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AN ERGONOMIC ANALYSIS OF THE CONTROLS PRESENT IN A TRACTOR WORKSTATION

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Abstract

In the cab of a tractor, the driver communicates information to the tractor using various control types (i.e., rotary switches, toggle switches, rocker switches, knobs, push buttons, hand–levers, and steering wheels). The published literature documents numerous design and ergonomic considerations that should be followed to maximize the operator's interaction with machine controls. This paper reviews the published literature and identifies guidelines related to seven types of controls, control placement, control labeling, and functional reach. Six agricultural tractor workstations, with manufacturing dates between 2003 and 2005, were analyzed to determine the degree to which tractor manufacturers comply with these published recommendations. Published design recommendations are being followed, however, some dimension values being used are less conservative than others. Separation distance is the most notable case; small separation distances are being used, perhaps to fit more controls into the limited space available within tractor cabs. Analysis revealed that 89% of controls are situated on the right-hand side of the workstation, but only 75% of controls fall within the functional reach envelope. Ninety-five percent of controls are labelled using either a symbol or text, with symbols being used most frequently.

Keywords: tractor controls, design guidelines, ergonomic analysis

INTRODUCTION

In the environment of the tractor cab, a control is the device that allows the tractor operator to 'communicate' with the tractor and attached implement by transmitting information to them (Purcell 1980). The functionality of a control panel in a tractor comprised of various individual controls depends upon the human operator's ability to interact with it. Thus, it is critical that human factors be considered when designing both individual controls and the entire control panel. Information on control design exists in the published literature, however, it is not known whether the published design recommendations are followed by designers of agricultural tractors or if they are appropriate for agricultural tractors.

This paper reviews the published literature and identifies guidelines related to the dimensions of seven types of controls (i.e., rotary switches, toggle switches, rocker switches, knobs, push buttons, hand levers, and steering wheels). In addition, the literature is reviewed to determine guidelines related to three aspects of control panel design: control placement, control labelling, and functional reach. Six tractor workstations, with manufacturing dates between 2003 and 2005, were analyzed to determine the degree to which tractor manufacturers comply with these published recommendations.

RECOMMENDED DIMENSIONS FOR CONTROLS

Rotary Switches

Pheasant (1986) noted that the rotary switch is the preferred control in situations where 2 to 24 settings are required. Rotary switches can have either a moving pointer and fixed scale or a moving scale and a fixed index, but a moving pointer with a fixed scale is preferred for most tasks (Van Cott and Kinkade 1972). The most important design dimensions that affect the operation efficiency of a rotary switch are its length, width, height, and its separation from other controls (US Department of Defense 1999). Pheasant (1986) suggested an optimum length of 25–30 mm, height of 15–25 mm, and separation of 50 mm. As can be seen from Table 1, most authors recommended the same minimum length, height, and separation values; in the case of width there is a maximum value of 25 mm. By reviewing the following table, it can be summarized that there are no significant differences between the various recommended dimensions. Acceptable dimensions for rotary switches are:

- Length: 25–76 mm
- Width: ≤ 25 mm
- Height: 12–75 mm
- Separation: ≥ 25 mm

Table 1. Recommended dimensions for rotary switches

Author(s)	Year of Publication	Length (mm)	Width (mm)	Height (mm)	Separation (mm)
Corlett & Clark	1995	12–70	≤ 25	12–70	25–50
Van Cott & Kinkade	1972	25–76	≤ 25	12–76	50*
Grandjean	1988	≥ 25	≤ 25	12–70	N/A
Sanders & McCormick	1993	25–76	12–25	≥ 12	N/A
NASA–STD–3000	1995	N/A	N/A	N/A	40*
MIL–STD–1472F	1999	25–100	≤ 25	16–76	50*
Pheasant	1986	25–30*	≤ 25	15–25*	50*
Weimer	1993	25–100	13–25	12–75	N/A
Konz	1990	N/A	N/A	N/A	25*

(*presented as being the optimum value)

Toggle Switches

Grandjean (1988) demonstrated that the toggle switch is the preferred control for on/off or other two–state selection. He also states that it may be used in three positions (e.g., on/standby/off), but the rotary switch is preferable in such cases. Similar findings have been presented by Pheasant (1986) and Weimer (1993). A further study from NASA (1995) regarding the operation efficiency of toggle switches showed that there are two important dimensions: 1) arm length between 13 and 50 mm and 2) separation (both horizontal and vertical) of 50 mm.

