

## Variability of thousand grain weights of seed batches of important arable and some horticultural crops

Variabilität der Tausendkorngewichte von Saatgutchargen wichtiger landwirtschaftlicher und gartenbaulicher Kulturen

### Abstract

The thousand grain weight (TGW) of seeds used for sowing varies because of natural mass variation within and between cultivars of a crop but also because of selection of sizes of seeds used for propagation by breeders and seed suppliers. The range of TGW data of 55 arable crops and 26 horticultural crops are presented as well as TGW data for 15 types of pelleted seeds of different crops. In addition to the mean and maximum and minimum values, different percentiles were calculated for most crops. This study presents TGW data of seed batches used for cultivar testing (most arable crops) as well as of seed lots used for seed coating with pesticides for the European market in the period of the harvesting years 2011–2018.

**Key words:** Thousand grain weight, mean, percentile, variability, seed treatment, pesticide regulation

### Zusammenfassung

Das Tausendkorngewicht (TKG) von Saatgut variiert natürlicherweise zwischen Sorten und Saatgutchargen aber auch durch Größensortierungen bei Züchtern und Saatguterzeugern. Die Spanne von TKG-Werten von 55 verschiedenen landwirtschaftlichen Kulturen, 26 Gemüsekulturen sowie von 15 Kulturen mit pilliertem Saatgut werden präsentiert. Neben Mittelwerten, Minimal- und Maximalwerten, wurden auch Perzentilwerte berechnet. Für die Zusammenstellung wurden die TKG Werte von Saatgutchargen landwirtschaftlicher Kulturen, die beim

Bundessortenamt zur Aussaat für die Sortenprüfung der Erntejahre 2011 bis 2018 kamen und von zumeist gartenbaulichen Kulturen genutzt, die in einer kommerziellen Saatgutbehandlungsanlage für den europäischen Markt behandelt wurden.

**Stichwörter:** Tausendkorngewicht, Mittelwert, Perzentile, Variabilität, Saatgutbehandlung, Pflanzenschutzgesetz

### Introduction

Seeds of many crops are treated with plant protection products (PPP) mainly to control fungal and insect pests. Dosing of PPP is expressed in amount of product either per number of seeds (e.g. per 1000 kernels or seed unit) or per mass of seeds (e.g. per kg or 100 kg). For a correct dosing during the treatment process the thousand grain weights (TGW) have to be taken into account in the case of dosing per unit. In the case of dosing per kg, the dose per seed can vary between seed lots of different TGW. Information on the TGW is not only required for correct dosing but also for assessing the risks of seed dressings for human health and the environment before the products are placed on the market. Exposure to toxicological relevant compounds in seed dressing products has to be estimated for operators handling the seed dressings and the treated seeds as well as for farmers sowing the treated seeds (EFSA, 2014). Treated seeds and contaminated dust are a source of exposure for bystanders, residents and the environment, which also has to be assessed to

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confirm a safe use of seed dressings. Treated seeds can also be consumed by birds and small mammals (e.g. EFSA, 2009). Therefore, it is important to have a realistic idea of the TGW values of different crops to assess exposure to humans and the environment. An analysis of the variability of TGW being used in the German market was carried out, which allows an improved assessment of potential risks of seed treatment products. There are TGW values recently published for different European countries (LUCCHESI et al., 2016), but the validity of the TGW data is not clear and the values seem to be assessed often only very roughly and some even may be wrong. Therefore, the validated data of mainly German seed lots may be useful also for other European countries and at least for those regions with comparable climatic and agricultural conditions.

### Material and methods

For most crops TGW data were used provided by the Federal Plant Variety Office in Germany, which is responsible for field evaluations for the official registration of cultivars. Breeders have to register new cultivars, which have to be tested over several years and at different locations. For the analysis all TGW data of seed lots sown by the Federal Plant Variety Office (data base 1, data input until 31<sup>st</sup> Dec 2017 into the internal web side) for the cultivar testings in the harvesting years 2011 to 2018 were used. Data of standard cultivars sown more than ones per year, were used only once for the analysis. TGW values were obtained by counting and balancing a minimum of 300 seeds (BSA data) or of 1000 seeds of each seed batch (SUET data).

A few specialized factories treat many other different types of seeds including the often small sized vegetable seeds with or without pelleting. Furthermore, seeds for the European market are often processed at these factories. Data of non-pelleted and pelleted seed batches of sugar beet and of several common horticultural crops were supplied by SUET Saat- und Erntetechnik GmbH (data base 2), a seed treatment company working for many breeders and for the international market and thus representing a wide variety of cultivars used in Europe and elsewhere.

