J. Agric. Sci. Mansoura Univ., 27 (9): 6345 - 6360, 2002

COMPARATIVE MANEUVERABILITY OF THREE GROUND DRIVE DEVICES UNDER EGYPTIAN RICE FIELD CONDITIONS

Abou-Elmagd, A.E.
Agricultural Engineering Dep., Fac. of Agric., Mansoura Uni. Egypt.

ABSTRACT

The maneuverability of three ground-drive devices has been investigated and compared within straight-line and angled traffic passes in the Egyptian rice field. *Three series of comparative maneuver tests were carried out, comprising the* comparisons between the crawler, pneumatic tire, and steel lug wheel types. The straight-line motion has been tested over 3 different soil moisture contents and at 5 different forward speed levels. Whiles, the angled motion have been studied as it's affected by tight and wide turning angles at the rice field boundaries.

The maneuverability of the tested running devices was evaluated and *compared in terms of the lugging ability of the vehicle, and the soil compaction* deduced by running each device in each maneuver test.

The results summarized in the following points: -

Comparing the crawler, and steel lug wheel types, the crawler was less lugging ability and more damaging the soil at the rice field boundaries.

The average propelling resistance of the angled pass exhibited of about 1.1-*1.16 times that propelling resistance of the straight-line motion.*

During the maneuvering by crawler, pneumatic tire, and steel lug wheel, the averages of vehicle engine loading were as 1.58, 3.72 and 1.21 kW/ton weight of the vehicle respectively. The wider turning radius reduced the soil damage (compaction), and satisfactory the propelling force requirements.

INTRODUCTION

The surface of paddy fields must be puddle immediately before transplanting until it is a semi-liquid mud condition. In addition, at the seasons of tillage for the next crop, where it is saturated or flooded conditions. This *environment presents very unfavorable conditions for operating the farm* vehicles. That is because of the slippage of tires and adhesion of sticky soil Taylor *et al.*, (1982) showed that on a muddy surface of the rice field, the coefficient of traction is lower, and travel reduction of the farm vehicle is higher than normal. Oida et al (1991) reported that the paddy field soil, is non-homogeneous, since its properties such as moisture content cohesion and adhesion shear resistance and friction angle of the wheel interface are different in the respective soil layers.

During the last three decades, many vehicle kinds of tractors, and self-propelled equipment of different ground drive devices have been operated in the Egyptian rice field. Witney (1988) reported that the ground-drive device of the *farm vehicle must fulfil* three requirements, namely: - traction; flotation; and maneuverability. In fact the traction performance of different running devices, has already been investigated, in some details in a lot of literatures (Wong *et al* (1984); Baladi, and Rohani (1984); and Itoh, and Oida (1990). Also, greater emphasis has been given to the way in which, the traction requirements interact with those for flotation however the additional weight necessary to increase the traction effort developed by the wheel or track causes soil compaction Abdel-Mageed et al (1989).

For mechanizing the Egyptian rice field, which is primarily small-size holdings, it is necessary to select high maneuver ability vehicle. That is because the operated vehicles normally make turns by applying the brake either in the inside crawler of combines or in the front-inside wheel of the rubber wheel tractors. The braking spots of the ground drive devices in the rice field are often damage due to the slippage of the running device. Milyahara, M., and Onishi, N (1995), indicated that the steeping force of the brake pedal required at a tire is about 98 to 147 N or almost as big as that required for making an emergency stop of a car. They indicated that this makes more difficult in other subsequent works in the rice field due to the soil compaction. They concluded that the final (proper) size of the most ground-drive device of the vehicle might be such that the overall width of the vehicle exceeds the legal limit for maneuverability on the headland and in the farm steering.

In fact, numerous investigations have been carried out on factors affecting compaction; these have been well summarized ASAE, and MSAE. The investigated factors included the soil moisture content, the vehicle load, the tire inflation, and the vehicle speed. EL-Sahrigi, and Abo-Habaga, (1993) indicated that the surface of paddy fields is susceptible to compaction. Consequently the crop yields can be depressed by that compaction damage. Hence the tractors and the other farm vehicles which are operated on these soft surfaces need the specially made running devices used with tires or instead of tires.

Tanaka, (1984), indicated that in the paddy fields, vehicles will begin to lose their mobility, when the sinkage rises above 10-15cm. He showed that the steel open lug wheel, or the floated lug wheel can cross even on the muddy soil surfaces by catching the comparatively hard layer under the soft layer by the lug tip, with help of easy sinkage. But in soil surface conditions, where there is not the considerable hard under-layer strong enough to support the vehicles, immobilization may be occurring. He concluded that on these surfaces, the vehicles, of less ground contact pressure like the vehicles with tracks or with floats must be used. He mentioned that rubber tracks are used as the running devices of the combine harvesters that are usually work on soft, moistened surfaces, That is because tracks have a low ground, contact pressure of 10-20 KPa (0.1-0.2 kg/cm2).

In fact, Dudzinski (1984) reported that maneuverability is one of the major performance characteristics, which determines both vehicle travel safety, and performance efficiency. He defined the maneuverability as a set of properties characterizing the vehicle capability to move following precisely the trajectories set by a driver. He added that to study vehicles maneuver there are two viewpoints upon which, the vehicle maneuverability is considered. One is to study the energy performance of a traction device in relation to its design parameters and terrain conditions. The energy performance of a driven traction device is usually defined by its pull, motion resistance, sinkage and slip in relation to its normal load, input torque and angular speed, That performance is of prime interest to all vehicle users.

