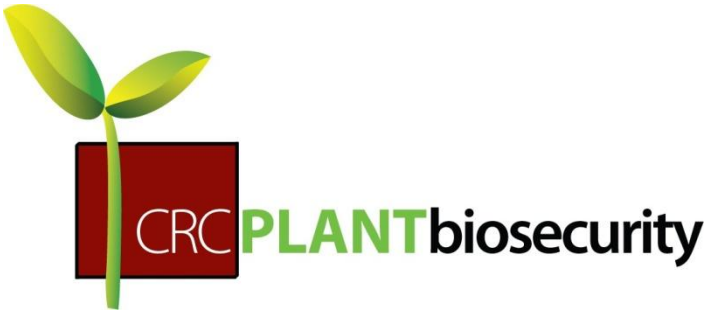

Cooperative Research Centre
for National Plant Biosecurity

Final Report

CRC40121

Biosecure packaging for the Transport of Emergency Plant Pest samples

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Table of contents

1 Executive Summary

This project (CRC40121) was developed from a recommendation of CRC40035 (Risk management processes for the movement of samples during an Emergency Plant Pest (EPP) incursion), to develop practical packaging standards to enable the safe, swift and legal transport of plant, soil and insect samples nationally and internationally. The recommendations resulting from this research will need to be endorsed by the various state and federal authorities in separate negotiations to further streamline the delivery of plant diagnostic samples by removing the requirement for movement certification.

The packaging recommendations and requirements were collated from surveys of over 30 government and private laboratories involved in the collection, diagnosis and transport of plant, insect and soil specimens. Laboratories were surveyed by either letter, personal contact or interrogation of website information.

Research of current legislation, including International Air Transport Association (IATA) packaging requirements for infectious substances category A and B, was carried out to identify testing methods for selected packaging. Tests selected were 1) a gravity drop test: dropping the packaged sample from 9 m and 2 m onto a hard surface; 2) temperature and drop testing: freezing the packaged sample for 24 hours then dropping 2 m onto a hard surface and 3) crush testing: placing the packaged sample under a weight representing 3m of the same packaging, as if the parcel was at the bottom of a 3m pile of similar packages.

Samples were packaged in the triple layer method of primary, secondary and tertiary packaging, with tests undertaken on primary alone, primary and secondary, and the triple package. Combinations of samples and different packaging were also sent via regular post and courier intrastate and interstate to evaluate the integrity of the various packages.

Results showed that the type of sample determined the triple packaging combination required. Packaging that failed testing as a primary package often maintained integrity when protected inside the secondary and tertiary packaging. For example, supermarket purchased freezer bags regularly split when filled with soil, seed or woody stems, however they maintained integrity when packed with light weight herbaceous material inside a more solid bag such as a press seal bag. Plastic food containers with screw lids, clip-on or normal lids could be easily deformed, split and crushed when not protected inside solid containers with padding. Paper envelopes were not suitable irrespective of the contents and padded bags and tough bags were unreliable in protecting odd shaped secondary packaging such as plastic food containers or 70 ml pots.

When packages were more than half full with heavy items such as seed or soil, the package integrity was not maintained. Soft fruit and items in liquid were found to require specialist leak proof vessels, such as screw cap liquid specimen jars. The safe transport of woody stems was best achieved when the stems were

wrapped in paper prior to placing in the primary packaging to prevent the packaging being pierced. Fragile items such as culture plates were best protected by wrapping in a protective layer such as bubble-wrap before placing in a primary package.

Primary packaging that proved reliable included press seal bags, 70 ml plastic screw cap specimen containers and 10 ml plastic screw cap tubes. Press seal bags were also the most reliable secondary packaging and worked well together as both the primary and secondary packaging. Kitchen sponges from the supermarket placed within the secondary package were a satisfactory absorbent for potential leakage for objects in fluid. Products purchased from Australia Post and commercial packaging companies such as Adelaide Packaging Supplies were generally stronger and more reliable than supermarket packages and were good forms of tertiary packaging. These included Tough bags, padded bags, and corrugated cardboard boxes. Irrespective of the sample or type of packaging, the primary/secondary combination should be secure within the tertiary package, in particular when corrugated cardboard boxes and biobottles are used to prevent the samples being tossed around.

Specialist biobottles available commercially for category B infectious substances transport passed all the testing and are highly recommended, however these are expensive and not as readily available for growers.

Express Post bags were not suitable as primary, secondary or tertiary packages due to holes in the bags from the manufacturing process. They were useful only as a fourth layer for registered postage and quick delivery.

