

Protein Quality of Different Wheat Species

Khoa Dang Tran^{1,2}, **Petr Konvalina**¹, **Ivana Capouchova**³, **Dagmar Janovska**⁴, **Magdalena Lacko-Bartosova**⁵, **Marek Kopecky**¹, and **Phuong Xuan Thi Tran**²

¹ Faculty of Agriculture, The University of South Bohemia in Ceske Budejovice, Studentska 1668, 37005 Ceske Budejovice, Czech Republic; trandangkhoa@hueuni.edu.vn, konvalina@zf.jcu.cz, mkopecky@zf.jcu.cz,

² Faculty of Agronomy, University of Agriculture and Forestry, Hue University 102 Phung Hung street, Hue City, Vietnam. ; tranthixuanphuong@hueuni.edu.vn

³ Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences, Kamycka 129 165 00 Praha 6 Suchdol, capouchova@af.czu.cz, zrckova@af.czu.cz.

⁴ Crop Research Institute, Drnovska 507/73, 16106 Praha Ruzyně, janovska@vurv.vz

⁵ Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra, Tr A. Hlinku 2, 94976 Nitra, Slovakia, magdalena.lacko-bartosova@uniag.sk.

List of Supplementary Tables

Table S1: List of all 26 wheat varieties used in this study and their abbreviations.

Table S2: Thousand grain weight and grain yield of wheat varieties.

Table S3: Means \pm standard error (SE) and ANOVA *F*-value (*p*-value) for the effects of harvest year, location, and wheat species on protein content, gluten content, gluten index (GI), sedimentation index (SDS test), and Zeleny test (ZT).

Table S4: Quality characteristics of varieties of different wheat species.

Table S5: Analysis of variance for protein fractions under three locations, four years, and different varieties.

Table S6: Contents of gluten, albumins + globulins, gliadins, glutenins, and insoluble remainder of different wheat species.

Table S7: Contents of gluten, albumins + globulins, gliadins, glutenins, and insoluble remainder of different wheat cultivars.

Table S8: Gluten development time at the C1 in Mixolab.

Table S9: Flour quality parameters of wheat varieties at C2, C3, C4, and C5 stage.

Table S1.

| Abbr. | Name of variety | Identifier ¹ | Origin ² | Botanical Variety |
|---|---------------------------------|-------------------------|---------------------|---------------------------------|
| Einkorn (<i>Triticum monococcum</i> L.) | | | | |
| J1 | no. 38 | 01C0204038 | GEO | <i>hohensteinii</i> Flaskb. |
| J2 | no. 44 | 01C0204044 | ALB | <i>vulgare</i> Koern. |
| J4 | no. 8910 | 01C0204542 | DNK | <i>macedonicum</i> Papag. |
| J6 | Schwedisches Einkorn | 01C0204053 | SWE | <i>vulgare</i> Koern. |
| Emmer (<i>Triticum diccocus</i> (Schrank) Schuebl) | | | | |
| D11 | Weisser Sommer | 01C0203993 | DEU | <i>diccocus</i> |
| D12 | May-Emmer | 01C0203990 | CHE | <i>diccocus</i> |
| D13 | from Brno | 01C0204022 | CZE | <i>rufum</i> Schuebl. |
| D14 | from Dagestan | 01C0204016 | RUS | <i>serbicum</i> A. Schulz |
| D17 | from Palestine | 01C0201261 | ISR | <i>serbicum</i> A. Schulz |
| D18 | from Taposzele | 01C0201280 | - | <i>semicanum</i> Koern. |
| D19 | Tabor | 01C0204318 | - | <i>rufum</i> Schuebl. |
| RU | Rudico | 01C0200948 | CZE | <i>rufum</i> Schuebl. |
| Spelt (<i>Triticum spelta</i> L.) | | | | |
| SP1 | Ruzyne | 01C0201257 | CZE | <i>arduini</i> (Mazz.) Koern. |
| SP2 | Tabor 22 | 01C0204322 | - | <i>duhamelianum</i> Koern. |
| SP4 | Tabor 23 | 01C0204323 | - | <i>duhamelianum</i> Koern. |
| SP6 | VIR St. Petersburg | 01C0204865 | CZE | <i>album</i> (Alef.) Koern. |
| SP7 | Spalda bila jarni | 01C0200982 | CZE | <i>album</i> (Alef.) Koern. |
| SP8 | Kew | 01C0200984 | - | <i>caeruleum</i> (Alef.) Koern. |
| SP9 | no. 8930 | 01C0204506 | - | <i>album</i> (Alef.) Koern. |
| Aestivum (<i>Triticum aestivum</i> L.) – landraces forms | | | | |
| PP6 | Postoloprtska presivka 6 | 01C0200044 | CZE | <i>lutescens</i> (Alef.) Mansf. |
| RCCP | Rosamova ceska cervena presivka | 01C0200051 | CZE | <i>milturum</i> (Alef.) Mansf. |
| CP | Cervena perla | 01C0100124 | CZE | <i>milturum</i> (Alef.) Mansf. |
| KP | Kasticka presivka 203 | 01C0200031 | CZE | <i>milturum</i> (Alef.) Mansf. |
| Control (<i>Triticum aestivum</i> L.) – modern varieties | | | | |
| SWK | SW Kadrij | 01C0104877 | SWE | <i>lutescens</i> (Alef.) Mansf. |
| VK | Vanek | 01C0204800 | DE | <i>lutescens</i> (Alef.) Mansf. |
| JR | Jara | 01C0200100 | CZE | <i>lutescens</i> (Alef.) Mansf. |