The second application is the prediction of the changes of soil conditions caused by the passage of the ground device. This is of great interest to agricultural engineers in the evaluation of soil compaction caused by farm vehicles, and to construction equipment engineers in the assessment of the effectiveness of roller compactor.

Voohees and Walker (1977) found that the first pass of a wheel on loose soil did about 80 percent of the total compaction, which resulted from, passes in the same spot. Raghavan et al., (1978) found that the compaction in a clay soil reached a maximum between 15 and 25% wheel slip. He found an increase of dry density from 0.25 to 0.48 g/cm3 occurred due to wheel slip. Taylor *et al.* (1982) measured the bulk density and sinkage during 4 passes of tire for 3 tilled soils and 2 dynamic loads. They found that 75% of the bulk density and almost 90% of the sinkage occurred on the first pass. Siemens, (1989) indicated that the surface contact area of the track was several times more than pneumatic tire. He also reported that stresses applied by a track were only approximately one-half that of the pneumatic tire. He indicated that the increase in soil compaction due to traffic would be greatest when the moisture content is near field capacity.

The Japanese type combines are primarily used to harvest rice in Egypt. Haruo ESAKI (1984) showed that the Japanese combines are equipped with crawlers with a mean ground contact pressure as low as 15-25 KPa (0.15-0.25 Kgf /cm^2). He added the ratio of length to width of the crawler's ranges 3.2 to 3.5. While its weight (W) ranges between 400-and 3000 Kg. Also, that combine weight W is correlated with the cutter bar length Lc (cm) as follows: W=2Lc-550 .He added that the position of the static center of gravity of them is positioned at a distance Gz (cm) equal to the product of ground contact length of the crawler (cm) by a constant value ranges between 0.55 and 0. 90.

From the forgoing review, It is confined that the time of passes increases by increasing the overlapping of traffic passes, which is occurred mainly at the field boundaries. It is also confined that time increases by increasing the slip ratio during the straight-line motion. That may be lead to increasing of the vehicle sinkage and the soil bulk density. Consequently the soil compaction beneath the traffics of the high slip may be increased.

Looking ahead, it appears that knowledge about the maneuvering process of the running devices in the rice field (especially in Egypt) is indispensable for a manger aiming to the optimum ground-device performance. Hence, the objective of the present study has been proposed to provide guiding principles for the rational selection of the best running device design to suit the maneuver in the rice field. We mainly focused on the propelling resistance and the soil compaction, which are coupled to the maneuver of three different running devices as they perform different maneuver systems under different soil moisture conditions in the rice field.

MATERIALS AND METHODS

The present study investigated and compared the maneuverability of three differed running-device vehicles within straight-line and angled maneuver motions over different moisten pattern in the Egyptian rice field. These devices were being deduced, as they are equipped to their self-propelled vehicles.

The tested vehicles: -

The main specifications of the running vehicles and their coupled ground drive devices are shown in table (1). These vehicles are designed in Japan, and introduced to Egypt throw the collaboration of the Japanese International Cooperation Agency (JICA), and the Agricultural Engineering Research Institute (AEnRI).

Table (1): the main specifications of the tested running vehicles

Items		Rubber wheel tractor		Lugged wheel tractor		Crawler combine
Model		M 7500 DT		2500-I-SPR		RX 2100-U
Weight ,ton (KN)		2.57(25 26)		0.829 (8.14)		1.53(15.01)
Engine power (kW/rpm)		44.77 / 2700		9.70 /2200		14 72 / 3000
Running device data: -	Items	Front	Rear	front	Rear	Rubber Crawler
	Type	Pneumatic	Pneumatic	Steel	Steel	
	Size	9.5/9-24	16.9/14-30			
	Inflation, Kpa	160	120	--------	--------	--------
	Static load, KN	4.63	8.03	3.645	4.455	15.01
	Diameter, mm	1070	1463	600	900	
	Sec. Height, m	0.206	0 321			
	Len.*width mm	Wheel base=1200mm		W.b=1200mm		1212*350
	Contact pressure Kg_f/cm^2(KPa)	0.22	0.28	0 17	0.18	0.180 (18)
Steering Type		Front-wheel		Power		Skid

It is to be noted that all the attachments of tested vehicles were not included in the tests, and only the types and the sizes of the running systems are considered in this study. For example the combine had the cuter bar attachments, and the steel wheel tractor had the transplanted attachments but they were not in use Fig (1). Also for the steel wheel tractor the circular ring plate connects the float type lugs, and the lugs can be folded to the direction of the center of wheel when the tractor runs or to be tested on the hard surface or paved road.

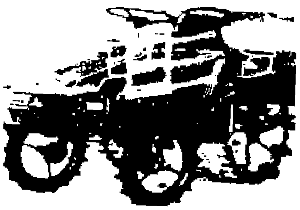


Fig (1): The tested steel tractor without attachments

The mobility patterns: -

The tests were carried out in rice fields in an area of two feddans at" Rice Mechanization Center" farm, at Meet El-Deeba. Kafr El-Shiekh Governorate". The field was just as it was left after the rice had been harvested.To determine the particle size distribution, cacao, organic matter and soil textural class (table 2), soil samples were collected through the depth (0-30 cm) and analyzed according to Rowell (1994).