There was no difference in integrity of packages when transported via post or courier.

Recommendations for suitable biosecure packaging for diagnostic samples have been developed for each sample type. This information should be disseminated to stakeholders as a CRC branded guide or pamphlet.

2 Aims and objectives

The aim of this project was to develop protocols acceptable to all relevant stakeholders for biosecure packaging to enable the safe, swift and legal transport of plant, soil and insect samples nationally and internationally.

The objective was to identify suitable packaging and formulate guidelines for transport of Emergency Plant Pests (EPP) consistent with UN regulations.

Using biosecure packaging will reduce the risks involved with movement of samples potentially containing EPP's within Australia and internationally, and the aim of this project was to develop packaging standards that can be used for the secure and legal containment and transport of these samples for diagnosis. In the

recent independent review of SPHDS, a sub-committee of plant health committee, (PHC) on plant health diagnostic standards, the difficulties with packaging and transport of test samples between states was highlighted as an issue that must be resolved to ensure the development of a successful national diagnostic system for EPPs. In addition, we were advised that the recently proposed changes to the UN regulations for transport of dangerous goods would include quarantine plant pathogens in the definition of infectious agents. Unless this issue is addressed it is likely that the movement of samples between diagnostic laboratories during an incursion will be illegal under the current plant health acts of the states and territories and will not be accepted by Australia Post or courier companies due to their dangerous goods status.

This project addressed one of the recommendations of the Project CRC40035, which reviewed the process of moving EPP samples during incursions and determined critical control points to manage risks.

3 Key findings

3.1 Technical report

3.1.1 Materials and Methods

3.1.1.1 Engagement with Stakeholders

Emails invited stakeholders involved in the collection, diagnosis and transport of plant, insect and soil specimens in over 30 government and private laboratories within Australia to participate in the project through sharing of information via a survey (Appendix 1).

Websites of diagnostic organisations were viewed to gain an understanding of their requirements and current recommendations when collecting and packaging samples for diagnostics.

3.1.1.2 Packaging Performance Tests

The tests were based on the IATA *Infectious Substances Shipping Guidelines* chapter 6 (ref 3). Packages were purchased from commercial suppliers and tested alone and in combination with different contents to test the effects of different combinations on maintaining package integrity. Packages were deemed to have failed if the integrity of the package was compromised, or the sample was not maintained in a suitable condition for testing.

Packaging contents

Packaging was filled with items commonly sent to diagnostic laboratories and included soil, seed, woody stems, herbaceous plants, soft and hard fruit or

vegetables, fluid with seed (to represent insects in medium) and culture plates (Petri-dish with agar medium).

Packaging

Packaging was sourced from commercial packaging companies such as Adelaide Packaging Supplies, Sarstedt, Australia Post and local supermarkets (Table 1). Samples were placed in single, double then triple packaging of varying combinations prior to testing.

Table 1. Packaging tested.

Type	Name/brand	Purchased from
Freezer bags	Coles® own brand	Local supermarket
Press seal bags (approx 50µm)	Glad®, Multix®	Local supermarket
Solid plastic containers with clip lid	Glad®	Local supermarket
Hard plastic containers with non clip lid	Décor Tellfresh®	Local supermarket
Screw cap containers, soft side rigid base	Multix®	Local supermarket
Hard plastic screw cap container	Glad®	Local supermarket
Express Post bag	Australia Post®	Australia Post
Thick card bag	Tough Bag	Adelaide Packaging Supplies
Padded post bag		Adelaide Packaging Supplies
A4 Envelope	Craft® envelope	Australia Post
Bubble wrap		Australia Post
Cardboard box, with corrugated cardboard	Australia Post®	Australia Post
Bio bottle	Diagnostic product range P.I. 650 UN3373	BioBottle Australia
70 ml screw cap plastic specimen container	75.9922.723	Sarstedt
10 ml plastic tube with screw cap	62.9924.284	Sarstedt
Sponge	Edco®	Local supermarket
Newspaper		Local newsagent
Predicta B root test kit		SARDI Diagnostics
Soil and plant material kits		APAL, Australian Perry Laboratory
Wine sample collection bottles		Australian Wine Research Institute

Performance tests

Packages were tested at 98% capacity and at 100-250 g weight of contents, procedures as per Chapter 6, IATA Infectious Substances Shipping Guidelines 9th (2008) and 10th (2009) editions (ref 3).

Drop test

- Drop test free fall from 9 m on to rigid, flat, horizontal surface (IATA infectious substances A standards).
- Drop test free fall from 2 m (IATA infectious substances standards minimum height is 1.2 m).

