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**ASPAC
Soil Proficiency Testing
Program Report**

2021

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Foreword

This is the latest of ASPAC's many inter-laboratory proficiency program (ILPP) reports for soils since 1993. This reporting format for soils has applied since ASPAC's 2004-05 annual program (see Rayment *et al.* 2007)¹. Nowadays, ILPPs for common soil chemical tests have three "rounds" each of four carefully prepared and milled air-dry soils. Similar annual programs for milled plant tissue samples operate concurrently (e.g., Lyons *et al.* 2013)².

This ILPP continued ASPAC's Australasian focus and targeted laboratories in the private, government and university sectors that provide soil testing services for a range of purposes. These mostly locate in Australia, New Zealand, Oceania, and in parts of South-east Asia.

The Service Provider for ASPAC is Global Proficiency Ltd. This company operates mainly out of New Zealand, with key personnel and contact details provided on page iv.

Technical aspects of this ILPP were specified and over-sighted by ASPAC's Laboratory Proficiency Committee (LPC), recent membership of which is listed on page iv. In addition, LPC members and two key personnel from the Service Provider participate annually in a Technical Advisory Group (TAG), chaired by a senior representative of the Service Provider.

The ASPAC-LPC and the ASPAC Executive Committee also appreciate the efforts made by laboratories who utilized this method-specific proficiency program. By participating, they share a commitment to and responsibility for perceived measurement quality across Australasia, noting that proficiency in measurement is only a component of laboratory accreditation to Australian Standard AS ISO/IEC 17025:2018, and New Zealand Standard NZS ISO/IEC 17025:2018, which should be an achievement goal for laboratory managers.

An electronic copy of this report, and other similar completed annual program reports, can be downloaded from ASPAC's public web site at www.aspac-australasia.com.

Dr Roger Hill
Convenor, ASPAC-LPC

¹ Rayment, G.E., Peverill, K.I., Hill, R.J., Daly, B.K., Ingram, C. and Marsh, J. (2007). ASPAC Soil Proficiency Testing Program Report 2004-05. (73 + vi pp.) ASPAC, Melbourne, Victoria.

² Lyons, D.J., Rayment, G.E., Daly, B.K., Hill, R.J., Ingram, C. and Marsh, J. (2013). 'ASPAC Plant Proficiency Testing Program Report 2008-09'. (47 + vi pp.) ASPAC, Melbourne, Victoria.

Acknowledgements

Those commissioned by GPL to prepare soil samples and confirm homogeneity prior to circulation for proficiency testing purposes [Department of Environment and Science (DES) Queensland, Australia] are acknowledged, as are operational staff of GPL.

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^A **Note:** GPL, under its "SoilChek" logo, is accredited by IANZ (the New Zealand accreditation authority) to ISO/IEC 17043 standard, noting that IANZ is a full member of both the International Laboratory Accreditation Cooperation (ILAC), and Asia Pacific Laboratory Accreditation Cooperation (APLAC). GPL is also recognized by NATA (National Association of Testing Authorities of Australia) as a proficiency provider.

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1. Introduction

This not-for-profit, annual ASPAC Soil Proficiency Testing Program Report for 2021 documents program methodology, summary statistics, and a full listing of results by test for three “rounds” of soil chemical testing. For historical details on earlier annual soil ILPP’s undertaken by ASPAC, refer to Rayment *et al.* (2007) referenced earlier in this report. These reports are also available for downloading from ASPAC’s public web site at www.aspac-australasia.com.

The report includes an outline of how ASPAC now confers performance-based, method-specific certification to laboratories that regularly participate. To respect confidentiality, the cross-reference between laboratory name and laboratory identification number is not included. However, laboratories certified as proficient for specific tests in this annual program were documented at the time on ASPAC’s public web site.

2. Program Details

2.1 Responsibilities

GPL- see page iv -under its “Soil Chek” arrangements, was contracted by ASPAC as the soil ILPP provider for 2021. Accordingly, GPL had responsibility on a “round-by-round” basis for sourcing and preparation of samples, for ensuring the samples met international and/or within-country quarantine requirements, and for the timely supply of samples to participating laboratories. GPL also undertook data analysis and “round-by-round” reporting for ASPAC and assembled the summary and “raw” data provided in Section 3 and Appendix 4, respectively, of this report.

