



phenoLytics

.... thinking seed tech different

phenoCheck and phenoTest

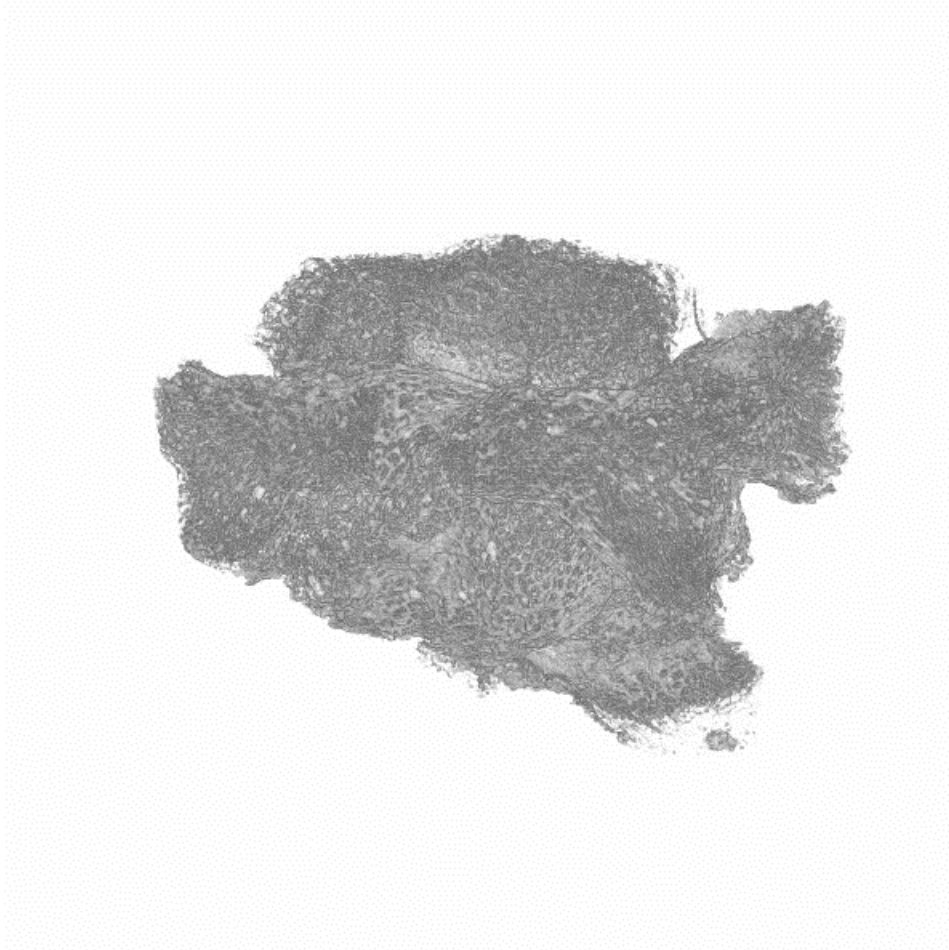
Enabling tools
for high-throughput
morphological phenotyping
of seeds and developing seedlings
using 3D Xray computed tomography