Freeze and drop test

- Drop test free fall from 2 m following temperature preconditioning of 24 hrs at -20°C, drop test within 15 min of removal from freezer (IATA infectious substances B standards).

Stacking test

- Packages placed for a period of 24 hrs under a weight equivalent to the total weight of identical packages if stacked to a height of 3 m.

Transport tests

Samples were packaged in triple packaging that had maintained integrity in laboratory tests and sent via TNT couriers to three interstate diagnostic laboratories or via Australia Post to four laboratories. Recipients completed a reporting form on the condition of the package and the sample (Appendix 2). Packages were deemed to have failed if the integrity of the package was compromised, or the sample was not maintained in a suitable condition for testing.

3.1.2 Results

3.1.2.1 Stakeholder engagement

Fifteen of 30 identified stakeholders responded to the written inquiries and four to phone interviews, with 12 websites for private agriculture companies, diagnostic companies and government departments accessed for relevant packaging information.

Most stakeholders provide packaging instructions on their web site or will supply verbal instructions on request. Companies that provide a kit for sample collection include packaging instructions. These recommendations are aimed at ensuring samples arrive in good condition for diagnosis with two respondents structuring their recommendations to IATA triple packaging guidelines. The majority of samples received by diagnostic laboratories are considered low risk and are often for export testing requirements. For these samples double bagging is considered sufficient but one laboratory is developing new recommendations for high risk materials.

Researchers collecting material from the field for transport tend to double bag, while samples collected for posting are packaged to a high standard.

3.1.2.2 Packaging performance tests

The thicker press seal bags were the most consistently effective primary or secondary packaging for most samples. The exception was woody stems, which unless pre wrapped with paper, pierced the plastic. Fragile samples needed to be supported in the packaging with filler such as newspaper to prevent movement.

Results for all the tests are tabled in Appendix 3.

Drop test - Free fall 9 m onto hard surface

Primary package only:

The following package and sample combinations failed.

- All packages filled to capacity (Fig 1).
- Freezer bags with heavy sample.
- All press seal bags full with seed or soil.
- Plastic containers with soil or seed (Fig 2).
- All hard plastic containers.
- Tough bags, envelopes with heavy sample (Fig 1).
- Envelopes.
- 70 ml screw cap specimen container.
- Express post bags (manufacturing holes).

Figure 1. Press seal bags filled completely with seed (left), or paper bags with soil (right) did not maintain integrity when dropped 9m.

The following package and sample combinations passed.

- Press seal bags with 100g of seed, woody stems, and soft fruit (culture plates and fruit were damaged if not protected with additional wrapping).
- Plastic containers with light weight herbaceous materials or soft fruit and vegetables (Fig 2).
- Corrugated cardboard boxes and biobottles.

Figure 2. plastic containers dropped from 9m maintained integrity when used for light herbaceous material (left), but not with soil or seed (right).

Primary and secondary packaging:

The following package and sample combinations failed.

- Plastic containers failed in the less sturdy packaging of express post bags and envelopes.
- Plastic containers deformed or split on impact when containing soil, seed and hard fruit or vegetables.
- Envelopes failed with soil and seed, and were easily damaged with all other samples.
- Freezer bags often failed.
- Express Post bags, Jiffy and Tough bags did not maintain integrity as secondary packaging when the primary bags were filled to capacity with seed or soil.
- Plastic containers deformed but were less likely to split inside Tough bag, padded bag, corrugated cardboard box or another plastic container, or with light weight materials such as herbaceous leaves.

The following package and sample combinations passed.

- Press seal bags in Tough Bag (except soil), padded bag, corrugated cardboard box or another press seal bag.
- 70 ml pots packed in press seal bags, envelope, Jiffy and Tough bags.
- Corrugated cardboard boxes as secondary packages.
- Plastic containers remained undamaged with light weight materials.

Drop Test: Triple packaging free fall 2 m onto a hard surface

The following package and sample combinations failed.

- Press seal bags with 100g seed contained within press seal bags and plastic container.
- Press seal bags with 100g soil in plastic container and envelope.
- Freezer bag with 100g seed within a plastic container and padded bag.
- Freezer bag with herbaceous material within a plastic container and tough bag.

- Freezer bags with soft fruit inside secondary packaging of press seal bags, plastic containers and Tough bags.
- Unwrapped woody stems pierced all press seal bags and freezer bags even when triple packed.
- Plastic container carrying a 70 ml pot half full with water cracked when in an envelope as the tertiary package.

