Status of Sugar Beet Harvesting in Europe

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Introduction

Sugar beets are the most valuable agricultural field crop in Europe. Farmers receive roughly \$60/t due to the market regulations in the European Union (EU). This gives the farmer a net income in Germany of at least \$800/acres, using no irrigation. Because of this, the harvesting techniques are highly developed. Many efforts and strategies are taken to minimize losses and assure high quality of the harvested product; i.e.low dirt tare. In 1996 2.9 Billion tons of dirt (soil, stones) were delivered into the sugar factories in Germany.Therefore, the governement is considering a fine of \$30 per ton of dirt. Permanent improvements have been nescessary to meet the economical and ecological needs. The Department of Agricultural Engineering (Institut fuer Landtechnik) of the Rh.-Fr.-Wilh.University of Bonn together with the sugar beet grower association, the sugar industry, and the farm machinery industry have been evaluating the harvesters and other equipment at the same location since 1979. The tests took place every four years l since 1984. In the paper are presented the test results of 1996 and a numerical review of the harvesters presently in use.

Material and Methods

The test area is located on the farm Juliusspitalgut Seligenstadt near Wuerzburg, Germany.The crop data of the test field are planted to final stand, row distance 20 inches (50 cm), beet spacing 19 cm, variety Patricia of KWS, population 86.358 beets/ha (34.543 beets/ acre), yield 692.6 tons/ha (27.7 tons/acre), 19.3 % sugar content.

The test is based on the I.I.R.B. test standard and therefore the the crop data are taken one week before the test. This allows all manufacturers of test machines to adjust their harvester for optimized working quality with regard to topping, lifting depth, root damage, dirt tare, and beet loss. Individual beets are measured for their maximum diameter, **fig. 1**. The crop on the test field is then statistically described by an average beet size of 500 beets. Since the distribution is close to a normal distribution, an average beet size and its breakage loss can be calculated, **fig. 2**.

Beet mass losses are due to root breakage and none-harvested beets and beet pieces greater then 4.5 cm. Both may occur in the soil or above the soil surface. The beet losses are measured immediatly after the harvest by collecting beets and pieces above the ground. Then the test area is cultivated twice at depth of 8 inches (20 cm) over a 200 m length. The collecting area is divided into four parts of 50 m, giving four replications. The depth of the lifting devices and the soil moisture are also measured with four replications per machine. The harvesting speed is agreed to by the manufacturer to be 6 (+/- 0.5) km/h for the 2- and 3-row tanker and to be 5.5 (+/- 0.5)km/h for the 6-row tanker.

Beet topping quality was visually evaluated for 500 beets with classes conforming to the I.I.R.B. standard, **fig. 2**, given in parts percentage.

Dirt tare is generally determined as the ratio of the mass of dirt (soil and stones) to the mass of clean beet (without leaves) plus the dirt. The representative sampling of the harvested beets is most important. There were five samples of 50 kg taken twice when unloading the tank of the harvester. The mass of clean beets was determined by washing the sample. The technical data of the washing system are shown in **fig. 3**.

Beet surface damage is generally given as the open area per 100 beets (sq cm/100 beet). The areas of topping and root breakage are not considered. Areas are measured by two axels and and calculated as square for 500 beets taken. The amount of surface damage represents the mechanical damage intensity to the beet in the machine during the transport and cleaning process.

Selection of Test Machines

In Europe thereare presently roughly 40 harvesters of more than 20 manufacturers on the market. The technical data of the harvesters based on the number of rows and systems are given in **table 1**. As an average, they require on power more then 35 kW per row with investment costs of $ 1000 per kW or more then $ 60,000 per row. For the 2- and 3-row tanker the tractor is included. Harvesters with little or no tank capacity cost less. Two-year statistics of the I.I.R.B. provides the percentage of the area harvested by the different machine systems respectivly types. For Germany, the situation is given in **fig. 4**. That is why only 2-, 3-, and 6-row tankers have been included in the test, **table 2**. The table includes also selected data of the machines tested, as power required or installed, share type, transport mechanism, tire dimensions, tank capacity, as well as the actual price at the date of the test.

The boundary conditions for selecting the appropriate harvesting system are: 25 to 35 field days for harvesting; 75 to 90 days for the sugar factories are working. For minimizing the dirt tare, the harvest out of a tilth soil is prefered. Therefore for wet harvesting conditions the share of two-phase harvesting systems is decreasing. The 8- and 12-row topper and lifter machines did not gain ground. For european conditions, the following season capacities can be calculated for the different harvesting systems: 1-row tanker, trailed, 35 to 45 ha/year (87.5 to 112.5 acres/year); for 2-row tanker, trailed, 70 to100 ha/year (175 to 250 acres/year); for 3- row tanker, trailed and selfpropelled, 100 to 125 ha/year (250 to 212.5 acres/year), for 6-row tanker, selfpropelled, to300 ha/year (750 acres/year) and in two shifts to 500 ha/year (1250 acres/year). Under more favorable conditions the selfpropelled 6-row tanker may harvest a maximum of 1000 ha/year (2500 acres/year).