ASPAC’s LPC- see page iv- had responsibility to implement and resolve matters of policy and to provide guidance on technical matters specific to soil chemical testing both to GPL and to laboratory participants. The LPC also undertook occasional checks and audits for quality control purposes, participated in the earlier mentioned TAG, contributed to training workshops, and assisted (on request) laboratory managers with technical aspects on measurement improvement. As always, laboratory managers were encouraged to seek help from ASPAC when shown to be operating at levels of measurement performance below their peers.

Participants receive or have a unique, confidential laboratory number, subsequently used to identify the origin of each result presented in program reports and lists of results. This identification number has typically carried forward from one annual program to the next, but code numbers changed in 2014-15 and beyond.

ASPAC’s web-site manager and others updated the public web site with details on method-specific certifications and lists of laboratories that undertook those soil tests. The proficiency data used was supplied by GPL and oversighted by the Convener of the ASPAC-LPC.

2.2 Soil program participation

Some 68 laboratories submitted results for at least one soil test in 2021, 4 less than in 2020. Names and other summary contact details for the participants are provided in Appendix 1. There were 43 laboratories involved from Australia, the same as in 2020 (QLD=10; NSW=9; VIC=9; WA=9; SA=4; TAS=1; ACT=1), 9 from New Zealand, the same as 2020, and 16 (decrease of 4) from Asia and the south Pacific, including 2 each from Fiji, Papua New Guinea, Philippines, Samoa, and Uruguay, and 1 each from Indonesia, Lao Peoples Democratic Republic, Myanmar, New Caledonia, Sri Lanka and Thailand.

The most reported results (see Table 2.1) across the three “rounds” combined were submitted for method 4A1 (43 average for pH, 1:5 soil-water) followed by method 3A1 (41 average for electrical conductivity, 1:5 soil-water). The median was 17 laboratories for each method.

There were no additions this year to the list of certifiable test methods. Participants were invited to test and report Infra-Red spectroscopy results for the first time, with several laboratories providing Total Nitrogen and Total Organic Carbon results.

Table 2.1. Test methods, corresponding method codes and the arithmetic average number of results per round submitted by participating laboratories in the ASPAC 2021 soil ILPP.

Soil Tests - Certified	Method Codes ⁱ	Number of results submitted by participating laboratories		
		Mar 21	Jun 21	Sep 21
Air Dry Moisture	2A1	32	29	32
Electrical conductivity 1:5 soil-water	3A1	43	39	41
Soil pH, 1:5 soil-water	4A1 + 4A3	45	41	44
Soil pH, 1:5 0.01 M CaCl ₂	4B1 + 4B3 + 4B2 + 4B4	34	33	33
Water soluble Cl — Pooled	5A1 + 5A2 + 5A3	28	27	27
Organic Carbon — W&B	6A1	19	16	17
Total Organic C — Pooled	6B1 + 6B3	22	22	20
Total C — Dumas	6B2	27	26	29
Total Organic Matter (%)	6G1	9	9	9
Total N — Dumas	7A5	29	30	31
Total N — Pooled	7A1 + 7A2 + 7A3	11	10	10
Water Soluble Nitrate N — autocolour	7B1 + 7B2	18	18	16
KCl Extractable Nitrate N — autocolour	7C2	24	23	24
KCl Ext. Ammonium N — autocolour	7C2	30	29	28
Total P — all methods %	Pooled	23	23	25
Colwell Extractable P	9B1 + 9B2	29	28	26
Olsen Extractable P	9C1 + 9C2	27	25	23
Bray-1 Extractable P	9E1 + 9E2	9	9	11
Acid Extractable P	9G1 + 9G2	12	13	13
Phosphorus buffer index - Colwell	9I2a + 9I2b + 9I2c ⁱ	19	19	19
Phosphorus buffer index - Unadjusted	9I4a + 9I4b + 9I4c ⁱⁱ	13	12	12
Phosphate Extractable S	10B1 + 10B2 + 10B3	10	10	11
KCl 40 Extractable S	10D1	15	16	14
DTPA Extractable Fe	12A1	27	25	26
DTPA Extractable Cu	12A1	26	24	26
DTPA Extractable Mn	12A1	28	25	26
DTPA Extractable Zn	12A1	27	25	25
CaCl ₂ Extractable B — manual colour	12C1 + 12C2	20	21	21
Exchangeable Ca — 1M NH ₄ Cl extract	15A1	18	19	17