Table 2 presents various recommended toggle switch sizes from selected authors. A careful examination shows that almost all the authors give the same recommendations for both dimensions. Evidently, the toggle switch is a highly standardized control. Consequently, acceptable dimensions for toggle switches are:

- Arm Length: 12–50 mm
- Separation: ≥ 50 mm

Table 2. Recommended dimensions for toggle switches

Author(s)	Year of Publication	Arm Length (mm)	Horizontal Separation (mm)	Vertical Separation (mm)
Corlett & Clark	1995	13–50	≥ 12	75*
Van Cott & Kinkade	1972	13–50	25*	50*
Grandjean	1988	12–50	50*	50*
Sanders & McCormick	1993	12–50	50*	≥ 50
NASA–STD–3000	1995	13–50	50*	50*
MIL–STD–1472F	1999	13–50	50*	50*
Pheasant	1986	15–50	50*	50*
Weimer	1993	12–50	50*	50*
Konz	1990	N/A	19*	N/A

(* presented as being the optimum value)

Rocker Switches

The US Department of Defense (1999) conducted laboratory studies regarding the usefulness of rocker switches. They found that rocker switches may be used in lieu of toggle switches for functions requiring two discrete positions. They also may be used for applications where toggle switch handle protrusions might snag the operator's sleeve or where there is insufficient panel space for separate labelling of switch positions. In addition they established the basic dimensions for a rocker switch (width, length, and the separation between centres). Their recommendations for the previously mentioned dimensions are: minimum width of 6 mm, minimum length of 12 mm, and minimum separation of 19 mm.

Although it is difficult to find relevant information on design requirements for this specific type of control, the available published literature is in accordance with the dimensions that NASA (1995) provides. Design recommendations concerning the width, length and separation for rocker switches are given in Table 3. The majority of authors agree with the following dimensions:

- Width: ≥ 6 mm
- Length: ≥ 12 mm
- Separation: ≥ 19 mm

Table 3. Recommended dimensions for rocker switches

Author(s)	Year of Publication	Width (mm)	Length (mm)	Separation (mm)
Corlett & Clark	1995	25*	15*	N/A
Van Cott & Kinkade	1972	N/A	N/A	N/A
Grandjean	1988	N/A	N/A	N/A
Sanders & McCormick	1993	N/A	N/A	N/A
NASA–STD–3000	1995	≥ 6	≥ 12	≥ 19
MIL–STD–1472F	1999	≥ 6	≥ 12	≥ 19
Pheasant	1986	12–15*	25–30*	50*
Weimer	1993	≥ 6	≥ 13	N/A
Konz	1990	N/A	N/A	25*

(***** presented as being the optimum value)

Knobs

Grandjean (1988) noted that knobs should be used when low activation forces or precise adjustments of a continuous variable are required. This statement can explain the reason why, in modern tractors, knobs are more popular compared to other types of controls. In tractors, there are a variety of operations that require adjustments on a continuous scale for gaining accuracy (Purcell 1980). For most tasks, a moving knob with fixed scale is preferred over a moving scale with fixed index according to studies conducted by the US Department of Defense (1999). A further study by Van Cott and Kinkade (1972) showed that the dimensions of knobs should be within the limits specified in Table 4. Within these ranges, knob size is relatively unimportant, and it can be easily grasped and manipulated.