Since the tank capacity may reach 27 tons, the chassis design becomes increasingly important. The top models will have all-wheel steering, 4DW, eventually 6WD and different steering regimes. When having offset the harvesting unit by 800 mm, those steering regimes will allow a once- over pass of the wheels with a total width of 4.4 m. Because of the close relation between tire inflation pressure and upper soil zone compaction, the wheel loads of tractors and harvesters were measured and the inflation pressure calculated, based on the tire dimensions and working speed.

Results

The harvesting speed was kept within the given limits. The field capacity of the two-row tanker reached the expected roughly 40 tons/hr, the three-row tanker averaged 57.9 tons/hr and the six-row tanker 118.8 tons/hr with a maximum of 130.7 tons/hr. In the two-phase harvesting system the topper-lifter was measured with 102.7 tons/hr and the selfpropelled loader -tanker 311.7 tons/hr, **table 3**.

The total **beet mass loss** differed from 1.1 to 3.1 %, **table 3**. The highest share had the root breakage with 0.6 to 2.2 %. For the first time of the test, the average stayed below 2 %, what means that sugar beet harvesting has became very efficient compared to 20 years ago with 7.5 % total mass loss. However, the loss accounts economically still to up to $100/ha ($40/acre).

The **dirt tare** differed under very favourable harvesting conditions (av. 17.4 % soil m.c.w.b.) from 3.0 till 11.5 %, **table 3**. The average of 5.8 % was only half of the annual dirt tare percentage of the sugar beet delivered to the sugar factories in 1996 in Germany. The minimum of 3.0 % was reached by the experimental version of the IRS Bergen op Zoom, causing higher surface damage and sugar loss during storage. This may be important, since the present post harvest techology consists of a part- time storage on the field site and followed by a loader - cleaner, which will take off up to 65 % of the dirt in the beet pile. Those loader-cleaner have been also tested, but the results are not included in this paper.

The **beet topping quality** is influenced by the uniformity of the crop, particularly the top height, **fig . 5**, the shape of the beet, represented by **fig. 2**, and the topper design. By I.I.R.B standards, up to 56.7 % were topped correctly, **table 3**. By international agreement however, the under topped may be added to the class of correctly topped, summing up to an average of 75.1 % (as in 1992 test) with a range of 64.6 to 80.6 %. In comparison the range amounted from 53.7 to 92.1 % at the I.T.B. demonstration in Berny-en-Santerre in 1994. Most critical are the percentage of overtopped beets of up to 17.6 % matching with a high percentage of correct topped beets by I.I.R.B. standard. This may cause an economical loss of $65/ ha ($26/acre), based on the biotechnical data, **fig. 2**.

The **beet surface damage**, with an average of 96.3 sq cm/ 100 beets, was exceptional low, **table 3**.

The **weight of the harvester** was measured by using the wheel loads during the field test. The weight increases with the number of rows harvested, **fig. 6**. The difference of the dead and total weight is equivalent to the tank capacity of beets plus dirt (soil, stones, leaves, etc.), **table 2**. The 2-/ 3-row tanker will usually not exceed 20 tons and the 6-row tanker with a tank only for intermediate hauling usually not more than 25 tons. The 6-row tanker, having an average weight of 40 tons, once had a weight up to 54 tons. The differences in single wheel loads, **fig.**

7, are not so much different, but still exceeded to over 10 tons. This is compensated by high volume, low pressure tires (Terra tires) leading to an almost identical required tire inflation pressure. The 6- row tanker averaged a required pressure as low as 21 psi. As a result, they do not compact the upper soil zone any more then harvesters of lower row numbers . The actual soil compaction under test conditions were tested in conjunction with the DLG and the University of Halle. It was proven, that even high wheel loads will not lead to an increased soil density below 12 inches, due to the soil conditions on the test site. Under wet harvesting conditions, however, soil compaction may occur. On the other hand, since due to the field sizes in Europe, the harvesters operate up to 50 % of their running time on the road instead of be in the field, most harvesters will have higher, non- soilconserving tire pressure. Surveys under practical conditions have shown, that only roughly 25% of the harvesters had the appropriate tire pressure and were often not measured or were unknown.
Harvester information systems are becoming increasingly important for the reasons discussed as well as for precision farming. They will include yield sensors, positioning systems, tire pressure control, etc. besides monitoring of harvester elements, **fig. 8**.