¹GRIN (<https://grinczech.vurv.cz/gringlobal/search.aspx>); ²Abbreviations of countries comply with ISO 3166-1 α-3.

Table S2.

| Species | Variety | TGW(g) | GYLD (t ha ⁻¹) |
|--------------------------|---------|-----------------|----------------------------|
| Einkorn | J1 | 26.41 ± 0.18 g | 2.57 ± 0.18 dg |
| | J2 | 25.92 ± 0.20 g | 2.54 ± 0.19 dg |
| | J4 | 24.87 ± 0.48 g | 2.64 ± 0.23 dg |
| | J6 | 25.67 ± 0.27 g | 2.59 ± 0.17 dg |
| Emmer | D11 | 32.53 ± 0.37 df | 2.83 ± 0.24 cg |
| | D12 | 32.56 ± 0.28 df | 2.83 ± 0.18 cg |
| | D13 | 32.81 ± 0.32 cf | 2.98 ± 0.17 cg |
| | D14 | 33.41 ± 0.29 ce | 2.91 ± 0.15 cg |
| | D17 | 31.25 ± 0.31 f | 2.29 ± 0.14 fg |
| | D18 | 31.92 ± 0.27 ef | 2.14 ± 0.19 g |
| | D19 | 33.34 ± 0.37 ce | 2.88 ± 0.17 cg |
| | RU | 34.68 ± 0.29 c | 3.24 ± 0.25 be |
| | SP1 | 38.86 ± 0.46 b | 3.07 ± 0.15 cf |
| Spelt | SP2 | 40.44 ± 0.57 ab | 3.57 ± 0.24 ac |
| | SP4 | 41.05 ± 0.45 a | 3.58 ± 0.19 ac |
| | SP6 | 40.96 ± 0.41 a | 3.22 ± 0.17 be |
| | SP7 | 39.71 ± 0.41 ab | 2.76 ± 0.15 cg |
| | SP8 | 40.38 ± 0.50 ab | 3.54 ± 0.14 ac |
| | SP9 | 41.03 ± 0.63 a | 3.34 ± 0.20 bd |
| | PP6 | 34.03 ± 0.39 cd | 2.39 ± 0.16 eg |
| Bread wheat landraces | RCCP | 33.32 ± 0.48 ce | 2.48 ± 0.15 eg |
| | CP | 34.68 ± 0.40 ce | 2.44 ± 0.18 eg |
| | KP | 33.25 ± 0.55 cf | 2.60 ± 0.16 dg |
| Control - Bread wheat | SWK | 40.87 ± 0.16 ab | 4.28 ± 0.21 a |
| | VK | 40.19 ± 0.15 ab | 4.07 ± 0.19 ab |
| | JR | 38.90 ± 0.35 b | 3.08 ± 0.23 cf |

Mean values ± S.D. associated with different lowercase letters are significantly different within each column at p-value < 0.05 .