When panel space is extremely limited, knobs should approximate the minimum values and should have resistance as low as possible without permitting the setting to be changed by vibration or by accidental touching of the control. Height, diameter, and separation between adjacent edges of knobs should conform to the values given in Table 4. A careful review on the various design recommendations and especially on the optimum values confirms the fact that the majority of the authors provide the same dimensions for knobs. Like the toggle switch, the knob is also a highly standardized control with unquestionable value due to its simple mode of operation. Therefore, its recommended acceptable dimensions can be summarized as:

- Height: 12–25 mm
- Diameter: 12–100 mm
- Separation: ≥ 50 mm

Table 4. Recommended dimensions for knobs

Author(s)	Year of Publication	Height (mm)	Diameter (mm)	Separation (mm)
Corlett & Clark	1995	12–70	25–100	25–50
Van Cott & Kinkade	1972	12–25	50*	50*
Grandjean	1988	15–25	35–75	50*
Sanders & McCormick	1993	12–25	50*	50*
NASA–STD–3000	1995	N/A	N/A	N/A
MIL–STD–1472F	1999	12–25	10–100	50*
Pheasant	1986	15–25	15–30*	50*
Weimer	1993	12–25	10–100	50*
Konz	1990	N/A	N/A	25*

(***** presented as being the optimum value)

Push Buttons

The US Department of Defense (1999) conducted experiments on the operation of push buttons. They concluded that this type of control should be used when a control or an array of controls is needed for momentary contact or for actuating a locking circuit, particularly in high–frequency–of–use situations. In addition, they showed that push buttons should not be used for discrete control where the function's status is determined exclusively by the position of the switch (e.g., an on–off push button that is pressed in and retained to turn a circuit on and pressed again to release the push button and turn the circuit off).

Their results agreed with previous findings presented by Van Cott and Kinkade (1972) and Pheasant (1986). Van Cott and Kinkade (1972) showed the benefits of using push buttons. They mentioned that, in most cases, push buttons require only a small amount of panel space. In addition, they can be operated quickly and simultaneously with other push buttons in an array and they can be identified easily by their position within an array or by their associated display signal. The main disadvantage as Hunt and Orlansky (1953 and 1949, cited by Van Cott and Kinkade 1972) note is that push button control setting is not easily identified, visually or tactually. As a solution, Van Cott and Kinkade (1972) suggested the use of a concave surface to deal with tactual problems and the use of a positive indication of control activation to deal with visual problems.

Later, NASA (1995) developed a dimension guide for push buttons. Their design recommendations for the diameter and separation between adjacent edges are given in Table 5. All the author's recommendations are similar and the following dimensions can be used as a guide:

- Diameter: 12– 25 mm
- Separation: ≥ 50 mm

Table 5. Recommended dimensions for push buttons

Author(s)	Year of Publication	Diameter (mm)	Separation (mm)
Corlett & Clark	1995	12–25	15–22
Van Cott & Kinkade	1972	≥ 12	12–50
Grandjean	1988	12–15	50*
Sanders & McCormick	1993	≥ 12	50*
NASA–STD–3000	1995	≤ 40	N/A
MIL–STD–1472F	1999	10–25	50*
Pheasant	1986	12–15	50*
Weimer	1993	10–19	50*
Konz	1990	N/A	50*

(***** presented as being the optimum value)

Hand Levers

The hand lever is a very important control in the agricultural industry and for many years was the primary control that was used in tractors. Although its use today has been partly replaced by other types of controls, it still remains an easy and simple method to make a number of adjustments in tractors (Purcell 1980). Corlett and Clark (1995) and Weimer (1993) demonstrated the use of hand levers. Their main conclusion was that hand levers may be used when high forces or large displacement are involved or when multidimensional movements of controls are required. Furthermore, they categorized hand levers as being either rigid or spring–loaded and reached the conclusion that spring–loaded levers are preferred because their control positions can be determined visually. On the other hand, they showed that due to the fact that hand–levers have a limited range of movement, they are usually unsatisfactory for precise positioning over a wide range of adjustments. The disadvantage mentioned can explain the partial, or in some cases the total, replacement of hand levers as a primary control from old to modern tractors.