Soil Tests - Certified	Method Codes ⁱ	Number of results submitted by participating laboratories		
		Mar 21	Jun 21	Sep 21
Exchangeable K — 1M NH ₄ Cl extract	15A1	17	18	16
Exchangeable Mg — 1M NH ₄ Cl extract	15A1	18	19	17
Exchangeable Na — 1M NH ₄ Cl extract	15A1	16	17	17
Exchangeable Ca — 1M NH ₄ OAc extract	15D3	18	19	17
Exchangeable K — 1M NH ₄ OAc extract	15D3	17	18	16
Exchangeable Mg — 1M NH ₄ OAc extract	15D3	18	19	17
Exchangeable Na — 1M NH ₄ OAc extract	15D3	23	18	23
Exchangeable Al — 1M KCl extract	15G1	16	17	16
Extractable K – Bicarbonate	18A1	13	14	13

Soil Tests – Not Certified ⁱⁱ	Method Codes ⁱ	Number of results submitted by participating laboratories		
		Mar 21	Jun 21	Sep 21
Aqua Regia Aluminium (mg/kg)	17B1 + 17B2 + 17C1	15	17	16
Aqua Regia Arsenic (mg/kg)	17B1 + 17B2 + 17C1	12	13	14
Aqua Regia Boron (mg/kg)	17B1 + 17B2 + 17C1	12	13	14
Aqua Regia Calcium (mg/kg)	17B1 + 17B2 + 17C1	16	17	17
Aqua Regia Cadmium (mg/kg)	17B1 + 17B2 + 17C1	11	13	11
Aqua Regia Cobalt (mg/kg)	17B1 + 17B2 + 17C1	14	16	16
Aqua Regia Chromium (mg/kg)	17B1 + 17B2 + 17C1	14	16	17
Aqua Regia Copper (mg/kg)	17B1 + 17B2 + 17C1	16	17	17
Aqua Regia Iron (mg/kg)	17B1 + 17B2 + 17C1	15	16	16
Aqua Regia Potassium (mg/kg)	17B1 + 17B2 + 17C1	15	17	17
Aqua Regia Magnesium (mg/kg)	17B1 + 17B2 + 17C1	16	17	17
Aqua Regia Manganese (mg/kg)	17B1 + 17B2 + 17C1	15	17	17
Aqua Regia Molybdenum (mg/kg)	17B1 + 17B2 + 17C1	10	11	11
Aqua Regia Sodium (mg/kg)	17B1 + 17B2 + 17C1	14	15	15
Aqua Regia Lead (mg/kg)	17B1 + 17B2 + 17C1	12	13	13
Aqua Regia Sulphur (mg/kg)	17B1 + 17B2 + 17C1	12	13	13
Aqua Regia Selenium (mg/kg)	17B1 + 17B2 + 17C1	10	12	10
Aqua Regia Silicon (mg/kg)	17B1 + 17B2 + 17C1	8	9	9
Aqua Regia Zinc (mg/kg)	17B1 + 17B2 + 17C1	15	17	17

Soil Tests – Not Assessable ⁱⁱⁱ	Method Codes ⁱⁱ	Number of results submitted by participating laboratories		
		Mar 21	Jun 21	Sep 21
Total Nitrogen IR (%)	7A6a + 7A6b	1	2	2

Soil Tests – Not Assessable ⁱⁱⁱ	Method Codes ⁱⁱ	Number of results submitted by participating laboratories		
		Mar 21	Jun 21	Sep 21
Total Org C IR (%)	6B4a + 6B4b	3	2	2

- ⁱ Unless otherwise indicated, soil method codes are as defined by Rayment, G.E. and Lyons, D.J. (2011). *Soil Chemical Methods - Australasia*. CSIRO Publishing, Collingwood, Victoria, Australia.
- ⁱⁱ NOT CERTIFIED table lists tests for which there were sufficient results reported for statistical analysis (>7) but are not yet part of the certification program.
- ⁱⁱⁱ NOT ASSESSABLE table lists tests for which there were insufficient results reported for statistical analysis (<7) and are not yet part of the certification program.