Table S3.

| | Protein (%) | Gluten (%) | GI | SDS test ml | ZT ml |
|---------------------|----------------|-----------------|----------------|----------------|----------------|
| Harvest year | | | | | |
| 2012 | 15.27 ± 0.24 b | 36.38 ± 0.73 b | 24.78 ± 1.62 c | 39.68 ± 1.44 d | 29.68 ± 0.48 b |
| 2013 | 16.18 ± 0.21 a | 42.47 ± 0.68 a | 33.89 ± 1.47 a | 52.88 ± 1.58 a | 30.75 ± 0.56 a |
| 2014 | 13.96 ± 0.23 c | 34.39 ± 0.69 c | 29.16 ± 1.51 b | 48.16 ± 1.38 b | 26.27 ± 0.54 d |
| 2015 | 15.18 ± 0.14 b | 37.06 ± 0.52 b | 29.66 ± 1.52 b | 41.35 ± 0.93 c | 28.46 ± 0.47c |
| Location | | | | | |
| CRIP | 13.49 ± 0.22 c | 31.08 ± 0.51 c | 29.46 ± 1.32 | 42.89 ± 1.23 b | 25.77 ± 0.43 b |
| CULS | 16.57 ± 0.13 a | 42.67 ± 0.58 a | 29.95 ± 1.39 | 49.48 ± 1.21 a | 28.65 ± 0.57 a |
| USB | 15.47 ± 0.13 b | 38.85 ± 0.43 b | 28.55 ± 1.31 | 44.16 ± 1.24 b | 26.16 ± 0.42b |
| Species | | | | | |
| control | 12.76 ± 0.32 b | 30.87 ± 1.12 d | 68.78 ± 2.19 a | 65.28 ± 1.68 a | 42.39 ± 1.02 a |
| aestivum | 13.15 ± 0.21 b | 33.07 ± 0.84 cd | 41.46 ± 1.34 b | 56.56 ± 1.34 b | 35.98 ± 0.79 b |
| einkorn | 15.59 ± 0.24 a | 36.35 ± 1.03 bc | 14.37 ± 0.47 d | 28.97 ± 0.83 c | 14.06 ± 0.64 c |
| emmer | 15.95 ± 0.22 a | 37.96 ± 0.48 b | 15.35 ± 0.62 d | 33.06 ± 0.84 c | 15.78 ± 0.74 c |
| spelt | 15.76 ± 0.22 a | 42.19 ± 0.57 a | 35.68 ± 0.94 c | 57.29 ± 0.81 b | 34.26 ± 0.67 b |
| ANOVA | | | | | |
| Main effects | | | | | |
| Harvest year (Y) | 152 (<0.05) | 171 (<0.05) | 46 (<0.05) | 223 (<0.05) | 152(<0.05) |
| Location (L) | 646 (<0.05) | 650 (<0.05) | 2 (ns) | 95 (<0.05) | 560 (<0.05) |
| Species (S) | 18 (<0.05) | 13 (<0.05) | 53 (<0.05) | 25 (<0.05) | 19 (<0.05) |
| Interactions | | | | | |
| Y × L | 139 (<0.05) | 59 (<0.05) | 13 (<0.05) | 22 (<0.05) | 112 (<0.05) |
| Y × S | 10 (<0.05) | 10 (<0.05) | 10 (<0.05) | 19 (<0.05) | 16 (<0.05) |
| L × S | 9 (<0.05) | 21 (<0.05) | 4 (<0.05) | 10 (<0.05) | 12 (<0.05) |
| Y × L × S | 6 (<0.05) | 8 (<0.05) | 6 (<0.05) | 3 (<0.05) | 7 (<0.05) |

The different lowercase letters are significantly different within each row at p-value < 0.05 .

Table S4.

