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 seed. 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
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 (Lucchiesi 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 31st 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-pelletted and pelletted 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-pelletted 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 pelletted beet seeds are in addition relevant for the handling of treated seeds and exposure in the environment. TGW values of pelletted seeds as well as of non-pelletted seeds of sugar beets are less dependent on natural variation but more on variability during the industrial processing. TGW values of non-pelletted 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, 95th and 90th as well as 5th and 10th 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-pelletted seeds) and 2 (pelletted 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-pelletted 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 (Lucchiesi 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 5th and 95th 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 5th and 95th percentile in relation to the mean mass have seeds of carrots (DAUCS), Italian ryegrass (LOLMU), winter oilseed rape (BRNSW), radish (RAPSC) and winter rye (SECCW). The high seed mass variability for BRNSW and SECCW may be explained by the intensive breeding programs in this crop with hybrid and non-hybrid cultivars. Generally, for pelletted seeds the TGW variability is less compared to non-pelletted 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 pelletted 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 | EPPO code | Data base | Mean | Std | No | 95th percentile | 90th percentile | 5th percentile | 10th percentile |
|---------------------|----------------|-----------|-----------|------|-----|----|----------------|----------------|---------------|----------------|
| **Arable crops**    |                |           |           |      |     |    |                |                 |               |                |
| Forage pea          | Pisum sativum subsp. arvense | 3ARAC | PIBSA 1 | 246.0 | 39.7 | 91 | 309.5          | 290.0           | 179.0         | 196.0          |
| Vining peas         | Pisum sativum subsp. arvense |         | PIBSA 1 | 172.9 | 25.3 | 45 | 212.2          | 203.6           | 136.2         | 154.0          |
| Field bean          | Vicia faba subsp. minor | VIFCM    | VICSA 1 | 560.6 | 89.4 | 69 | 711.4          | 655.2           | 410.2         | 447.2          |
| Common vetch        | Vicia sativa | VICSA 1 | 52.4 | 8.7  | 8   | 8.7           | 8               | 8             | 8              |
| Blue lupin          | Lupinus angustifolius | LUPAN 1 | 146.7 | 23.2 | 45  | 186.2         | 179.1           | 116.4         | 119.4          |
| White lupin         | Lupinus albus | LUPAL 1 | 347.0 | 91.9 | 2   | 347.0         | 91.9            | 2             | 2              |
| Soybean             | Glycine max | GLXMA 1 | 202.3 | 27.4 | 46  | 240.0         | 232.0           | 154.0         | 160.7          |
| Lucerne             | Medicago sativa | MEDSA 1 | 2.02 | 0.20 | 21  | 2.02          | 2.02            | 1.70          | 2.01           |
| Red clover          | Trifolium pratense | TRFR 1 | 2.26 | 0.52 | 110 | 3.10          | 2.93            | 1.60          | 1.70           |
| White clover        | Trifolium repens | TRFR 1 | 0.69  | 0.07 | 25  | 0.83          | 0.79            | 0.60          | 0.60           |
| Egyptian clover     | Trifolium alexandrinum | TRFA 1 | 2.94 | 0.40 | 11  | 2.94          | 0.40            | 1.10          | 0.60           |
| Crimson clover      | Trifolium incarnatum | TRFIN 1 | 3.69 | 0.40 | 5   | 3.69          | 0.40            | 1.50          | 1.50           |
| **Birdsfoot trefoil** | Lotus corniculatus | LOTCO 1 | 1.28 | 0.16 | 12  | 1.28          | 0.16            | 0.60          | 0.60           |
| Winter barley       | Hordeum vulgare | HORVV 1 | 55.5 | 6.8  | 1397 | 67.0         | 64.0            | 44.5          | 46.4           |
| Spring barley       | Hordeum vulgare | HORVS 1 | 56.4 | 5.4  | 538  | 65.0         | 63.0            | 47.0          | 49.0           |
| All barley          | Hordeum vulgare | HORVX 1 | 55.7 | 6.5  | 1935 | 66.0         | 64.0            | 45.0          | 47.0           |
| Winter wheat        | Triticum aestivum | TRIAW 1 | 49.2 | 5.9  | 1700 | 58.8         | 56.4            | 38.8          | 41.2           |
| Spring wheat        | Triticum aestivum | TRIAS 1 | 47.0 | 4.9  | 305  | 55.0         | 53.0            | 38.0          | 41.0           |
