Institute for
Agri-Food Research and Innovation

Validating and using new methods for detecting plant diseases

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Validating and using a new detection method

- Validation?
- Mathematical odyssey
- Example: screening symptomatic plants for phytophthora ramorum using a *new LFD* before a more expensive established test
- Don’t wait until you have a detection method to validate it.

Validating a new method?

- My new method; what is it good for?

- Estimate real world outcomes with and without the detection technology using well designed validation data
- So, for a rapid on-site LFD test…

In a world…

- …without LFDs

Test plants by looking for symptoms; send symptomatic plants to be tested in a lab

- … with LFDs

Test plants by looking for symptoms; test plants with LFDs, maybe based on symptoms; send plants to be tested in a lab depending on symptoms and LFD

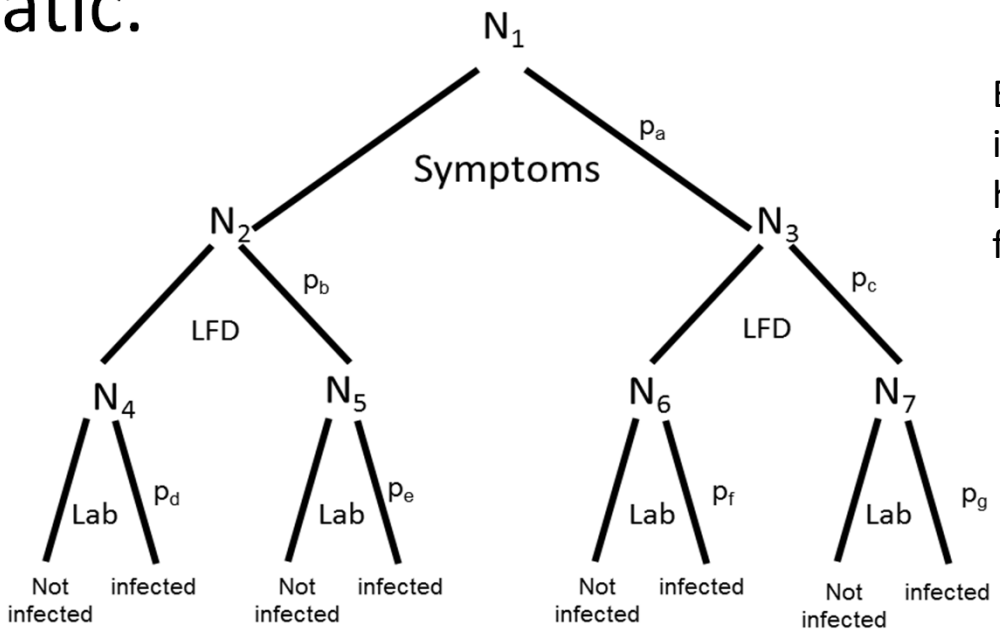
- What are costs and outcomes in each world

Validation data?

- Test infected and uninfected plants as assessed by a gold standard method; report false negative and false positive rates.