A comprehensive guide regarding hand lever design was given by Corlett and Clark (1995). In this guide, three factors are presented as important when operating a hand lever: displacement, separation, and activation force. Weimer (1993) suggested a maximum displacement of 355 mm, a value that has been accepted by the majority of the authors listed below and it is still in use in the design industry. Early work by Van Cott and Kinkade (1972) defined the minimum separation of hand levers at the value of 50 mm. NASA (1995) published a guide in which the proper values of activation forces for hand–levers were categorized according to their type (e.g., one hand push–pull levers, two handed push–pull levers, one handed right–left lever). The maximum resistance for a hand push–pull lever was 20 kg based on the maximum arm strength of the 5^{th} percentile male. A closer examination of the maximum activation force values given from other sources shows that there are also some different suggestions. An explanation for this discrepancy in values can be the fact that some authors probably did not consider the maximum arm strength of the 5^{th} percentile male which is 19 kg.

Design recommendations concerning the displacement, separation, and activation force for hand levers are given in Table 6. Acceptable values are:

- Displacement: ≤ 355 mm
- Separation: ≥ 100 mm
- Activation Force: ≤ 16 kg

Table 6. Recommended dimensions for hand levers

Author(s)	Year of Publication	Displacement (mm)	Separation (mm)	Activation force (kg)
Corlett & Clark	1995	≤ 355	50–100	≤ 16
Van Cott & Kinkade	1972	≤ 355	50–100	≤ 14–23
Grandjean	1988	≤ 350	N/A	≤ 13
Sanders & McCormick	1993	≤ 355	100*	9–45
NASA–STD–3000	1995	N/A	N/A	≤ 22
MIL–STD–1472F	1999	≤ 355	100*	0.9–14
Pheasant	1986	100–200*	100*	N/A
Weimer	1993	≤ 355	100*	≤ 13
Konz	1990	N/A	N/A	N/A

(***** presented as being the optimum value)

Steering Wheel

Purcell (1980) describes the steering wheel as the most important control in the tractor cab. He mentions that the driver's left hand must be available for steering at all times. Special consideration is given to the following three dimensions: diameter, rim thickness, and angle to the horizontal plane.

According to Pheasant (1986), a 380 mm diameter is at the lower limits of acceptability and 400–440 mm would probably be better, giving additional torque to the weaker driver. In addition, an ideal rim thickness is 20 to 35 mm for heavy machines such as tractors. Studies conducted by Howe et al. (1992) proved that a vertical wheel might be more easily accommodated. However, at the same time, he showed that the maximum force (torque) was exerted on a horizontal wheel, although paradoxically the speed of rotation was maximal when the wheel was vertical. He, therefore, recommended that the axis of the wheel (i.e., the steering column) should be 40–60° to the horizontal plane, in which position 70% of the maximum force can be exerted. This concept is also supported by other design specialists (Van Cott and Kinkade 1972; Konz 1990; and Weimer 1993).

Table 7 illustrates different design recommendations for the diameter, rim thickness, and angle to the horizontal plane for a steering wheel. Most of the authors agree with the following recommendations:

- Diameter: 400–510 mm
- Rim Thickness: 19–32 mm
- Angle to the Horizontal Plane: 40°–60°

Table 7. Recommended dimensions for steering wheels

Author(s)	Year of Publication	Diameter (mm)	Rim thickness (mm)	Angle to the horizontal (°)
Corlett & Clark	1995	200–500	20–50	N/A
Van Cott & Kinkade	1972	381–457	19–50	30–60
Grandjean	1988	180–500	N/A	N/A
Sanders & McCormick	1993	180–533	19–50	N/A
NASA–STD–3000	1995	N/A	N/A	N/A
MIL–STD–1472F	1999	400–510	19–32	45*
Pheasant	1986	380–440*	20–40*	50–60*
Weimer	1993	180–530	20–50	30–60
Konz	1990	400–510	20–32	45*

(***** presented as being the optimum value)

HUMAN FACTORS CONSIDERATIONS FOR CONTROL PANELS

Placement of Controls

According to the literature, the placement of controls seems to be the most important ergonomic factor which ensures safe and efficient operation. As Van Cott and Kinkade (1972) noted, controls should be arranged in such a way to minimize the requirement for operators to change their position solely to operate a control. A further study by Woodson (1992) confirmed this suggestion. Specifically, he showed that all controls should be positioned so that, in manipulating them, operators do not appreciably move their nominal eye reference and possibly miss seeing important events occurring outside or on the principal internal display.