| Species | Variety | Protein content (%) | Wet gluten content (%) | Gluten index | SDS test (mL) | Zeleny test (mL) |
|-------------|-----------------------|---------------------|------------------------|-----------------|-----------------|------------------|
| Einkorn | J1 | 16.19 ± 0.54 ab | 36.53 ± 2.02 bd | 15.00 ± 1.12 i | 34.75 ± 1.26 fi | 18.32 ± 1.14 d |
| | J2 | 16.37 ± 0.52 ab | 36.35 ± 1.78 bd | 12.67 ± 0.87 i | 32.67 ± 1.38 gi | 16.71 ± 1.17 d |
| | J4 | 15.15 ± 0.37 ad | 36.92 ± 1.80 ac | 15.83 ± 0.81 i | 21.67 ± 1.08 i | 9.59 ± 0.68 d |
| | J6 | 14.66 ± 0.39 ad | 36.01 ± 2.08 bd | 14.08 ± 0.98 i | 27.08 ± 1.36 hi | 11.66 ± 0.94 d |
| | D11 | 16.00 ± 0.44 ac | 39.65 ± 1.50 ac | 22.17 ± 2.27 fi | 43.41 ± 1.43 dg | 18.14 ± 0.92 d |
| | D12 | 16.02 ± 0.39 ac | 38.51 ± 1.34 ac | 17.83 ± 1.43 hi | 43.58 ± 1.75 dg | 19.30 ± 1.07 cd |
| Emmer | D13 | 15.07 ± 0.42 ad | 32.60 ± 1.63 cd | 12.17 ± 0.72 i | 28.58 ± 1.54 hi | 15.37 ± 0.79 d |
| | D14 | 15.24 ± 0.38 ad | 36.20 ± 1.58 bd | 12.17 ± 0.93 i | 21.83 ± 1.25 i | 10.17 ± 0.76 d |
| | D17 | 17.50 ± 0.55 a | 41.03 ± 1.26 ac | 14.92 ± 1.00 i | 28.67 ± 1.48 hi | 14.97 ± 0.94 d |
| | D18 | 16.81 ± 0.57 ab | 38.81 ± 1.60 ac | 11.17 ± 0.88 i | 25.41 ± 1.60 i | 13.17 ± 0.86 d |
| | D19 | 16.14 ± 0.47 ab | 39.86 ± 1.76 ac | 12.42 ± 1.10 i | 32.83 ± 1.45 gi | 15.78 ± 0.74 d |
| | RU | 15.52 ± 0.43 ac | 37.69 ± 1.50 ac | 20.58 ± 1.86 gi | 40.83 ± 1.62 eh | 19.54 ± 0.77 cd |
| | SP1 | 15.60 ± 0.39 ac | 41.59 ± 1.45 ac | 34.83 ± 2.53 df | 47.17 ± 1.80 cf | 30.49 ± 1.11 cd |
| Spelt | SP2 | 15.82 ± 0.41 ac | 42.31 ± 1.57 ac | 40.17 ± 2.23 ce | 59.92 ± 2.12 ac | 37.18 ± 1.89 ab |
| | SP4 | 16.07 ± 0.37 ac | 42.53 ± 1.21 ac | 35.42 ± 2.50 cf | 58.92 ± 1.83 ac | 34.60 ± 1.34 b |
| | SP6 | 16.06 ± 0.47 ac | 44.38 ± 1.63 ab | 31.92 ± 2.37 dg | 59.92 ± 2.11 ac | 34.24 ± 1.96 b |
| | SP7 | 14.71 ± 0.39 ad | 37.25 ± 1.41 ac | 34.67 ± 2.73 df | 54.50 ± 2.34 be | 30.49 ± 2.37 bc |
| | SP8 | 15.56 ± 0.33 ac | 42.48 ± 1.35 ac | 41.75 ± 1.76 ce | 63.25 ± 2.21 ab | 40.11 ± 2.11 ab |
| | SP9 | 16.37 ± 0.41 ab | 45.29 ± 1.34 a | 31.00 ± 2.04 eh | 57.75 ± 1.83 bc | 33.48 ± 1.34 b |
| | Bread wheat landraces | PP6 | 13.24 ± 0.49 ce | 32.79 ± 1.78 bd | 30.83 ± 1.90 eh | 56.25 ± 1.63 bd |
| RCCP | | 13.68 ± 0.53 be | 35.10 ± 1.13 bd | 41.17 ± 2.43 ce | 57.58 ± 2.71 bc | 37.67 ± 1.56 ab |
| CP | | 13.09 ± 0.32 ce | 33.47 ± 1.56 bd | 48.83 ± 1.58 bc | 60.33 ± 2.63 ac | 39.55 ± 1.40 ab |
| Bread wheat | KP | 12.86 ± 0.47 de | 31.09 ± 1.85 cd | 45.00 ± 2.52 bd | 52.42 ± 2.08 ce | 33.82 ± 2.22 b |
| | JR | 13.45 ± 0.45 ce | 34.21 ± 1.70 bd | 58.83 ± 2.50 b | 58.92 ± 2.10 ac | 37.83 ± 2.05 ab |
| | VK | 12.87 ± 0.33 de | 30.98 ± 1.53 cd | 67.51 ± 2.44 ab | 64.00 ± 2.23 ab | 41.47 ± 2.17 ab |
| | SWK | 12.13 ± 0.41 e | 27.52 ± 1.08 d | 78.6 ± 2.13 a | 71.83 ± 1.90 a | 46.89 ± 2.38 a |