Table (2); Soil analysis of the experimental field

Clay %	Silt %	Clay+ Silt %	Fine Sand %	Coarse Sand %	CaCOa %	Organic Matter %	Soil Tex. Class
52.31	17.88	70.19	26.82	2.99	1.43	0.91	Clay

Methodology

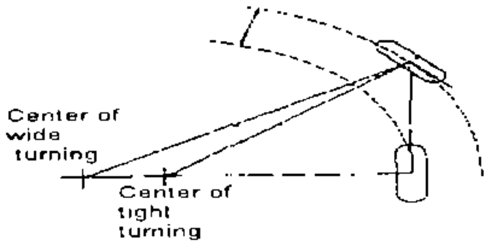
Three groups of experiments were planned to study that maneuverability. Every group was performed in every soil moisture content conditions. Since the treatments and their replicates of each individual group were performed over a series of soil moisture conditions from wet to dry. The averages soil moisture content of the mobility patterns were three approximate levels of 50.4, 45.7 and 38.5% (db). The soil moisture content was determined as an average for soil samples that were taken from three different depths (0-10), (10-20) and (20-30) cm. It was estimated according to the screw auger method of Rowell (1994).

The first group of experiment

That group included 72 comparative tests. It was performed in both straight-line, and angled motions to look into the effects of four mobility pattern conditions and three propelling speeds on the lugging ability of the tested devices. It should be noted that lugging ability is the measure of the capability of the ground drive system to overcome load increase in the field caused by the condition of the mobility pattern and by the propelling speed. Hence, three factors are considered to evaluate that ability. These factors are the propelling resistance (PR) (to propel the vehicle at zero-load) the, propelling coefficient (ŁC), and the increment rate in lugging ability (ŁR%).

In order to determine the propelling resistance (PR) an auxiliary tractor was used to pull each tested vehicle over various surface conditions in both straight-line, and angled motion. The investigated surface conditions were pavement and 3 paddy surfaces at moisture contents of 50.4, 45.8,and38.5% respectively. Hitching a spring dynamometer to the drawbar of that tractor made the pulling tests. Hence the pulling force to propel the tested vehicle was measured at starting and when operating the auxiliary tractor at low and high fuel governor setting in the first gear. In the straight-line motion each tested vehicle was pulled for a 50m long. While in the angled motions, the pull was inspected when the auxiliary tractor was turning on the circumference of a pre remarked circle of about 30 m diameter over the above mentioned surface conditions Fig (2).

For purposes of direct comparison the propelling resistance (PR) is expressed in KN of pull per ton of vehicle gross weight. It is quotient of the measured pull divided by the weight on the driving members. That weight, in the case of crawler device, being the weight of the combine itself 15.01KN(1.53 ton). While the corresponding weights in the case of the steel and the rubber wheels are about 8.14and 25.26 KN (0.829and2.57tons) respectively.



Fig(2) Turning center and radius of the auxillrary tractor during the angled motion

The coefficient of propelling (ŁC), could be estimated as the ratio of the propelling resistance (PR) divided by the vehicle weight. While the decrement rates in lugging ability was verified by determining the increment (ŁR%) of the propelling resistance. That could be estimated by dividing the difference between the propelling resistance obtained over a certain field moisture condition (PRm) and the corresponding resistance obtained over pavement (PRp) by (PRp) as follows: -

$$\text{£R\%} = \frac{PRm - PRp}{PRp} 100 \text{ ....\%. ....(1)}$$

The second group of experiment

That group included 15 self-propelling tests for each of the tested vehicles themselves. It was performed to show, on one end, the changes of vehicle slip (SL%) as affected by the running speed and soil moisture content. On the other end to show the soil compaction coupled with that slip. That could be done by driving each tested vehicles only in straight-line motion at five forward speed levels of about o.42, 0.55, 0.69, 0.83, and 0.97 m/sec over the three different soil moisture content levels.

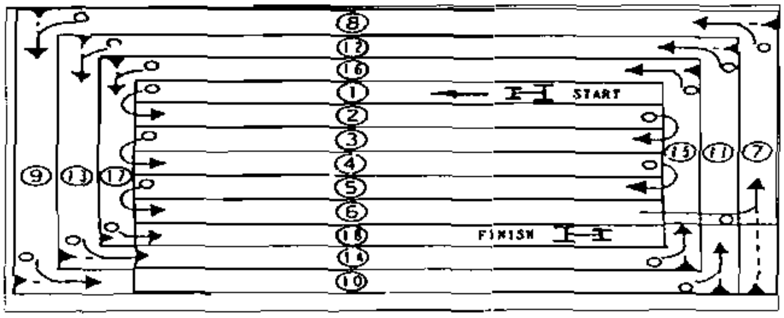
The soil compaction, induced by each device, was determined after passing the vehicle; it could be explored in terms of the change in soil bulk density (BD), which were taken beneath each running device. The, (BD), was estimated according to the method of Rowell (1994).

The third group of experiment

The braking spots of the ground drive devices in the rice field are often damage due to the stepping forces of the running device. Fig (3) shows that multiple traffic (wheel or crawler) passes are occurred on the same track. Hence other series of 18 comparative tests could be set up in angled turning motion at the rice field boundaries. These tests was to look into the effects of the overlapping of traffic passes on the soil bulk density (BD) and the soil surface encountered sinkage depth (Z) over thee different moisture conditions. The parameters (Z) and (BD) were measured mainly in the braking zones after two angled paths. The first of resulted from turning at angle of 90 ^{0} (Sharp or tight turning. That path type is shown in Fig (3) by the numbers 15,and 17. While the second path resulted from turning at angle of 180 ^{0} (wide turning) is shown in Fig (3) by the numbers 7,9,11,and 13. It should be noted that parameter Z was measured from the base area of the soil surface. The effects of the tested devices on sinkage was characterized by a sinkage improvement factor, (ZF) which was estimated as follows:

$$ZF = \frac{Z2 - Z1}{Z1} 100 \ldots\ldots \%. \ldots\ldots \ldots (2)$$

Where Z1 is the sinkage depth per ton weight of the vehicle in the straight-line paths of Fig (3), and Z2 is the corresponding sinkage depth at the rice field boundaries. Logically, The ground drive device that will be exhibited high (Zf) values will be evaluated as less maneuverability device, and vice versa.



