The benefits of tractor reverse drive controls – grassland mowing as an example

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In reverse driving the object is directly in front of the driver, which promotes the ease of work. Photos: Markku Lätti

With the help of tractor reverse drive controls, the workload of the driver can be eased significantly. According to a study, the reverse drive controls clearly decreased working postures where the back or the neck are twisted. The faster turning also made the work more rapid when compared with mowing done in a normal forward with a tractor equipped with a front mower – trailed mowing machine combination with a corresponding operating width. The faster working speed also means shorter exposure time. In reverse driving, a slightly wider operating width was achieved near the headland than in driving forward. By combining automatic steering with reverse drive, the operating width can be utilised even more efficiently. In reverse drive, there is slightly less body vibration than with the comparison work machinery. The benefits of the reverse drive controls are especially evident when working for a long stretches.

Grassland mowing is seasonal work, the time of which is determined by the growth and the weather. The work is typically piecework in nature, that is to say, the aim is to complete it in as little time as possible. Increasingly large and powerful machinery has been developed to help dealing with increasing work areas. Despite this, the increasing amount of work easily means longer work days inside the tractor cab. Sitting for long periods of time combined with twisted work postures and the vibration of the whole body are risk factors increasing the burden of musculoskeletal system related to driving.

In summer 2012, a joint study by Valtra Ltd., Elho Ltd. and TTS aimed to find out how working backwards affects the labour time consumption and working postures and the body vibration of the driver through the seat in grassland mowing compared to traditional mowing forwards. Another aim was to find out how automatic steering affected these variables in mowing on reverse drive.

Arrangement of mowing research

The measurements were conducted in the Parikkala-Saari area on consecutive days during harvesting of the first ensilage yield. The comparison experiments were mowing driving forwards and mowing on reverse drive. The other comparison pair was mowing on

The tractors and mower conditioners used in the study: on the left Valtra T163D equipped with reverse drive controls and Elho Duett 7300, on the right T163V and Elho Arrow 3700F & Elho Arrow 3700 mower conditioner combination.

reverse drive with automatic steering and manual steering. Reasonably large field parcels were selected for the study, which were divided in two or more parts of approximately equal growth and size, which then were mowed on the same day. This way (at least) one experiment pair was ensured for each field parcel. The measurements were repeated in such a way that three repetitions were gained for methods studied, each the size of 3.6 hectares on average.

Two tractors and mowing machines were used in the study: a Valtra T163D tractor equipped with reverse drive controls and Elho Duett 7300 (operating width 725 cm) mower conditioner, and a Valtra T163V tractor equipped with front PTO and Elho Arrow 3700F (front mower) and Elho Arrow 3700 (trailed mowing machine) mowing machine combination (the combination operating width 725 cm). The tractors used for the study had precisely the same kind of tyres (Trelleborg 650/65 R42 + 540/65 R30) but the tyre pressure in the reverse drive tractor (Valtra T163D) was clearly higher (1.8 bar) especially in the rear tyres than in the tractor driven forward (Valtra T163V; 1.2 bar). The pressure of the front tyres was also slightly higher (1.5 bar vs. 1.2 bar). The tractor seats differed slightly from each other. The seat of the Valtra T163D tractor was Valtra Evolution (Grammer MSG95EL/741) and the seat of the Valtra T163V tractor was a basic air suspension seat (Grammer MSG95AL/731).

The reverse drive controls (TwinTrac) include a seat rotating 180 degrees and control arm rest, rear steering wheel, rear pedals and other controls. Reverse drive controls are available for Valtra's N, T and S series tractors.

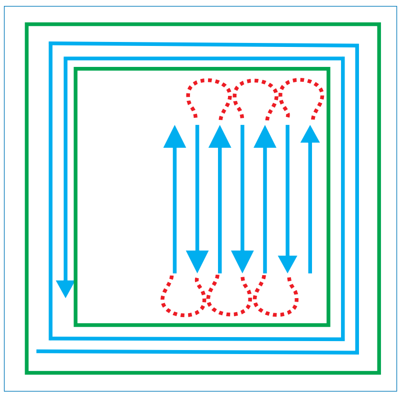
The Elho Duett mower conditioner coupled with the tractor equipped with reverse drive controls is especially meant to be used with reverse drive controls. It comprises two 3.7-metre cutting bars that have been coupled with the fitting frame. This way the sideflows can be raised for transportation with a push of a button.