Non-pelleted seeds of sugar beets may be of importance for risk evaluation during the seed treatment process only for operators exposed during the pesticide application, whereas the pelleted beet seeds are in addition relevant for the handling of treated seeds and exposure in the environment. TGW values of pelleted seeds as well as of non-pelleted seeds of sugar beets are less dependent on natural variation but more on variability during the industrial processing. TGW values of non-pelleted sugar and fodder beet seeds were taken from data of the Federal Plant Variety Office as well as of SUET.

Data of all years were pooled and mean, median, 95<sup>th</sup> and 90<sup>th</sup> as well as 5<sup>th</sup> and 10<sup>th</sup> percentiles were calculated using MS Excel. For crops for which less than 20 values were available, no percentiles were calculated. EPPO codes (<https://gd.eppo.int/>) for crops were used to ensure a definite identification of crops.

### Results and discussion

The results are presented in Tables 1 (non-pelleted seeds) and 2 (pelleted seeds) and common English crop names are given. In addition, scientific names as well as the hierarchical organized EPPO codes are shown to enable clear information on the crop. The complete Tables 1 and 2 containing German common names, median and minimum and maximum values are available as online supplement. The TGW data of winter and spring forms of cereals and of non-pelleted sugar and fodder beet are quite near to each other and are presented individually and in a pooled form. For most other crops it is not clear, whether they may be pooled or better kept separate. However, pooling data for e.g. all types of cabbage crops results in a wider range of TGW for different seed batches.

The TGW values presented represent a large variety of different cultivars over several years and are of higher validity than TGW data published by EPPO (LUCCHESI et al., 2016), which were handed to EPPO by country representatives and in some cases do not seem to be of high validity. The data seem not always to be of high validity, because even in adjacent countries TGW values were provided e.g. between 2 and 10 g for *Linum sativum* (LIUUT), 2 and 431 g for *Pisum sativum* (PIBSX) and 70 and 450 g for *Lupinus* spp. (LUPPS). However, differences in the TGW may also occur because of different use forms of a crop, e.g. LIUUT used for fibre or oil production or PIBSX used for fodder, for greening purpose or different vegetable uses. All data provided by the internationally active seed treatment company SUET may allow an easier use in the whole of Europe, because cultivars of different climatic zones are included. For data extrapolation between regions, more care has to be given to crops, such as maize with very different cultivars used in different climatic regions in Europe. Generally, the relevance of different TGW values for the risk assessment increases with the mass difference between 5<sup>th</sup> and 95<sup>th</sup> percentile values in relation to the mean weight. While for sugar beet and spring barley, both with many data points, this difference is less than 33% of the mean mass, the difference for other crops is more than 50%. Within crops with a sufficient high seed batch number (more than 200) the highest difference between 5<sup>th</sup> and 95<sup>th</sup> percentile in relation to the mean mass have seeds of carrots (DAUCS), Italian ryegrass (LOLMU), winter oilseed rape (BRSNW), radish (RAPSC) and winter rye (SECCW). The high seed mass variability for BRSNW and SECCW may be explained by the intensive breeding programs in this crop with hybrid and non-hybrid cultivars. Generally, for pelleted seeds the TGW variability is less compared to non-pelleted seeds. But it has to be taken into account that data of only one seed treatment company were available and that customers may demand different sized seed pills depending on the use type. However, regarding TGW values of pelleted sugar beet seeds other seed treatment facilities provided similar mean values as SUET.

**Table 1. Thousand grain weights (TGW) of seed batches of important arable crop cultivars used in Germany and of some horticultural crops used for seed treatment for the European market, 2011–2018 (data base 1: seed batches for cultivar testing of the Federal Plant Variety Office in Germany/data base 2: seed batches used for commercial seed treatment for the European market at SUET, Eschwege, Germany). German common names, median and minimum and maximum values are shown in the online available supplement.**