All other combinations of packaging with a range of samples passed.

Drop Test: Triple packaging Temperature conditioning at -20°C for 24 hours then free fall 2 m onto a hard surface

Packages were more easily damaged following temperature treatment. The following failed.

- The 70 ml pots containing frozen liquid broke when dropped.
- Freezer bags with soil or seed (data not shown).
- Plastic containers with soil or seed.
- Envelopes.

All other combinations of packaging with a range of samples passed.

Stacking test

Triple packaged samples were placed under an equivalent weight as if 3m of the same packages were stacked on top. This is a static test and does not include any movement to simulate actual transport which would greatly increase the risk of damage to the packaging

- Freezer bags with woody stems or soil failed.
- All other packaging combinations passed.

Posting or courier transport of triple packaging,

There was no difference between postage or courier so results have been combined.

Primary Packages:

- Freezer bags containing seed, soil and woody stems failed consistently resulting in a loss of contents into the secondary package.
- Freezer bags were more likely to maintain integrity when containing herbaceous plant material.
- The use of freezer bags was discontinued after the first set of posted packaging as they proved unreliable.
- Press seal bags with seed, soil and herbaceous material maintained integrity.
- Woody stems punctured primary packages.
- Woody stems wrapped in bubble wrap punctured primary packages (Fig 3).

- Woody stems wrapped in wet or dry newspaper did not puncture primary packaging.
- 70 ml pots and 10 ml tubes containing seed, liquid and soft fruit did not puncture or leak.
- Culture plates wrapped in bubble wrap arrived undamaged with no loss of agar from the plates.
- Damaged plastic secondary containers were found to puncture primary packaging.

Secondary packages:

- Woody stems punctured primary and secondary packages when combinations of freezer bags and press seal bags were used (Fig 3).
- Woody stems did not puncture different types of plastic containers.
- All types of plastic containers in Tough and Express Post bags were dented, cracked or crushed with some damage to the primary package, allowing loss of contents into the tertiary package (Fig 4).
- Plastic containers padded inside corrugated cardboard boxes to prevent movement arrived intact.

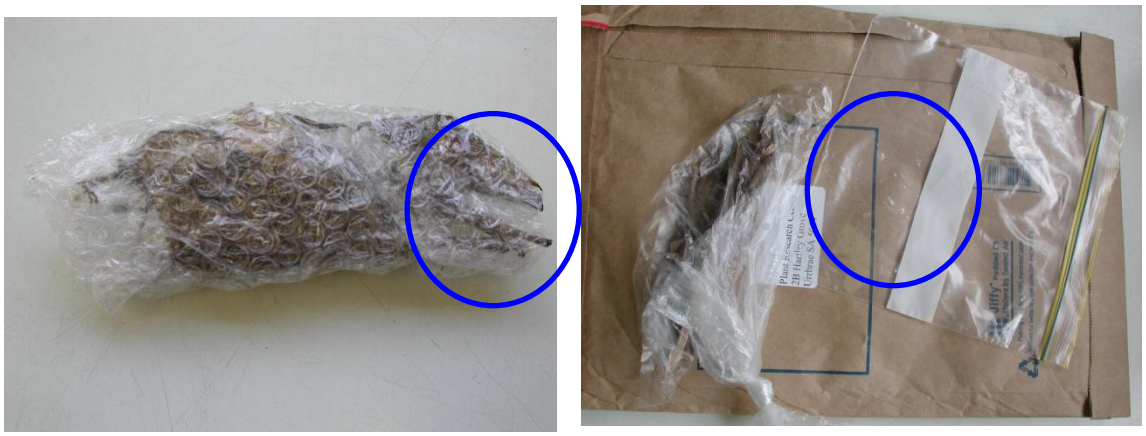

Figure 3. Woody stems puncture bubblewrap (left) and when placed unwrapped in plastic bags also punctured the secondary packaging (right).

Tertiary packages:

- As press seal bags were not sufficient to hold woody stems another set of packages was posted with the stems first wrapped in bubble wrap before placement into a press seal bags as primary container. This system also failed, the woody stem went straight through the bubble wrap, primary and secondary containers and even one tertiary package.
- Woody stems wrapped in wet or dry newspaper did not puncture packaging.
- The majority of Tough bags and padded post bags arrived undamaged when contents were in freezer or press seal bags (Fig 4) except for one punctured Tough bag containing woody stems. Occasional minor damage occurred to these bags when odd shaped internal packaging was used

such as 70 ml pots and plastic containers. However one bag of each failed when the glue holding the package together did not hold.