All driving during the study was done by the same person. This eliminates any differences caused by individual differences. The driver was a professional tractor driver and experiences test driver in various tractor-related tasks. The driving speed was kept to approximately 6.0 km/h. The standardised, reasonably slow driving speed minimised the variation in the growth and field surface shapes.

The mowing of the field parcel progressed in roughly three stages:

A. the mowing of the edges of the whole parcel with circular cutting scheme and dividing the parcel into sub-parcels by driving through it. This was done without measurements.
B. the mowing of the edges of the sub-parcels with circular cutting scheme (headland driving) provided that the edge of the sub-parcel was normal, in other words, that it may have a ditch or some other obstruction
C. the mowing of the central part of the sub-parcel with lane driving scheme.

In spiral cutting scheme, the corners were driven in a way required by the situation: reversal turn or looping turn. In lane driving, the turns were correspondingly made with a looping turn. When cutting forward four rounds were completed and in reverse drive three rounds were completed.



Each sub-parcel was first mowed by driving around it for 3–4 rounds, after which the centre of the sub-parcel was mowed with lane driving cutting scheme.

The sideflows of the mower conditioner can be lifted up with a push of a button during transportation.

Acquisition of research data

The times used for turns and actual mowing were measured separately. Moreover, the time used for circular mowing was determined separately. Small and easily movable equipment was used in gathering information about the driver's workload: a miniature camera was used to chart the driver's work postures and a wireless measuring device to measure the vibration of the whole body.

For the purposes of the work posture analysis, the work postures were recorded with a miniature camera attached to the cab (GoPro Hero) which took a photo at five second intervals. The back and head postures were coded during the analysis utilising the OWAS method principles and the assessment method of body-part specific postural load. In accordance with the OWAS system, back postures twisted over 20 degree are considered as twisted postures. Correspondingly, head postures twisted over 45 degrees are considered as twisted postures in the OWAS system.

Vibration measurements were implemented with the HealthVib® WBW measuring system, the sensor of which was installed on the seat and the wireless receiver on the driver's side inside a box located in front of the side window. The device recorded the effective values of vibration at one second's intervals. With the help of the programme belonging to the device, it was possible to receive data about the vibration volume and the prevalent coordinate direction during the period studied.

The actual operating widths were measured with a tape measure by first marking the edge of the processed (mowed) area in the field within a metre of the edge of the growth not yet mowed. The operating widths were measured both from the middle of the sub-parcels and one end of the sub-parcel within 2–10 metres of the mowed headland.

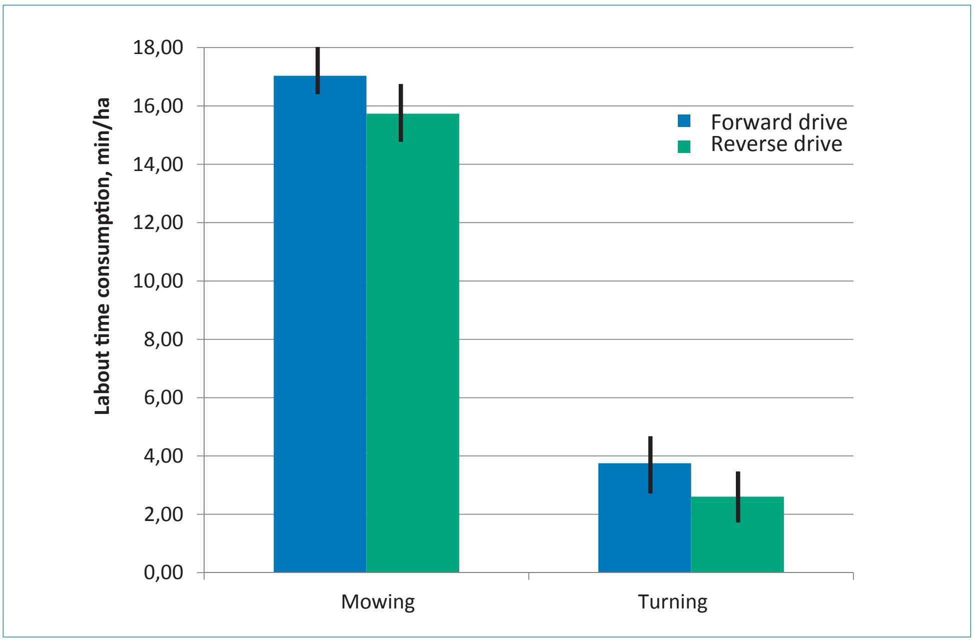
The mowed areas were measured with a GPS device (Garmin GPSMAP® 60Cx). The areas were measured separately for the entire cultivated parcel and for the sub-parcels divided for the study. With the help of these areas, it was possible to also calculate the area of the circular mowing (the edge of the parcel) and division mowing of the sub-parcels.