Within column values followed by the same letter are not significantly different at *p*-value < 0.05

Table S5.

| Source | Df | Mean squares | | | | |
|-----------|-----|---|----------------------|----------|-----------|-----------|
| | | Gluten content (mg 100 g ⁻¹) | Albumins + Globulins | Gliadins | Glutenins | Insoluble |
| Year | 3 | 71,125** | 4.0** | 56.4** | 25.6** | 102.1** |
| Location | 2 | 96,571** | 251.4** | 43.9** | 66.1** | 317.8** |
| Variety | 25 | 39,650** | 118.9** | 168.9** | 246.4** | 262.6** |
| Y × L | 6 | 62,914** | 5.7** | 15.4** | 9.8** | 5.0** |
| Y × V | 75 | 1192** | 3.4** | 11.0** | 8.2** | 10.2** |
| L × V | 50 | 1859** | 15.2** | 30.1** | 35.3** | 49.5** |
| Y × L × V | 150 | 1279** | 2.6** | 6.1** | 3.4** | 10.0** |
| Error | 622 | 455 | 3.9 | 16.7 | 9.8 | 16.2 |

** , significant at $p < 0.01$; Y, year; L, location; and V, variety.

Table S6.

| Species | Gluten content (mg 100 g ⁻¹ of protein) | Albumins + Globulins (%) | Gliadins (%) | Glutenins (%) | Insoluble remainder (%) |
|--------------------------|---|-----------------------------|---------------|---------------|----------------------------|
| Einkorn | 154.10 ± 3.67c | 26.67 ± 0.26bc | 27.79 ± 0.28e | 27.64 ± 0.28c | 17.76 ± 0.36a |
| Emmer | 195.57 ± 3.50b | 28.68 ± 0.13a | 29.92 ± 0.26d | 27.71 ± 0.26c | 13.67 ± 0.27b |
| Spelt | 249.09 ± 3.27a | 27.05 ± 0.19b | 30.88 ± 0.21c | 29.96 ± 0.18b | 12.12 ± 0.27c |
| Landraces of bread wheat | 264.28 ± 3.68a | 26.21 ± 0.21c | 32.06 ± 0.26b | 30.71 ± 0.29b | 10.87 ± 0.30c |
| Bread wheat | 253.18 ± 3.71a | 20.93 ± 0.22d | 34.74 ± 0.24a | 37.12 ± 0.33a | 7.31 ± 0.25d |

Mean values ± S.D. associated with different lowercase letters are significantly different within each column at p -value < 0.05.

Table S7.

