2021 Quinoa Referee Statistical Analysis performed by Dr. Riad Baalbaki

Results:

* Percentage gemination (first and final count), as well as abnormal and dead seeds, significantly differed among samples (Tables 1, 2). Samples had a range of quality.
* Using either 15 or 20 oC as test temperature had no effect on final percentage germination, when averaged over all other factors (Table 3). Abnormal and dead result differences were minimal, although significant (Table 3).
* With a single exception (Lab 9, sample 4), no lab produced significantly different results when germination was evaluated at 15 and 20 oC (Tables 4, 5, 6, and 7).
* Results among labs, within the same sample and temperature, showed a wide range of variation, but the extent of variability among labs depended on the sample being tested, and was not affected by temperature (Table 8).

*All statistical analysis and results were based on arc sin transformed percentage data. Original values are presented in tables.*

Table 1. Analysis of variance (MS) of final, abnormal and dead quinoa referee results (arc sine transformed data) using four different samples at two germination temperatures and tested in 11 labs at 4 replications of 100 seeds each.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***SV*** | ***df*** | *MS* | | |
| ***Germination-final (%)*** | ***Abnormal***  ***(%)*** | ***Dead***  ***(%)*** |
| **Sample (A)** | 3 | 4128.0\*\* | 2697.2\*\* | 2708.2\*\* |
| **Temperature (B)** | 1 | 2.10 | 264.33\*\* | 268.7664\*\* |
| **Lab (C)** | 10 | 178.73\*\* | 356.90\*\* | 201.4873\*\* |
| **A x B** | 3 | 59.63\*\* | 9.72 | 101.7452\*\* |
| **A x C** | 30 | 28.34\*\* | 48.27\*\* | 30.48385\*\* |
| **B x C** | 10 | 14.68 | 80.99\*\* | 48.30863\*\* |
| **A x B x C** | 30 | 13.75\* | 12.59 | 14.81765 |
| **Within** | 264 | 8.88 | 9.20 | 11.42082 |
| **Total** | 351 | 51.58 | 48.49 | 44.36083 |

Table 2. Analysis of variance (MS) of first count results (arc sine transformed data) using four different samples at two germination temperatures and tested in 11 labs at 4 replications of 100 seeds each.

|  |  |  |
| --- | --- | --- |
| ***SV*** | ***df*** | ***MS***  ***Germination-first count (%)*** |
| **Sample (A)** | 3 | 12740.5\*\* |
| **Temperature (B)** | 1 | 1032.02\*\* |
| **Lab (C)** | 7 | 270.80\*\* |
| **A x B** | 3 | 1486.80\*\* |
| **A x C** | 21 | 109.92\*\* |
| **B x C** | 7 | 116.21\*\* |
| **A x B x C** | 21 | 72.62\*\* |
| **Within** | 192 | 18.71\*\* |
| **Total** | 255 | 211.17\*\* |

Table 3. Differences in final germination between the two temperatures (15 and 20 oC), over all samples and labs.

|  |  |  |  |
| --- | --- | --- | --- |
| **Temperature (oC)** | **Final germination (%)** | **Abnormal**  **(%)** | **Dead**  **(%)** |
| 15 | 56.2a | 24.1a | 26.1b |
| 20 | 56.0a | 22.3b | 28.8a |

Means with the same letter, for each component, do not significantly differ (THSD; p ≤ 0.05).

Table. 4. Final germination (%) of sample 1, at the two test temperatures, for each lab.

|  |  |  |
| --- | --- | --- |
| **Lab** | **Temperature (oC)** | **Final germination (%)** |
| 1 | 15 | 55a |
|  | 20 | 52a |
|  |  |  |
| 2 | 15 | 46a |
|  | 20 | 51a |
|  |  |  |
| 3 | 15 | 48a |
|  | 20 | 54a |
|  |  |  |
| 4 | 15 | 38a |
|  | 20 | 31a |
|  |  |  |
| 5 | 15 | 51a |
|  | 20 | 46a |
|  |  |  |
| 6 | 15 | 51a |
|  | 20 | 43a |
|  |  |  |
| 7 | 15 | 42a |
|  | 20 | 47a |
|  |  |  |
| 8 | 15 | 47a |
|  | 20 | 37a |
|  |  |  |
| 9 | 15 | 50a |
|  | 20 | 48a |
|  |  |  |
| 10 | 15 | 50a |
|  | 20 | 45a |
|  |  |  |
| 11 | 15 | 46a |
|  | 20 | 45a |

Means with the same letter, for each lab, do not significantly differ (THSD; p ≤ 0.05).

Table. 5. Final germination (%) of sample 2, at the two test temperatures, for each lab.

|  |  |  |
| --- | --- | --- |
| **Lab** | **Temperature (oC)** | **Final germination (%)** |
| 1 | 15 | 56a |
|  | 20 | 54a |
|  |  |  |
| 2 | 15 | 56a |
|  | 20 | 55a |
|  |  |  |
| 3 | 15 | 50a |
|  | 20 | 52a |
|  |  |  |
| 4 | 15 | 43a |
|  | 20 | 41a |
|  |  |  |
| 5 | 15 | 56a |
|  | 20 | 52a |
|  |  |  |
| 6 | 15 | 47a |
|  | 20 | 50a |
|  |  |  |
| 7 | 15 | 47a |
|  | 20 | 41a |
|  |  |  |
| 8 | 15 | 43a |
|  | 20 | 44a |
|  |  |  |
| 9 | 15 | 52a |
|  | 20 | 50a |
|  |  |  |
| 10 | 15 | 53a |
|  | 20 | 45a |
|  |  |  |
| 11 | 15 | 47a |
|  | 20 | 43a |

Means with the same letter, for each lab, do not significantly differ (THSD; p ≤ 0.05).