Left: For the working posture study, the working postures of the driver were photographed with a miniature camera and body vibration was measured with a vibration sensor installed on the seat. Right: The seat during reverse drive.

Agile turning and easier control of operating width increase the speed of working

Labour time consumption, including turns, was on average slightly smaller when moving backward (18.3 min/ha) than when mowing forward (20.8 min/ha). This is explained by slightly faster driving speed (even though the aim was to standardise the speed). When studying the turn-specific times, it can be added that on reverse drive the turn-specific times were faster than when driving forward both in looping turns of lane driving and especially in cornering during circular mowing. The differences are statistically extremely significant (risk level 0.1%). A shorter tractor-machine combination is faster when turning than a long combination and takes less space.

On reverse drive, a slightly wider (on average 7 cm) operating width was achieved near the headland than in driving forward. Hence, keeping the direction/operating width would appear to be easier in reverse drive mowing. There was no difference in operating widths measured in the centre of the parcel's side.

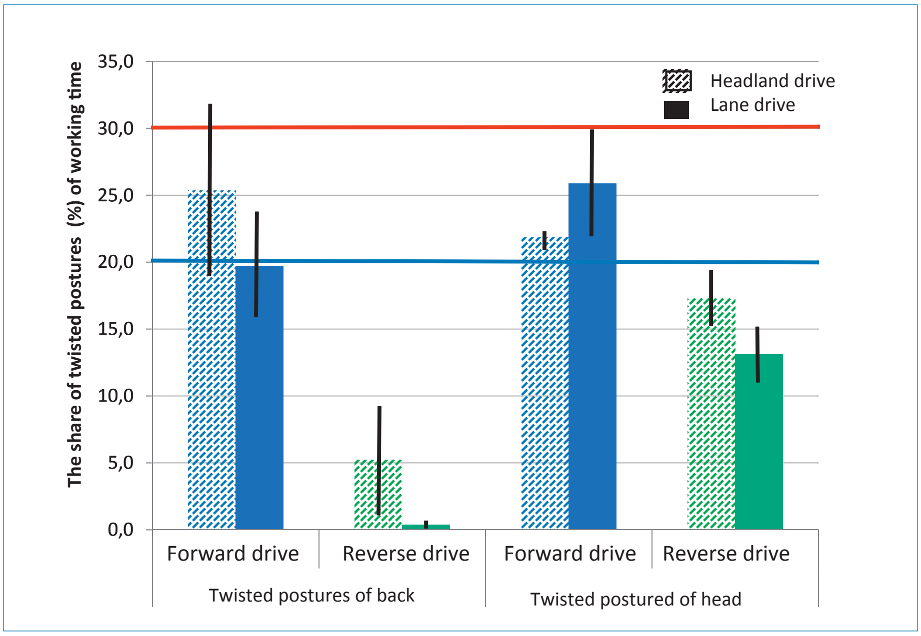


Labour time consumption (min/ha) during actual mowing and turns in strip mowing and their variations (average ± standard deviation; indicated with vertical lines) when driving forward and backward.

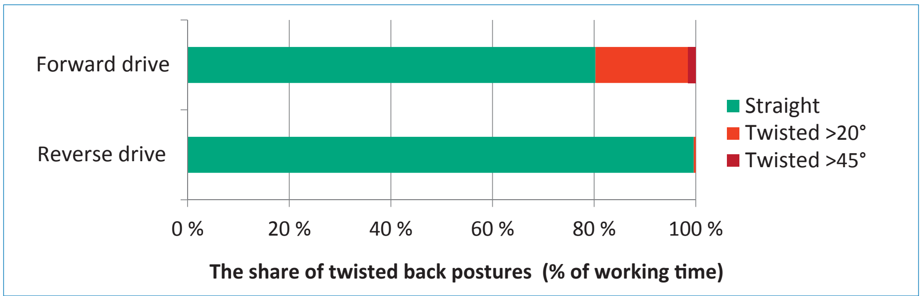
Improved working postures are a major benefit

The share of twisted postures of the back when driving forward exceeded the recommended frequency (recommendation: at most 20% of the working time) with the exception of one study period. The share of twisted head positions was so large on one forward driving research period that according to recommendations (recommendation: at most 30% of the working time) measures would have to be taken to reduce that twisted positions. On reverse drive, the shares of both the twisted back and head postures remained within the recommendations during all research periods. When driving forward the share of twisted work postures was 16–23 % (headland driving 25% on average) of the working time. Driving backward the share was 0.4% (headland driving 5.2%).