| All wheat           | Triticum aestivum | TRZAX 1 | 48.8 | 5.8  | 2005 | 58.0         | 56.0            | 38.7          | 41.0           |
| Winter durum wheat  | Triticum durum | TRZDW 1 | 48.7 | 5.2  | 46   | 57.6         | 56.5            | 41.6          | 42.4           |
| Spring durum wheat  | Triticum durum | TRZDS 1 | 53.7 | 7.4  | 77   | 66.1         | 63.0            | 43.2          | 44.6           |
| All durum wheat     | Triticum durum | 3DWHC 1 | 51.8 | 7.1  | 123  | 63.0         | 60.2            | 42.0          | 43.5           |
| Spelt *             | Triticum spelta | TRZSP* 1 | 123.0 | 17.4 | 109  | 152.8        | 144.3           | 97.0          | 100.4          |
| Winter rye          | Secale cereale | SECCW 1 | 37.3 | 5.9  | 423  | 47.7         | 45.0            | 28.3          | 30.3           |
| Spring rye          | Secale cereale | SECCS 1 | 37.3 | 4.7  | 8    | 37.3         | 4.7             | 8             | 12             |
| All rye             | Secale cereale | SECC 1, 2 | 37.3 | 45.0 | 431  | 47.6         | 45.0            | 28.3          | 30.3           |
| Winter triticale    | x Triticosecale rimpai | TLWLI 1 | 52.6 | 6.9  | 396  | 64.0         | 61.8            | 40.2          | 43.3           |
| Spring triticale    | x Triticosecale rimpai | TLISO 1 | 48.2 | 6.4  | 12   | 48.2         | 6.4             | 12            | 12             |
| All triticale       | x Triticosecale rimpai | 3TRIC 1 | 52.4 | 6.9  | 408  | 63.8         | 61.6            | 40.0          | 43.2           |
| Spring oat          | Avena sativa | AVESA 1 | 43.6 | 5.5  | 185  | 52.8         | 50.0            | 36.0          | 37.0           |
| Maize               | Zea mays | ZEAMX 1 | 289.8 | 39.1 | 1858 | 353.0        | 340.0           | 224.9         | 238.0          |
| Sweet corn          | Zea mays subsp. saccharata | ZEAMS 2 | 122.0 | 18.1 | 50   | 155.4        | 152.2           | 102.7         | 102.7          |
| Sorghum             | Sorghum bicolor | SORVU 1 | 31.6 | 4.1  | 73   | 38.0         | 37.0            | 25.0          | 27.0           |
| Sunflower           | Helianthus annuus | HELAN 2 | 60.3 | 15.6 | 111  | 80.8         | 78.3            | 32.5          | 40.2           |
| Flax                | Linum usitatissimum | LIUUT 1 | 6.82 | 0.92 | 34   | 8.50         | 7.94            | 5.56          | 5.73           |
| Sugarbeet, non-pelleted | Beta vulgaris subsp. vulgaris var. altissima | BEAVA 1, 2 | 10.7 | 1.1  | 3164 | 12.5         | 12.1            | 9.0           | 9.4            |
| Fodder beet, non-pelleted | Beta vulgaris subsp. vulgaris var. crassa | BEAVC 1, 2 | 11.6 | 2.8  | 191  | 16.7         | 16.1            | 8.1           | 8.6            |
| All beet, non-pelleted | Beta vulgaris | 3BEEC 1, 2 | 10.7 | 1.3  | 3355 | 12.7         | 12.2            | 8.9           | 9.3            |
| Winter rape         | Brassica napus | BRSNW 1 | 5.58 | 1.14 | 1428 | 7.84         | 7.10            | 4.00          | 4.30           |
| Radish              | Raphanus sativus subsp. oleiferus | 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 | database | mean   | std    | no | 95th percentile | 90th percentile | 5th percentile | 10th percentile |
|---------------------|-----------------|-----------|----------|--------|--------|----|----------------|----------------|---------------|----------------|
| winter turnip rape  | Brassica rapa   | BRSSA 1   | 4.51     | 0.34   | 24     | 4.90| 4.90           | 4.01           |               | 4.05           |
| cow cabbage         | Brassica oleracea var. medullosa | BRSOM 1 | 4.03     | 0.70   | 11     | 4.08| 4.02           | 4.00           |               | 4.01           |
| brown mustard       | Brassica juncea | BRSJU 1   | 2.57     | 0.85   | 8      | 2.80| 2.75           | 2.00           |               | 2.15           |
| white mustard       | Sinapis alba    | SINAL 1   | 6.92     | 0.99   | 193    | 8.30| 8.10           | 5.40           | 5.80          |                |
| bristle oat         | Avena strigosa  | AVESG 1   | 20.0     | 3.6    | 46     | 23.8| 23.1           | 11.1           | 14.2          |                |
| westerwolds ryegrass| Lactum multiflorum subsp. gaudini | LOLMG 1 | 3.84     | 0.98   | 77     | 5.35| 5.23           | 2.60           | 2.70          |                |
| perennial ryegrass  | Lactum perenne  | LOLPE 1   | 2.68     | 0.75   | 187    | 3.86| 3.63           | 1.65           | 1.76          |                |
| Italian ryegrass    | Lactum multiflorum | LOLMU 1 | 3.66     | 1.00   | 265    | 5.06| 4.90           | 2.30           | 2.40          |                |
| hybrid ryegrass     | Lactum × hybridum | LOLBO 1 | 3.76     | 0.66   | 21     | 4.42| 4.42           | 2.20           | 3.14          |                |