- Several Australia Post Cardboard boxes were dented or slightly torn in the corners but there was no damage to the secondary or primary packaging, including plastic containers.

Figure 4. Plastic containers inside Tough bags did not survive postage while the Tough bag maintained integrity (Left). A small amount of soil leaked from primary press seal bag but was contained within the secondary press seal bag when posted in a Tough bag (right).

3.1.3 Conclusions

The type of packaging and the way the samples are packaged is important in maintaining the integrity of packages to ensure that samples are delivered securely and in good condition.

For example plastic containers packaged loose inside Tough bags or padded envelope style bags were not sufficiently protected and some were crushed. However the same containers remained intact when packaged inside corrugated cardboard boxes secured with scrunched up newspaper to prevent movement.

Fragile and sharp items required extra padding with specific items to prevent then either braking or puncturing the packaging, for example using bubble wrap with culture plates and wrapping woody stems in newspaper. Generally corrugated cardboard boxes were a good tertiary packaging; although they were occasionally dented in the corners they remained intact.

The packaging is even more important when samples are to be sent longer distances. Packaging of samples sent interstate was more likely to fail than samples send locally, possibly due to the increased handling.

There was no advantage in using either a courier company or Australia Post regarding the integrity of the package: weaker packaging failed by either method of transport.

3.1.4 References

1) Australian Standard® AS 4834-2007, *Packaging for surface transport of biological material that may cause disease in humans, animals and plants*, Standards Australia, Sydney

2) Australian Quarantine & Inspection Services, *Movement protocol for live/viable quarantinable material for OPS analysis*, Department of Agriculture, Fisheries and Forestry

3) *Infectious Substances Shipping Guidelines 10th Edition*, International Air Transport Association, Montreal-Geneva 2009

4) Plant Health Australia, *Emergency Response Deed*, Department of Agriculture, Fisheries and Forestry

5) United Nations, *Transport of Dangerous Goods Model Regulations 16th edition* Vol I and II, E.09.VIII.2, 978.92-1-139136.7, New York and Geneva 2009

6) Australia Post website http://auspost.com.au/index.html

3.2 Recommendations for biosecure packaging

Recommended triple packaging combinations for maintaining integrity of the samples are:

- Soil or seed:
  - Primary package – press seal bag, no more than ½ full
  - Secondary package – press seal bag
  - Tertiary packaging – tough bag, padded bag, corrugated cardboard box or biobottle

- Herbaceous material
  - Primary package – press seal bag
  - Secondary package – press seal bag
  - Tertiary packaging – tough bag, padded bag, corrugated cardboard box or biobottle

- Woody stems
  - Primary package – moist or dry newspaper then press seal bag
  - Secondary package – press seal bag
  - Tertiary packaging – tough bag, padded bag, corrugated cardboard box or biobottle

- Culture plates or tubes
  - Primary package – bubble wrap then press seal bag
  - Secondary package – press seal bag

- Tertiary packaging – tough bag, padded bag, corrugated cardboard box or biobottle

- Fruit and vegetables
  - Primary package –
    - A-70 ml screw cap specimen container
    - B- Press seal bag
  - Secondary package –
    - A- absorbent sponge and press seal bag
    - B – plastic container
  - Tertiary packaging – corrugated cardboard box or biobottle

- Insects/samples in liquid
  - Primary package – 10 to 70 ml screw cap specimen container
  - Secondary package – absorbent sponge and press seal bag
  - Tertiary packaging – corrugated cardboard box or biobottle

Note: all packaged samples within a corrugated cardboard box or biobottle **must** be padded to prevent movement of the packaged sample within.
The press seal bags should be at least 50µm thick.

4 Implications for stakeholders

The findings are relevant to the movement of diagnostic samples, particularly for identification during incursions and the subsequent surveillance requirements. These findings are also relevant to the movement of international samples, both to and from Australia.

The recommended packaging methods could be used as a basis for sending and receiving all samples, with recommendations provided by receival laboratories being the best method for packaging.

If negotiations are successful with the various sate and federal authorities the requirement for movement certification could be removed when samples are packaged in the recommended packaging. This would mean the movement of samples between designated laboratories could be streamlined for both ad hoc samples and during incursion management.

The findings will also provide assurance to all persons submitting samples to a laboratory for diagnosis, including samples for routine non quarantine testing, that the samples will arrive complete and in a suitable condition.

5 Recommendations

- That the CRCNPB endorse the recommendations for biosecure packaging.