The **pheno**Check

High-throughput 3D phenotyping of seeds
using 3D x-ray computer tomography

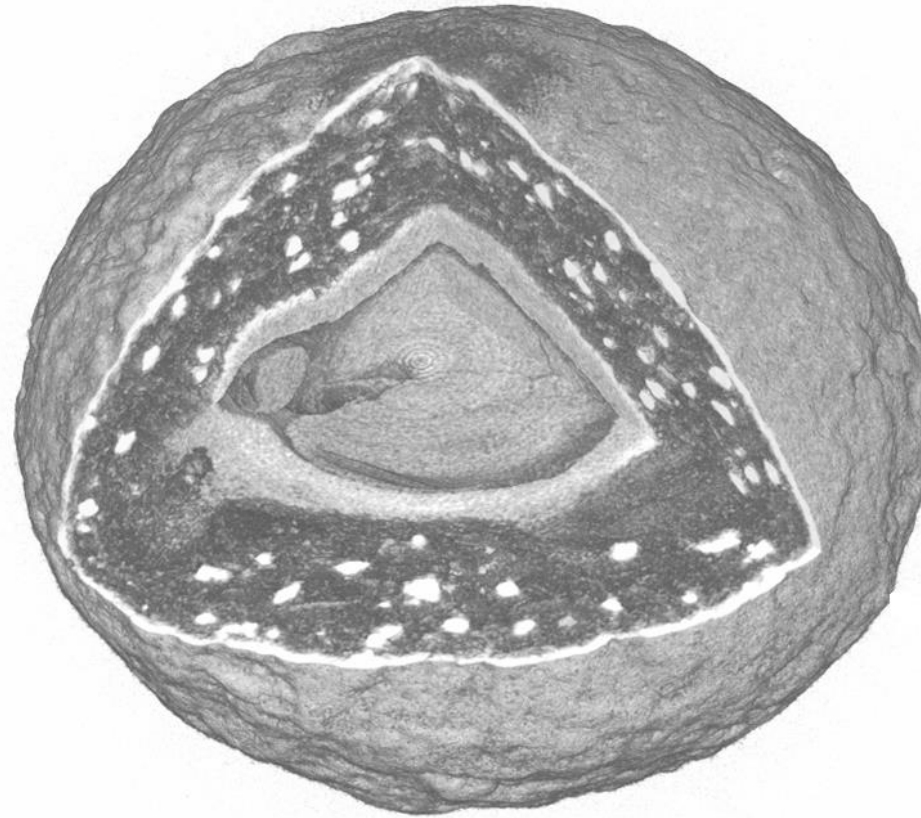
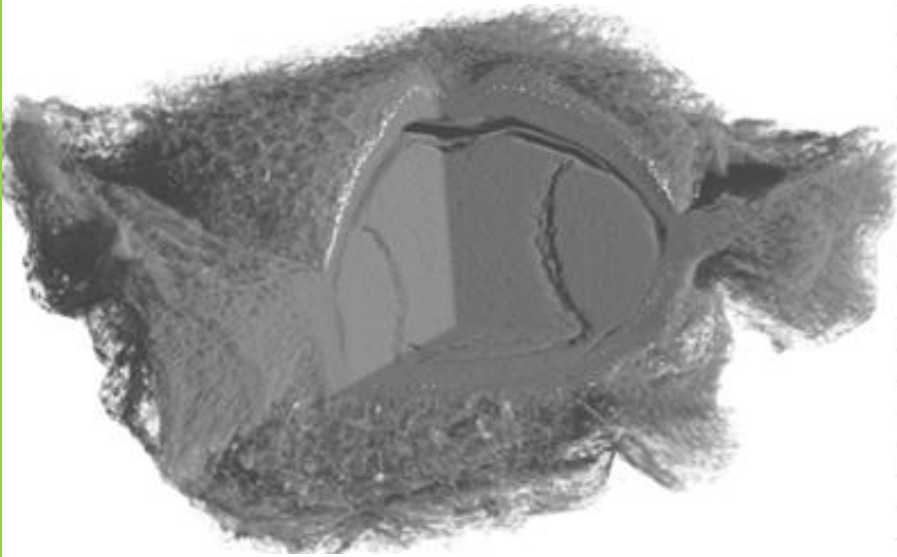
phenoCheck