Conclusions
A harvester test at the same location in four- year intervals provides the farmer as well as the sugar and farm machine industry with the nescessary informations for optimization of sugar beet harvesting. The test data also enable the extension service and scientist to develope expert and decision support systems. As a result of the test the state of the art of sugar beet harvesting is defined. According to the test and connected surveys, harvesters today have a field capacity from 40 tons/hr to 130 tons/hr, a tank capacity from 5.5 t (two row) to 26 t (six row) and an average harvesting quality of 5.8 % dirt tare, 1.9 % total mass loss and 75.1 % acceptable topping. Appropriate chassis design, according to steering and tire dimensions avoid irreversable soil compaction. Optimized machine adjustment and precision farming will require sugar beet information systems.

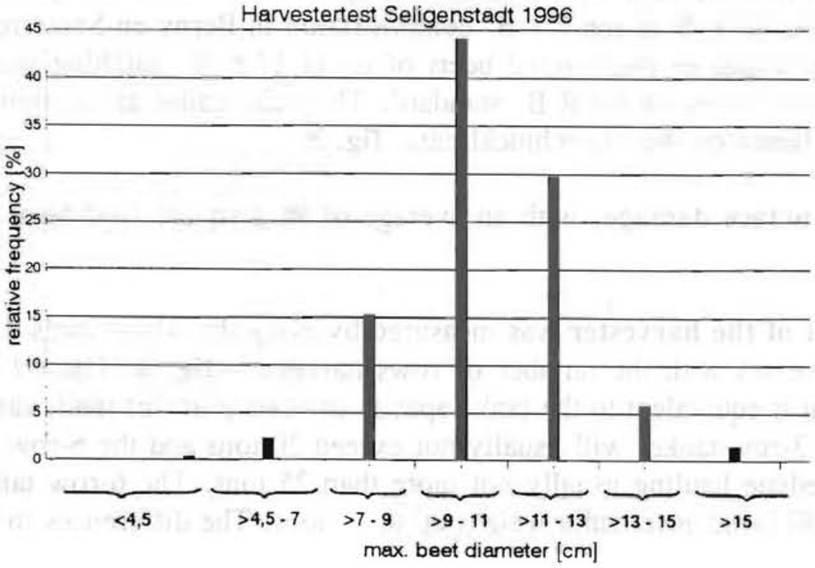

fig. 1: Frequency of max. beet diameter of sugar beet on the test field

TABLE 1: TECHNICAL DATA OF SUGAR BEET HARVESTERS

IIRB-Abbr.: trail.=trailled; SP=Self Propelled; KRB 1 to 6=1 to 6 row-tanker; KRBL 6=6-row-direct loader with intermediate tank; KRL 6=6-row-direct loading; KR 6=6-row-windrower; LB=loader-tanker; [1]=Row distance 45 cm; [2]=2 and 3-axles machine

Machine typ/ Harvesting system	Number of harvesters	Engine power Required or installed [kW]	Price (incl. VAT) [DM]	Lifter typ	Cleaning and transport mechanism	Tire dimensions: tractor and harvester	Total weight [t]	Tank capacity [t]
KRB 1, trail.	3	20 to 50	75,000 to 85,000	Share lifter	Turbine Elevator	Tractor 500-R26.5	10 to 13	2.7 to 4.1
KRB 2, trail.	6	40 to 80	80,000 to 130,000	Share lifter Oppelwheels	Turbine, Axial rolls Disk rolls, Elevator	Tractor 700-R26.5	16 to 20	4.2 to 6.6
KRB 3, trail.	4	70 to 100	100,000 to 170,000	Share lifter Oppel wheels	Conveyor belt Turbine, Axial rolls Elevator	Tractor 800/45-R30.5 Tractor	21 to 24	5.5 to 10
KRB 3, SP	3	140 to 180	290.000 to 340,000	Share lifter	Conveyor belt Turbine, Axial rolls Belt elevator	12.4-R28 480/70-R28 or all 800/45-R30.5	11 to 18	7.3 to 12
KRB 6 [2], SP	11	210 to 310	380,000 to 680,000	Share lifter Oppel wheels	Conveyor belt Turbine, Axial rolls Brushes Belt elevator	800/65-R32 800/65-R32 or rear 73*44-R32	31 to 54	10 to 27
KRBL 6, SP	3	140 to 210	400,000 to 500,000	Share lifter	Conveyor belt Turbine, Axial rolls Brushes, Belt elevator	710/70-R38 or 700/65-R38 700/50-R25.5 or 700/65-R38	24 to 26	7 to 9
KRL 6, SP	5	160 to 240	300,000 to 380,000	Oppel wheels Disk lifter Share lifter	Turbine Belt elevator	12.4-R36 650/70-R34	11 to 15	0 to 3.5
KR 6 [1], trail. + LB, trail.	3	90 to 140	150,000 to 220,000	Share lifter Disk lifter	Conveyor belt Turbine, Axial rolls Belt elevator	Tractor (normal and crop tires) 700/65-R38	22 to 28 LB trail.	9 to 14
KR 6, trail. + LB, SP [2]	3	90 to 120 180 to 280	450,000 to 600,000	Share lifter Disk lifter	Conveyor belt Turbines, Axial rolls Elevator	Tractor 800/65-R38 73*44-R32	28 to 45 (LB, SP)	15 to 26