english common name	scientific name	EPO Code	data base	mean	std	no	95th percentile	90th percentile	5th percentile	10th percentile	
<b>arable crops</b>		3ARAC									
forage pea	<i>Pisum sativum subsp. arvense</i>	PIBSA	1	246.0	39.7	91	309.5	290.0	179.0	196.0	
vining peas	<i>Pisum sativum subsp. arvense</i>	PIBSA	1	172.9	25.3	45	212.2	203.6	136.2	154.0	
field bean	<i>Vicia faba subsp. minor</i>	VICFM	1	560.6	89.4	69	711.4	655.2	410.2	447.2	
common vetch	<i>Vicia sativa</i>	VICSA	1	52.4	8.7	8					
blue lupin	<i>Lupinus angustifolius</i>	LUPAN	1	146.7	23.2	45	186.2	179.1	116.4	119.4	
white lupin	<i>Lupinus albus</i>	LUPAL	1	347.0	91.9	2					
soybean	<i>Glycine max</i>	GLXMA	1	202.3	27.4	46	240.0	232.0	154.0	160.7	
lucerne	<i>Medicago sativa</i>	MEDSA	1	2.02	0.20	21	2.30	2.23	1.70	2.01	
red clover	<i>Trifolium pratense</i>	TRFPR	1	2.26	0.52	110	3.10	2.93	1.60	1.70	
white clover	<i>Trifolium repens</i>	TRFRE	1	0.69	0.07	25	0.83	0.79	0.60	0.60	
Egyptian clover	<i>Trifolium alexandrinum</i>	TRFAL	1	2.94	0.76	11					
crimson clover	<i>Trifolium incarnatum</i>	TRFIN	1	3.69	0.40	5					
birdsfoot trefoil	<i>Lotus corniculatus</i>	LOTCO	1	1.28	0.16	12					
winter barley	<i>Hordeum vulgare</i>	HORVW	1	55.5	6.8	1397	67.0	64.0	44.5	46.4	
spring barley	<i>Hordeum vulgare</i>	HORVS	1	56.4	5.4	538	65.0	63.0	47.0	49.0	
all barley	<i>Hordeum vulgare</i>	HORVX	1	55.7	6.5	1935	66.0	64.0	45.0	47.0	
winter wheat	<i>Triticum aestivum</i>	TRIAW	1	49.2	5.9	1700	58.8	56.4	38.8	41.2	
spring wheat	<i>Triticum aestivum</i>	TRIAS	1	47.0	4.9	305	55.0	53.0	38.0	41.0	
all wheat	<i>Triticum aestivum</i>	TRZAX	1	48.8	5.8	2005	58.0	56.0	38.7	41.0	
winter durum wheat	<i>Triticum durum</i>	TRZDW	1	48.7	5.2	46	57.6	56.5	41.6	42.4	
spring durum wheat	<i>Triticum durum</i>	TRZDS	1	53.7	7.4	77	66.1	63.0	43.2	44.6	
all durum wheat	<i>Triticum durum</i>	3DWHC	1	51.8	7.1	123	63.0	60.2	42.0	43.5	
spelt *	<i>Triticum spelta</i> *	TRZSP*	1	123.0	17.4	109	152.8	144.2	97.0	100.4	
winter rye	<i>Secale cereale</i>	SECCW	1	37.3	5.9	423	47.7	45.0	28.3	30.3	
spring rye	<i>Secale cereale</i>	SECCS	1	39.5	4.7	8					
all rye	<i>Secale cereale</i>	SECCE	1	37.3	45.0	431	47.6	45.0	28.3	30.3	
winter triticale	<i>x Triticosecale rimpaii</i>	TTLWI	1	52.6	6.9	396	64.0	61.8	40.2	43.3	
spring triticale	<i>x Triticosecale rimpaii</i>	TTLSO	1	48.2	6.4	12					
all triticale	<i>x Triticosecale rimpaii</i>	3TRIC	1	52.4	6.9	408	63.8	61.6	40.0	43.2	
spring oat	<i>Avena sativa</i>	AVESA	1	43.6	5.5	185	52.8	50.0	36.0	37.0	
maize	<i>Zea mays</i>	ZEAMX	1	289.8	39.1	1858	353.0	340.0	224.9	238.0	
sweet corn	<i>Zea mays subsp. saccharata</i>	ZEAMS	2	122.0	18.1	50	155.4	152.2	102.7	102.7	
sorghum	<i>Sorghum bicolor</i>	SORVU	1	31.6	4.1	73	38.0	37.0	25.0	27.0	
sunflower	<i>Helianthus annuus</i>	HELAN	2	60.3	15.6	111	80.8	78.3	32.5	40.2	
flax	<i>Linum usitatissimum</i>	LIUUT	1	6.82	0.92	34	8.50	7.94	5.56	5.73	
sugarbeet, non-pelleted	<i>Beta vulgaris subsp. vulgaris var. altissima</i>	BEAVA	1, 2	10.7	1.1	3164	12.5	12.1	9.0	9.4	
fodder beet, non-pelleted	<i>Beta vulgaris subsp. vulgaris var. crassa</i>	BEAVC	1, 2	11.6	2.8	191	16.7	16.1	8.1	8.6	
all beet, non-pelleted	<i>Beta vulgaris</i>	3BEEC	1, 2	10.7	1.3	3355	12.7	12.2	8.9	9.3	
winter rape	<i>Brassica napus</i>	BRSNW	1	5.58	1.14	1428	7.84	7.10	4.00	4.30	
radish	<i>Raphanus sativus subsp. oleiferus</i>	RAPSO	1	13.2	2.4	220	17.2	16.7	9.7	10.4	