○ Zones of braking the inner wheel

Fig (3): **Zones where the changes in soil bulk densities and sinkage depths were expected at different turning angles of 90°, and 180°**

RESULTS AND DISCUSSION

The maneuverability was inspected in both turning and straight-line motions. The results of the comparative performances of the three tested drive devices may be visually assessed from the following headings: -

1- Effects of the running devices on the vehicle lugging ability-:

Table (3) shows the averages of typical propelling resistance (PR) data, which accomplished the three, tested running vehicles under different maneuver conditions. These data are tabulated in descending order of the average pull obtained from 3 replications for each of 72 pulling tests. It may be observed that (PR) of the steel wheel tractor exhibited the lowest values over the four tested surface conditions and at any pulling speed. That resistance reaches its lowest value (0.45 kN) over the pavement surface at high pulling speed. While it attains its peak value (1.27 kN) on the paddy field of 50.4% moisture content at the starting of angled pull.

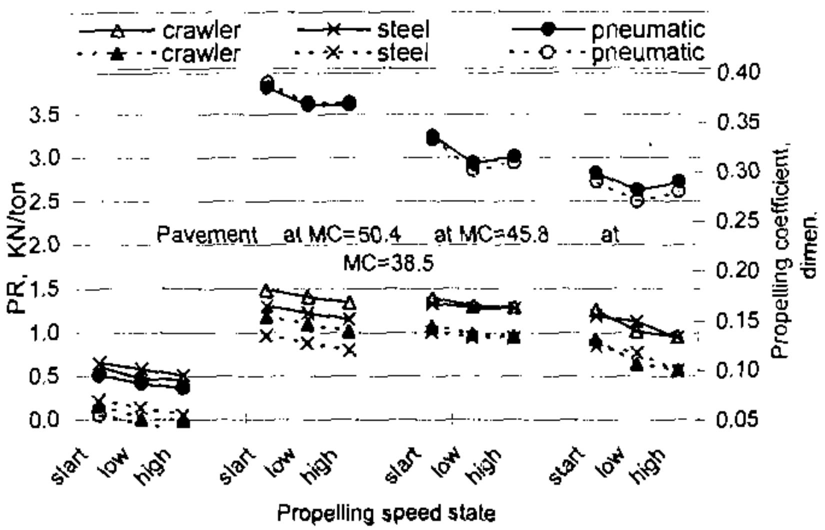
The highest propelling resistance values can be seen as the pneumatic tire is pulled at any speed over moisture content of 50.4%.

Table (3): The propelling resistance and coefficient of propelling coincided the 72 comparative pulling tested.

Maneuver variables			The propelling resistance and coefficient of propelling coincided the tested vehicles, of different maneuvering conditions					
Mobility pattern	Motion condition	Speed , m/sec	Crawler of1.53, ton(15.01KN(		Steel of 0 .829 ton(8.14KN(		Pneumatic of 2.57ton(25.26KN(	
			PR. (KN)	Coeff. (£c)	PR. (KN)	Coeff. (£c)	PR. (KN)	Coeff. (£c)
Pavement	Straight	start	0.98	0.065	0.57	0.070	1.389	0.055
		low	0.78	0.052	0.51	0.063	1.162	0.046
		high	0.75	0.050	0.45	0.055	1.010	0.040
	Average		0.84	0.056	0.51	0.063	1.187	0.047
	Angled	start	1.07	0.072	0.66	0.081	1.424	0.056
		low	0.86	0.057	0.59	0.072	1.191	0.047
		high	0.83	0.055	0.51	0.063	1.036	0.041
	Average		0.92	0.061	0.59	0.072	1.217	0.048
Paddy field of 50.4% MC	Straight	start	2.33	0.155	1.11	0.136	9.851	0.390
		low	2.21	0.147	1.04	0.128	9.346	0.370
		high	2.10	0.140	0.98	0.121	9.346	0.370
	Average		2.21	0.147	1.04	0.128	9.515	0.377
	Angled	start	2.56	0.171	1.27	0.156	10.10	0.400
		low	2.43	0.162	1.20	0.147	9.58	0.379
		high	2.31	0.154	1.13	0.139	9.58	0.379
	Average		2.43	0.162	1.20	0.148	9.75	0.386
Paddy field of 45.8%MC	Straight	start	2.18	0.145	1.13	0.139	8.412	0.333
		low	2.06	0.137	1.09	0.134	7.629	0.302
		high	2.03	0.135	1.08	0.133	7.805	0.309
	Average		2.09	0.139	1.10	0.135	7.948	0.315
	Angled	start	2.39	0.160	1.30	0.160	8.622	0.341
		low	2.26	0.151	1.25	0.154	7.819	0.310
		high	2.23	0.149	1.25	0.153	8.000	0.317
	Average		2.30	0.153	1.27	0.156	8.147	0.323
Paddy field of 48.5% MC	Straight	start	1.98	0.132	1.02	0.125	7.325	0.290
		low	1.61	0.107	0.96	0.118	6.820	0.270
		high	1.52	0.101	0.81	0.100	7.073	0.280
	Average		1.70	0.113	0.93	0.114	7.073	0.280
	Angled	start	2.18	0.145	1.17	0.144	7.509	0.297
		low	1.77	0.118	1.10	0.136	6.991	0.277
		high	1.67	0.111	0.94	0.115	7.250	0.287
	Average		1.87	0.125	1.07	0.131	7.250	0.287