TABLE 2: TECHNICAL DATA OF THE SUGAR BEET HARVESTERS TESTED IN 1996

Machine typ/ Harvesting system	Manufacture Spezification	Engine power [kW/HP]	Price (incl. VAT) [DM]	Lifter typ	Beet transport after the lifter	Cleaning and transport mechanism	Tire dimensions front (f.) / middle (m.) /rear (r.) right (ri.), left (le.)	Measured tank capacity [t]
KRB 2, trail.	Stoll V 202	min. 51/70	117,357	Share lifer	1 Turbine	1 Turbine	ri. LP 600-R26.5 le. LP 500-R26.5	62
KRB 3, trail.	Thyregod T-7	min. 88/120	172,500	Oppel wheels	1 Turbine	1 Turbine Elevator cleaning (Conveyor belts)	ri. + le. 23.1-R26	55
KRB 3, trail.	Tim S 312	min. 81/110	158,000	Oppel wheels	1 Turbine	1 Turbine Elevator cleaning (Rubber rolls)	ri. + le. 600/60-R30.5	71
KRB 3, SP	Barigelli B/3-4X4	192/261	310,000	Share lifter	1 Turbine	1 Conveyor belt 2 Turbines	f. 12.4-R28 r. 73X44.00-R32	73
KRB 6, SP	Barigelli B/6-4X4	268/364	540,000	Share lifter	2 Turbinee	1 Conveyor belt 2 Turbines	f. 800/65 -R32 r. 73X44.00 -R32	162
KRB 6, SP	Holmer Terra Dos	308/420	598,000	Share lifter	6 Axial rolls	1 Conveyor belt 3 Turbines	f. 800/65-R32 r. 73x44.00-R32	184
KRB 6, SP	IRS Prototyp	250/340	530,000	Share lifter	7 Axial rolls	6 Axial rolls 3 Turbines 8 Brushes	f. 800/65-R32 r. 800/65-R32	96
KRB 6, SP	Ropa R 26.50 K	309/420	672,750	Share lifter	6 Axial rolls	1 Conveyor belt 3 Turbines 4 Axial rolls	f. 800/65-R32 m. 73x44.00-R32 r. 66x43.00-R25	263
KRB 6, SP	Tim SR 2500	260/354	530,000	Share lifter	5 Axial rolls	1 Conveyor belt 4 Turbines Elevator cleaning (Rubber rolls)	f. 800/65-R32 r. 800/65-R32	130
KRBL 6, SP	Holmer/Claas on system trac Xerion	184/250	450,000	Share lifter	5 Axial rolls	Elevator cleaning (Conveyor belts) 3 Turbines	f. 700/65-R38 r. 700/65-R38	71
KRBL 6, SP	Kleine SF 10	210/285	419,260	Share lifter	3 Axial rolls 2 Turbines	3 Turbines	f. 710/70-R38 r. 700/50-R25.5	90
KR 6 (trac.moun)	Gilles K+ASC 48-32	min. 88/120	total	Share lifter	2 Turbines Swath	2 Turbines	f. 230/95-R44 r. 230/95-R48 (4 wheels)	
+ LB, SP	Gi-Trac RB 300	294/400	552,000			2 Conveyor belts 3 Turbines	f. 23.1- R26 m. 23.1-R26 r. 30.5-R32	210