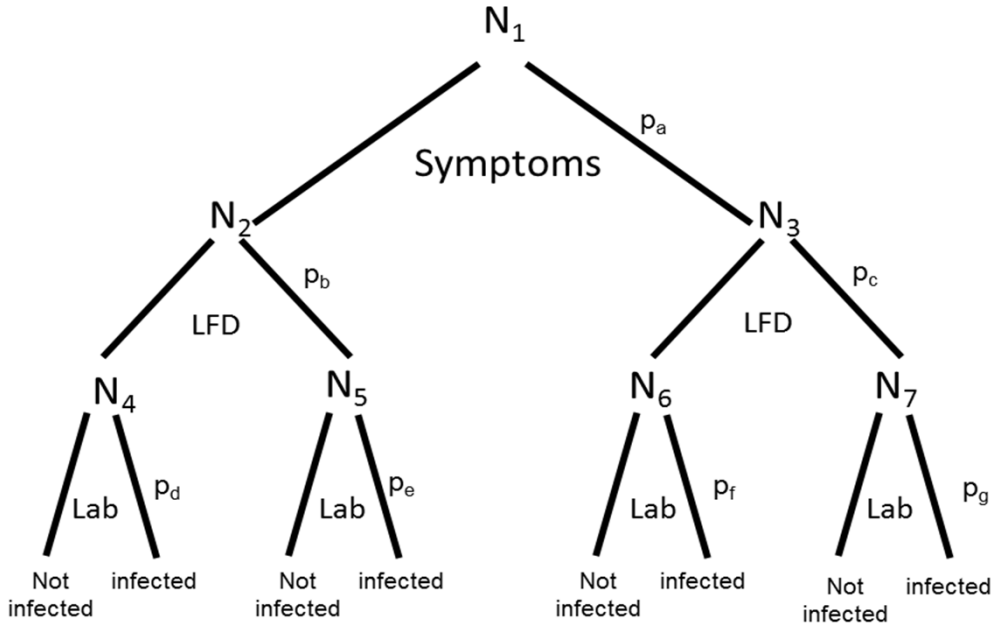
Validation data

- Test some symptomatic and non-symptomatic plants by all methods and also get an estimate of the proportion symptomatic.



Each set of plants at a lower level is either all of the plants from a higher level, or a random sample from the higher level