Objective high-throughput measurement of seed quality parameters



phenoCheck

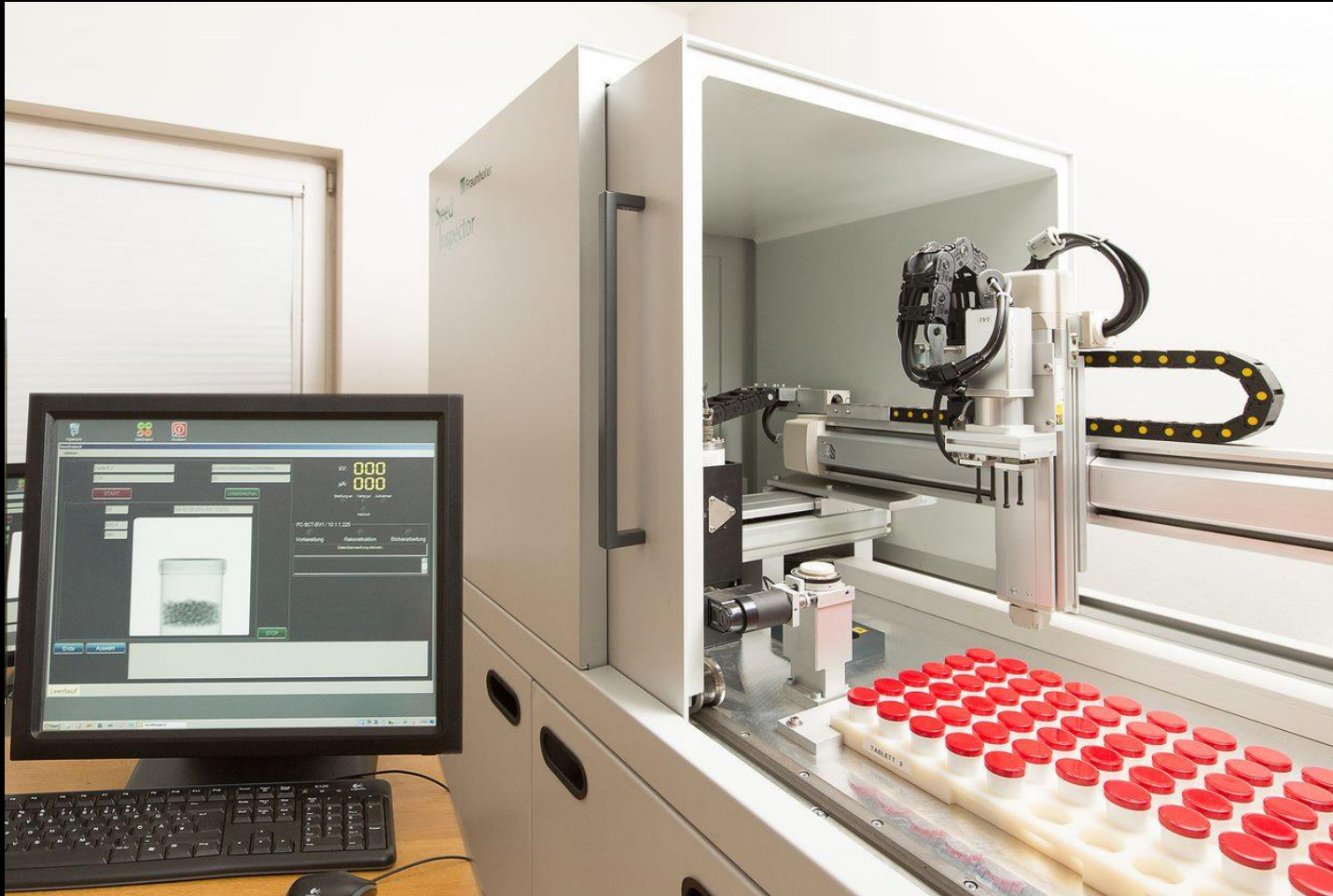
Objective high-throughput measurement of seed quality parameters



phenoLytics

phenoCheck

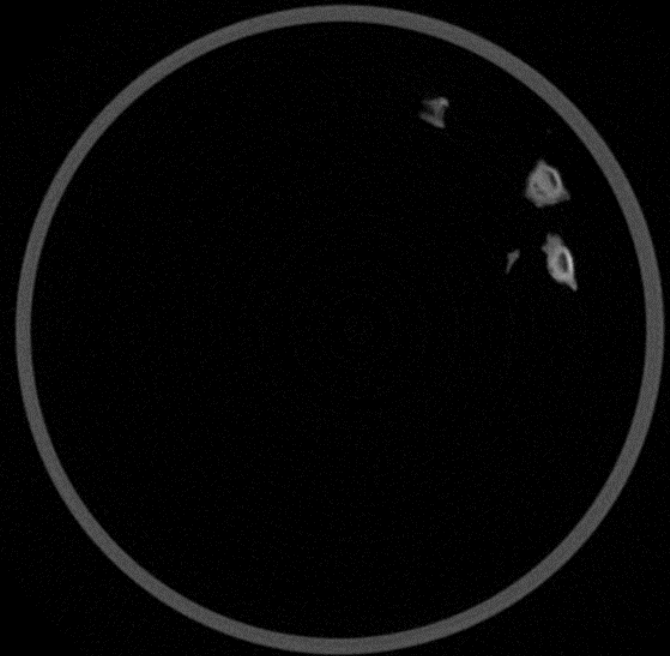
Objective high-throughput measurement of seed quality parameters
- hundreds of seeds analyzed in 3 minutes