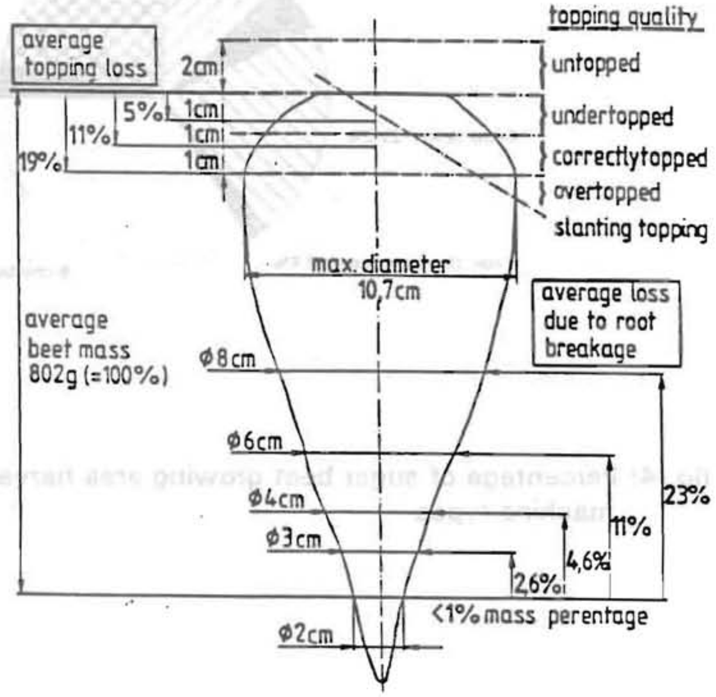

fig. 2: Breakage status of sugar beet on the test field and topping quality

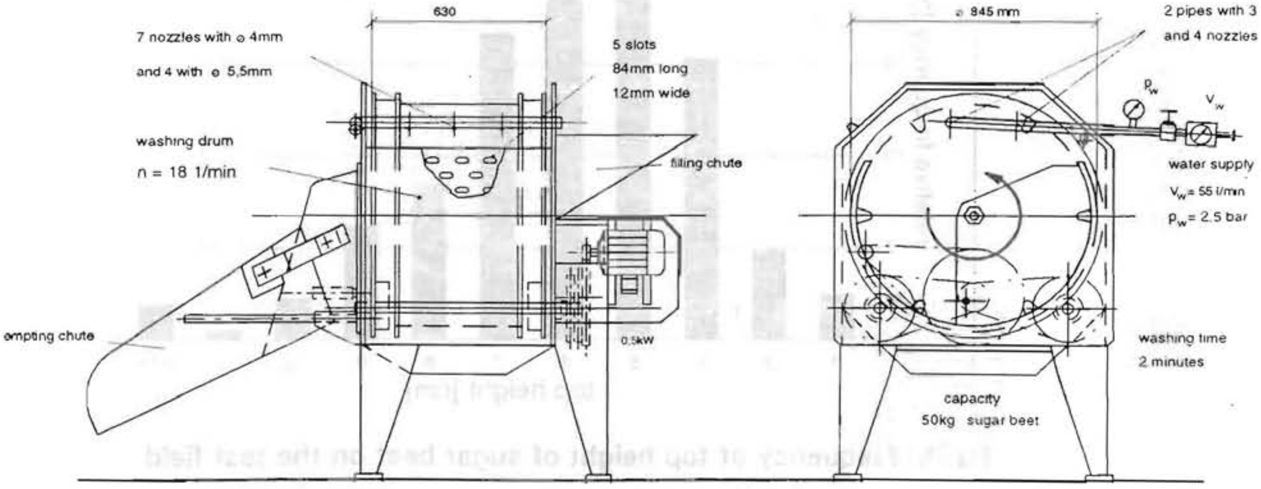

fig. 3: Beet washer type BISO 630, washing time 2 min., capacity 50 kg

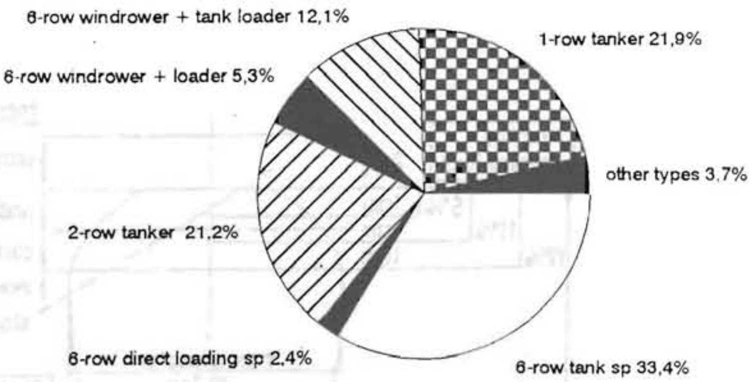

fig. 4: Percentage of sugar beet growing area harvested by different machine types