Many authors emphasized the contribution of control placement in safety of tractors (Purcell 1980; Grandjean 1988). This issue is one of the most serious challenges that designers must face as many accidents in the United States were caused due to the bad placement of controls (National Safety Council 1978).

In 1980, Purcell developed a guide on the human factor in farm equipment design. In this guide, he suggested that all controls in the tractor cab which required accurate manipulation must be grouped on the right hand side of the operator, leaving his left hand available for steering at all times.

Control Labelling

Control labelling is an important issue for operators working with any control layout. Studies conducted by Sanders and McCormick (1993) showed that the identification of controls is essentially a coding problem. Making controls easy to identify decreases the number of times a wrong control is used and reduces the time required to find the correct control (Van Cott and Kinkade 1972). Labels and symbols (or icons) are common methods of identifying controls.

Labels are probably the most common method of identifying controls and should be considered the minimum coding required for any control. Early work by Chapanis et al. (1949) showed that adequate space, visibility, and lighting are the prerequisites for using this method. Generally, a large number of controls can be coded with labels and, if properly chosen, the operator does not require much training to comprehend the intended meaning. Extensive use of labels as the only means of coding controls is not desirable (Sanders and McCormick 1993; Van Cott and Kinkade 1972). A disadvantage is that labels take time to read and thus should not be the only coding method where speed of operation is important.

Corlett and Clark (1995) defined the proper location of labels. They demonstrated that labels should be placed above the control so that the hand will not cover them when the operator is reaching for the control. Also, the label should be visible to the operator before reaching for the control. Van Cott and Kinkade (1972) concluded that readability is affected by the size of the letters in the label. Specifically, they noticed that the optimal height of characters varies with distance of the viewer from the label.

To enhance a text label, the designer should add symbols that are meaningful and familiar to the operator. For agricultural vehicles, ASABE has established a guide which presents different standardized graphical symbols that can be used on operator controls (ASABE S304.7 2000).

Functional Reach

Important components must be placed in convenient locations so that they can be reached without undue arm exertion (i.e., without shoulder stretching). Pheasant (1986) defines the term 'functional reach grip' as the horizontal distance from the operator's shoulder to the tip of the thumb, measured with the subject's shoulders against the seat, the arm extended forward, and the index finger touching the tip of the thumb.

Purcell (1980) combined a graphical layout and anthropometric data published by McFarland et al. (1953) and NASA (1978) to develop a graphic solution for optimum seating placement and location of controls in tractors. According to this solution the maximum reach zone (i.e., finger grip) of a 2.5th male percentile was defined at 750 mm covering a 180° envelope in front of the operator's shoulders.

MATERIALS AND METHODS

Determination of the Control Dimensions

In this study, data were collected from six tractor workstations (i.e., John Deere 8220, Case IH MX 230, Buhler–Versatile 2210, New Holland TG 285, Fendt 920 Vario, and Caterpillar Challenger MT665B), with manufacturing dates between 2003 and 2005. Dimensions of the controls were determined using a common measuring tape. Activation force was determined using a dynamometer. Measurement details related to the specific dimensions of controls are described below (Table 8).

Determination of the Control Panel Characteristics

The following criteria were used to evaluate three human factors characteristics of the control panels present in the tractors (Table 9).