phenoCheck

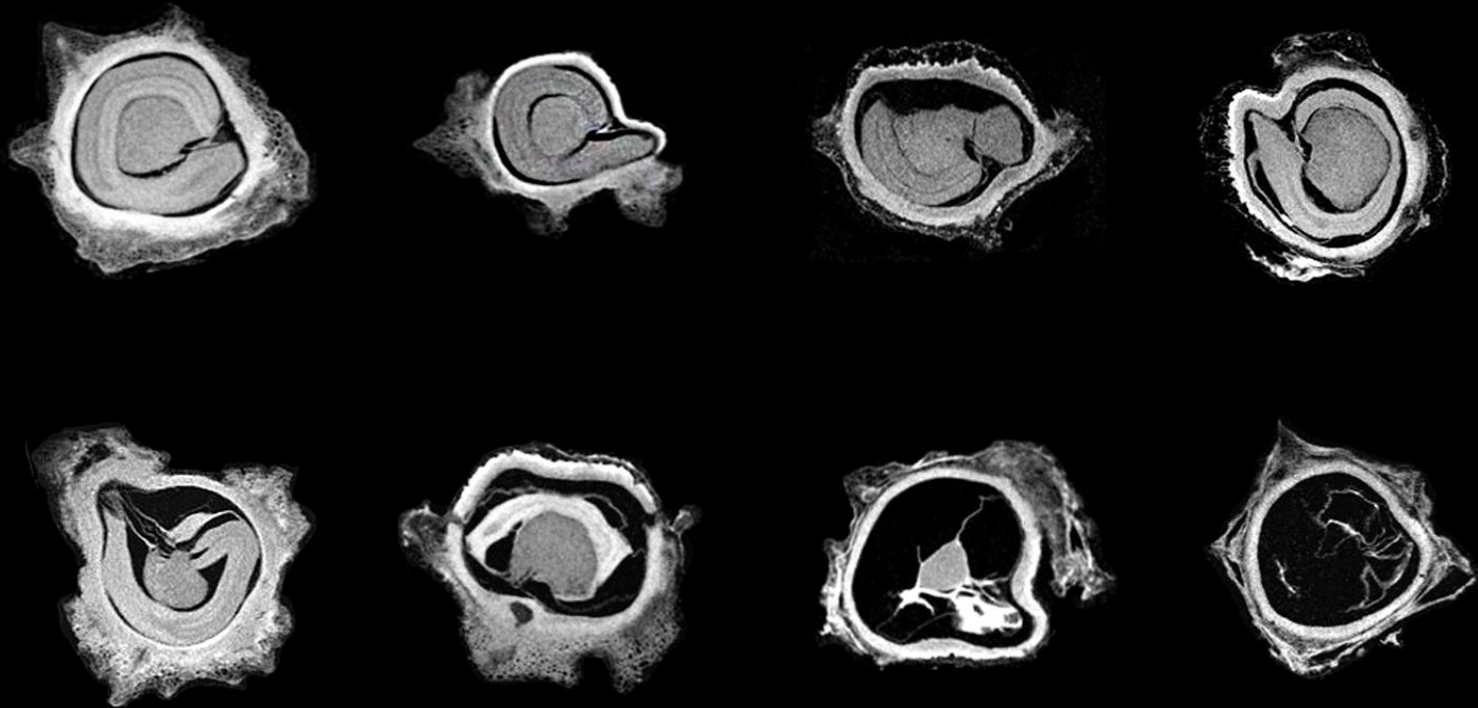
Objective high-throughput measurement of seed parameters in 3D

- Automatic 3D reconstruction of each individual seed
- Segmentation and measurement of all internal and external seed parameters



