

Results of testing special machinery for forage harvesting in alpine regions

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Abstract

Two-axle mowers can be used for slopes up to an inclination of 60 %. Their engine performance ranges between 32 and 80 kW. They are not only equipped with a front-wheel steering but also with a rear-wheel and an all-wheel steering. The front power lift is front-axle supported and equipped with a weight transfer system. Two-axle mowers can be used for mowing, tedding and swathing as well as for light traction. When working in horizontal lines transporters can be used for slopes up to an inclination of 45 %, when working in perpendicular lines they can be used for an inclination up to 60 %. The engine performance ranges between 29 and 80 kW. Due to the use of quick release mechanisms, one person can often rapidly change the diverse modular units, such as loaders, tippers, farmyard manure spreaders or liquid manure tanks. The good slope suitability, the low pressure on the soil and the good maneuverability make two-axle mowers and transporters also suitable for working on municipal areas and preserving the countryside if used in combination with special additional machinery.

Keywords: Mountain farm mechanization, two-axle mower, agricultural transporter, landscape care

1. Introduction

Alpine agriculture forms the basis for the sustainable use (tourism, water supply, settlement) of Austria's alpine regions. Due to long winters, the harvest of winter forage has to be attributed special importance even on steep slopes. Alpine areas are ecologically sensitive regions. Consequently, for a sustainable development of alpine agriculture it has to be guaranteed that the soil is protected from any harm and that mechanization of forage harvesting is safe. The paper gives an overview of the state of the art of the special machinery for forage harvesting on steep slopes.

2. Materials and Methods

Tests were carried out based on the Austrian, European and ISO standards (Austrian Standards, 2007; European Council, 1976, 1978, 1997, 2009a, 2009b, 2009c; International Organization for Standardization, 1996; OECD, 2014).

In addition to tests on test benches, field tests on steep slopes were performed for determining the slope suitability under different working conditions.

3. Results and Discussion

3.1. Two-axle mower

Two-axle mowers can be used up to a slope inclination of approx. 60 %. These slope inclinations can only be achieved at optimal conditions (dry ground with maximum grip) and excellent knowledge of driving and terrain.

3.1.1. Technical Description

The construction consists of two axles that are linked by means of a central tube. Engine, gearbox and cabin are mounted on the rear axle or on the central tube. The front axle is connected to the central tube by means of a swivel joint.

The engines used are water-cooled 4-stroke diesel engines with four cylinders, which are partly equipped with turbochargers. The rated power ranges between 32 and 80 kW. The rated speed ranges between 2,600 and 2,800 min⁻¹. Maximum torque ranges between 158 and 420 Nm for an engine speed range of 1,100 to 1,600 min⁻¹. Torque increase amounts up to 43%.

The electrical system operates with 12 V. Three-phase alternators with 40 – 140 A are used. The capacity of the battery amounts to 60 – 105 Ah.

Two-axle mowers are equipped with reverse gear with two groups (8 forward and 8 reverse gears). Models that are more powerful are also offered with an additional crawl gear group. The reverse gears are fully synchronized, the group gears, however, are frequently not synchronized. The maximum speed ranges between 20 and 40 km/h. The clutch is a single dry plate clutch.

Hydrostatic drives with variable displacement pump and variable displacement motor became prevalent. Frequently, a two-stage mechanic gear is added to the hydrostatic drive. The maximum speed ranges between 30 and 40 km/h.

Generally, two-axle mowers are equipped with an all-wheel drive. The drive of the front axle can be switched off. More powerful two-axle mowers are equipped with a permanent all-wheel drive.

The differential in the front and rear axle can be locked. The differential locks can be preselected and are frequently

switched electro-magnetically. The locking of the differential is indicated by a control light on the dashboard.

The service brakes are twin-circuit servo drum brakes operating on all wheels. The parking brake blocks the rear wheels or all four wheels. Some types are equipped with an automatic spring-loaded parking brake.

The steering is operated hydrostatically. Apart from a front steering, two-axle mowers are equipped with a rear, all-wheel or crab steering. The steering types can be switched during operation. The turning-circle diameter ranges between 7.2 and 11.6 m with front steering and 5.8 and 6.9 m with all-wheel steering.

Two-axle mowers are equipped with power take-off shafts at the front and the rear. The power take-off clutch is constructed as single plate clutch or as a multi-disk clutch. The rear power take-off rotates clockwise. The front power take-off rotates either counter-clockwise or clockwise. The speed amounts to 540, 750 or 1,000 min⁻¹.



Figure 1. Two-axle mower equipped with a disk mower.

Two-axle mowers are equipped with a three-point front power lift and a three-point rear power lift. The front power lift, which is mounted to the front axle, can be equipped with a device that enables a hydraulic shifting of the attachment by ±200 up to ±315 mm. The lower links are equipped with a quick-hitch system. The front power lift is equipped with a hydraulic weight transfer system, which transfers an adjustable part of the weight of the attachment to the front axle. Vibration absorption systems for road travel are available for more powerful types. The maximum continuous lifting force amounts to 8.8 and 20.0 kN. The maximum continuous lifting force of the rear power lift ranges between 9.3 and 18.0 kN.