Table 8. Measurement details related to the specific dimensions of controls

Dimension	Control type	How dimension was measured
Length	Rotary switch	Distance of the switch from the top to the edge.
	Rocker switch	Half the distance of the total length.
Width	Rotary & Rocker switch	Thickness of the switch based on its front surface.
Height	Rotary switch	Depth of the switch based on its side surface.
	Knob	The vertical length of the knob.
Separation	Rocker switch	Distance between the centers.
	All other types	The minimum distance between two controls of the same type.
Arm length	Toggle switch	Vertical length from the base to the top of the switch.
Diameter	Knob, push button, steering wheel	For knob and push button, outside diameter of the control was measured. For steering wheel, diameter was measured from the inside of the rim.
Displacement	Hand-lever	Maximum travel distance through its range of motion.
Activation force	Hand-lever	Maximum force recorded by dynamometer during movement of the lever through its range of motion.
Rim thickness	Steering wheel	Maximum vertical thickness.
Tilt angle	Steering wheel	Not measured; taken directly from the specifications for the tractor.

Table 9. Criteria used to evaluate three human factors characteristics of control panels in agricultural tractors

Human factors characteristic	How human factors characteristic was assessed
Placement of controls	Each tractor cab was reviewed to determine the number of controls that were located on the right-hand side of the operator. The right-hand side was identified using a line joining the midpoint of the seat and the centre of the steering wheel.
Control labelling	Each tractor cab was reviewed to determine the number of controls that had an associated label or symbol. Labels or symbols that were located beneath the control were considered to not exist. For labels, the text height had to be at least 2.5 mm to be counted. For symbols to be counted, they had to be consistent with standard symbols for agricultural equipment described in ASABE S304.7 (2000).
Functional reach	Each tractor cab was reviewed to determine the number of controls located within 750 mm (covering a 180° reach envelope) from the seat reference point (U.S. Department of Defense 1976).

RESULTS AND DISCUSSION

Control Dimensions

Mean and standard deviations were calculated for the relevant dimensions for the seven control types based on measurements from the six agricultural tractors (Table 10). For ease of comparison, Table 10 also shows the recommended values based on the published literature. In general, the measured dimensions agreed with the recommended values. Separation distance was the one notable exception for several of the control types.

Another way to view the data is to show the proportion of controls that met the recommended values for each relevant dimension. As seen in Table 11, high proportions of the controls met the recommended values with separation distance being the notable exception. Although it may be tempting to conclude that tractor designers do not follow the published recommendation for separation distance between controls, such a conclusion would be difficult to prove. For example, Tables 1, 3, 4, and 5 all show that some authors recommended separation distances much less than 50 mm. Recommended values, as presented in this paper, represent the view of the majority of sources surveyed. However, the observed separation distances are consistent with the less conservative values recommended by a small number of the sources. Thus, there is sufficient evidence to conclude that the controls being used in tractors are consistent with the published design recommendations for controls.

It is important to note that control panel space is quite limited inside tractors. It is possible that designers have specifically chosen to use the less conservative separation distances so that more controls can be placed in the limited space available. Care must be taken to avoid the crowding of controls that could contribute to accidental activation and potential harm to the machine or operator (Sanders and McCormick 1993). The use of control types that combine more than one operation (i.e., multifunction controls) in an effective manner is one potential solution to saving space because the total number controls will be reduced.

Control Panel Characteristics

Of the 355 controls present in the six tractors, 316 (89%) were placed on the right-hand side of the control panel to be operated by the driver's right hand. Unfortunately, we did not record the function of the 39 controls that were placed to the left of the operator's seat (i.e., we do not know whether these controls are expected to be operated while the tractor is being driven or whether it is expected that they will be operated while the tractor is stationary). If they are not relevant to operation of the tractor during driving, their placement on the left-hand side of the control panel may be irrelevant.

Of the 355 controls, 337 (95%) were labelled with either a text label with a minimum text height of 2.5 mm or a symbol consistent with ASABE standard S304.7 (2000). Designers of agricultural tractors tend to rely on symbols rather than text labels.