- That the CRCNPB produce a pamphlet or similar outlining the recommendations to be supplied freely through the laboratories, post

offices and on web sites etc for access by persons needing to package samples for diagnostics.

- That the CRCNPB through SPHDS and PHC negotiate with the respective state and federal authorities to streamline sample movement between laboratories by minimising the paperwork required when using the endorsed packaging.

6 Abbreviations/glossary

ABBREVIATION	FULL TITLE
CRCNPB	Cooperative Research Centre for National Plant Biosecurity
EPP	Emergency plant pest
IATA	International Air Transport Association
PHC	Plant Health Committee
SPHDS	Subcommittee for Plant Heath Diagnostic Standards

7 Plain English website summary

CRC project no:	CRC40121
Project title:	Biosecure packaging for the Transport of EPP samples
Project leader:	Barbara Hall
Project team:	Mrs Barbara Hall Dr Kathy Ophel Keller Dr Alan McKay Dr Pauline Glocke Ms Tanya Matic Ms Jan Gooden Dr Nancy Kelly Ms Dominie Wright Dr James Cunnington
Research outcomes:	The outcome of this research was that there are suitable packaging products readily available from supermarkets, Australia Post and commercial packaging suppliers that can be used to provide effective and secure packaging of the full range of potential diagnostic samples. Protocols for biosecure packaging have been developed that use products that are readily

	available, conform to IATA specifications, and maintain integrity of sample contents when posted or couriered between laboratories.
Research implications:	These packaging protocols are relevant to the movement of both routine diagnostic samples and quarantine samples for diagnosis, both domestically and internationally. The recommended packaging methods could be used as a basis for sending and receiving all samples and be provided by receival laboratories as a best method for packaging. There is the potential for streamlining sample movement between laboratories by alleviating some of the paperwork required providing assurance that the samples will arrive complete and in a suitable condition.
Research publications:	Development of Biosecure Packaging for Transport of Emergency Plant Pest Samples, Global Biosecurity 2010 Conference Abstract and Poster.
Acknowledgements:	Dr Nancy Kelly, Ms Dominie Wright, Dr James Cunnington for participating in the survey of posted packaging. Mrs Jan Gooden for all her help and information from the first phase CRC 40035

8 Appendices.

8.1 Appendix 1. Survey form for stakeholders.

CRC40121

Biosecure packaging for the Transport of EPP samples

E-mail Response to Packaging Samples

Company/Individual	Date Replied	Items received for testing	Kit supplied or purchased	Information supplied

8.2 *Appendix 2. Evaluation form for packaging and contents.*

Packaging Survey CRC 40121

Please fill out the questions below and return to Pauline Glocke at either
Fax 08 8303 9424: or post to: Plant Research Centre, Hartley Grove Urrbrae 5064

or Email pauline.glocke@sa.gov.au

Type of packaging

Tertiary
Secondary
Primary
Contents

The integrity of the packaging	**Please circle. If yes, describe damage.**
Are there any puncture/breaks/tears in the outer tertiary packaging	
Yes / No	
Are there any puncture/breaks/tears in the secondary packaging	
Yes / No	
Are there any puncture/breaks/tears in the primary packaging	
Yes / No	

Contents

Have the contents of the package	**Please circle. If yes, describe extent of loss.**
Escaped from the primary packaging	
Yes / No	

Escaped from the primary packaging but contained within the secondary

	Yes		No	

Escaped from the secondary packaging but contained within the tertiary

	Yes		No	

Escaped from the tertiary packaging

	Yes		No	

8.3 Appendix 3. Results tables for packaging tests.

Table 2. Results of primary packaging with drop test - Free fall 9 m onto hard surface. √= passed; X = failed; - = not tested. For packaging descriptions see Table 1.

	Contents of the package					
Primary package	**Seed**	**Soil**	**Woody Stems**	**Herb*. material**	**Fruit**	**Culture Plates**
Freezer bag	X	X	√	√	√	X
Freezer bag full	X	X	-	-	-	-
Press seal 100g	√	√	√	√	√	X
Press seal full	X	X	-	-	-	-
Solid plastic	X	X	√	√	√	X
Hard plastic	X	X	√	√	-	X
Plastic crew cap	X	X	-	-	X	X
Express bag	-	-	-	-	X	√
Tough bag 100g	√	√	X	√	√	√
Tough bag full	X	X		-	-	-
Padded bag 100g	√	√	√	√		√
Padded bag full	X	X		-	X	-
Craft A4 envelope	X	X	X	√	X	√
70 ml specimen	X	-	-	-	-	-
Corrugated cardboard box	-	-	-	-	-	X

*Herbaceous material (leaves, flowers, soft non-woody stems and roots)

Table 3. Results of primary and secondary packaging with drop test - Free fall 9 m onto hard surface.√= passed; X = failed; - = not tested (Primary package result on the left, secondary on the right). For packaging descriptions see Table 1.