Table. 6. Final germination (%) of sample 3, at the two test temperatures, for each lab.

|  |  |  |
| --- | --- | --- |
| **Lab** | **Temperature (oC)** | **Final germination (%)** |
| 1 | 15 | 77a |
|  | 20 | 73a |
|  |  |  |
| 2 | 15 | 76a |
|  | 20 | 72a |
|  |  |  |
| 3 | 15 | 76a |
|  | 20 | 74a |
|  |  |  |
| 4 | 15 | 69a |
|  | 20 | 74a |
|  |  |  |
| 5 | 15 | 73a |
|  | 20 | 72a |
|  |  |  |
| 6 | 15 | 67a |
|  | 20 | 72a |
|  |  |  |
| 7 | 15 | 69a |
|  | 20 | 71a |
|  |  |  |
| 8 | 15 | 74a |
|  | 20 | 71a |
|  |  |  |
| 9 | 15 | 72a |
|  | 20 | 73a |
|  |  |  |
| 10 | 15 | 70a |
|  | 20 | 71a |
|  |  |  |
| 11 | 15 | 71a |
|  | 20 | 70a |

Means with the same letter, for each lab, do not significantly differ (THSD; p ≤ 0.05).

Table. 7. Final germination (%) of sample 4, at the two test temperatures, for each lab.

|  |  |  |
| --- | --- | --- |
| **Lab** | **Temperature (oC)** | **Final germination (%)** |
| 1 | 15 | 74a |
|  | 20 | 76a |
|  |  |  |
| 2 | 15 | 60a |
|  | 20 | 61a |
|  |  |  |
| 3 | 15 | 60a |
|  | 20 | 61a |
|  |  |  |
| 4 | 15 | 48a |
|  | 20 | 55a |
|  |  |  |
| 5 | 15 | 55a |
|  | 20 | 55a |
|  |  |  |
| 6 | 15 | 53a |
|  | 20 | 61a |
|  |  |  |
| 7 | 15 | 50a |
|  | 20 | 56a |
|  |  |  |
| 8 | 15 | 51a |
|  | 20 | 57a |
|  |  |  |
| 9 | 15 | 48a |
|  | 20 | 60b |
|  |  |  |
| 10 | 15 | 60a |
|  | 20 | 52a |
|  |  |  |
| 11 | 15 | 52a |
|  | 20 | 60a |

Means with the same letter, for each lab, do not significantly differ (THSD; p ≤ 0.05).

Table. 8. Differences in percentage final germination among labs for the same sample, at the same test temperature.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Sample 1** | |  | **Sample 2** | |
| **Lab** | **15 oC** | **20 oC** |  | **15 oC** | **20 oC** |
| **1** | 55.3 | 51.5 |  | 56.3 | 53.8 |
| **2** | 46.3 | 51.0 |  | 55.8 | 54.5 |
| **3** | 47.5 | 53.8 |  | 49.5 | 51.8 |
| **4** | 38.0 | 30.5 |  | 43.0 | 41.0 |
| **5** | 51.3 | 46.3 |  | 56.3 | 51.5 |
| **6** | 50.8 | 42.8 |  | 47.3 | 50.0 |
| **7** | 41.5 | 46.5 |  | 46.5 | 41.3 |
| **8** | 47.0 | 37.3 |  | 43.3 | 43.8 |
| **9** | 50.0 | 48.0 |  | 51.8 | 49.5 |
| **10** | 49.8 | 45.0 |  | 53.3 | 45.0 |
| **11** | 45.5 | 45.0 |  | 47.0 | 43.3 |
| **Range** | **38.0-55.3** | **30.5-53.8** |  | **43.3-56.3** | **41.0-54.5** |
|  | | | | | |
|  | **Sample 3** | |  | **Sample 4** | |
| **Lab** | **15 oC** | **20 oC** |  | **15 oC** | **20 oC** |
| **1** | 76.5 | 72.5 |  | 74.0 | 76.0 |
| **2** | 75.8 | 71.5 |  | 59.5 | 60.5 |
| **3** | 75.5 | 73.5 |  | 60.3 | 60.5 |
| **4** | 69.0 | 73.8 |  | 47.8 | 54.5 |
| **5** | 73.0 | 72.3 |  | 55.0 | 54.5 |
| **6** | 66.8 | 71.5 |  | 52.5 | 60.5 |
| **7** | 69.0 | 70.5 |  | 50.3 | 55.5 |
| **8** | 73.8 | 70.5 |  | 50.8 | 56.8 |
| **9** | 71.8 | 72.8 |  | 48.0 | 59.8 |
| **10** | 70.3 | 71.0 |  | 69.5 | 51.8 |
| **11** | 70.8 | 70.3 |  | 52.0 | 60.3 |
| **Range (%)** | **66.8-76.5** | **70.3-73.5** |  | **48.0-74.0** | **51.8-76.0** |

***Crit. D (p ≤ 0.05) =*** *11.6%.*