Validation data: cost of an inspection plan



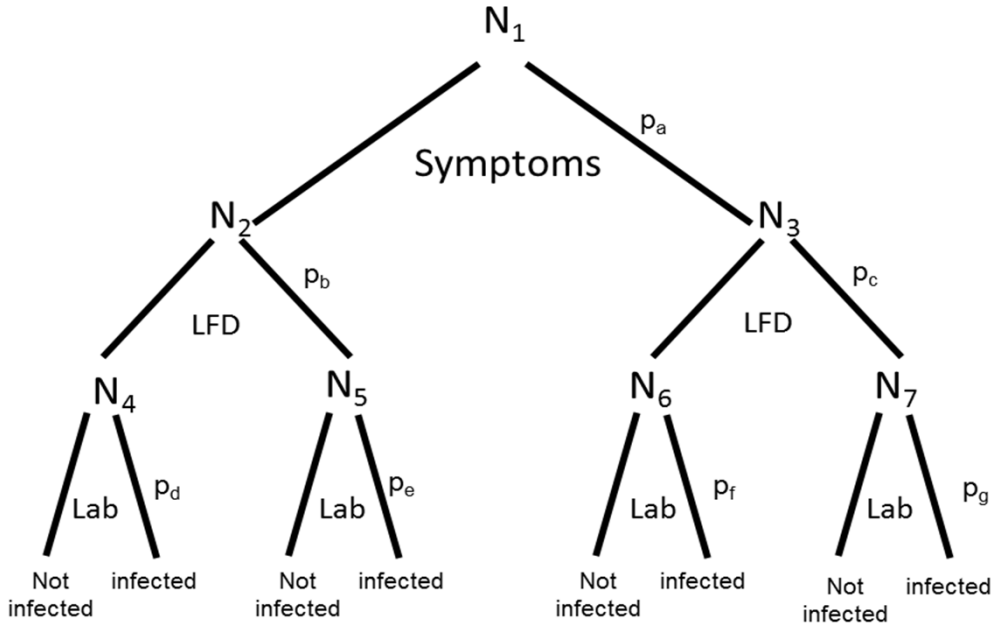
Without LFDs

$Cost = inspection + p_a \times Lab$

With LFDs

$Cost = inspection + p_a \times LFD + p_a p_c \times Lab$

Validation data: cost of an inspection plan



Without LFDs

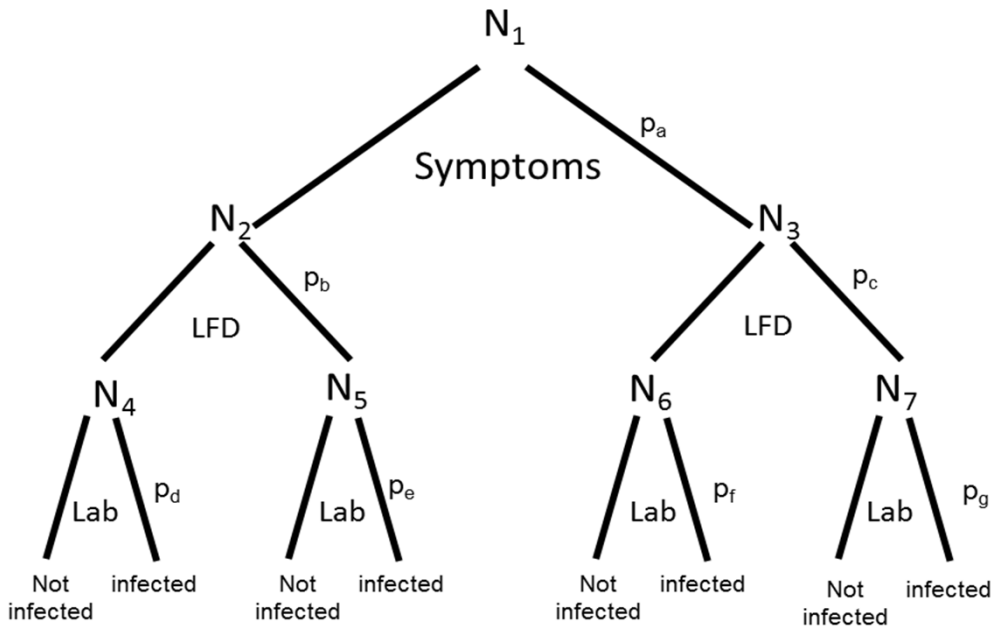
$Cost = inspection + p_a \times Lab$

With LFDs

$Cost = inspection + p_a \times LFD + p_a p_c \times Lab$

Maybe cheaper with LFD

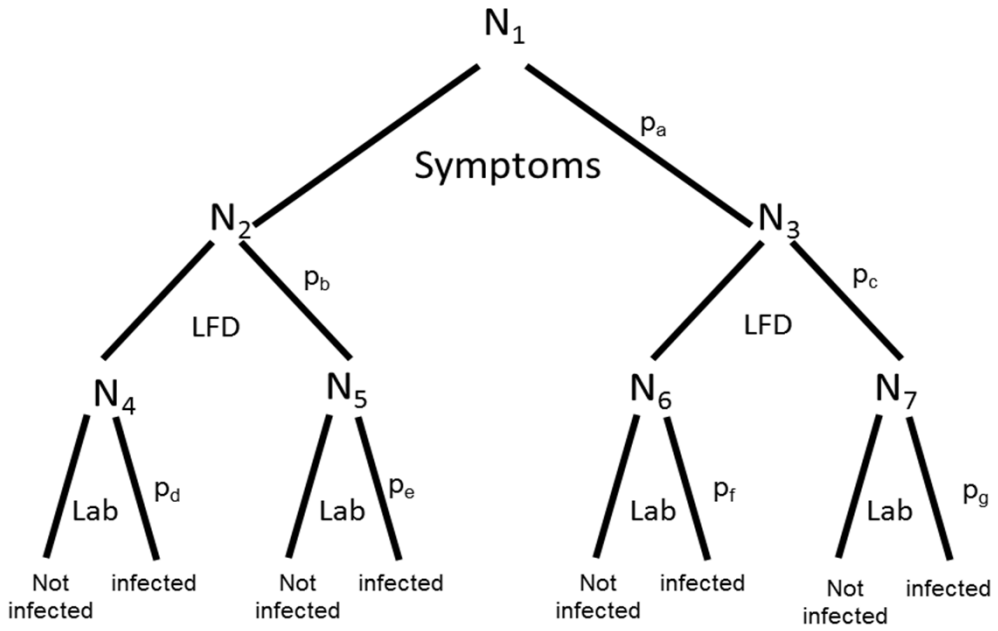
Validation data: performance of an inspection plan