Table 1. Continued

english common name	scientific name	EPPO Code	data base	mean	std	no	95th percentile	90th percentile	5th percentile	10th percentile
winter turnip rape	<i>Brassica rapa</i>	BRSSA	1	4.51	0.34	24	4.90	4.90	4.01	4.05
cow cabbage	<i>Brassica oleracea</i> var. <i>medullosa</i>	BR SOM	1	4.03	0.70	11				
brown mustard	<i>Brassica juncea</i>	BRSJU	1	2.57	0.85	8				
white mustard	<i>Sinapis alba</i>	SINAL	1	6.92	0.99	193	8.30	8.10	5.40	5.80
bristle oat	<i>Avena strigosa</i>	AVESG	1	20.0	3.6	46	23.8	23.1	11.1	14.2
westerwolds rye-grass	<i>Lolium multiflorum</i> subsp. <i>gaudini</i>	LOLMG	1	3.84	0.98	77	5.35	5.23	2.60	2.70
perennial ryegrass	<i>Lolium perenne</i>	LOLPE	1	2.68	0.75	187	3.86	3.63	1.65	1.76
Italian ryegrass	<i>Lolium multiflorum</i>	LOLMU	1	3.66	1.00	265	5.06	4.90	2.30	2.40
hybrid ryegrass	<i>Lolium</i> × <i>hybridum</i>	LOLBO	1	3.76	0.66	21	4.42	4.42	2.20	3.14
meadow fescue	<i>Schedonorus pratensis</i>	FESPR	1	2.29	0.51	28	3.46	3.05	1.84	1.90
tall fescue	<i>Schedonorus arundinaceus</i>	FESAR	1	2.64	0.24	16				
timothy	<i>Phleum pratense</i>	PHLPR	1	0.48	0.10	22	0.64	0.60	0.35	0.38
smooth-stalked meadowgrass	<i>Poa pratensis</i>	POAPR	1	0.32	0.10	15				
cocksfoot	<i>Dactylis glomerata</i>	DACGL	1	1.12	0.14	22	1.41	1.30	0.95	0.98
festulolium	<i>Festulolium</i> sp.	FETSS	1	3.83	0.60	9				
phacelia	<i>Phacelia tanacetifolia</i>	PHCTA	1	1.96	0.31	21	2.40	2.40	1.65	1.74
<b>vegetables</b>		<b>3VEGC</b>								
onion	<i>Allium cepa</i>	ALLCE	2	3.94	0.44	1736	4.70	4.51	3.26	3.41
leek	<i>Allium porrum</i>	ALLPO	2	3.13	0.50	123	4.03	3.91	2.36	2.45
salad onion	<i>Allium fistulosum</i>	ALLFI	2	2.60	0.83	162	4.41	4.01	1.90	1.93
chives	<i>Allium schoenoprasum</i>	ALLSC	2	1.41	0.12	50	1.63	1.52	1.16	1.22
carrot	<i>Daucus carota</i> subsp. <i>sativus</i>	DAUCS	2	1.73	0.45	453	2.60	2.34	1.14	1.22
asparagus	<i>Asparagus officinalis</i>	ASPOF	2	10.8	2.4	44	15.4	14.8	7.8	8.2
radish	<i>Raphanus sativus</i> var. <i>niger</i>	RAPSN	2	12.3	2.3	36	14.9	14.5	7.1	9.6
small radish	<i>Raphanus sativus</i>	RAPSR	2	9.73	1.50	12				
Cucurbita hybrids	<i>Cucurbita</i> hybrids	CUUHY	2	163.1	57.0	172	268.5	252.1	81.9	95.0
chicory	<i>Cichorium intybus</i>	CICIN	2	1.65	0.12	46	1.89	1.80	1.47	1.49
lettuce	<i>Lactuca sativa</i>	LACSA	2	0.99	0.18	48	1.28	1.24	0.68	0.75
white rocket	<i>Diplotaxis erucoides</i>	DIPER	2	0.28	0.02	340	0.32	0.31	0.24	0.25
spinach	<i>Spinacia oleracea</i>	SPQOL	2	10.8	2.4	44	15.4	14.8	7.8	8.2
beet root	<i>Beta vulgaris</i> subsp. <i>vulgaris</i> var. <i>conditiva</i>	BEAVD	2	10.5	2.9	39	16.2	13.7	7.0	7.6
swiss chard	<i>Beta vulgaris</i> subsp. <i>vulgaris</i> var. <i>cicla</i>	BEAVV	2	11.8	2.7	31	15.7	15.1	7.6	9.0
dill	<i>Anethum graveolens</i>	AFEGR	2	1.42	0.25	46	1.88	1.85	1.09	1.15
parsley	<i>Petroselinum crispum</i>	PARCR	2	1.87	0.38	153	2.54	2.40	1.34	1.43
basil	<i>Ocimum basilicum</i>	OCIBA	2	1.59	0.26	140	2.01	1.95	1.16	1.25
cauliflower	<i>Brassica oleracea</i> var. <i>botrytis</i>	BR SOB	2	4.44	1.05	36	5.92	5.57	2.56	3.39
broccoli	<i>Brassica oleracea</i> var. <i>italica</i>	BR SOK	2	5.36	0.77	19				
kohlrabi	<i>Brassica oleracea</i> var. <i>gongylodes</i>	BR SOG	2	3.98	0.79	20	5.27	5.09	2.77	3.18
brussels sprouts	<i>Brassica oleracea</i> var. <i>gemmifera</i>	BR SOF	2	4.95	0.91	35	6.17	5.88	3.42	3.81