Primary/ Secondary package	**Results of primary secondary packages with various contents**						
	Water	**Seed**	**Soil**	**Woody Stems**	**Herb* material**	**Fruit**	**Culture Plates**
Freezer/freezer bag 100 g	-	X √	√ √	√ √	X √	√ √	√ √
Freezer/press seal 100g	-	√ √	√ √	√ √	-	√ √	√ √
Freezer/solid plastic	-	X X	-	-	-	X √	-
Freezer hard plastic	-	X X	X X	-	-	X √	-
Freezer/ Express	-	X X	X X	X X	X X	√ √	√ √
Freezer/Tough	-	X √	X √	√ √	X √	√ √	√ √
Freezer/ Padded	-	√ √	X √	X √	X √	√ √	√ √
Freezer/envelope	-	X √	X X	X √	X √	X √	√ X
Freezer/box	-	X √	X √	-	-	-	-
Freezer/plastic screw cap	-	-	X √	-	-	X X	-
Press seal/press seal	-	X √	√ √	√ √	√ √	√ √	√ √
Press seal/solid plastic	-	√ √	√ √	-	-	X √	-
Press seal/hard plastic	-	√ √	-	√ √	-	X √	-
Press seal/Express	-	√ X	X X	√ √	√ √	X √	√ √
Press seal/Tough	-	√ √	X X	√ √	√ √	√ √	√ √
Press seal/padded	-	√ √	X √	√ √	√ √	√ √	√ √
Press seal/envelope	-	X √	X X	√ √	√ √	√ √	√ X
Press seal/box	-	√ √	√ √	-	-	-	-
Press seal/plastic screw cap	-	-	X X	X X	-	-	-
Hard plastic/Express bag	-	X X	X X	√ √	√ √	X √	-
Hard plastic/Tough	-	X √	X √	√ √	√ √	-	-
Hard plastic/Padded	-	√ √	√ √	X √	√ √	-	-
Hard plastic/envelope	-	√ X	X √	√ √	√ √	√ X	-
Hard plastic/box	-	√ √	-	-	-	-	-
Envelope/Express	-	X X	X √		√ √	X √	√ √
Envelope/Tough bag	-	X √	X √	X √	√ √	√ √	√ √
Envelope/Padded bag	-	√ √	X √	√ √	√ √	√ √	√ √
Envelope/envelope	-	X √	X √	X √	X √	√ √	X √

Primary/ Secondary package	Results of primary secondary packages with various contents						
	Water	**Seed**	**Soil**	**Woody Stems**	**Herb* material**	**Fruit**	**Culture Plates**
Plastic screw cap/box	-	-	X X	-	-	-	-
70 ml/press seal	√ √	-	-	-	-	-	-
70 ml/Tough	√ √	-	-	-	-	-	-
70 ml/padded	√ √	-	-	-	-	-	-
70 ml/envelope	√ √	-	-	-	-	-	-

*Herbaceous material (leaves, flowers, soft non-woody stems and roots)

Table 4. Results of triple packaging with drop test - Free fall 2 m onto hard surface. √ = passed; X = failed; - = not tested (primary on left, secondary in middle, tertiary on the right). For packaging descriptions see Table 1.