| Species | Variety | Gluten content (mg 100 g ⁻¹) | Albumins + Globulins (%) | Gliadins (%) | Glutenins (%) | Insoluble remainder (%) |
|-----------------------------|---------|---|-----------------------------|-----------------|-----------------|----------------------------|
| Einkorn | J1 | 153.87 ± 6.21 g | 24.48 ± 0.27 gh | 27.01 ± 0.27 f | 28.69 ± 0.36 df | 20.48 ± 0.39 a |
| | J2 | 146.41 ± 6.67 g | 25.56 ± 0.51 fg | 29.47 ± 0.39 ce | 28.78 ± 0.50 df | 16.01 ± 0.75 ac |
| | J4 | 159.89 ± 7.13 g | 29.24 ± 0.38 b | 25.78 ± 0.57 cf | 28.04 ± 0.68 g | 16.78 ± 0.66 ab |
| | J6 | 155.78 ± 9.18 g | 27.43 ± 0.37 cf | 28.82 ± 0.62 df | 27.44 ± 0.54 df | 17.67 ± 0.72 ab |
| | D11 | 184.23 ± 9.22f g | 29.01 ± 0.46 ab | 28.57 ± 0.52 df | 28.71 ± 0.27 df | 13.63 ± 0.79 dg |
| | D12 | 191.17 ± 9.57 dg | 27.18 ± 0.17 cf | 28.10 ± 0.50 ef | 29.46 ± 0.27df | 15.06 ± 0.45 ce |
| Emmer | D13 | 191.46 ± 8.93 dg | 28.37 ± 0.29 ac | 28.51 ± 0.69 df | 28.61 ± 0.32 df | 13.62 ± 0.64 dg |
| | D14 | 189.91 ± 11.11 eg | 29.78 ± 0.30 a | 34.67 ± 0.43 ab | 20.43 ± 0.61 h | 15.01 ± 0.68 ce |
| | D17 | 208.23 ± 10.27 cf | 28.33 ± 0.37 ad | 28.43 ± 0.45 df | 27.28 ± 0.31 g | 15.73 ± 0.89 ce |
| | D18 | 197.78 ± 11.32 cg | 29.24 ± 0.30 ab | 28.32 ± 0.43 df | 27.36 ± 0.60 g | 15.11 ± 0.40 ce |
| | D19 | 197.38 ± 10.03 cg | 27.69 ± 0.32 be | 31.37 ± 0.34 bd | 30.12 ± 0.63 cd | 12.19 ± 0.64 fi |
| | RU | 204.39 ± 9.21 cf | 30.02 ± 0.25 a | 31.28 ± 0.70 bd | 28.78 ± 0.34 df | 9.94 ± 0.58 ik |
| | SP1 | 247.67 ± 9.58 be | 26.89 ± 0.37df | 33.89 ± 0.25 ab | 28.71 ± 0.48 df | 10.78 ± 0.53 hj |
| | SP2 | 252.34 ± 10.48 ad | 26.03 ± 0.61 fg | 29.61 ± 0.53 ce | 30.80 ± 0.47 ce | 14.64 ± 0.65 ce |
| | SP4 | 258.11 ± 7.04 ac | 25.56 ± 0.51 fg | 30.91 ± 0.35 ce | 30.67 ± 0.59 ce | 12.51 ± 0.67 eh |
| | SP6 | 247.66 ± 7.03 be | 26.11 ± 0.57 ad | 28.07 ± 0.17 ef | 30.33 ± 0.27 ce | 11.22 ± 0.41 hj |
| Spelt | SP7 | 246.32 ± 8.13 be | 27.93 ± 0.27 eg | 31.34 ± 0.27 ce | 31.88 ± 0.17 cd | 12.31 ± 0.45 dg |
| | SP8 | 255.59 ± 9.91 ad | 29.01 ± 0.33 ac | 31.11 ± 0.51 ce | 28.56 ± 0.65 df | 11.26 ± 0.38 hi |
| | SP9 | 235.86 ± 8.23 cf | 27.79 ± 0.23 be | 31.41 ± 0.57 ce | 31.01 ± 0.34 cd | 10.20 ± 0.47 ik |
| | PP6 | 267.48 ± 6.94 a | 26.41 ± 0.46 eg | 32.26 ± 0.38 ac | 30.82 ± 0.31 cd | 10.31 ± 0.76 ik |
| | RCCP | 266.14 ± 7.31 ab | 26.07 ± 0.26 eg | 28.17 ± 0.42 ef | 31.92 ± 0.63 cd | 13.67 ± 0.68 dg |
| Bread wheat landraces | CP | 273.78 ± 9.38 a | 25.67 ± 0.37 fg | 32.04 ± 0.59 ac | 30.89 ± 0.68 cd | 11.33 ± 0.35 gj |
| | KP | 260.32 ± 8.56 ab | 27.03 ± 0.39 df | 35.53 ± 0.53 a | 28.67 ± 0.20 df | 8.54 ± 0.35 jk |
| | JR | 245.89 ± 10.34 ce | 22.41 ± 0.24 hi | 35.31 ± 0.19 a | 35.19 ± 0.25 ab | 6.91 ± 0.27 k |
| Bread wheat | VK | 251.04 ± 9.93 ad | 20.12 ± 0.25 i | 35.12 ± 0.24 a | 37.34 ± 0.28 ab | 7.91 ± 0.31 k |
| | SWK | 252.88 ± 12.41 ad | 20.42 ± 0.17 i | 33.68 ± 0.25 ab | 38.67 ± 0.34 a | 7.24 ± 0.39 k |

Mean values ± S.D. associated with different lowercase letters are significantly different within each column at p-value < 0.05.