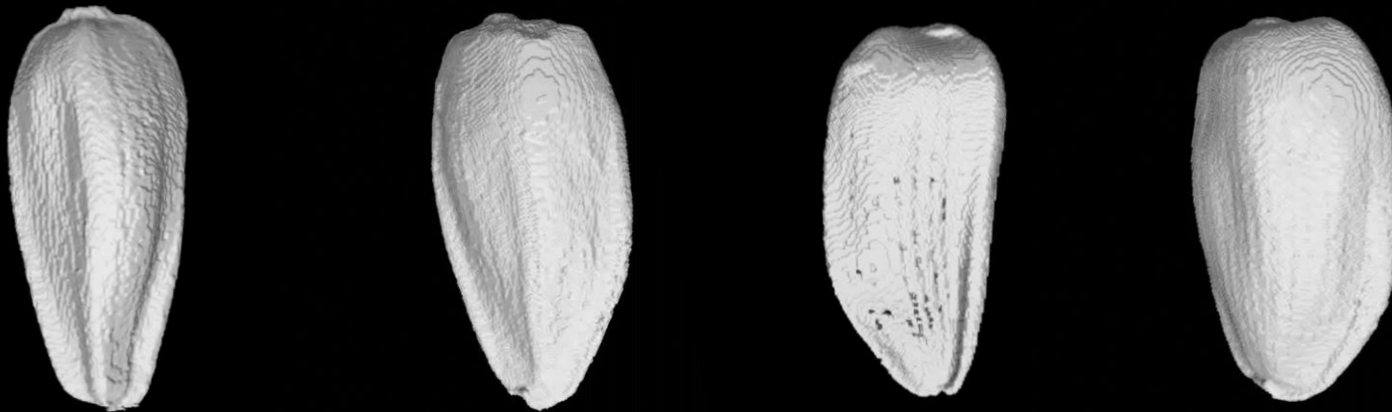
phenoCheck

Objective high-throughput 3D measurement of seed quality parameters



phenoCheck

Objective high-throughput measurement of seed quality parameters



phenoCheck
Corn

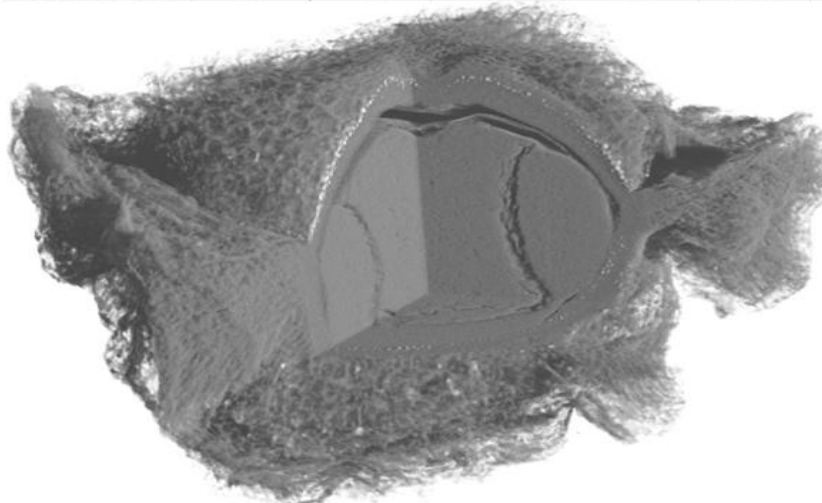


phenoLytics

phenoCheck

Data file output: objective measurement of seed and pellet parameters

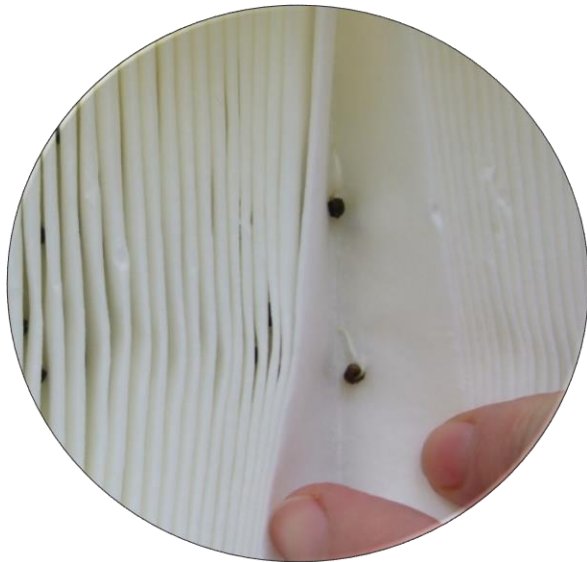
Partie	Samen- /Keimling- Nr.	V_Gesamt /mm ³	V_Perikarp/ mm ³	V_Hartkoer per/mm ³	V_Samen hoehle/m m ³	V_Embryo /mm ³	V_Hohlr aeume/ mm ³	d_Knaeul Max/mm	d_Knaeul Min/mm	d_Samen hoehle_ Max/mm	d_Samen hoehle_ Min/mm	KFG
RC2000180_P22	1	8,49	1,85	3,41	3,23	3,06	0,17	4,26	1,88	2,39	1,34	94,88
RC2000180_P22	2	8,88	1,73	3,27	3,89	3,60	0,28	3,93	1,79	2,69	1,28	92,70
RC2000180_P22	3	8,64	1,64	3,15	3,85	3,52	0,33	4,43	1,80	2,77	1,22	91,43
RC2000180_P22	4	8,64	2,01	3,37	3,25	2,87	0,38	4,29	1,64	2,62	1,11	88,27
RC2000180_P22	5	11,10	1,18	5,02	4,90	3,50	1,40	3,80	2,00	3,06	1,35	71,48
RC2000180_P22	6	10,46	1,46	3,82	5,19	3,72	1,47	3,88	1,87	2,90	1,22	71,65
RC2000180_P22	7	8,71	1,03	3,13	4,54	3,92	0,62	3,60	1,90	2,84	1,45	86,30
RC2000180_P22	8	7,48	1,18	2,84	3,47	3,09	0,38	3,82	1,65	2,75	1,15	89,14
RC2000180_P22	9	8,50	1,88	3,05	3,58	3,15	0,43	4,07	1,83	2,58	1,20	88,02