Without LFDs: Infected= $(1-p_a)(p_b p_e + (1-p_b)p_d)$

With LFDs: Infected= $(1-p_a)(p_b p_e + (1-p_b)p_d) + p_a(1-p_c)p_f$

Validation data: performance of an inspection plan



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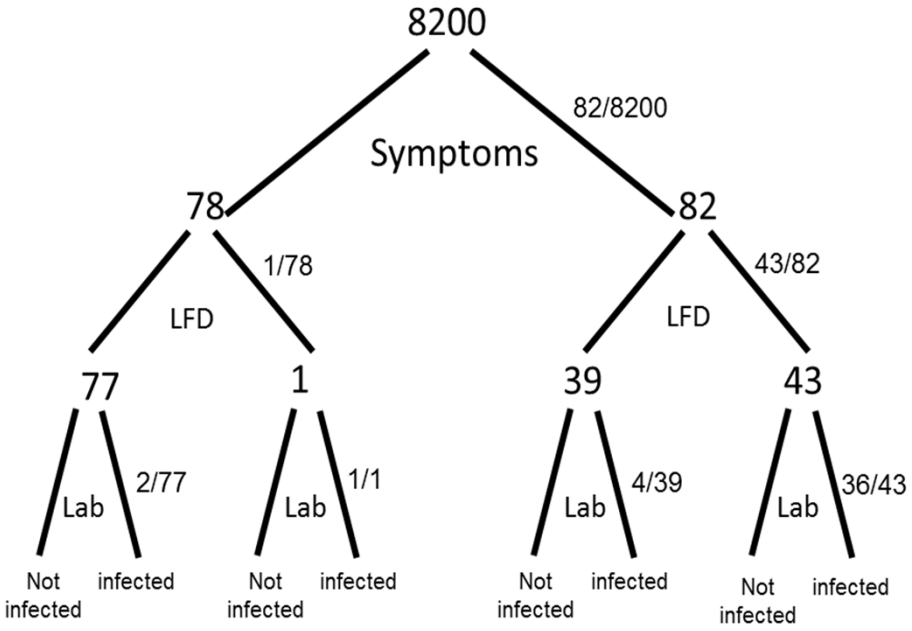
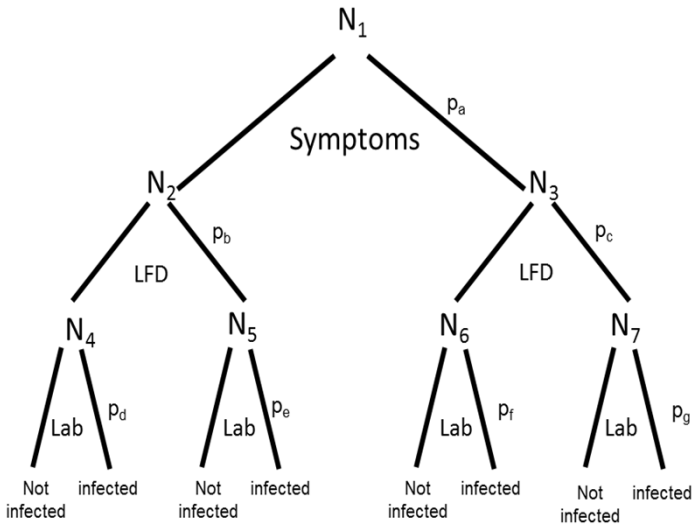
With LFDs: Infected= $(1-p_a)(p_b p_e + (1-p_b)p_d) + p_a(1-p_c)p_f$

