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Tillage Effect and Power Requirements of Rotary Harrows with Different Rotor Geometries

Rotary harrows with a working width of 3 m have 10, 12, or 14 tine carriers. Since there are no known studies on differences in crumb formation and power requirements, such examinations were carried out as part of a field trial. It was shown that, given the same rotational speed of the rotors, the required pto power increases with a diminishing number of rotors. With regard to the comminution effect expressed by the „weighted average aggregate diameter", however, no significant differences were able to be determined.

The compact design of rotary harrows allows them not only to be used alone, but also in combination with drills and precision drills. For combined tillage, combinations of a rotary harrow, a compression roller, and a mounted drill are therefore predominant [2]. Since area capacity is sufficient under most conditions and road transport is problem-free, the working width generally chosen is 3 m. At this working width, rotary harrows featuring 10, 12, and 14 tool carriers (rotors) are offered. Like with all tillage measures, the efficiency of power transfer is of great importance in addition to fulfilling the requirements of plant protection. For this reason, it was the goal of this study to establish the effects of the different rotary harrow designs (10, 12, and 14 tine carriers at a working width of 3 m) on crumb formation and the power requirements (pto power).

For this purpose, three rotary harrows featuring 10, 12, and 14 tine carriers (rotor diameter 33 cm, 25 cm, and 22.5 cm) and otherwise identical equipment were used for seedbed preparation (working depth 10 cm, working speed 7.5 km/h) on a freshly ploughed field (sandy loam) in the spring of 2004. Each rotary harrow was used at two different rotational speeds both with and without a soil grader. All four variants were repeated five times. The measuring distance (lot) of each repetition had a length of 40 m. Over a distance of 30 m, the driving torque and the rotational speed were measured using a torquemeter hub and used to calculate power values. In order to determine crumb formation, five soil samples per repetition (25 per variant) were taken from the cultivation horizon (0 to 8 cm), and their aggregate size distribution after air drying was measured through sieve analysis. The ìweighted average aggregate diameterî (GMD) was used as a measure of crumb formation [1, 3].

$GMD = \sum(n_i \cdot d_i) / \sum n_i \quad [g \cdot mm/g]$

n_i = weight of the aggregate size class i

d_i = class center of the aggregate size class i (sieve sizes used: 40 - 20 - 10 - 5 - 2.5 - 1.25 mm)

Results

Pto Power Requirements

Based on the power values recorded at 400 Hz and calculated from torque measurement and rotational speed, an average value per variant was determined. Thus, the approximately 6,000 individual values of each measurement (30 per measuring path) were used

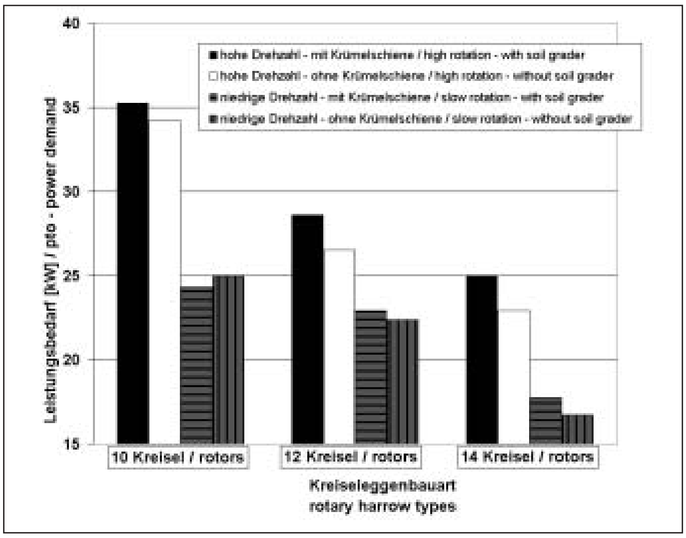

Fig. 1: Pto power requirements of investigated rotary harrow designs at different adjustments

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Keywords

Tillage, rotary harrow, pto - power, crumb formation

to form the average value and a total average value for all five repetitions. For the four variants and the three rotary harrows examined, these values are shown in *Figure 1*. The determined power requirements of 17 to 35 kW were low, which must be attributed to the very favourable soil structure in the spring of 2004. The table shows that pto power decreases with a growing number of rotors. This reduction is the result of lower tool speeds due to smaller rotor diameters in the variants which feature 12 or 14 rotors. (The sum of the tool paths per revolution of all rotors is approximately the same in all three designs.) In the variants where rotor rpm is reduced, the power requirements of all rotary harrows decrease at approximately the same rate as the tine speed. Regression analysis confirms linear dependence of the power requirements upon tool speed ($r^2 = 0.95$).