Table 1. Location of center of gravity of a two-axle mower (BLT Wieselburg, 2016).

Equipment	Dimension	Value [mm]
Basic vehicle	Distance in forward direction from the vertical plane containing the axis of the rear wheels	750
	Distance from the median longitudinal plane of the vehicle (“+” right and “-“ left from median longitudinal plane of the vehicle)	+35
	Height above ground	660
Basic vehicle with disc mower	Distance in forward direction from the vertical plane containing the axis of the rear wheels	1,130
	Distance from the median longitudinal plane of the vehicle (“+” right and “-“ left from median longitudinal plane of the vehicle)	+30
	Height above ground	680
Basic vehicle with belt rake	Distance in forward direction from the vertical plane containing the axis of the rear wheels	1,020
	Distance from the median longitudinal plane of the vehicle (“+” right and “-“ left from median longitudinal plane of the vehicle)	+40
	Height above ground	750

The height above ground of the center of gravity of two-axle mowers is generally lower than 800 mm.

Two-axle mowers are all equipped with Terra tyres (e.g. 26x12.00-12, 31x15.50-15, 33x15.50-15, 425/55R17, 440/50R17). For extreme inclinations dual tyres can be used.

The cabin models range from open cabins with a windscreen to cabins equipped with air conditioning. With some two-axle mowers the lateral tilt of the seat can be adjusted to the inclination of the slope manually or automatically, so that the driver can sit in an upright position. The gearing lever or the lever for the hydrostatic drive are a multi-function lever that includes operating devices for the front power lift, the weight transfer system, the steering mode or the additional hydraulic devices.

The mass of two-axle mowers ranges between 1,420 and 2,800 kg. The permissible total weight ranges between 22.1 and 41.2 kN. The permissible axle loads amount to 14.2 – 23.5 kN for the front and rear axle. The most important dimensions are summarized in Table 2.

Table 2. Key dimensions of two-axle mowers.

Dimension	mm
Length	2,975 – 4,090
Width	1,885 – 2,620
Height	1,925 – 2,220
Wheelbase	1,665 – 2,300
Track width	1,565 – 1,682
Ground clearance	155 – 265

3.1.2. Safety Technology and Ergonomics

Noise emission can be identified as a major problem with numerous two-axle mowers. Measurements have demonstrated that the noise at the ear of the operator ranges between 80 – 98 dB (A) according to the configuration of the cabin.

3.1.3. Attachments

For forage harvesting double-knife cutter bars or disc mowers are used. For tedding belt-type side rakes or rotary tedders are added on. Swathing is performed with rotary swathers or with belt-type side rakes. For soil cultivation or for transport activities two-axle mowers are less suitable.

For municipal services and landscaping two-axle mowers can be equipped with a flail mower, a road sweeper, a snowplough, a snowblower, a sand or salt spreader, a lawn mower or other lawn care machinery.



Figure 2. Transporter equipped with a loader wagon.

3.2. Transporter

Agricultural transporters are mainly used for transporting harvested products or spreading organic manure. Furthermore, transporters can be used for mowing when equipped with a mower attached to the front power lift or for tedding with an attached rotary tedder.

If the transporter is equipped with a loading device it can be used for slopes up to an inclination of 45 % when driving in horizontal lines and when driving in perpendicular lines for slopes up to an inclination of approx. 60 %. These operation limits can only be reached by proficient drivers with exact knowledge of terrain.

3.2.1. Technical Description

Transporters can be divided into two main types of construction. In the first type the engine, the gearbox and the front axle are screwed together to form a unit. This unit is combined with the central tube, which is screwed together with the rear axle. A swivel joint connects the front unit and the central tube. The cabin is mounted to the front unit. The rear axle and the central tube carry the attachments. The second type of construction is equipped with a front frame, which carries the engine, the gearbox, the front axle and the cabin. The rear frame is screwed onto the rear axle. The front and the rear frame are connected by means of a swivel joint. The rear frame carries the attachments.

Water-cooled 4-stroke diesel engines with four cylinders, which are partly equipped with turbochargers, are used. Their rated power ranges between 49 and 80 kW. The rated speed amounts to 2,200 up to 2,600 min^{-1} . The maximum torque ranges between 229 and 420 Nm at an engine speed of 1,000 to 1,600 min^{-1} . The torque increase amounts to 54 %.

The electrical system works with 12 V. Three-phase alternators with 105 – 220 A are used. Normally the capacity of the battery amounts to 95 – 135 Ah.

Normally, transporters are equipped with reverse gear with 8, 16, 20, 24 or 32 forward gears and 8, 12, 16 or 20 reverse gears. Some types are offered with a crawling gear group. The reversing gears are fully synchronized, whereas the group gears are not always synchronized. The clutch is either a single or a dual dry plate clutch. More powerful transporters are offered with a combination of hydrostatic drive and a mechanical gear. This allows a stepless drive over the whole speed range or the lower part of the speed range. The maximum speed ranges between 30 and 40 km/h. However, even models with 50 km/h maximum speed are offered.