Greater increase can be seen in (PR) as the moisture content of the rice field was at 50.4 %. This consequently resulted in higher values of propelling resistance for all tested devices. It can be seen from table (3) that at starting and at all angled motions lower the propelling resistance becomes quite high, as soil moisture is high That is may be due to the higher soil metal adhesion effect, consequently the pull was increased. At high of forward speed level the PR value attains approximately smaller than starting. That is because the towed wheels or crawler does not appreciably stick or sink. At that case the value of PR does not increase. That is may be the reason caused the angled pulling exhibited propelling resistance of about 1.1-1.16 times that PR of the straight line motion.

Although the actual pull vary widely between the three compared vehicles the relative pulling force (pull/weight) values may be of the same order. Hence the coefficient of propelling (£C) for the tested ground devices, could be estimated as the ratio of the propelling resistance (PR) divided by the vehicle weight. The average values of (£C) over different mobility surface, and at different pulling speed are cleared in fig (4) in dotted lines and are belonging to the right Y-axis.



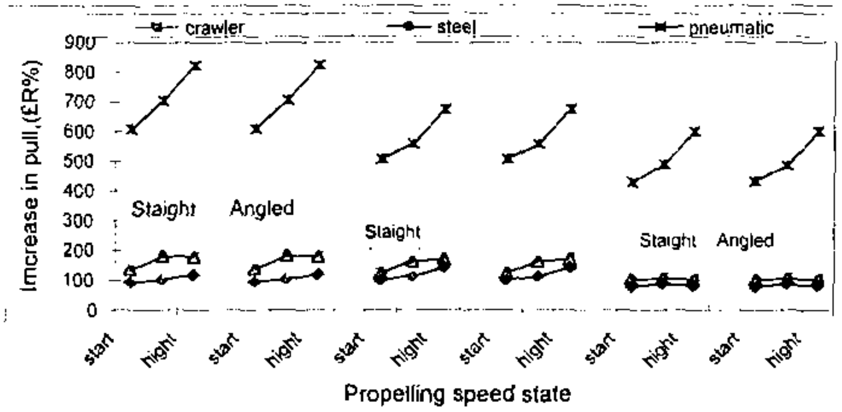
Fig(4):Propelling resistance of the tested devices per ton weight of the vehicle and propelling coefficient under different staight line maneuver

These data show in general that the crawler and the steel lug wheel are exhibited almost the same (£C) values over all tested surface conditions. It may be said that the maneuver behavior of the steel-lug wheels is similar for the crawler.. In the other hand it is worth emphasizing that by the use of the pneumatic tire is possible to double the coefficient of propelling (£C). It is resulted in more than double (£C) value when compared the pneumatic tire with the crawler or the steel lug wheel at the paddy surface of 50.4% moisture content.

The differences in the PR and (£C) values that are shown in table (3) become more serious if recalculated the vehicle engine load due to the propelling resistance per ton of vehicle weight. That may be estimated by multiplying the propelling resistance per ton of vehicle weight by the speed in m/sec. Hence for example working at 1m/sec in a rice field of 50.4% moisture content the average vehicle engine loading may be as 1.58, 3.72 and 1.21 kW/ton for using, crawler pneumatic, and steel devices respectively.

The propelling resistance per ton weight of the tested devices under different surface and speed conditions is shown in solid lines in fig (4) at the left Y-axis. The right Y-axis shows the corresponding (£C) values in dotted lines.

Also the corresponding increment ratio (£R%) in lugging ability of the tested ground devices could be estimated according Eq (1) and shown in Fig (5).



Fig(5): The increse in the proelling resistance of the tested devices under different maneuvering conditions

Fig. (5) shows the accepted limits of the factor £R for the three tested ground drive devices when operating under different operation conditions. It is easily noticed that increasing soil moisture decreased the (£R%) values especially at starting speed. However the £R values when starting are within the recorded £R limits at high propelling speed It is indicated from Fig. (4) that operating on the three other investigated field conditions exhibited some £R% values less than the recommended minimum £ value. Thus the suitable ground device type under these field condition should be those speeds which exhibited more £R% values. Thus the viable propelling should be at £R value more than 25% according to Barger *et al* (1984). Thus from the point of £R% value view, the forward speed values required to proper propelling by the tested devices should either equal or not exceed the following values: 1.8, 2.16, and 2.52 for the proper operating over the rice field by crawler, steel wheel and pneumatic tire respectively.

That increasing each of forward speed decreased the £R% values. However the £R% values when operating over field at 50.4% are not within the accepted £R% limits. But the opposite data trend of table (3) can be noticed at starting pull That may be due to the soil-metal adhesion which is higher in the case of the steel and crawler devices than the pneumatic tire. This data trend is agreed with Abd El-Mageed (1994). That stated that the draft is always increase as the forward speed increase, and it has a linear correlation depending on the soil type and moisture condition.

2-Effects of the running devices traffic on soil compaction

The soil compaction as indicated by bulk density was measured under the traffic of the running devices at different soil moisture contents and five different self-propelled speeds of the tested vehicle. Fig (6) shows the percent of slip accomplished the tested running devices and the soil bulk density deduced by that slip under 5 different running speeds and 3 soil moisture conditions. Solid lines represent the percent of slip (SL%), and the dotted lines show the soil bulk density (BD).