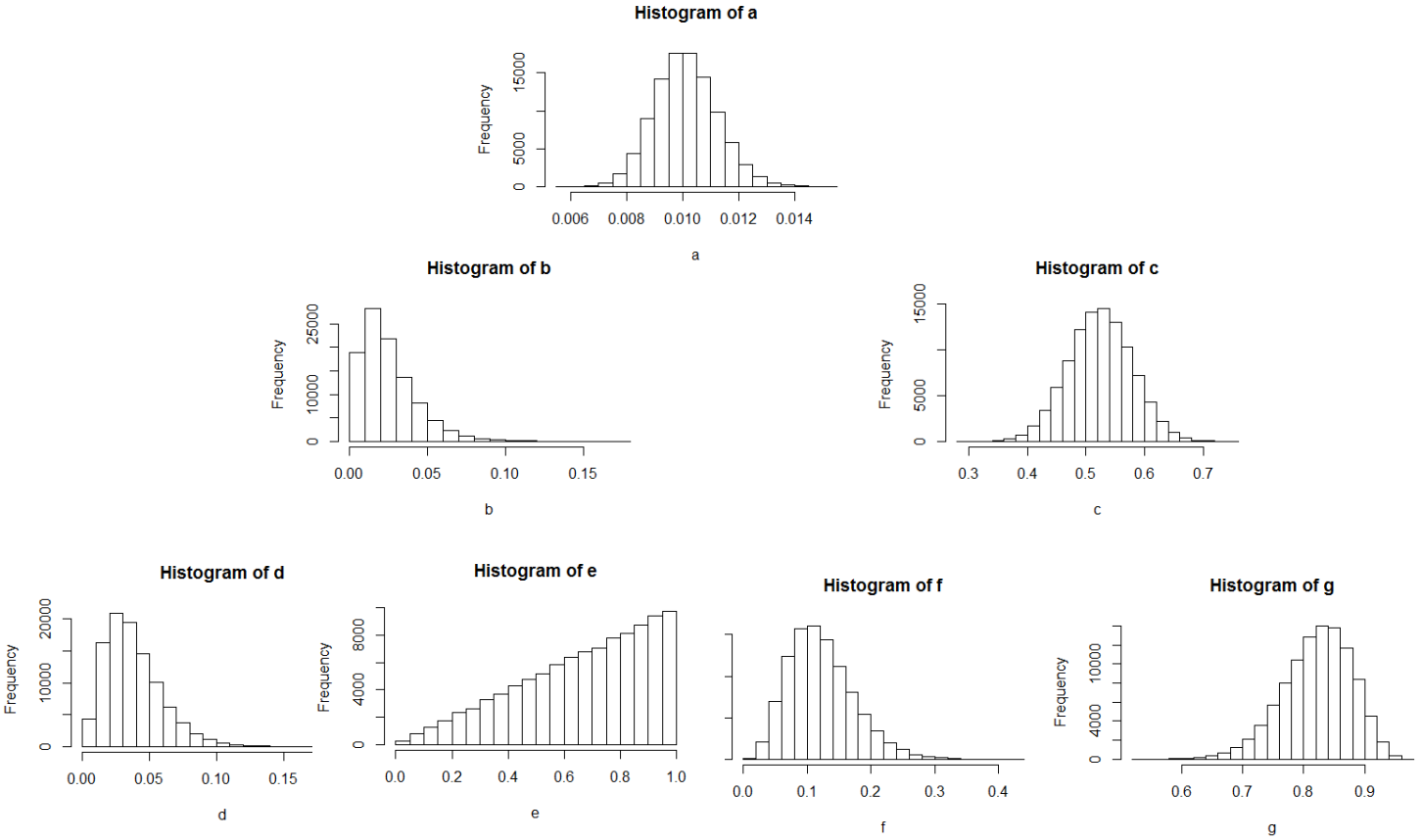
Maybe more infected plants slip through

Observations



Uncertainty associated with estimates

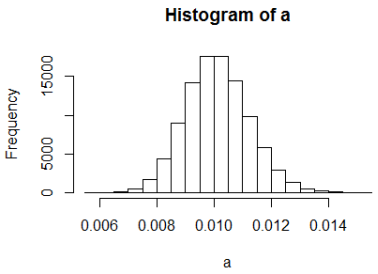


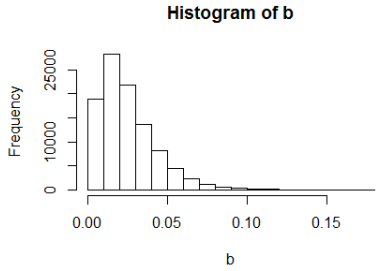


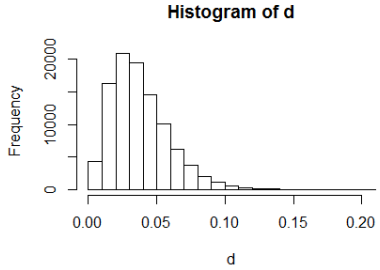
Uncertainty associated with derived estimates:

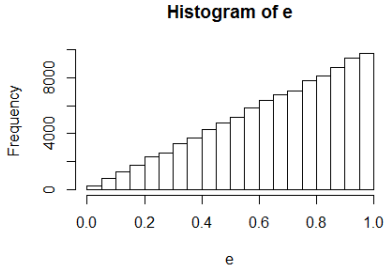
Proportion infected in plants that pass a an inspection plan

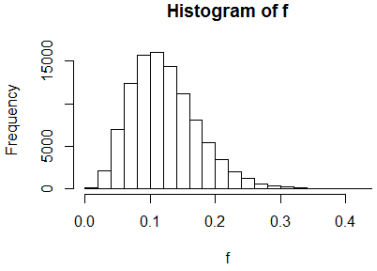
Infected= $(1 - p_a)(p_b p_e + (1 - p_b)p_d) + p_a(1 - p_c)p_f$







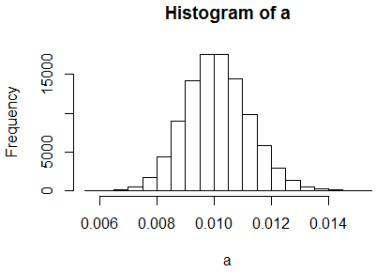


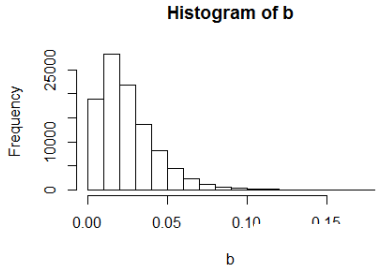


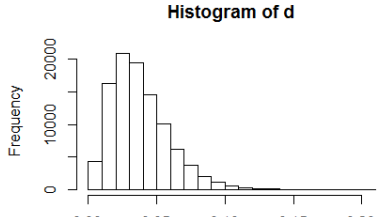
Uncertainty associated with derived estimates:

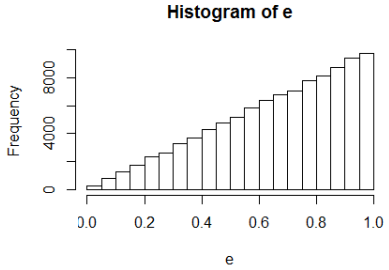
Proportion infected in plants that pass a an inspection plan

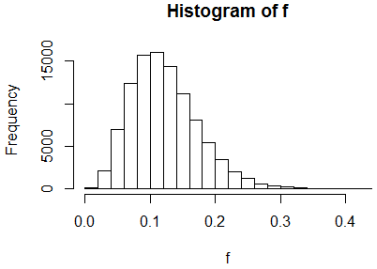
Infected= $(1-p_a)(p_b p_e + (1-p_b)p_d) + p_a(1-p_c)p_f$

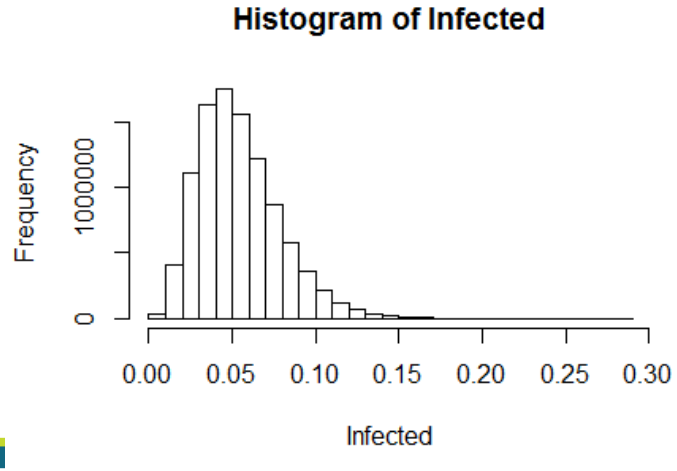












Is using the LFD as a screening test in inspection useful?