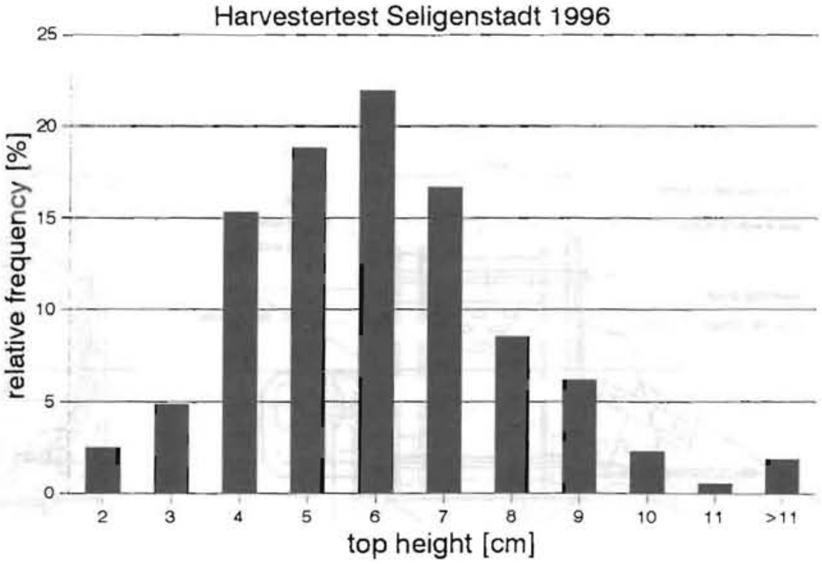

fig. 5: Frequency of top height of sugar beet on the test field

Tab. 3.1: Results of the harvestertest

Nr	Harvest-system	Manufacture specification		Speed km/h	field capacity t/h	Lifting depth cm	Soil moisture content %	Dirt tare %
1	KRB 2	STOLL V 202		5,8	39,4	8,5	16,3	5,5
2	KRB 3	BARIGELLI B3 SF		5,2	53,1	7,8	18,3	11,5
3	KRB 3	THYREGOD T 7		5,3	53,8	7,5	16,8	4,5
4	KRB 3	TIM S 312		6,4	66,7	8,4	18,2	3,5
Average KRB 3				5,6	57,9	7,9	17,8	6,5
5	KRB 6	BARIGELLI B 6		6,1	126,4	7,5	16,6	7,0
6	KRB 6	HOLMER TERRA DOS		5,5	115,0	7,8	16,6	8,7
7	KRB 6	IRS		5,2	108,4	6,8	16,7	3,0
8	KRB 6	ROPA R 26.50 K		6,3	130,7	8,0	19,1	7,8
9	KRB 6	TIM SR 2500		5,5	113,5	7,9	17,1	3,3
Average KRB 6				5,7	118,8	7,6	17,2	6,0
10	KRL 6	CLAAS/HOLMER Sys. XERION		5,8	119,7	5,7	17,1	4,7
11	KRL 6	KLEINE SF 10		5,6	115,5	9,0	19,5	5,6
Average KRL 6				5,7	117,6	7,35	18,3	5,2
12	KR + LB	GILLES SA	KR LB	4,9 15,0	102,7 311,7	11,1	16,4	5,5
Total Average						8,0	17,4	5,8

Tab. 3.2: Results of the harvestertest

Nr	Harvest-system	Manufacture specification		Speed km/h	Topping quality % untopped leaves > 2cm	< 2cm	under topped	correct topped	over topped	slanting topped	Surface damage cm²/100 beets
1	KRB 2	STOLL V 202		5,8	1,4	10,0	39,6	41,2	4,0	3,8	80
2	KRB 3	BARIGELLI B3SF		5,2	7,0	11,6	24,4	40,2	14,2	2,6	60
3	KRB 3	THYREGOD T 7		5,3	1,6	4,3	23,6	56,7	8,2	5,6	27
4	KRB 3	TIM S 312		6,4	1,2	3,6	19,8	56,6	13,8	5,0	68
Average KRB 3				5,6	3,27	6,50	22,60	51,17	12,1	4,40	51,7
5	KRB 6	BARIGELLI B 6		6,1	4,2	9,6	35,8	35,6	9,2	5,6	201
6	KRB 6	HOLMER TERRA DOS		5,5	2,2	1,8	24,2	54,6	14,0	3,2	34
7	KRB 6	IRS		5,2	1,8	10,2	49,2	31,4	4,2	3,2	60
8	KRB 6	ROPA R 26.50 K		6,3	2,0	4,0	21,0	50,8	15,4	6,8	60
9	KRB 6	TIM SR 2500		5,5	2,0	4,8	28,2	43,8	15,0	6,2	38
Average KRB 6				5,7	2,4	6,1	31,7	43,2	11,6	5,0	78,6
10	KRL 6	CLAAS/HOLMER Sys. XERION		5,8	1,0	7,8	32,6	42,6	10,8	5,2	200
11	KRL 6	KLEINE SF 10		5,6	2,6	2,8	19,8	49,0	17,6	8,2	198
Average KRL 6				5,7	1,8	5,3	26,2	45,8	14,2	6,7	199
12	KR + LB	GILLES SA	KR LB	4,9 15,0	5,2	9,2	45,2	34,8	1,8	3,8	129
Total Average					2,7	6,6	30,3	44,8	10,7	4,9	96,3