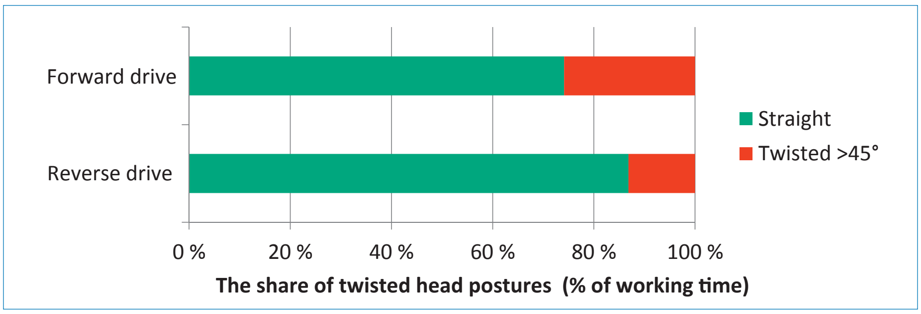
A major benefit of reverse drive controls is improved working posture.



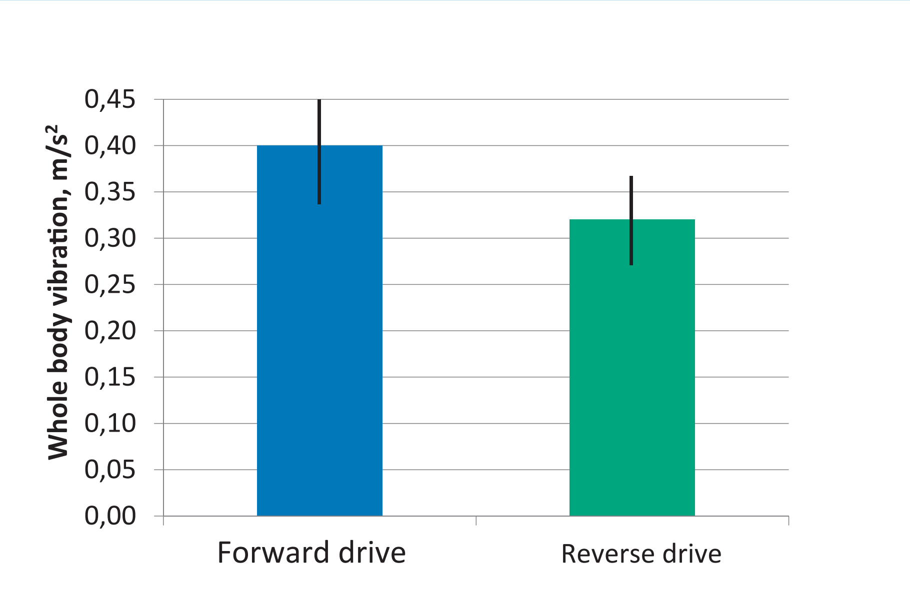
The share of twisted positions of the back and the head (%) in headland driving (in circular cutting scheme; the light colour) and strip mowing (dark colour) when driving forward and backward. Back postures twisted over 20 degree are considered as twisted postures. Correspondingly, head postured twisted over 45 degrees are considered as twisted postures. The blue cross-line indicates the share of twisted back postures and the red line the share of twisted head postures after which measures should be taken to decrease them. Average ± standard deviation has been indicated with vertical lines.



The distribution of back postures (%) in straight, twisted (20 - 45°) and strongly twisted (>45°) postures in strip mowing forward and backward.



The distribution of head positions (%) in straight and twisted (>45°) positions in strip mowing forward and backward.



The average vibration on the body (m/s²) and its variation (average ± standard deviation; indicated with vertical lines) when driving forward and backward.

In both tractor-machinery combinations, the vibration measured from the driver's seat was clearly under the action value of 0.5m/s² for body vibration.

Experiment-specific operating widths (m) from the middle ("in the middle") of a sub-parcel and at the one end of the sub-parcel measured at 2–10 metres' distance from the mowed headland ("at the edge") and statistically significant differences (a: difference statistically significant; b: difference extremely statistically significant; c: difference almost statistically significant).