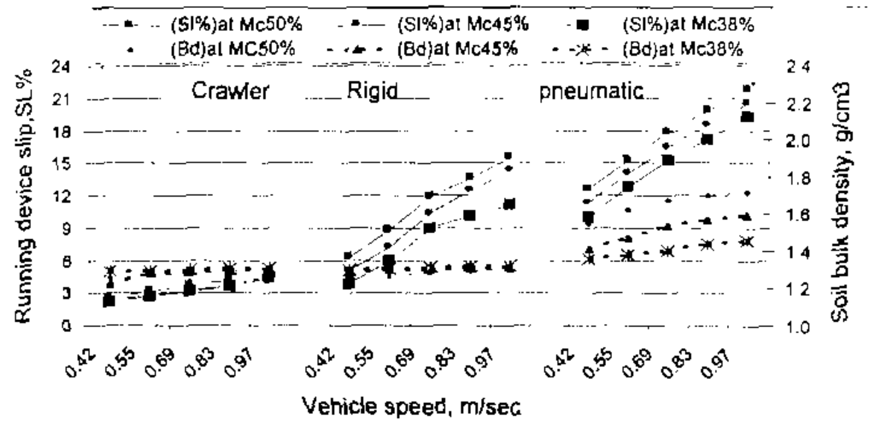


Fig (6): the percent of slip accomplished the tested running dsvices and the soil bulk density deduced by that slip

Figure (6) indicates also that pneumatic type device gave higher wheel slip rates than that resulted from both crawler and steel. Consequently, the highest Increase in soil bulk density due to slip was obtained with the pneumatic type device and the lowest was obtained with crawler running devices

It can be seen that at the highest rice field moisture content (50.4%), there was an increment in soil bulk density with increasing vehicle speed. . Similar results were obtained at 45.8 and 38.5% soil moisture content. That result trend was obviously seen with the pneumatic tire tractor than crawler and steel ground drive devices. However, the Increment rate in bulk density decreased at 38.5% soil moisture content.

In general, one can say that at the soil moisture range of the experiment, the bulk density increased with increasing slip. But, the increment rate was found to be weakening with increasing vehicle slip and decreasing the soil moisture content. It can be seen also that the increase in speed traffic passes causes a slight increase in soil compaction. This trend was more obvious with low soil moisture. The above results are in agreement with Siemens (1989).

The results indicated that pneumatic wheel tractor at any tested speed resulted in the highest soil bulk density. The differences between the effects of both crawler and the steel lug wheel, on soil bulk density were small. That is may be due to the similarity in their contact pressures. That attributed to larger contact area of both crawler and floated steel lug wheel in comparison with the pneumatic. Hence, the soil bulk density in the straight-line motion with crawler was very slightly low in comparison with the steel lug wheel. This is because the less differences.

On the other hand, the soil bulk density of pneumatic wheel tractor was higher than the crawler tractor came at the and the steel lug wheel because the contact pressure for running device for pneumatic tractor tire (0.28 kg/cm2) was higher than that of crawler (0.180 kg/cm2.)

It must be noted that the range of slip, which could be obtained with pneumatic tire, was 10.031 to 20.52%. The corresponding figures were very small with the crawler (2.548-4 81%). While that range of slip, with the steel lug wheel was 6.24 to 15.55. %. The corresponding ranges of soil bulk density were 1,258 to 1.302; 1.270 to 1.305; and 1.55 to 1.722 g/cm3 for running the crawler, steel, and pneumatic device types respectively at forward speed from 0.42 to 0.97 m/sec respectively. It could be noticed that the slip on the field of 50.4 % moisture content is much more than the others, at any gear setting or fuel throttle opening. However, over the three compared track surface, the average slip data were 3.4, 9.89, and 16.18% for driving the crawler, steel, and pneumatic ground- drive device types respectively. Generally, it can say that increasing slip ratio tends to increase soil bulk density and the high values of moisture content magnify this effect.

3- Effect of the overlapping traffic passes on soil bulk density and sinkage depth

The overlapping of traffic passes (multiple inverse and forward passes) occurred mainly at the rice field boundaries.

Effect of turning radius on soil bulk density:

Table (4) shows the soil bulk density due to the tight and wide turning vehicular pass respectively. These data are shown as both soil bulk density (BD) and sinkage depth (Z) are affected by the multiple maneuver of the three compared ground devices over three different soil moisture contents.

It can be observed in general that for all tested ground devices that, decreasing the turning radius increases the contact pressure on soil and consequently more compaction, that may be attributed to the increase in braking zones due to the tight turning which causes increasing in soil bulk density. This effect was slightly decreased by decreasing soil moisture content and contact pressure of tested ground devices.

Table (4): Sinkage depth coincided each tested vehicles, and soil bulk density due to different overlapping maneuver conditions

Maneuver conditions		The tested ground drive type								
MC %.	Turning angle^0	crawler of Kubota			Rigid wheel			pneumatic wheel		
		BD ,g/cm3	Z, Mm	factor Zf	BD ,g/cm3	Z ,mm	factor Zf	BD ,g/cm3	Z, mm	factor Zf
50.4	90^0	1.437	73.6	23.1	1.306	73.5	25.9	1.710	165.4	42.8
	180^0	1.318	62.1	20.3	1.309	73.1	18.5	1.623	159.6	40.6
	Average	1.378	67.9	21.7	1.308	73.3	22.2	1.667	162.5	41.7
45.8	90^0	1.321	65.0	20.4	1.305	59.5	17.3	1.675	145.8	41.9
	180^0	1.314	41.2	18.2	1.304	43.2	16.8	1.593	115.3	39.8
	Average	1.318	53.1	19.3	1.305	51.4	17.0	1.634	130.5	40.9
38.5	90^0	1.308	39.1	15.1	1.298	37.4	14.3	1.566	103.5	39.2
	180^0	1.305	32.8	12.0	1.297	28.7	11.5	1.473	91.2	36.8
	Average	1.307	36.0	13.5	1.298	33.1	12.9	1.520	97.4	38.0
Average vehicle		1.334	52.3	18.2	1.303	52.6	17.4	1.607	130.1	40.2

The highest values of soil bulk density were obtained by the tight turning of the pneumatic tire at the highest soil moisture content.