2.3 Tests and methods

The three proficiency “rounds” for soils – each comprised of four samples – were offered in March, June and September, 2021. Participants were invited to analyse each sample by the methods listed and/or coded in Table 2.1. Participants were not required to submit results for all of the methods listed, noting that selected methods, including phosphate buffer index (Colwell) and phosphate buffer index (Olsen), were “scored” as one method each, irrespective of which analytical finish was used. This “pooling” also occurred for extractable P tests and some others, with details provided in Table 2.2. ‘Pooling’ test results is done for tests which the LPC deem to be equivalent and should therefore yield the same results. The most common instance is where a common extraction may have different analytical finishes, e.g. atomic absorption spectroscopy (AAS) or inductively coupled plasma optical emission spectroscopy (ICP-OES). Grouping these tests together reduces the total number of tests and also provides larger datasets for statistical analysis. Data summaries in Section 3 also indicate where there was method “pooling”.

Participating laboratories were required by ASPAC to report all tests either air dry (40°C) or oven dry (105 °C) soil-weight basis (not a soil-volume basis), as per the reporting guidelines published by Rayment and Lyons (2011). Indeed, routine soil fertility tests in Australia are mostly reported on an air-dry (40°C) soil-weight basis. Those results reported on an oven-dry result in this report therefore required a final calculation using the air-dry moisture percentage included in the program as method-code 2A1.

Table 2.2. Method “pooling” summary for the ASPAC 2021 soil ILPP

Soil Tests	Method Codes	Number of results submitted by participating laboratories
Soil pH, 1:5 0.01 M CaCl ₂ - direct, pooled air dry	4B1 + 4B2 + 4B3 + 4B4	33
Soil pH, soil/water suspension - NEW	4A1 + 4A3	43
Water Soluble Cl – Pooled	5A1 + 5A2 + 5A3	27
Total Carbon – Pooled %	6B1 + 6B3	21
Total Nitrogen – Pooled %	7A1 + 7A2 + 7A3	10
Total P – pooled % oven dry	Pooled	23

Soil Tests	Method Codes	Number of results submitted by participating laboratories
Colwell Extractable P – pooled mg/kg air dry	9B1 + 9B2	28
Olsen Extractable P – pooled mg/kg air dry	9C1 + 9C2	25
Bray-1 Extractable P – pooled mg/kg air dry	9E1 + 9E2	10
Acid Extractable P – pooled mg/kg air dry	9G1 + 9G2	13
Phosphorous Buffer Index (Colwell) L/kg dry wt	9I2a + 9I2b + 9I2c	19
Phosphorous Buffer Index (Unadj) L/kg dry wt	9I4a + 9I4b + 9I4c	12
Phosphate Extractable S, pooled mg/kg air dry	10B1 + 10B2 + 10B3	10
Hot CaCl ₂ Extractable B – pooled mg/kg air dry	12C1 + 12C2	21
Aqua Regia Metals	17B1 + 17B2 + 17C1	17

2.4 Sample preparation and identification

In common with practices since the 2004-05 soils program, potential samples were assessed for homogeneity by laboratories accredited to ISO/IEC 17025 standard. Specifically, 10 containers of each sample were selected at random and batched according to the principles described by Thompson and Wood (1993)³. These sub-samples were then tested in duplicate for Total N by Dumas Combustion.

Results from the homogeneity testing were subsequently statistically assessed according to ISO REMCO Protocol N231 "*Harmonised Proficiency Testing Protocol*" of January 1992. All prepared soils were rated as homogenous, as demonstrated in Appendix 2. In addition to testing for homogeneity, the soil samples were irradiated or otherwise rendered biologically benign to comply with international and/or national biosecurity regulations or requirements⁴.

Ultimately, the samples used in the three "rounds" of the 2021 program were distributed and coded as follows: March 2021 (Round 3) ASS 2103-1 to 2103-4; June 2021 (Round 6) ASS 2106-1 to 2106-4; and September 2021 (Round 9) ASS 2109-1 to 2109-4. The association between sample code and origin of the various soils is provided in Table 2.3.

³ Thompson, M and Wood, R. (1993). International harmonized protocol for proficiency testing of (chemical) analytical laboratories. *Journal of AOAC International* **76** (4), 926 – 940.

⁴ Rayment, G.E. (2006). Australian efforts to prevent the accidental movement of pests and diseases in soil and plant samples. *Commun. Soil Sci. Plant Anal.* **37**, 2107-2117.