	Result of primary/secondary/tertiary packaging with different contents						
Triple packaging	**Water**	**Seed**	**Soil**	**Woody Stems**	**Herb* material**	**Fruit**	**Culture Plates**
2 press seal in Express	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
2 press seal in Tough	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
2 press seal in padded	-	√ √ √	√ √ √	X √ √	√ √ √	-	-
2 press seal in envelope	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
2 press seal in box	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
2 press seal in screw cap	-	X √ √	√ √ √	X √ √	√ √ √	-	-
Freezer/press seal/Express		√ √ √	√ √ √	X √ √	√ √ √		
Freezer/press seal/Tough	-	√ √ √	√ √ √	X √ √	√ √ √	X √ √	-
Freezer/ press seal/ padded	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
Freezer/press seal/ envelope	-	√ √ √	√ √ √	X √ √	√ √ √	-	-
Freezer/ press seal/ box	-	√ √ √	√ √ √	X √ √	√ √ √	-	-
Freezer/ press seal/ screw cap		√ √ √	√ √ √	X X X	√ √ √	X √ √	X √ √
Freezer/ plastic/ Express	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
Freezer/ plastic/ Tough	-	√ √ √	√ √ √	X √ √	X √ √	-	-
Freezer/ plastic/ padded	-	X √ √	√ √ √	X √ √	√ √ √	X √ √	-
Freezer/ plastic/ envelope	-	√ √ √	√ √ X	X √ X	√ √ √	-	-
Freezer/ plastic/ box	-	√ √ √	√ √ √	X √ √	√ √ √	-	-
Press seal/plastic/express	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
Press seal/ plastic/ Tough	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
Press seal/plastic/padded	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
Press seal/ plastic/ envelope	-	√ √ √	X √ √	√ √ X	√ √ X	√ √ X	-
Press seal/ plastic/ box	-	√ √ √	√ √ √	√ √ √	√ √ √	-	-
Pot/ press seal/ envelope	√ √ X	-	-	-	-	-	-
Pot/plastic/envelope	√ X √	-	-	-	-	-	-

*Herbaceous material (leaves, flowers, soft non-woody stems and roots)

Table 5. Results of triple packaging with freezing (-20°C for 24 hours) drop test - Free fall 2 m onto hard surface. √= passed; X = failed; - = not tested (primary on left, secondary in middle, tertiary on the right). Woody stems and fruit were not tested. For packaging descriptions see Table 1.

	Result of primary/secondary/tertiary packaging with different contents		
Triple packaging	**Seed**	**Soil**	
Press seal/ screw cap/ Tough	√ X √	X X √	
Press seal/ screw cap/ padded	√ √ √	√ X √	
Press seal/ screw cap/ envelope	X X X	-	
Press seal/ screw cap/ box	√ √ √	√ X √	
Press seal/ plastic/ Tough	√ √ √	√ √ √	
Press seal/ plastic/ padded	√ X √	√ X √	
Press seal/ plastic/ envelope	√ √ X	√ X X	
Press seal/ plastic/ box	√ √ √	√ √ √	
Press seal/ bio bottle/ box	√ √ √	-	
	Culture Plates		
Press seal/ bubble wrap/ Express	√ √ √		
Press seal/ bubble wrap/ Tough	√ √ √		
Press seal/ bubble wrap/ padded	√ √ √		
press seal /bubble wrap/ box	√ √ √		
2 press seal/ screw cap	√ √ √		
	Water		
Pot & sponge/ press seal/ Tough	√ √ √		
Pot & sponge/ press seal/ padded	√ √ √		
Pot & sponge/ press seal/ envelope	√ √ √		
Pot & sponge/ press seal/ box	√ √ √		
Pot & sponge/ press seal/ press seal	X √ √		
Pot & sponge/ plastic/ Tough	√ √ √		
Pot & sponge/ plastic/ padded	√ X √		
Pot & sponge/ plastic/ envelope	√ √ √		
Pot & sponge/ plastic/ box	√ X √		
Kits	**Water**	**Soil**	**Herbaceous material***
Soil kit (SARDI diagnostics)	-	X √ -#	-
Soil kit (APAL)	-	√ √ √	-
Wine kit (AWRI)	√ √ √		-
Plant material kit (APAL)	-	-	√ √ √

*Herbaceous material (leaves, flowers, soft non-woody stems and roots)

No tertiary package provided

Table 6. Results of triple packaging crush test on soil and woody stems. Packaged samples were placed under an equivalent weight as if 3m of the same packages were stacked on top. √= passed; X = failed; - = not tested (primary on left, secondary in middle, tertiary on the right). For packaging descriptions see Table 1.

	Result of primary/secondary/tertiary packaging with different contents	
Triple packaging	**Soil**	**Woody Stems**
Press seal / press seal/ Tough	√ √ √	√ √ √
Press seal / press seal/ padded	√ √ √	√ √ √
Press seal / press seal/ box	√ √ √	√ √ √
Freezer/ press seal/ Tough	X √ √	x √ √
Freezer/ press seal/ envelope	√ √ √	√ √ √
Freezer/ press seal/ box	√ √ √	√ √ √
Press seal/ plastic/ Tough	√ √ √	√ √ √
Press seal/ plastic/ padded	√ √ √	√ √ √
Press seal/ plastic/ box	√ √ √	√ √ √
Press seal/ screw cap/ Tough	√ √ √	√ √ √
Press seal/ screw cap/ padded	√ √ √	√ √ √
Press seal/ screw cap/ box	√ √ √	√ √ √