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Determination of the Performance of Some Windrowing Rakes Used for Alfalfa and Grass Hay

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ABSTRACT : A field test was conducted to compare five different rakes used for alfalfa and grass hay windrowing in order to determine their effective working width, width efficiency and field capacity. Width efficiency and field capacity were substantially higher for the multiple unit rotary tedder and the universal rotary tedder. The values of width efficiency for these rakes were obtained as 99% and 97% respectively. Field capacity was twice as high for the multiple unit rotary tedder as compared to all other rakes used in this study. The values of average effective field capacity obtained in the two plants were found to be as 3.37, 1.79, 1.52, 1.43 ha/h and 1.40 ha/h for multiple unit rotary tedder, universal rotary tedder, finger-wheel side delivery rake, cylindrical-reel side delivery rake and chain-finger side delivery rake, respectively.

Key words: Rakes, windrowing, field capacity, effective working width.

INTRODUCTION

Forage production enhances the soil organic matters, reclaims the physical and chemical properties of the soil, decreases erodibility, facilitates drainage, takes place in combat against pests and prevents losses arisen from natural and economic risks within the agricultural enterprise. Forage production, additionally, is a foremost factor affecting the animal production. Therefore, in developed countries, 25% - 60% of total cultivated area has been allocated to forage production (Baysal et al., 1995; Tosun, 1996), but in Turkey the area allocated to forage production is only 2.45 % of total crop production area (Anon., 1996).

On the other hand, the cost of forage production is one of the most important inputs of animal production. Feed costs in beef cattle husbandry are about 70-80% of the production inputs without of ownership costs of livestock (Akbaş and Alçiçek, 1996), 40% to 60% of these costs are machinery costs (Arın et al., 1992). Choosing the appropriate machines in each operation of production can reduce the machinery costs. Haymaking is a sequence of operations which may include cutting, mechanical conditioning (crushing or crimping), windrowing, tedding or inversion, raking, baling and transport. Having an important function in this sequence, rakes are used to form the forage in a swath into a windrow and to invert previously formed windrows to promote faster drying. There are a few popular types of rakes in relation to their constructive properties, operational parameters and functions. The total number of rakes available in Turkey is 63674 (Anon., 2000), almost all of them are ground driven finger-wheel side delivery rakes. Whereas the pto driven rakes are popular in the developed countries.

Rotz (1993) compared three different rakes, namely parallel bar, finger-wheel and rotary rakes, in terms of field capacity, labor, fuel and power requirements, dry matter losses and total costs. For the three rakes, the value of field capacity was obtained as 1.78 ha/h, labor requirement 0.19 h per 1 t product.

Ülger and Bastaban (1982) compared primitive raking implement, used by man, single horse-drawn dump rake, finger-wheel side delivery rake, chain-type side delivery rake and cylindrical-drum side delivery rake in terms of effective working width, travel speed, fuel consumption, forage weight windrowed in the field, field capacity, labor and machinery costs. The cylindrical-drum side delivery rake was the most appropriate rake for tedding and windrowing alfalfa. The values of the travel speeds were obtained as 7.16, 7.12 and 7.02 km/h, and field capacities 1.57, 1.45 and 1.71 ha/h with finger-wheel, chain-type and cylindrical-drum side delivery rakes, respectively.

Arın (1982) obtained the values of field capacity of finger-wheel side delivery rake and cylindrical side delivery rake drawn by MF-135 tractor as 1.03 ha/h and 1.3 ha/h, respectively. When these rakes were drawn by MF-178 tractor the values of field capacity of the same rakes were 1.05 ha/h and 1.36 ha/h, respectively.

The effects of rake type and plant moisture level during windrowing on dry matter losses were found to be significant ($p<0.01$) and their effects also on crude protein losses were not significant ($p>0.05$). The rakes driven by pto had the highest values of losses. The losses of dry matter were obtained as 1.31-15.76 % for multiple unit rotary tedder and universal rotary tedder, followed by the cahin-finger rake, finger-wheel rake and cylindrical-reel rake as 2.51-11.83 %, 1.36- 10.94 % and 1.73-11.64 % respectively. While the moisture content within windrow manipulation decreased, the losses of dry matter determined at the end of process increased. In general, the values of dry matter losses obtained with alfalfa were higher than those obtained with grass (Öztürk, 1998).