Table 2.3. Sample identification and the origin of the samples included in the ASPAC 2021 soil ILPP

Sample ID	Round ID	Sample Origin	Previous Rounds
ASS 2103-1	Round 3 20210315	QLD - Australia	N/A
ASS 2103-2		NSW - Australia	N/A
ASS 2103-3		NSW - Australia	ASS1906-3
ASS 2103-4		VIC - Australia	ASS1909-4
ASS 2106-1	Round 6 20210608	New Zealand	N/A
ASS 2106-2		USA	ASS1903-1
ASS 2106-3		NSW - Australia	ASS2003-3
ASS 2106-4		USA	ASS1906-4
ASS 2109-1	Round 9 20210913	TAS - Australia	ASS2006-3
ASS 2109-2		SA - Australia	N/A
ASS 2109-3		QLD - Australia	N/A
ASS 2109-4		SA - Australia	ASS1909-3

2.5 Data analysis and periodic reporting

Laboratory results, after submission to the Service Provider, were entered into a database and double-checked for data transfer accuracy and required soil-moisture status prior to data processing.

The non-parametric assessment of laboratory performance for each sample and method (and/or “pooled” methods) was performed by an iterative statistical procedure similar to that used in the WEPAL inter-laboratory proficiency programs of Wageningen University. This procedure^{5,6,7,8} is suited to datasets of as few as six to seven laboratories, although larger laboratory populations are preferred. An outline of the median / MAD statistical procedure is provided in Appendix 3, with terms described in Table 2.4. In addition to medians and MADs, other statistical parameters (also described in Table 2.4) were calculated before and following the omission of non-conforming results. The “raw” data submitted by participating laboratories on a test-by-test basis are documented in Appendix 4, sometimes after rounding only for table formatting purposes.

Results submitted by each laboratory were expected to reflect the procedural and reporting guidelines in the chapter on that topic in Rayment and Lyons (2011). Like other programs nationally and internationally, the program did not accept as a numeric value a result reported as less than (<) or greater than (>) a specified number. In cases where the expected value was below the laboratory’s lower limit of reporting, the expectation was that the laboratory would report a value half way between that value and zero. For high values, dilution was the option.

⁵ Houba, V.J.G., Uittenbogaard, J. and Pellen, P. (1996). Wageningen evaluating programmes for analytical laboratories (WEPAL), organization and purpose. *Commun. Soil Sci. Plant Anal.* **27**, 421-429.

⁶ Montford, M.A.J. van. (1996). Statistical remarks on laboratory–evaluating programs for comparing laboratories and methods. *Commun. Soil Sci. Plant Anal.* **27**, 463-478.

⁷ Rayment, G.E., Miller, R.O. and Sulaeman, E. (2000). Proficiency testing and other interactive measures to enhance analytical quality in soil and plant laboratories. *Commun. Soil Sci. Plant Anal.* **31**, 1513-1530.

⁸ Whitehouse, M.W. (1987). Medians and MADs - Statistical methodology used at Wageningen, The Netherlands, for interlaboratory comparisons in the plant exchange program. Ag. Chem. Br. Report, ACU87/36. 10 pp. (Qld Dept. Primary Ind., Brisbane.)

Interim “round” reports, summarizing measurement performance relative to the performance of all laboratories in the program that undertook the same test/s, were routinely and promptly e-mailed to laboratory participants. The main purpose of the interim reports was to provide feedback and to enable laboratories to take prompt action where appropriate. Interim reports also provided an opportunity to correct for data-transfer and data-processing misinterpretations. In addition, regular Newsletters from the Service Provider went to participating laboratories, adding to the information provided in ASPAC’s own Newsletter to its members (the *ASPAC Digest*).

Laboratories that participated in the 2021 soil ILPP each received from the Service Provider (on behalf of ASPAC) a laboratory specific, confidential, annual summary report. Each laboratory’s data for the 12 soil samples, the aggregate data from all participants, other relevant statistical data, and whether or not the test/s received ASPAC Certification (if applicable) were provided. The laboratory code number was included.

2.6 ASPAC certification of laboratories for soil tests

Subject to satisfactory measurement performance for twelve samples across three sequential “rounds”, typically over the twelve-month period, ASPAC awarded participating laboratories with a printed, signed and dated *Certificate of Proficiency*. The *Certificate of Proficiency* identified performance for each test that met criteria set in advance by ASPAC. Method specific certification applied when a laboratory incurred no more than four demerit points for the twelve samples in the program year.

Demerit points (if any) were allocated through the identification of “outliers” and “stragglers” (see Appendix 3) by the “median / MAD” statistical procedure mentioned earlier in this report. Two demerit points were allocated to each statistical “outlier”, while a statistical “straggler” was allocated one demerit point. As no sample result could be both an “outlier” and a “straggler”, a maximum of two demerit points is all that could accrue per sample for a specific test.