For the final characteristic, 265 of 355 controls (75%) were located within 750 mm of the seat reference point. We did not record the function of the 90 controls that were situated outside the functional reach envelope, but it is safe to assume that some of these controls would need to be operated during operation of the tractor. Therefore, the operator would have to assume less comfortable positions during the long working hours which could increase the risk of pain and injury to the back and shoulders (National Safety Council 1978). Manufacturers should be more aware of the arrangement of control issues if they want to achieve not only easier control accessibility for all the potential operators but also a user–friendly workstation environment.

Table 10. Values recommended from the literature for seven different types of controls (top half of table); mean and standard deviation dimension values for seven different types of controls (bottom half of table)

Dimension	Rotary Switch	Toggle Switch	Rocker Switch	Knob	Push Button	Hand Lever	Steering Wheel
Recommended Values							
Length (mm)	25–76		≥ 12				
Width (mm)	≤ 25		≥ 6				
Height (mm)	12–75			12–25			
Separation (mm)	≥ 25	≥ 50	≥ 19	≥ 50	≥ 50	≥ 100	
Arm length (mm)		12–50					
Diameter (mm)				12–100	12–25		400-510
Displacement (mm)						≤ 355	
Activation force (kg)						≤ 16	
Rim thickness (mm)							19–32
Tilt angle (°)							40–60
Measured Values							
Length (mm)	47±0		20±5				
Width (mm)	11±0		18±3				
Height (mm)	10±0			15±5			
Separation (mm)	42±0	35±22	41±47	34±17	18±45	104±91	
Arm length (mm)		23±9					
Diameter (mm)				31±14	19±5		398±8
Displacement (mm)						76±38	
Activation force (kg)						1±2	
Rim thickness (mm)							29±2
Tilt angle (°)							63±21

Table 11. Proportion of controls that met the published design recommendations

Dimension	Rotary Switch	Toggle Switch	Rocker Switch	Knob	Push Button	Hand Lever	Steering Wheel
Length (mm)	2/2		66/73				
Width (mm)	2/2		72/73				
Height (mm)	0/2			39/51			
Separation (mm)	2/2	13/30	43/73	11/51	16/167	9/21	
Arm length (mm)		28/30					
Diameter (mm)				51/51	147/167		4/6
Displacement (mm)						21/21	
Activation force (kg)						21/21	
Rim thickness (mm)							6/6
Tilt angle (°)							4/6

Table 12. Criteria used to evaluate control labelling – Sample analysis for Fendt tractor workstation

Control	Was text label above control?	Was symbol above control?	Was text > 2.5 cm in height?	Was symbol consistent with ASABE S304.7?	Was label acceptable?
PTO engagement	No text label	Yes	No text label	Yes	Yes
Throttle	No text label	Yes	No text label	Yes	Yes
Cigarette lighter	No text label	No	No text label	Yes	No
3–point hitch	No text label	Yes	No text label	Yes	Yes
Differential lock	No text label	Yes	No text label	Yes	Yes
Windshield Wipers	No text label	Yes	No text label	Yes	Yes
Headlights	No text label	Yes	No text label	Yes	Yes
Fan speed	Yes	No symbol	Yes	No symbol	Yes
Seat back adjustment	No text label	No	No text label	Yes	No

CONCLUSIONS

The following conclusions were derived from this study:

1. There is sufficient evidence to conclude that the controls being used in tractors are consistent with the published design recommendations for controls.
2. Of the recommendations used for various control dimensions, the least conservative values were chosen for separation distance. Perhaps this is an indication that space is a premium inside a tractor cab.
3. As recommended, most controls (89%) are located so that they can be operated by the driver's right hand.
4. Designers of agricultural tractors tend to use symbols rather than text labels. The majority of controls (95%) are labelled using either a symbol or text.
5. Only 75% of controls were located within the functional reach envelope (i.e., 750 mm from the seat reference point). It is speculated that space may be a limiting factor due to the large number of controls required to operate modern agricultural equipment.

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