62 km h^{-1} highest mulching speed as observed by Moeinfar et al. (2014).

3.8 Effects of tractor PTO Speeds on actual tractor forward speeds

ANOVA in Table 2 shows a major difference in tractor PTO speeds affecting actual tractor forward speeds. Tukey's means of separation have also been carried out and mean with the same letters are not substantially different. Figure 7 shows important variations in actual tractor forward speeds between tractor PTO speeds at 540 and 1000 rpm. The 540 rpm tractor PTO speed is the smallest with a mean value of 0.61 km h^{-1} and the highest actual tractor forward speed with an average value of 0.74 km h^{-1} of 1000 rpm. The result found that the quicker the actual tractor forward speed, the higher the tractor PTO speed as reported by Ranjbarian et al. (2017).

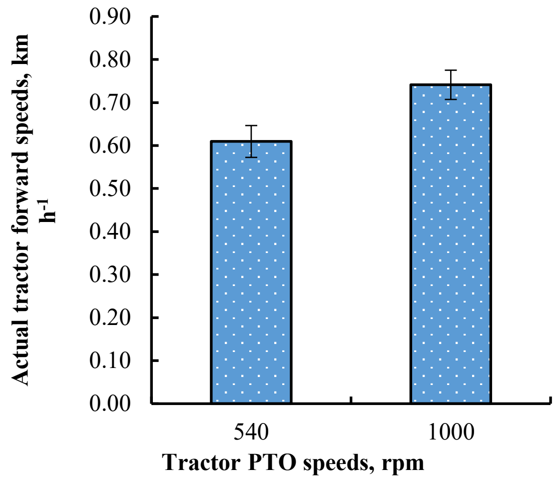

Figure 7 Effects of tractor PTO speeds on actual tractor forward speeds

3.9 Effects of blade lifting angles and tractor forward speeds on actual tractor forward speeds

The impact on actual tractor forward speeds between the combinations studied of blade lifting angles and tractor forward speeds shows that one of the average tractor forward speeds is expressively distinct. Based on the mean comparison performed by Tukey's and the average is not substantially different with the same letters. Figure 8 shows that blade with 0° lifting angle showed no significant difference with average values of 0.77, 0.70

and 0.70 km h^{-1} for 1, 3 and 5 km h^{-1} speed levels. This implies that no important modifications are acknowledged on actual tractor forward speeds at any stage of tractor forward speeds during mulching of oil palm fronds. The tractor-mounted mulcher tool works on adverse draft. Also, there was no significant difference in the blade with a lifting angle of 60°. It is evident that tractor forward speeds of 1, 3 and 5 km h^{-1} did not have any significant effects on actual tractor forward speeds of 0.84, 0.77 and 0.84 km h^{-1} respectively.

Blade with a lifting angle of 120° showed no important distinction with tractor forward speeds of 1, 3 and 5 km h^{-1} with mean values of 0.69, 0.62 and 0.63 km h^{-1} respectively with actual tractor forward speeds. Similarly, the blade with a lifting angle of 150° showed no significant distinction between the three tractor forward speeds of 1, 3 and 5 km h^{-1} for the actual tractor forward speeds when the oil palm fronds were mulched. No significant change in the actual tractor forward speeds at any level of tractor forward speed as reported by Nkakini (2015).

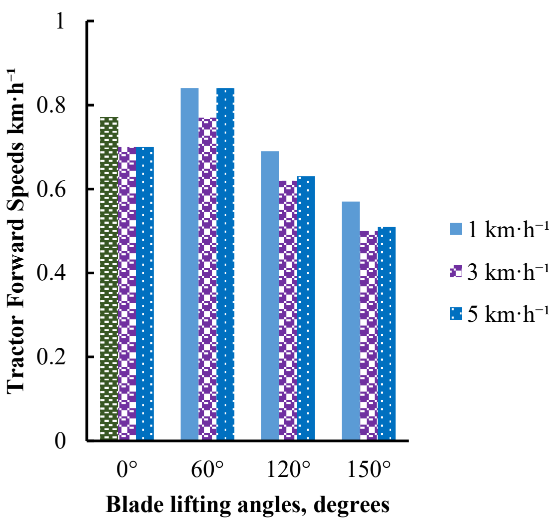

Figure 8 Effects of blade lifting angles and tractor forward speeds on actual tractor forward speeds

3.10 Linear and quadratic regression on the effects of blade lifting angles, tractor forward speed and tractor PTO speed on actual forward speed

In order to assess if blade lifting angles, tractor forward speed and tractor PTO speed can significantly predict actual tractor forward speed, the multiple linear regression analysis was used. The results of the linear regression demonstrated in Table 3 gave a significant effect, p <0.0014 and the R^2=0.2275 which is too low to predict the model. Invariably, the models could not be used to determine the effect caused by various test factors on the actual tractor forward speed due to non-reliability of the models. However, quadratic regression analysis was conducted to predict the Actual Tractor forward speed and the result gave a significant effect at p <0.0005, the quadratic coefficient indicating (R^2= 0.97) in the variance on actual tractor forward speed which is a significant predictor. Conclusively, quadratic regression is considered fit to predict actual tractor forward speed due to reliability of the models as agreed by Bietresato et al. (2015).

Table 3 Linear and quadratic regression on the effects of blade lifting angles, tractor forward speed and tractor PTO speed on actual forward speed

	Model	Equation	Sig. F	R^2	Adj. R^2
Actual Forward speed	Linear	$ActForS = 0.276 + 0.0023Btype - 0.0199Fs - 0.0003PTOS$	0.0005	0.2275	0.1934
	Quadratic	$ActForS = -0.000Btype^2 + 0.0008type - 0.020Fs - 0.000PTOS + 0.377$	0.0014	0.97	0.183

Note: ActForS- Actual Forward speed, Bt.- Blade Lifting Angles, Fs.- Forward speed, PTOS. – Tractor PTO speed

4 Conclusion

The results of this experiment on a mulching depth variation due to different tractor forward speeds shows that pulverizing oil palm fronds at different forward speeds has significant effect on mulching depth. The average value for the actual forward speed revealed that best forward speed was obtained by Blade with 120° at Tractor forward speed of 1 km h^{-1} and the Tractor PTO speed of 540 rpm having 0.57 km h^{-1} as actual tractor forward speed. The determination coefficient (R^2) of these regression models were 0.27 (linear) and 0.973 (quadratic), which meant that the models had a favourable fitting degree and can be applied to predict mulching depth during pulverizing oil palm fronds.

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