The average power requirement for the multiple unit rotary tedder was obtained to be by 18.84 kW which was higher 7% than that of the universal rotary tedder, 67% than those of the chain-finger rake and finger-wheel rake, 87% than that of cylindrical-reel rake. The average values of fuel consumption determined within windrowing process were 10.4 l/h (3.08 l/ha) for the multiple unit rotary tedder, 9.9 l/h (5.59 l/ha) for the universal rotary tedder, 9.0 l/h (6.21 l/ha), 8.9 l/h (5.91 l/ha) and 8.9 l/h (6.55 l/ha) for the chain-finger, finger-wheel and cylindrical-reel rakes respectively (Öztürk, 1998).

In this field study, five rakes were tested in alfalfa and grass hay windrowing to determine the effective working width, width efficiency (the ratio of effective width to theoretical width), theoretical field capacity, effective field capacity, field capacity and the ratio of effective field capacity to effective working width.

MATERIAL AND METHOD

Material

Five rakes were used to perform the windrowing treatments (Table 1 and Figure 1). The first two rakes were a multiple unit rotary tedder (MRT) and a universal rotary tedder (URT). The active fingers mounted around the rotors of the multiple unit rotary tedders were at the vertical position during the operation. The active fingers of the universal rotary tedder, which were jointly mounted to the rotors with the aid of springs, were operated by a centrifugal effect. The third and fourth rakes were a chain finger side delivery rake (CFDR) and a finger-wheel side delivery rake (FWDR). The active fingers of the chain finger rake were mounted to two parallel belts, which rotate perpendicular to the travel direction at the vertical axis. The working width of the finger wheel rake could be changed without relatively changes of the frame components due to the angle of direction of the rake.

The fifth rake was a tractor-drawn cylindrical-reel side delivery rake (CRDR) used active fingers mounted to the bars of the reel driven by tire through a mechanical transmission. The finger wheel rake has been widely used by the farmers in the Eastern Anatolia region while the other rakes are not in use in the same area.

Method

Experiments were performed on a 15 m X 50 m size plot for alfalfa and grass hay windrowing separately. The windrows were produced at 30-40% moisture content after mowing the forage with the use of a rotary drum mower (Rotz ve Sprott, 1984; Rotz, 1993). The CFDR, FWDR and CRDR produced one windrow with a double travel (back-and-forth mode of operation), the URT produced one windrow at one travel, and the MRT produce double windrow at one travel. Considering these differences between the rakes, the effective working width was determined.

As recommended by Kanafojski and Karwowski (1976), the travel speed of the tractor during windrowing was selected as 7 km/h. In order to provide the selected travel speed, DJRVS II speed radar and a DJMS100 monitor of DICKEY-John were used (Bastaban, 1994). But, the average speed values calculated using travel time elapsed and plot length were considered for calculating the field capacity. In order to calculate the field capacity, effective operating time and idle travel time at field ends were measured with a stopwatch. Three longitudinally consecutive plots, on which the same treatment was performed, were used to measure the effective operating time. 10% of the total effective operating time was considered as rest stops time and preparing and supply time (Özden and Soğancı, 1996).

Table 1. Technical data of the rakes used in experiment.

Technical data	Rakes used				
	MRT	URT	CFDR	FWDR	CRDR
Working width (bt), mm	5500	3000	2000	2600	2200
P.T.O. speed, r.p.m	540	350-540	540	-	-
Number of unit	4 rotor	2 rotor	2 belt 11 lugs	4 finger-wheel	4 Rafter
Diameter of rotor, mm	-	980	-	-	-
Diameter of circular path, mm	1420	1500	-	-	-
Diameter of finger-wheel, mm	-	-	-	1440	-
Number of tines per unit	8 double tine	10 double tine	2 double tine	40	16 double tine
Diameter of tine, mm	9	9	6	7	6
Number of tyre	4	2	3	-	4
Linkage	Cat. I + II	Cat. I + II	Cat. I + II	Cat. I + II	Trailer hitch