Table 1. Continued

english common name	scientific name	EPPO Code	data base	mean	std	no	95th percentile	90th percentile	5th percentile	10th percentile
white cabbage	<i>Brassica oleracea</i> var. <i>capitata</i>	BR SOL	2	4.74	1.17	19				
Chinese cabbage	<i>Brassica rapa</i> subsp. <i>pekinensis</i>	BR SPK	2	3.39	0.74	53	4.51	4.41	2.39	2.46
turnip	<i>Brassica rapa</i>	BR SSP	2	2.29	0.40	43	2.72	2.59	1.51	1.64
swede	<i>Brassica napus</i> subsp. <i>rapifera</i>	BR SNA	2	2.86	0.49	21	3.38	3.37	2.08	2.20
all vegetable Brassicas	<i>Brassica</i> spp.	BR SOX	2	3.74	1.24	288	5.73	5.44	2.05	2.31

\* TGW of spikeletes with 2–3 seeds including 20–30% glum

**Table 2. Thousand grain weights (TGW) of pelleted seed batches used for commercial seed treatments for the European market by SUET, Eschwege, Germany (data base 2). German common names, median and minimum and maximum values are shown in the online available supplement.**

type of pill	english common name	scientific name	EPPO Code	mean	std	no	95th percentile	90th percentile	5th percentile	10th percentile
field pill	sugarbeet	<i>Beta vulgaris</i> subsp. <i>vulgaris</i> var. <i>altissima</i>	BEAVA	30.2	2.8	3629	33.8	33.3	24.7	26.2
field pill	fodder beet	<i>Beta vulgaris</i> subsp. <i>vulgaris</i> var. <i>crassa</i>	BEAVC	28.1	1.7	113	31.0	29.4	25.8	26.4
field pill	onion	<i>Allium cepa</i>	ALLCE	13.3	1.1	8				
field pill	leek	<i>Allium porrum</i>	ALLPO	23.9	6.8	19				
mini pill	carrot	<i>Daucus carota</i> subsp. <i>sativus</i>	DAUCS	5.58	0.42	17				
field pill	carrot	<i>Daucus carota</i> subsp. <i>sativus</i>	DAUCS	10.8	2.4	44	15.4	14.8	7.8	8.2
field pill	small radish	<i>Raphanus sativus</i>	RAPSR	20.9	1.3	10				
pot pill	types of vegetable Brassicas	<i>Brassica</i> spp.	BR SOX	25.6	1.8	40	28.0	27.4	22.9	23.3
field pill	types of vegetable Brassicas	<i>Brassica</i> spp.	BR SOX	10.1	3.5	13				
field pill	chicory	<i>Cichorium intybus</i>	CICIN	9.46	0.41	43	10.12	10.02	8.87	8.98
field pill	lettuce	<i>Lactuca sativa</i>	LACSA	12.5	1.7	13				
pot pill	lettuce	<i>Lactuca sativa</i>	LACSA	42.0	1.8	3				
field pill	white rocket	<i>Diplotaxis eruroides</i>	DIPER	38.1	1.7	39	40.9	40.0	35.5	36.0
field pill	spinach	<i>Spinacia oleracea</i>	SPQOL	25.0	2.6	41	29.0	28.5	21.1	21.5
field pill	parsley	<i>Petroselinum crispum</i>	PARCR	10.3	1.1	19				

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