| meadow fescue       | Schedonorus pratensis | FESPR 1 | 2.29     | 0.51   | 28     | 3.46| 3.05           | 1.84           | 1.90          |                |
| tall fescue         | Schedonorus arundinaceus | FESAR 1 | 2.64     | 0.24   | 16     | 2.40| 2.40           | 1.65           | 1.74          |                |
| vegetables          |                |           |          |        |        |     |                |                |               |                |
| onion               | Allium cepa     | ALLCE 2   | 3.94     | 0.44   | 1736   | 4.70| 4.51           | 3.26           | 3.41          |                |
| leek                | Allium porrum   | ALLPO 2   | 3.13     | 0.50   | 123    | 4.03| 3.91           | 2.36           | 2.45          |                |
| salad onion         | Allium fistulosum | ALLFI 2 | 2.60     | 0.83   | 162    | 4.41| 4.01           | 1.90           | 1.93          |                |
| chives              | Allium schoenoprasum | ALLSC 2 | 1.41     | 0.12   | 50     | 1.63| 1.52           | 1.16           | 1.22          |                |
| carrot              | Daucus carota subsp. sativus | DAUCS 2 | 1.73     | 0.45   | 453    | 2.60| 2.34           | 1.14           | 1.22          |                |
| asparagus           | Asparagus officinalis | ASPOF 2 | 10.8     | 2.4    | 44     | 15.4| 14.8           | 7.8            | 8.2           |                |
| radish              | Raphanus sativus var. niger | RAPSN 2 | 12.3     | 2.3    | 36     | 14.9| 14.5           | 7.1            | 9.6           |                |
| small radish        | Raphanus sativus | RAPSR 2 | 9.73     | 1.50   | 12     | 16.2| 13.7           | 7.0            | 7.6           |                |
| Cucurbita hybrids   | Cucurbita hybrids | CUUHY 2 | 163.1    | 57.0   | 172    | 268.5| 252.1          | 81.9           | 95.0          |                |
| chicory             | Cichorium intybus | CICIN 2 | 1.65     | 0.12   | 46     | 1.89| 1.80           | 1.47           | 1.49          |                |
| lettuce             | Lactuca sativa  | LACSA 2   | 0.99     | 0.18   | 48     | 1.28| 1.24           | 0.68           | 0.75          |                |
| white rocket        | Diplotaxis erucoides | DIPER 2 | 0.28     | 0.02   | 340    | 0.32| 0.31           | 0.24           | 0.25          |                |
| spinach             | Spinacia oleracea | SPQOL 2 | 10.8     | 2.4    | 44     | 15.4| 14.8           | 7.8            | 8.2           |                |
| beet root           | Beta vulgaris subsp. vulgaris var. conditiva | BEAVD 2 | 10.5     | 2.9    | 39     | 16.2| 13.7           | 7.0            | 7.6           |                |
| swiss chard         | Beta vulgaris subsp. vulgaris var. cicla | BEAVV 2 | 11.8     | 2.7    | 31     | 15.7| 15.1           | 7.6            | 9.0           |                |
| dill                | Anethum graveolens | AFEGR 2 | 1.42     | 0.25   | 46     | 1.88| 1.85           | 1.09           | 1.15          |                |
| parsley             | Petroselinum crispum | PARCR 2 | 1.87     | 0.38   | 153    | 2.54| 2.40           | 1.34           | 1.43          |                |
| basil               | Ocimum basilicum | OCIBA 2 | 1.59     | 0.26   | 140    | 2.01| 1.95           | 1.16           | 1.25          |                |
| cauliflower         | Brassica oleracea var. botrytis | BRSOB 2 | 4.44     | 1.05   | 36     | 5.92| 5.57           | 2.56           | 3.39          |                |
| broccoli            | Brassica oleracea var. italica | BRSOK 2 | 5.36     | 0.77   | 19     | 5.67| 5.57           | 2.56           | 3.39          |                |
| kohlrabi            | Brassica oleracea var. gongylodes | BRSOG 2 | 3.98     | 0.79   | 20     | 5.27| 5.09           | 2.77           | 3.18          |                |
| brussels sprouts    | Brassica oleracea var. gemmifera | BRSOF 2 | 4.95     | 0.91   | 35     | 6.17| 5.88           | 3.42           | 3.81          |                |
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References

EFSA (European Food Safety Authority): Guidance on the assessment of exposure of operators, workers, residents and bystanders in risk assessment for plant protection products. EFSA Journal 2014; 12(10):3874, 55pp. https://www.efsa.europa.eu/de/efsajournal/pub/3874.

EFSA (European Food Safety Authority): Guidance of EFSA. Risk Assessment for Birds and Mammals. EFSA Journal 2009; 7(12):1438, 139 pp. https://www.efsa.europa.eu/de/efsajournal/pub/1438.

Lucchesi, V., V. Zlot, U. Heimbach; 2016: Results of the EPPO Survey on dose expression for seed treatment and authorized dose for plant protection products in general. EPPO Bulletin 46, 618-624.