Three (3) was set as the maximum number of demerit points for a specific test, that could be accrued in any one round of four samples. This was done so that unsatisfactory measurement for a test in one “round” did not in itself result in failure to be certified for that test across the three “rounds” in the designated 12-month period.

If a “round” was missed, the maximum number of three demerit points for every test in that “round” was allocated, unless very special circumstances applied and was known or advised expeditiously to ASPAC’s LPC through its Convenor. When the explanation was accepted, performance from the three most recently completed “rounds” was used to assess eligibility for certification. No exceptions applied to this annual program.

Finally, when six (6) laboratories or less submitted results for a particular test and/or sample (including for “pooled” tests), proficiency assessments could not be made statistically with an acceptable level of confidence and hence certification for the affected test/s could not be granted. Importantly, ASPAC’s *Certificates of Proficiency* are only issued on completion of each annual program of three “rounds”. Moreover, ASPAC provide details of certified laboratories by test on its public web site. Those certifications remain valid until superseded by corresponding findings from the next annual soil program.

Table 2.4. Statistical terms and their meanings in the context of this ASPAC annual report

<i>Statistical term</i>	<i>Meaning and/or derivation</i>
Count or number	Original population size.
Maximum i	The highest of a range of values, based on the initial data set.
Minimum i	The lowest of a range of values, based on the initial data set.
Median	The median is the score (value) at the 50 th percentile, also called the 2 nd quartile or 5 th decile. It is the score or potential score in a distribution of scores, above which and below which one-half of the frequencies fall. It is the middle observation of a sequentially sorted array of numbers, except in the case of an even sample size. Here it is the arithmetic mean of the two observations in the middle of the sorted array of observations. The median of a reasonably sized array of numbers is insensitive to extreme scores.
Mean ^A	The arithmetic mean (or average) is the sum of the values of a variable divided by their number. It represents the point in a distribution of measurements about which the summed deviations equals zero. The arithmetic mean is sensitive to extreme measurements.
MAD	The <u>M</u> edian of the <u>A</u> bsolute <u>D</u> eviations, calculated as the median of the absolute values of the observations minus their median.
Interquartile range (IQR)	This is calculated by subtracting the score at the 25 th percentile (referred to as the first quartile; Q ₁) from the score at the 75 th percentile (the third quartile; Q ₃). This value is affected by the assumptions made in the calculation of the first and third quartiles, particularly for low population sizes. Moreover, these differences exist within and across statistical software packages. Prior to the 2004-05 rounds, ASPAC used the algorithm employed by EXCEL and some others. For this program, the algorithm employed was that of SAS Method 4 ⁹ . In summary, IQR = Q ₃ -Q ₁ .
Normalized IQR	This equates to IQR x 0.7413, where the latter is a normalizing factor.
Robust % CV ¹⁰	The robust coefficient of variation (Robust % CV) = (100 x normalized IQR / median). For simplicity, the Robust %CVs shown are for the initial results, and for the “final” population of results for a test after the removal of any “outliers” or “stragglers”, following one or two iterations.
Integer “i” and the letter “f” associated with medians, means, MADs, IQR and Robust %CVs in data summaries.	The integer “i” relates to the initial data set. The letter “f” relates to the “final” data set, generated after one or two iterations, typically after removal of laboratories with statistical “outliers” (if any), and statistical “stragglers” (if any).

^A When the mean is greater than the median, the distribution is positively skewed. When the mean is lower than the median, the distribution is negatively skewed.

⁹ SAS Procedure Guide.

¹⁰ “Guide to NATA Proficiency Testing”. 27 pp. (National Association of Testing Authorities, Australia, December 1997).

3. Summary Statistics

This section provides summary data and associated statistics (values sometimes rounded for table formatting purposes) on all tests (plus key “pooled” combinations) for each of the 12 samples used across three soil “rounds” in 2020. The tabulations include initial and subsequent values for the iterative “median / MAD” procedure plus other parametric and robust statistics. Table 2.4 and Appendix 3 have the meaning or derivation of the terms and statistics used in the tabulated summaries.