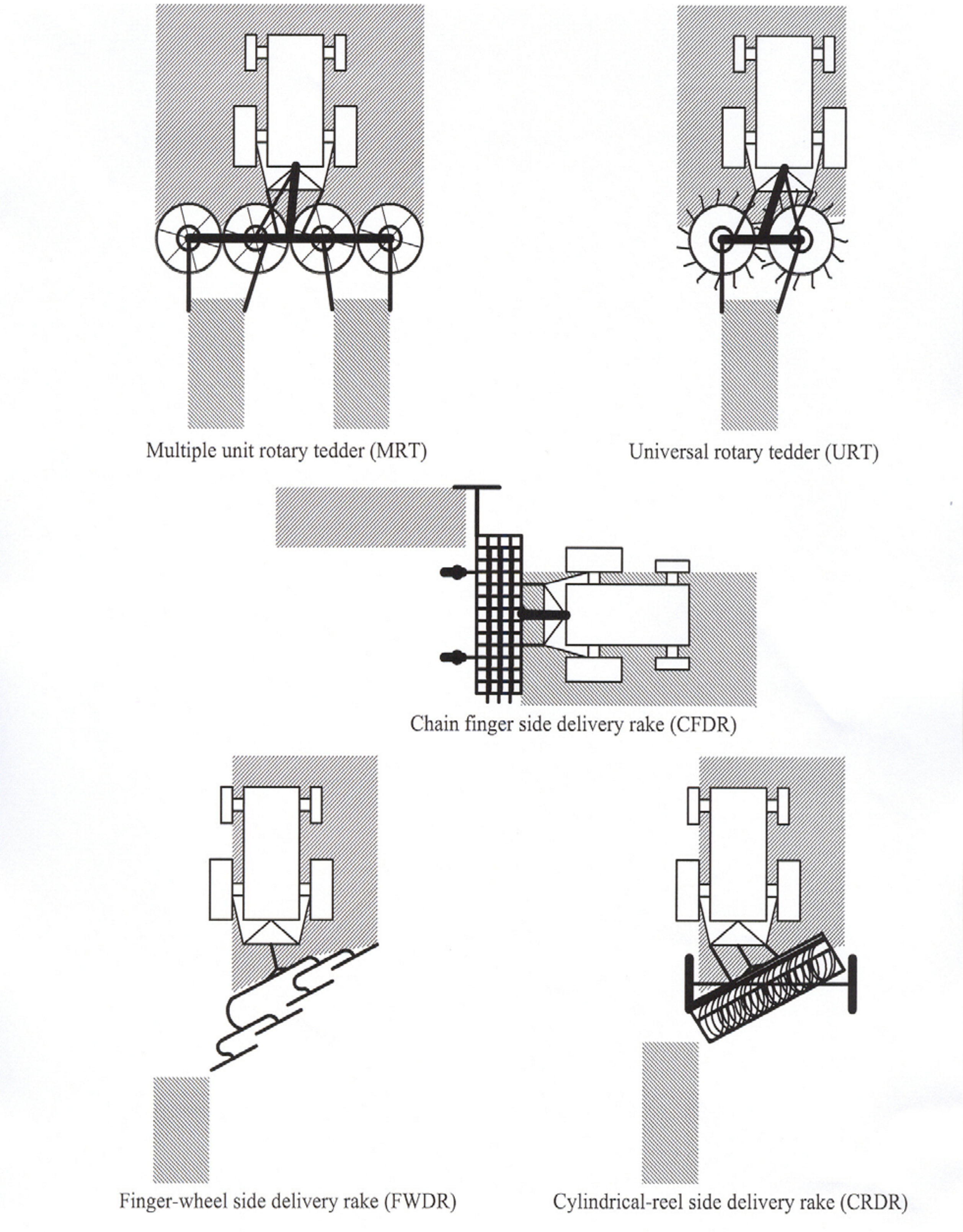

Figure 1. Rakes used in experiments.

RESULTS AND DISCUSSION

A summary of average values obtained from experiments and their LSD test estimates are given in Table 2.