It can be observed that at 50.31 % soil moisture content, the compaction resulted from the overlapping traffic passes of the pneumatic tire caused an increase of 41.17% and 39.14% in original soil bulk density for the sharp and the wide turning respectively. The corresponding values for the crawler and steel ground devices were 6.27% and 4.64% respectively. Similar trends were obtained for all traction devices at 45.87 and 38.57% moisture contents.

With respect to the crawler device type the contact area soil is always constant. For a given contact area, decreasing the turning radius the crawlers increases the contact pressure on soil and consequently more compaction,. Anyhow, the effect on soil bulk density coincided the steel ground device at the rice field boundaries is slightly lower than that of the crawler device by about 0.07g/cm^3. That is may be due to the larger side force, developed on the large contact area of the crawlers during turning.. So that the pressure change between the steel wheel and soil surface.

Effect of turning radius on sinkage depth.

The sinkage depths for the three tested ground devices are shown in Table (4). An increase in sinkage depth was observed by increasing time of passing due the turning radius. Decreasing soil moisture content decreased the magnitude of the turning radius effect. The turning radius has little effect on sinkage depth for the steel running device. But in the case of crawler and pneumatic tire a positive correlation was found between sinkage depth (cm) and soil moisture content.

At the highest level of soil moisture content (50.4%), the increment magnitude in sinkage depth due to decreasing the turning radius was 21.1and 124.3 mm for the overlapping passes of crawler and pneumatic tire respectively vehicles respectively. While the steel running device showed only similar effect at the 45.. 8%. The corresponding values were lower at 45.87% moisture content. While, at 38.57% moisture content, There is still an effect to the turning radius sinkage depth.

Table (4) sinkage depth of the three tested ground devices at different soil moisture contents. As the turning radius decreases (90 0) further the wheels sinkage increases (especially with the pneumatic wheel at high wheel slippage).

CONCLUSIONS

The present study investigated and compared the maneuverability of the three different running-devices under straight-line and overlapping traffic passes in the Egyptian rice field. The maneuver of both straight-line and angled motions have been studied over three approximated soil moisture content levels of 38.5, 45.8,and 50.3%, and at five different forward speed levels of about o.42, 0.55, 0.69, 0.83, and 0.97 m/sec. While, the overlapping traffic passes have been studied as they affected by different turning angle over the above mentioned soil moisture content levels.

The maneuverability has been inspected within two main indicators namely the lugging ability of each vehicle, and the soil compaction induced by driving each vehicle under different moisture and motion conditions.

The results could be summarized in the following points: -

The average propelling resistance of the angled pass exhibited of about 1.1-1.16 times that propelling resistance of the straight-line motion.

The average vehicle engine loading may be as 1.58, 3.72 and 1.21 kW/ton weight of the vehicle during the maneuvering over the rice field by crawler, pneumatic tire, and steel lug wheel, respectively.

The pneumatic tire in all maneuver tests gave the highest values of slip, sinkage and soil compaction.

Comparing the crawler, and steel lug wheel types, the crawler was less lugging ability and more damaging the soil at the rice field boundaries.

The results recommend the use of wider turning radius by slightly sliding the brake of the inner (inside) of any ground-drive member. That would be effective method for reducing the soil damage (compaction), and satisfactory the propelling force requirements.

REFERENCES

Abdel-Mageed, H.N. (1989). Effect of compaction and tillage method on corn yield and physical properties" of two soil types" Egyptian-German Conf. Ag. Mech. 4-6 Oct., Mansoura Univ., Egypt.

Baladi G. Y. and B. Rohani (1984). Development of a soil-wheel interaction *model". Proceedings of the Eighth International Conference* of ISTVS, Cambridge, U.K.

Barger, E.L.; J.B. Liljedahi: W.M. Carleton and E.G. Mckibben (1984). Tractors and their power units" Wiley Estern Private Limited. New Delhi ., 524 pages.

Dudzinski, P.A. (1984). Steering report of the Art report " J of *Terrramechanics, 21 (2): PP: 215-235*

El-Sahrigi, A.F. and Abo- Habaga (1993). Effect of seed– bed preparation systems on cereal crops yield and populations of some soil fauna" 5 th Conf. On Mechanization and Energy in Agriculture, 12-14 Oct., Kusdast, Turkey

Itoh H. and A. Oida (1990). Dynamic Analysis of turning performance of 4WD-4WS tractor on paved road", J. Terramechanics, 27(2): 125-143.

Milyahara, M. and N. Onishi (1995). Development of the" AD Bi-Speed Turn" System of Tractors" Proceedings of International Symposium on automatic, and robotics in bioproduction, and processing" 3-6 November ,Vol.2 Kobe Univ., Kobe Japan, pp:267-274.