2021: Air-Dry Moisture Content 2A1 (%)

Statistical parameters	Soil sample identification and values											
	<i>March 2021 (Round 3)</i>				<i>June 2021 (Round 6)</i>				<i>September 2021 (Round 9)</i>			
	ASS 2103-1	ASS 2103-2	ASS 2103-3	ASS 2103-4	ASS 2106-1	ASS 2106-2	ASS 2106-3	ASS 2106-4	ASS 2109-1	ASS 2109-2	ASS 2109-3	ASS 2109-4
No of results	32	32	32	32	29	29	29	29	32	32	32	32
Minimum	3.39	6.01	2.34	0.3	0.7	3.65	2.58	2.74	1.02	1.03	1.05	1.04
Maximum	7.69	9.03	4.76	7.42	1.64	8.11	7.3	4.2	3.4	3.6	6.01	5.79
Median i	4.39	7.49	2.81	0.908	1.11	7.2	4.93	3.73	2.59	3.1	5.46	4.17
Mean i	4.42	7.4	2.83	1.18	1.13	6.85	4.87	3.62	2.56	3.03	5.23	4.06
MAD i	0.275	0.465	0.185	0.1	0.11	0.58	0.36	0.16	0.155	0.2	0.245	0.235
IQR i	0.535	0.948	0.36	0.211	0.17	1.27	0.66	0.39	0.295	0.385	0.528	0.463
Robust CV % i	9	9	10	17	11	13	10	8	8	9	7	8
Median f	4.4	7.49	2.8	0.9	1.11	7.23	4.96	3.8	2.58	3.13	5.52	4.2
Mean f	4.36	7.4	2.77	0.889	1.13	7.16	4.96	3.79	2.57	3.15	5.45	4.18
MAD f	0.185	0.465	0.18	0.0945	0.08	0.5	0.33	0.12	0.1	0.16	0.195	0.2
IQR f	0.398	0.948	0.335	0.195	0.17	0.96	0.53	0.265	0.18	0.31	0.463	0.35
Robust CV % f	7	9	9	16	11	10	8	5	5	7	6	6
Outliers	4	0	1	3	3	3	4	6	4	3	2	4
Stragglers	2	0	0	1	1	0	0	0	3	0	2	1

4. Comments on Measurement Performance

The 12 soils tested in the 2021 program were sourced from a variety of geographic regions, with samples sourced from the USA, New Zealand, and from all Australian states except Western Australia. There were 7 soils tested that had been previously tested in 2019 and 2020.

This year half the soils in the program were alkaline. The two soils from Queensland were sodic soils, and one of them also highly saline. There were 4 acidic samples with measurable amounts of Aluminium between 0.15 and 2 cmol+/kg tested by laboratories this year, returning Robust CV%'s between 10 and 19. The remaining samples with no measurable Aluminium returned very high coefficients of variation, as would be expected from labs reporting "as measured" non-detectable concentrations.

No notable shift in test method performance was observed if considering the median of the 12 sample's coefficient of variations for each test method. As reported in Table 4.1, test methods with the widest and most narrow precision in 2021 were of a similar nature to the last few years with the best performing test methods comprised of Dumas combustion techniques, and both exchangeable and extractable cations, and those with less interlaboratory precision including aqua regia digestible elements.

Table 4.1. The six best performed and worst performed soil chemical tests for 2021, based on the median percent robust coefficients of variation (%CV as grand medians) of all twelve samples, after the removal of "outliers" and "stragglers", and excluding pH soil tests which are logarithmic and have been shown over the years to be in the range 1 - 2% CV.

Best (Lowest Robust %CVs)		Worst (Highest Robust %CVs)	
Soil Method	%CV	Soil Method	%CV
Total Carbon (6B2)	3	Aqua Regia Molybdenum (17B1/17B2/17C1)	31
Exchangeable Mg (15A1)	3	Aqua Regia Potassium (17B1/17B2/17C1)	31.5
Exchangeable Mg (15D3)	3	Exchangeable Al (15G1)	32.5
Extractable Mg - Mehlich3 (18F1)	3	"Aqua Regia" Silicon (17B1/17B2/17C1)	52
Extractable Ca - Mehlich3 (18F1)	3.5	Aqua Regia Boron (17B1/17B2/17C1)	62.5
Extractable K - Mehlich3 (18F1)	3.5	Aqua Regia Selenium (17B1/17B2/17C1)	66

Appendix 1: List of laboratories (including contact details) that participated in ASPAC's Soil ILPP in 2021, arranged by country

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Appendix 3: Statistical procedures used by ASPAC for its contemporary soil ILPP

Refer to Table 4 for a description of most statistical terms and their meaning. Of most significance is the “median / MAD” non-parametric, iterative procedure for identifying “outliers” (++) and “stragglers” (+) within datasets for particular tests and samples from multiple (typically 7 or greater) laboratories. See references in the body of the report for more details. Also, the median (μ) is regarded as a good estimate of the true mean, while the MAD; i.e., the median of the absolute deviations from the median, (@), is regarded as a good estimate of the standard deviation.