The travel speed slightly varied during windrowing due to undesired field conditions. In order to eliminate the effect of this variation on the field capacity, the travel speed was included into the statistical analysis as a covariant (Table 2). The covariant effect of the travel speed was found to be significant ($p<0.01$).

The high values of width efficiency were obtained with the MRT and URT which produced one windrow during one travel.

For both plant, the values of effective working width of CFDR and CRDR were found to be higher than those of their theoretical working width due to a gap between the material windrowed with the forward travel and the material windrowed with the backward travel. Therefore the values of width efficiency were obtained higher than 100%. On the contrary to these both rakes, the values of width efficiency of the third side delivery rake (FWDR) were obtained lower than 100% due to overlapping (Table 2).

The average effective field capacities of the MRT and URT (3.37 ha/h, 1.79 ha/h) had higher values than FWDR (1.52 ha/h), CRDR (1.43 ha/h) and CFDR (1.40 ha/h) for both alfalfa and grass hay due to high values of the effective working widths of the MRT and URT. The tractor-drawn CRDR had the lowest value of effective field capacity (1.39 ha/h) for alfalfa due to increasing in idle travel time at field ends.

The values of effective field capacity determined for rakes were lower 13-18% than those of their values of theoretical field capacity. This decrease percentage was 20% with CRDR for both plants. The values of field capacity were obtained 20-30% lower as compared with the effective field capacity values.

No differences in the values of effective field capacity per unit working width were apparent between the rakes. These average values for both alfalfa and grass hay were obtained as 0.64 ha/h.m for CFDR, followed by the MRT, FWDR, URT and CRDR as 0.62, 0.61 and 0.56 ha/h.m respectively. The trend of obtained parameters more or less had been similar for both alfalfa and grass hay.

CONCLUSION

On the basis of effective field capacity and width efficiency, the two rotary tedders had higher values than the side delivery rakes. The field capacity was twice as high for the multiple unit rotary tedder producing two windrows with a travel, compared to all other rakes; because the effective working width of this rake 5.48 m, around twice as wide, compared to those of all other rakes. Taking into consideration the high values of dry matter losses, caused by pto driven rakes specially at lower moisture contents, it is said that the use of multiple unit rotary tedder and universal rotary tedder has more advantages specially in large areas at the moisture content level above 40% in terms of the parameters investigated, when compared with the other rakes.

Table 2. A summary of average values obtained from the experiments and their LSD test estimates.

			Effective working width (be), m	**Travel speed, km/h**	**Width efficiency (be/bt), (%)**	**Theoretical field capacity, ha/h**	**Effective field capacity (Fg), ha/h**	**Field capacity, ha/h**	**Fg/be (ha/h)/m**
Alfalfa	**Rakes**	MRT	5.47	7.48	99.45 b*	4.06 a	3.43 a	2.90 a	0.63 a
		URT	2.90	7.27	96.67 bc	2.14 b	1.78 b	1.51 b	0.60 ab
		CFDR	2.26	7.58	113.17 a	1.66 d	1.40 c	1.20 c	0.64 a
		FWDR	2.41	7.31	92.82 c	1.78 c	1.54 c	1.30 c	0.63 a
		CRDR	2.41	7.17	109.70 a	1.78 c	1.39 c	1.19 c	0.55 b
		LSD (0.01)			4.075	0.0957	0.1760	0.1429	0.0709
Grass hay	**Rakes**	MRT	5.48	7.32	99.70 b	4.00 a	3.30 a	2.79 a	0.60 bc
		URT	2.91	7.31	96.89 b	2.11 b	1.79 b	1.52 b	0.62 ab
		CFDR	2.24	7.47	112.00 a	1.60 d	1.40 c	1.18 d	0.64 a
		FWDR	2.49	7.30	95.77 b	1.80 c	1.50 c	1.28 c	0.60 abc
		CRDR	2.44	6.90	110.76 a	1.80 c	1.47 c	1.26 cd	0.56 c
		LSD (0.01)			4.460	0.0839	0.1216	0.0957	0.0438

* The values not followed by the same letter are significantly different at the 1% level by the LSD test.

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