Tab. 3.3: Results of the harvestertest

Nr	Harvest-system	Manufacture specification	Speed	Mass losses %			
				Mass losses		Breakage losses	Total losses
			km/h	above soil	in soil	root - breakage	%
1	KRB 2	STOLL V 202	5,8	0,3	0,1	1,5	1,9
2	KRB 3	BARIGELLI B3 SF	5,2	0,4	0,1	1,2	1,7
3	KRB 3	THYREGOD T 7	5,3	0,9	0,2	1,4	2,5
4	KRB 3	TIM S 312	6,4	0,3	0,1	1,2	1,6
Average KRB 3			5,6	0,53	0,13	1,27	1,93
5	KRB 6	BARIGELLI B 6	6,1	0,4	0,4	1,4	2,2
6	KRB 6	HOLMER TERRA DOS	5,5	0,3	0,1	1,0	1,4
7	KRB 6	IRS	5,2	0,9	0,2	1,5	2,6
8	KRB 6	ROPA R 26.50 K	6,3	0,2	0,3	0,6	1,1
9	KRB 6	TIM SR 2500	5,5	0,2	0,1	1,3	1,6
Average KRB 6			5,7	0,40	0,22	1,16	1,78
10	KRL 6	CLAAS/HOLMER Sys. XERION	5,8	0,6	0,3	2,2	3,1
11	KRL 6	KLEINE SF 10	5,6	0,2	0,2	1,1	1,5
Average KRL 6			5,7	0,40	0,25	1,65	2,3
12	KR+LB	GILLES SA KR LB	4,9 15,0	0,2	0,2	1,7	2,1
Total Average				0,41	0,19	1,34	1,94