Test plan	**Cost per plant inspected(£)** Central estimate and 95% C.I			**Proportion of infected plants among those that "pass" (%)** Central estimate and 95% C.I		
DO NOTHING	**0**	**0**	**0**	**4.3**	**2.1**	**11.5**
Send symptomatic to Lab	1.38	1.13	1.68	3.8	1.6	11.1
Test symptomatic with LFD; send +ve to Lab	0.93	0.73	1.18	3.8	1.6	11.1
Send symptomatic and asymptomatic that give a +ve LFD to Lab	19.2	17.9	26.3	2.6	0.79	8.8

What if the LFD worked twice as well at half the cost?

Test plan	**Cost per plant inspected(£)** Central estimate and 95% C.I			**Proportion of infected plants among those that "pass" (%)** Central estimate and 95% C.I		
DO NOTHING	**0**	**0**	**0**	**4.3**	**2.1**	**11.5**
Send symptomatic to Lab	1.38	1.13	1.68	3.8	1.6	11.1
Test symptomatic with LFD; send +ve to Lab	0.92	0.72	1.17	3.8	1.6	11.0
Send symptomatic and asymptomatic that give a +ve LFD to Lab	16.8	14.6	24.8	1.3	0.31	6.9

Is using the LFD as a screening test during surveillance against a possible outbreak useful?

Scenario	Illustrative Infection prevalence at first detection(%) Estimate	95% CI		Relative Prevalence at first detection Estimate	95% CI	
Send symptomatic to Lab	**0.121**	**0.0593**	**0.336**	**1**	**1**	**1**
Test symptomatic with LFD; send +ve to Lab	0.0909	0.0458	0.253	0.750	0.660	0.873
Send symptomatic and asymptomatic that give a +ve LFD to Lab	0.469	0.288	1.75	3.87	1.55	10.5
Test symptomatic with cheaper improved LFD; send +ve to Lab	(0.0853)	0.0439	0.244	0.735	0.648	0.852

Based on rule of thumb described by Parnell et al (2015), modified for probability of detecting an infected plant

What if…..?

What if we had a device with similar performance to the LFD, but allowing the examination of a large number of plants in a on-site bulk test, or maybe by multispectral examination?

Rapid bulk screening for inspection

Test plan	**Cost per plant inspected(£)** Central estimate and 95% C.I			**Proportion of infected plants among those that "pass"** Central estimate and 95% C.I		
DO NOTHING	**0**	**0**	**0**	**4.3**	**2.1**	**11.5**
Send symptomatic to Lab	1.38	1.13	1.68	3.8	1.6	11.1
Test symptomatic with screen; send +ve to Lab	0.77	0.59	0.99	3.9	1.7	11.1
Send symptomatic and asymptomatic that give a +ve screen to Lab	3.00	1.76	10.1	2.6	0.079	8.8

Rapid bulk screening for surveillance against a new outbreak

Scenario	Illustrative* Infection prevalence at first detection(%) Estimate	95% CI		Relative Prevalence at first detection Estimate	95% CI	
Send symptomatic to Lab	**0.121**	**0.0593**	**0.336**	**1**	**1**	**1**
Test symptomatic with LFD; send +ve to Lab	0.0909	0.0458	0.253	0.750	0.660	0873
Test symptomatic with cheaper improved LFD; send +ve to Lab	0.0853	0.0439	0.244	0.735	0.648	0.852
Test symptomatic with bulk screen; send +ve to Lab	0.0749	0.0377	0.208	0.618	0.528	0.732
Test asymptomatic with bulk screen; send +ve to Lab along with symptomatic	0.0735	0.0516	0.300	0.606	0.498	1.74

Reflections

The validation was based on 160 tests; by careful design we can get a lot of information from those tests beyond the false positive and negative rates of a single method.

Using the framework to model potential technologies as well as different inspection plans can help focus plans.