Experiment	Operating width, m	
	At the edge	In the middle
Reverse drive – manual steering	6.98[a,c]	6.96[b]
Reverse drive – automatic steering	7.09[a]	7.11[b]
Forward drive – manual steering	6.91[c]	6,97

The share of twisted head positions when driving forward was 23–30% while driving backward it was 9–17%.

In circular mowing pattern (headland driving) the share of twisted back postures was greater both when mowing forward and backward when compared to the twisted back postures during sub-parcel mowing (strip mowing). On reverse drive, turning required less space and three rounds were needed for the headland driving in circular cutting scheme. When driving forward, one more round was needed. Consequently, the working posture load was eased with the reduction of demanding headland driving rounds.

Vibration-related risks are also reduced

The dominating direction with regard to body vibration in all measurements was sideways (Y-direction).The average vibration levels were correspondingly below the value (0.5 m/s²) at which measures have to be taken. The government decree on the protection of employees from hazards related to vibration (Valtioneuvoston asetus työntekijöiden suojelemisesta tärinästä aiheutuvilta vaaroilta 48/2005) determines 0.5 m/s² as the daily exposure action value to vibration and 1.15 m/s² as the limit value. When the action value is exceeded, the employer is obligated to implement vibration mitigation programme to reduce exposure and minimise hazards and damages. Correspondingly, when the limit value is exceeded, the employer must without delay take measures leading to reduction of exposure so that it is below the limit value.

The measured vibration of the tractor equipped with reverse drive controls was on average (0.32 m/s²) slightly smaller than the average vibration measured from the tractor used for driving forward (0.40 m/s²). Therefore, the vibration risk during mowing conditioning on reverse drive does not appear to grow. In addition to driving direction, the difference may be caused by the different vibration absorption of the individual tractors (tyre pressure, seat suspension, etc.) The smaller incidence of body vibration recorded for the reverse drive tractor in this study is probably explained by the more evolved seat – on the other hand, the clearly higher tyre pressure in the reverse drive tractor means that there has been considerably less vibration absorption. The difference between vibration values between driving directions is almost statistically significant (risk level 5%).

This study suggests, that reverse drive controls also reduce the risk caused by vibration. Even though the difference of body vi-

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In addition to mowing, reverse drive controls are used in shredder drive (pictured), cultivation of special plants and forestry.

bration volume when compared to forward mowing is not great, the clearly reduced twisted back postures reduce the harmfulness of vibration. The positive effect caused by improved working postures in the mitigation of the harmfulness of vibration is probably even greater than the benefits derived from the decrease of body vibration.

Automatic steering benefits include efficient utilisation of operating width and especially increased speed of the actual mowing

In addition to the above, the importance of automatic steering in reverse drive mowing was also studied. The comparison pair was mowing on reverse drive with automatic steering and manual steering. In this study, the automatic steering had no effect on the number of twisted positions of the back or the head when compared to manual steering while mowing on reverse drive. However, the efficiency of the utilisation of operating width could be improved further with automatic steering. The actual operating width in this study was 1.6–2.2% (on average 11–15 cm) wider when using automatic steering. On the other hand, on a rolling field with a wet hollow, the automatic steering left clearly more places un-mowed than the manual steering. This may have been affected by the changes in the position of the tractor (sinking/subsidence) and/or skidding.

The benefits of reverse drive controls more evident during long stretches of work

With regard to twisted back postures and body vibration, the mowing on reverse drive corresponds more to the load put on by harvesting-threshing than tractor work. There is very little difference between working postures, since the object is directly in front of the driver with regard to the direction and reasonably unobstructed, that is to say, the work seems to an outsider very much like driving a combine harvester. In addition to significant mass of tractors used for reverse drive approaches the mass of mid-sized combine harvesters – as a rule, the vibration caused by the vehicle decreases as the mass grows. The improved ergonomics is a feature promoting both the occupational health and ease of work. This is also evident in the improved working speed, which decreases exposure to load factors of driver's work. The benefits of the reverse drive controls are especially evident when working for a long period of time.

Reverse drive controls have been the speciality of a few tractor manufacturers for several years, for example, in the case of Valtra since early-1990s. It is mainly used in harvesting ensilage crop, especially in mowing but also in shredding. It is also much used in forestry and some in the cultivation special plants as well as municipal engineering and loading work.

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