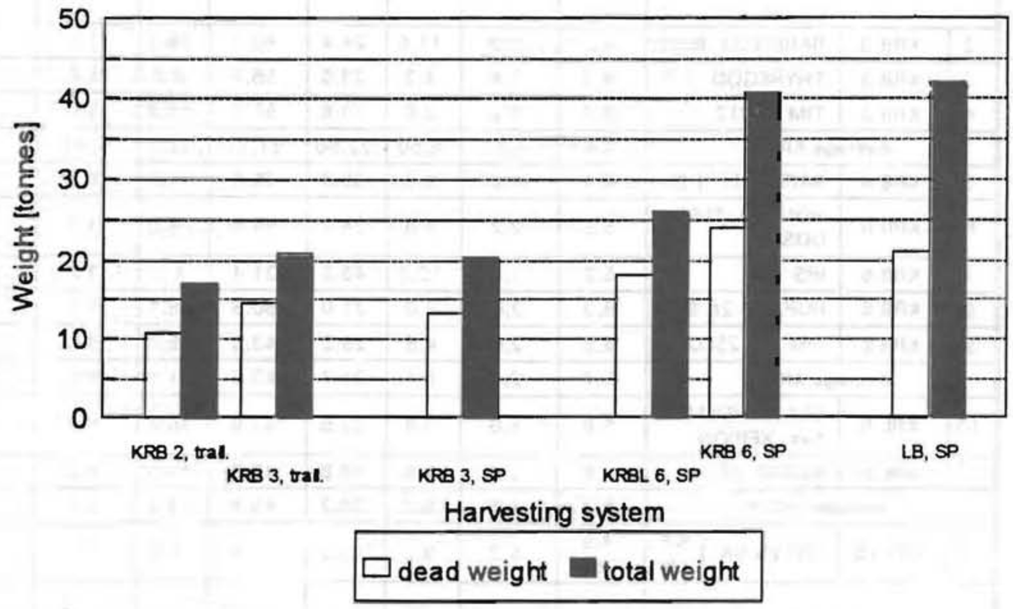

Figure 6: Harvester weight

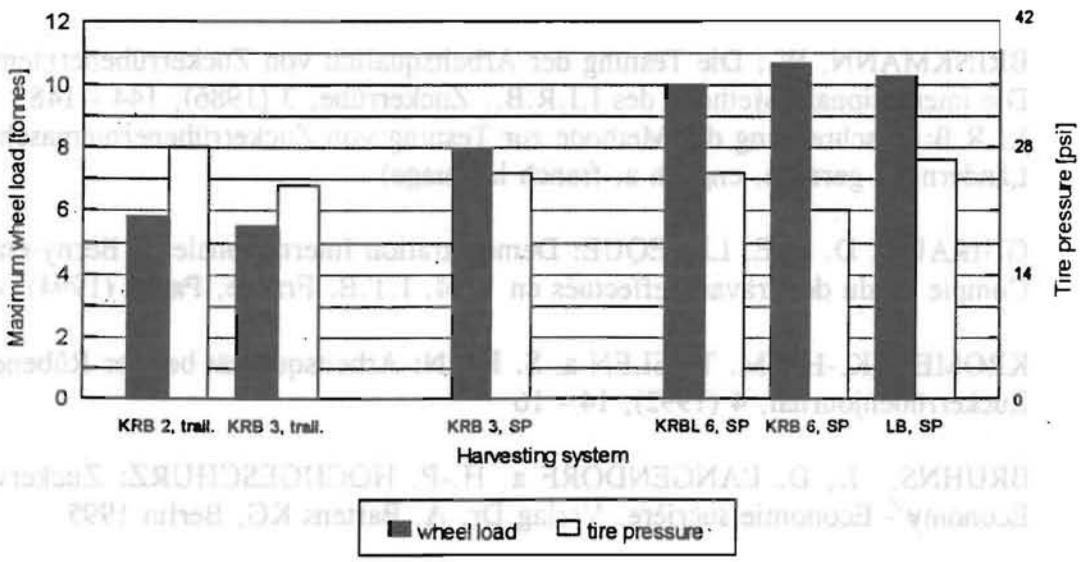

Figure 7: wheel load and required tire pressure

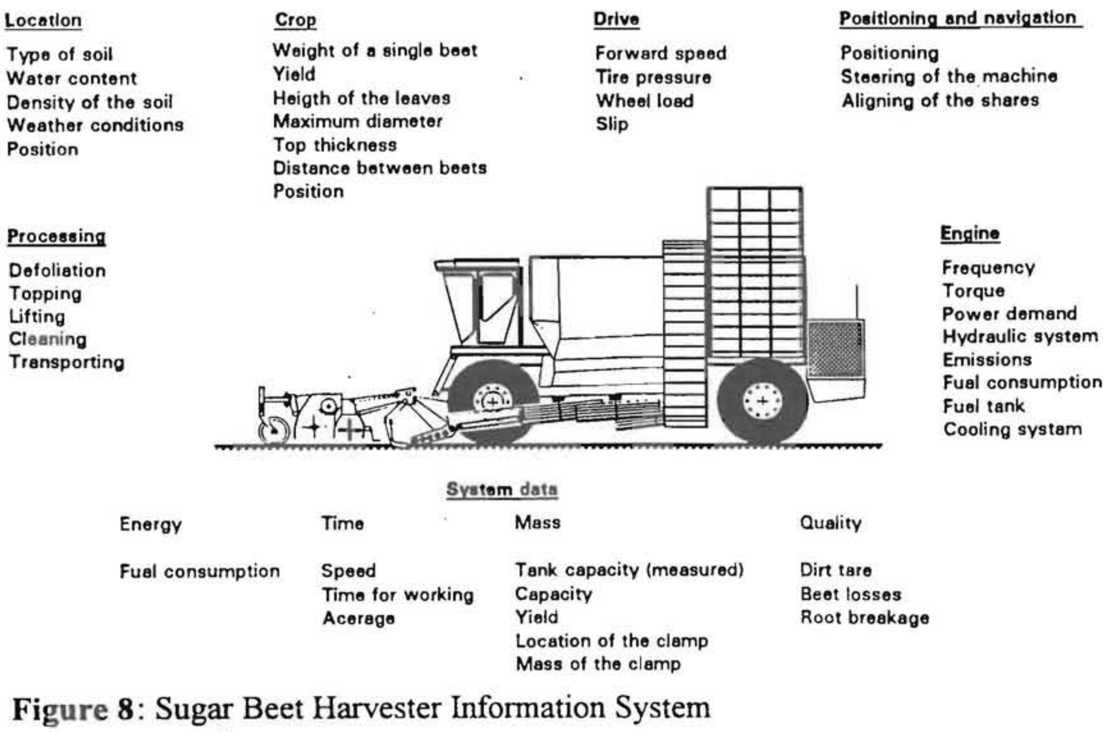

Figure 8: Sugar Beet Harvester Information System

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