Crumb Formation

Based on the GMDs of the 300 individual samples, average GMDs were calculated for the five samples of each individual repetition. The results showed that the average values within one variant (identical rotary harrow and setting) straggled to a different degree despite the very homogeneous soil (moisture, kind of soil). This manifests itself in relatively large standard deviations (*table 1*). Together with the weighted average aggregate diameters of the trial variants (average values between 7.81 and 11.35 mm), which straggle only slightly, the standard deviations of 1.97 to 3.30 mm result in GMD differences not being able to be statistically secured neither among the variants nor among the rotary harrows examined. Accordingly, the relationship between tool speed and crumb formation ($r^2 = 0.20$) established in a regression analysis was insignificant. Nevertheless, tendencies can be discerned. In those variants where rotor rpm is higher, all rotary harrows exhibit a slightly smaller GMD, i.e. a higher level of crumb formation than at the lower rpm. Even in the variants where rotor rpm is lower, the GMD reached was in the optimum range of 8 to 12 mm which is striven for in rape or sugar beet.

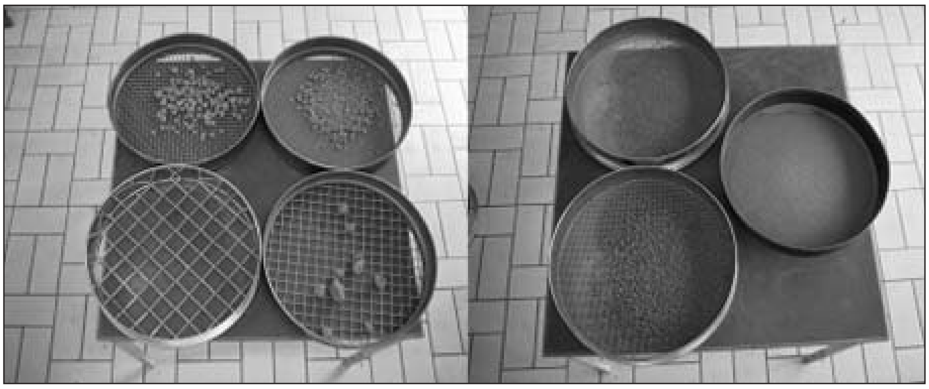

Fig. 2: Distribution of aggregate sizes on the sieves 40/20/10/5/2.5/1.25, and <1.25 mm

Future Prospects

Tillage is expected to meet great demands, which result from the culture- and environmental needs of the plants and economic constraints to reduce expenditures and costs. The goal is to find an optimum which meets the demands of the culture (optimal seedbed), growing environmental requirements (protection against erosion), and economic needs (ploughless tillage, few passes). With regard to the use of rotary harrows, attention must therefore focus on comminution efficiency, which results from the number and the speed of the tools as well as the travel speed, in order to fulfill the demands to be met by an optimal seedbed and economical machinery use.

The studies presented here have shown that rotor rpms common in practice or slightly reduced rotational speeds of the rotors lead to approximately identical, very great comminution effects during tillage after a spring plough furrow on medium soils despite different tool speeds (caused by different rotor diameters). Even though crumb formation was virtually identical, higher power requirements were determined at higher tool speeds which result from larger rotor diameters.

Therefore, the question arises whether it is necessary to reduce the rotor rpm / tool speed under favourable soil conditions more than usual at present in order to guarantee an optimized use of rotary harrows.

In addition, it will be interesting to see whether the results found can also be observed during autumn tillage on heavy soils which are difficult to cultivate or whether under these conditions the higher tool speed of rotors featuring larger diameters provides significantly better crumb formation.

Table 1: Weighted average aggregate diameter (GMD) of the individual variants and the rotary harrows

Varianten / variants	Kreisel je 3 m AB / number or rotors 3 m working width	Kreiseldrehzahl [U/min] / rotor rpm	mittlerer GMD / middle aggregate diameter [mm]	Stabwn GMD / standard deviation [mm]
niedrige Drehzahl mit Krümelschiene / slow rotation with soil grader	10	305	9,72	1,97
	12	328	10,84	2,89
	14	295	11,26	2,84
niedrige Drehzahl ohne Krümelschiene / slow rotation without soil grader	10	305	11,35	3,30
	12	328	10,87	2,69
	14	295	11,02	2,48
hohe Drehzahl ohne Krümelschiene / high rotation without soil grader	10	367	9,26	2,63
	12	364	10,13	2,97
	14	364	8,17	2,61
hohe Drehzahl mit Krümelschiene / high rotation with soil grader	10	367	7,81	2,22
	12	364	9,12	3,05
	14	364	8,90	2,92

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