Table S8.

| Variety | Time (min) | Torque (Nm) | Alfa (Nm.min⁻¹) | Amplitude | Stability (min) |
|----------------|-------------------|--------------------|-----------------------------------|------------------|------------------------|
| J1 | 2.26 ± 0.09 cd | 1.14 | - 0.05 ab | 0.06 | 3.43 ± 0.19 g |
| J2 | 1.83 ± 0.15 cd | 1.10 | - 0.05 ab | 0.07 | 2.32 ± 0.08 gh |
| J4 | 1.66 ± 0.08 d | 1.09 | - 0.04 a | 0.06 | 1.11 ± 0.17 h |
| D11 | 3.40 ± 0.20 bc | 1.09 | - 0.09 ce | 0.08 | 6.95 ± 0.25 de |
| D19 | 2.68 ± 0.21 cd | 1.13 | - 0.07 bd | 0.07 | 5.19 ± 0.31 f |
| RU | 2.75 ± 0.07 cd | 1.10 | - 0.07 bd | 0.07 | 6.12 ± 0.17 ef |
| SP6 | 3.59 ± 0.16 bc | 1.08 | - 0.08 ce | 0.08 | 8.23 ± 0.20 ad |
| SP7 | 3.50 ± 0.11 bc | 1.11 | - 0.08 ce | 0.08 | 7.56 ± 0.31 cd |
| SP8 | 4.23 ± 0.10 b | 1.09 | - 0.09 ce | 0.08 | 7.87 ± 0.29 bd |
| JR | 2.53 ± 0.27 cd | 1.14 | - 0.10 ef | 0.05 | 9.53 ± 0.13 ab |
| VK | 5.37 ± 0.29 ab | 1.08 | - 0.09 df | 0.07 | 8.99 ± 0.35 ac |
| SWK | 6.38 ± 0.17 a | 1.13 | - 0.12 f | 0.07 | 9.76 ± 0.11 a |

Mean values ± S.D. associated with different lowercase letters are significantly different within each column at p-value < 0.05.

Table S9.

| Variety | Torque C2 (Nm) | Beta (Nm.min ⁻¹) | Torque C3 (Nm) | Gamma (Nm.min ⁻¹) | Torque C4 (Nm) | Torque C5 (Nm) |
|---------|-------------------|---------------------------------|-------------------|----------------------------------|-------------------|-------------------|
| J1 | 0.32 ± 0.01 ad | 0.66 a | 1.64 ± 0.03 ac | - 0.06 | 1.16 ± 0.04 ab | 2.06 ± 0.06 a |
| J2 | 0.26 ± 0.02 cd | 0.39 bc | 1.48 ± 0.04 be | - 0.08 | 1.04 ± 0.05 ac | 1.79 ± 0.04 ab |
| J4 | 0.26 ± 0.03 d | 0.52 ac | 1.54 ± 0.10 be | - 0.07 | 1.20 ± 0.10 a | 1.98 ± 0.09 a |
| D11 | 0.31 ± 0.01 bd | 0.43 bc | 1.33 ± 0.08 de | - 0.09 | 0.60 ± 0.03 de | 0.94 ± 0.05 cd |
| D19 | 0.30 ± 0.03 bd | 0.34 c | 1.29 ± 0.05 e | - 0.08 | 0.79 ± 0.04 be | 1.29 ± 0.06 bd |
| RU | 0.35 ± 0.02 ad | 0.32 c | 1.40 ± 0.07 ce | - 0.05 | 1.07 ± 0.10 ac | 1.60 ± 0.05 ab |
| SP6 | 0.33 ± 0.01 ad | 0.56 ab | 1.54 ± 0.06 bd | - 0.11 | 0.74 ± 0.09 ce | 1.23 ± 0.11 bd |
| SP7 | 0.32 ± 0.01 bd | 0.57 ab | 1.60 ± 0.04 bc | - 0.09 | 1.01 ± 0.06 ac | 1.51 ± 0.07 ac |
| SP8 | 0.35 ± 0.02 ad | 0.54 ac | 1.54 ± 0.05 be | - 0.09 | 0.90 ± 0.04 ad | 1.46 ± 0.05 ac |
| JR | 0.41 ± 0.02 a | 0.60 ab | 1.86 ± 0.07 a | - 0.06 | 1.14 ± 0.10 ac | 1.44 ± 0.08 ac |
| VK | 0.36 ± 0.01 ac | 0.46 ac | 1.41 ± 0.08 be | - 0.11 | 0.47 ± 0.04 e | 0.74 ± 0.06 d |
| SWK | 0.39 ± 0.01 ab | 0.56 ab | 1.65 ± 0.07 ab | - 0.10 | 0.79 ± 0.07 be | 1.28 ± 0.12 bd |

Mean values ± S.D. associated with different lowercase letters are significantly different within each column at p-value < 0.05.