After tabulating the data with a separate column for each sample result and a separate row for each laboratory, calculations were applied iteratively. Each iteration operated at an action level of $[(X - \mu)/f@] > 2$, where “X” is the value reported by the laboratory (one replicate assumed), “ μ ” is the median of the population of values, and “f@” is a code for the Gaussian distribution of the sample size “n”, approximated by $[0.7722 + 1.604/n * t]$, with t = the Student’s “t” of 5% (two tailed), with n-1 degrees of freedom]. Note that for program reports up to and including 2009-10, Student “t’s” of 2.5% (two-tailed) were used.

Excluding any case when a laboratory reported no result (or a non-numeric value) [these were automatically excluded], the laboratories at first iteration with an “ASPAC score” > 2 were rated as “outliers” (++) . Following their removal (if any), the remaining population of laboratory data were subject to a second iteration involving a recalculation of the “ASPAC score”. Where this was again > 2 , relevant laboratories were rated as “stragglers” (+). The revised Student “t” at 5% (two tailed) makes the test slightly stricter than previously.

The other statistics summarized in Table 4 were calculated on the same populations of data. Only the first (i) and second (final; f) values appear in the data summaries in Section 3.

50033	2A1	3.8	6.9	2.4	1	1.4	7.5	5.1	4.1	2.5	2.9	5.2	4
50036	2A1	4.1	7.3	2.8	0.8	0.7 ††	6.4	4.3	3 ††	2.5	3.1	5.5	4
50037	2A1	3.39 ††	6.01	2.63	0.932	1.09	6.08	4.44	3.11 ††	2.65	3.28	5.55	4.25
50038	2A1	4.63	8.13	2.82	0.77	0.902	7.08	4.86	3.66	2.53	3.22	5.44	4.35
50038	2A1	4.19	8.07	2.91	0.86	0.953	7.12	4.93	3.74	2.52	3.27	5.52	4.39
50038	2A1	4.24	7.92	2.63	0.91								
50039	2A1	4.4	7.89	2.61	0.87	1.12	7.89	5.24	3.57	2.35	3.07	5.53	4.11
52435	2A1	4.52	6.94	2.93	0.852	1.23	6.84	4.54	3.59	2.46	2.9	4.89	3.49 †
52437	2A1	14.9 ††	24.6 ††	9 ††	3.1 ††	4.43 ††	28.1 ††	17.3 ††	13.4 ††	1.21 ††	1.32 ††	2.35 ††	1.72 ††
52491	2A1	4.4	7.84	2.59	0.74	0.868	6.83	4.34	2.74 ††	2.13 †	2.26 ††	4.69 †	3.37 ††
52526	2A1	3.99	6.53	2.34	0.6	0.7 ††	5.8	3.6 ††	2.8 ††	2.5	2.9	5.2	4
52527	2A1	4.7	7.5	3.1	1.2	1.4	7.4	5.4	4.2	3 †	3.4	5.7	4.4
52565	2A1	4.38	7.46	2.83	7.42 ††	1.18	8.11	5.33	3.89	2.43	2.88	5.45	4.22
52636	2A1	4.39	7.64	2.67	0.819	1.1	7.67	2.58 ††	3.63	2.57	3.13	5.58	4.13
52676	2A1	68.9 ††	7.2	2.4	0.8								
52688	2A1	4.25	7.48	2.67	0.98	1.22	7.88	5.33	3.73	2.5	3	5.3	4.2
52692	2A1	3.9	2.5 ††	2.2	1.3 ††	1.6 ††	7.3	3.3 ††	2.8 ††	1.6 ††	7.3 ††	3.3 ††	2.8 ††
52703	2A1									2.71	3.24	5.93	4.4
52847	2A1									2.3	2.8	5	3.8

52636	4B1	4.86	7.67	7.32	3.94	4.69	7.67	7.41	5.91	4.22	7.48 ††	7.76	5.9 ††
52692	4B1	4.65	7.56	7.18	3.76 ††	4.67	7.22 ††	6.97 ††	5.91	3.9 ††	7.37 ††	7.56 ††	5.39 ††