Oida, A. A. *Satoh; H. Itoh and K. Triralanasirichai (1991). Three-dimensional* stress distribution on a tire-sand contact surface J. Terramechanics, 28(4): 319-330.

Raghavan. G.S.V.; E. Mckyes and B. Beaulier (1978). Clay soil compaction due to wheel slip". Trans. of ASAE., 21 (4): 646-649.

Rowell, D.L. (1994). Soil methods of applications ".Longman Scientific, and Technology, Essex, England

Siemens, J.C. (1989). Soil compaction effects and causes". Agric. Eng. Dept. Cooperative Extension service, Univ. of Illinois

Tanaka, T.(1984). Operation in paddy fields: State-Of-The-Art report" J. of Terramechanics, 21(2): 153-179.

Taylor. J.H.; A.C. Trause; E.C. Burt and A.C. Bailey (1982). Multi-pass behavior of pneumatic tire in tilled soil. Trans, ASAE., 25: 1229-1231.1236

Voohees,M.L. and R.N. Walker (1977). Traction ability as a function of soil moisture". Trans., Of ASAE., 20 (6): 806-809.

Witney, B.O. (1988) Choosing and using farm machines" Produced by Longman Singapore Publishers (Pte) Ltd, 412 pp.

Wong J. Y.; M. Garber and J. Preston-Thomas (1984).Theoretical prediction and experimental substantiation of the ground pressure distribution and tractive performance of tracked vehicles". Proceedings of the Institution of Mechanical Engineers, Part D, No. 4

مقارنة مناورة ثلاث اجهزة تلامس مع الارض فى حقل الارز

على السيد أبو المجد
قسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة

ان المناورة المثلى الجرارات و الآلات الزراعية ذاتية الحركة تعتبر من أهم العوامل التى تضمن السلامة والامان ورفع كفاءة الأداء لهذه المركبات الزراعية خاصة فى ظروف التشغيل الصعبة و الغير ملائمة لذلك كان الهدف من هذا البحث "هو توفير قاعدة البيانات الخاصة بتقييم مناورة ثلاثة اجهزة تلامس مع الارض فى ظروف عالية الرطوبة خاص عند الدورانات فى نهاية المشوار وذيل حقل الأرز .والاجهزة المختبرة هى الكتينة والعجل الحديد المزود بقباقيب كاوتش والاطار الكاوتش.استخدم لهذا الغرض ثلاثة مركبات هى:- كمباين الحصاد ذى الكتينة الكاوتش وجرارين ذوى اربع عجلات كاوتش و حديد مزودة بقباقيب كاوتش.

وقد تم دراسة وتقييم مناورة الاجهزة الثلاثة من خلال نظامين للمناورة هما كما يلى :- نظام المرور فى خط مستقيم ونظام الدوران المتراكب فى نهاية الحقل.وقد تم تنفيذ البحث من خلال ثلاثة مجموعات من التجارب

خصصت المجموعة الاولى لدراسة مقاومة الاجهزة المختبرة عند المر ورفى خط مستقيم وفى خط منحنى تحت تاثير ثلاث مستويات مختلفة من الرطوبة (٤٥و٣٨ ؛ ٨و٤٥ ؛٤و٥٠%) وخمسة مستويات من السرعة الأمامية(٠،٤٢ ؛ ٠،٥٥ ؛ ٠،٦٨ ؛ ٠،٨٣ ؛ ٠،٩٧ م/ث) بينما تم تنفيذ معاملات نظام الدوران فى نهاية الحقل بزوايا دوران مختلفة وتحت مستويات مختلفة من السرعة الرطوبة المذكورة . وخصصت المجموعة الثانية لدراسة تأثير ٧٢ معاملة مناورة على دمج التربة وانزلاق الاجهزة المختبرة . بينما نفذت المجموعة الثالثة لدراسة تأثير نظامين للدوران فى نهاية الحقل على متطلبات الاجهزة المختبرة من القدرة لانجاز معاملة المناورة وكذلك درجة تأثير الجهاز على انضغاطية التربة وغرس المعدة.

وقد أشارت النتائج الى النقاط الهامة التالية:--

الجرار ذو العجلات الحديد والمزودة بقباقيب كاوتش. كان الاعلى كفاءة فى عمليات المناورة حيث تسبب فى حدوث أقل انضغاطية للتربة من خلال نظم المناورة الأربعة وتحت كل مستويات الرطوبة والسرعة المختبرة. وعلى النقيض فان الجرار ذو العجلات الكاوتش كان الاقل كفاءة فى عمليات المناورة.حيث سجل متوسط معدلات قدرة مقدارها ٥٨و١١ ؛ ٢١و١١ ؛ ٧٢و٣ كيلووات لكل طن من وزن المعدة لكل من الكتينة والعجل الحديد المزود بقباقيب كاوتش والاطار الكاوتش على الترتيب.سجل جهاز الكتينة اقل معدلات انزلاق ولكنة كان اكثر التصاقا بالتربة مما عمل على زيادة مقاومته للمناورة.

-وجد أن انضغاطية التربة تزداد بزيادة الرطوبة وزيادة وقت المناورة خاصة فى نظامى المرور المتعاقب والدوران المتراكب فى نهاية الحقل واختلف معدل الزيادة باختلاف نوع جهاز التلامس مع الارض. وقد تماثل غرس وكبس التربة فى اغلب معاملات المناورة . وأتضح ايضا انة يجب تجنب الدورانات الحادة فى حقل الارز لان ذلك يؤدى الى استخدام الفرامل بصورة متكررة الامر الذى يؤدى الى زيادة كل من معدلات كبس التربة وغرس المعدات.