Transporters are all provided with an all-wheel drive. They are either equipped with a front axle drive which can be switched off or with a permanent all-wheel drive with lockable longitudinal differential. Portal axles or axles with planetary gearboxes are used. The differential in the front and the rear axle can be locked. The pre-selectable differential lock is frequently switched electro-magnetically. The locking of the differential is indicated by a control light on the dashboard.

Table 3. Location of center of gravity of a transporter (BLT Wieselburg, 2015).

Equipment	Dimension	Value [mm]
Basic vehicle	Distance in forward direction from the vertical plane containing the axis of the rear wheels	2,470
	Distance from the median longitudinal plane of the vehicle (“+” right and “-“ left from median longitudinal plane of the vehicle)	-24
	Height above ground depending on the position of the suspension	710 – 780
Basic vehicle with self-loading wagon	Distance in forward direction from the vertical plane containing the axis of the rear wheels	1,630
	Distance from the median longitudinal plane of the vehicle (“+” right and “-“ left from median longitudinal plane of the vehicle)	-20
	Height above ground depending on the position of the suspension	820 – 890
Basic vehicle with manure spreader	Distance in forward direction from the vertical plane containing the axis of the rear wheels	1,970
	Distance from the median longitudinal plane of the vehicle (“+” right and “-“ left from median longitudinal plane of the vehicle)	+4
	Height above ground depending on the position of the suspension	800 – 870

More powerful transporters are offered with single wheel suspension; the suspension can be applied to the front wheels only or to all wheels. Mechanic suspension systems have to be equipped with a lock in order to be able to deactivate suspension when driving on slopes. Hydropneumatic suspension systems are equipped with level control, which regulates when driving on slopes and the weight of the load is changing.

The service brakes are hydraulically operated double-circuit braking systems, with or without power-assisted braking device, which acts on all four wheels. They are drum or disk brakes.

The parking brake blocks the rear wheels, the front wheels, or all four wheels. It is operated either mechanically or mechano-hydraulically. Gear brakes or brakes acting on the cardan shaft are also used.

The steering is hydrostatic. Apart from front steering all-wheel steering is also offered. The turning-circle diameter of the transporter ranges between 10.8 and 13.7 m with front steering.

Transporters are equipped with a rear power take-off. Upon request, front power take-off and mid-mounted power take-off are also available. They can be switched under load. The power take-off clutch can be a single or double plate clutch or a multi-disk clutch. The rear power take-off rotates clockwise, if requested also counter-clockwise. The speed amounts to 540, 750 or 1,000 min^{-1} .

Transporters can be equipped with a three-point power lift on the front or the rear or with an attachment board on the front.

The height above ground of the center of gravity of transporter is generally lower than 950 mm (see Table 3).

Transporters are all equipped with standard tyres with traction profile (e.g. 265/70R16, 285/80R16, 15.0/55-17.0, 425/55R17). For extreme slope inclination dual tyres can be used. Terra tyres have not found wide acceptance as transporters are frequently used on roads.

The cabin models range from open cabins with a windscreen to cabins equipped with air conditioning. The gear lever can be a multi-function lever.

The mass of the transporter without attachment ranges between 2,100 and 3,600 kg. The maximum permissible weight ranges between 49.1 and 98.1 kN. The most important dimensions are summarized in Table 4.

Table 4. Key dimensions of transporters.

Dimension	mm
Length	4,567 – 5,417
Width	1,770 – 2,770
Height of cabin	2,210 – 2,450
Wheelbase	2,600 – 3,250
Track width	1,662 – 1,750
Ground clearance	200 – 390

3.2.2. Safety Technology and Ergonomics

Noise emission can be identified as a major problem with numerous transporters. Measurements have demonstrated that the noise at the ear of the operator ranges between 81 – 91 dB(A) according to the equipment of the cabin and the manufacturer.

Because of the unfavorable position of the driver's seat, considerable physical stress is caused through whole-body vibration. Through a suspension of the transporter and the adequate selection of the driver's seat the stress can be drastically reduced.

3.2.3. Attachments

Loading devices (8 – 18 m^3 capacity), manure spreaders, slurry spreaders, loading platforms and tippers can be attached. One person can change the different attachments rapidly by using quick-hitch systems.

For municipal services and landscape conservation transporters can be equipped with a loading crane, a road sweeper, a snowplough, a snowblower or a sand or salt spreader.

4. Conclusions

Due to the good slope suitability, the low pressure on the soil and the good maneuverability make two-axle mowers and transporters also suitable for municipal services and landscape conservation.

This special machinery has already achieved a very high technical standard. However, it is rather expensive compared to traditional agricultural machinery and tractors. Simultaneously, enterprises in the Austrian alpine region are rather small and thus costs for mechanization are very high. In order to guarantee an efficient use of machinery the machines are partly used on more than one farm. As manpower is very expensive and not available for manual agricultural work, a safe and environmentally-friendly mechanization is a basic prerequisite for a sustainable agriculture in alpine regions.

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