RC2000180_P22	10	8,43	1,55	3,27	3,61	3,18	0,43	4,45	1,76	2,81	1,11	88,19
RC2000180_P22	11	7,35	1,03	2,71	3,62	3,17	0,45	3,51	1,81	2,75	1,33	87,51
RC2000180_P22	12	9,76	1,29	3,14	5,33	4,53	0,80	3,38	2,02	3,07	1,44	85,08
RC2000180_P22	13	9,31	1,84	3,54	3,92	3,39	0,53	4,22	1,96	2,77	1,34	86,40
						3,74	1,54	3,44	1,91	2,81	1,58	70,85
						4,00	0,64	3,97	1,95	2,97	1,41	86,30
						3,59	0,46	3,84	1,94	2,73	1,25	88,63
						4,01	0,45	3,51	1,95	2,87	1,40	89,95
						3,60	0,28	3,50	1,81	2,80	1,30	92,87
						2,22	0,42	3,59	1,60	2,53	1,09	84,02
						2,93	0,41	3,49	1,66	2,81	1,25	87,82
						3,71	0,30	4,22	1,75	2,79	1,30	92,47
						3,20	0,32	4,40	1,73	2,92	1,11	90,82
						2,36	0,78	4,03	1,65	2,54	1,13	75,05
						2,40	1,53	3,46	1,75	2,81	1,33	61,08
						3,23	1,08	4,56	1,68	3,03	1,30	75,00
						3,53	1,28	3,87	2,15	2,78	1,51	73,34
						3,55	0,23	4,10	1,89	2,80	1,30	93,97
						3,38	0,49	4,21	1,87	2,70	1,41	87,35
						2,81	0,35	4,02	1,68	2,56	1,23	88,94
						3,42	0,31	3,89	1,78	2,83	1,28	91,65
						3,65	0,29	3,85	1,89	2,90	1,13	92,75
RC2000180_P22	32	8,39	1,27	2,77	4,35	3,90	0,45	3,41	1,77	2,79	1,37	89,65



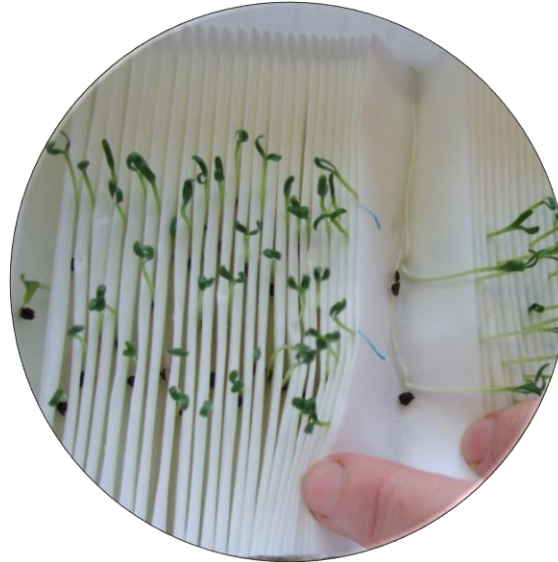
The ISTA-test method

Visual assessment of seedlings for germination

2 days



7 days



14 days



Constraints and limitations of the visual assessment in ISTA-/ AOSA-tests

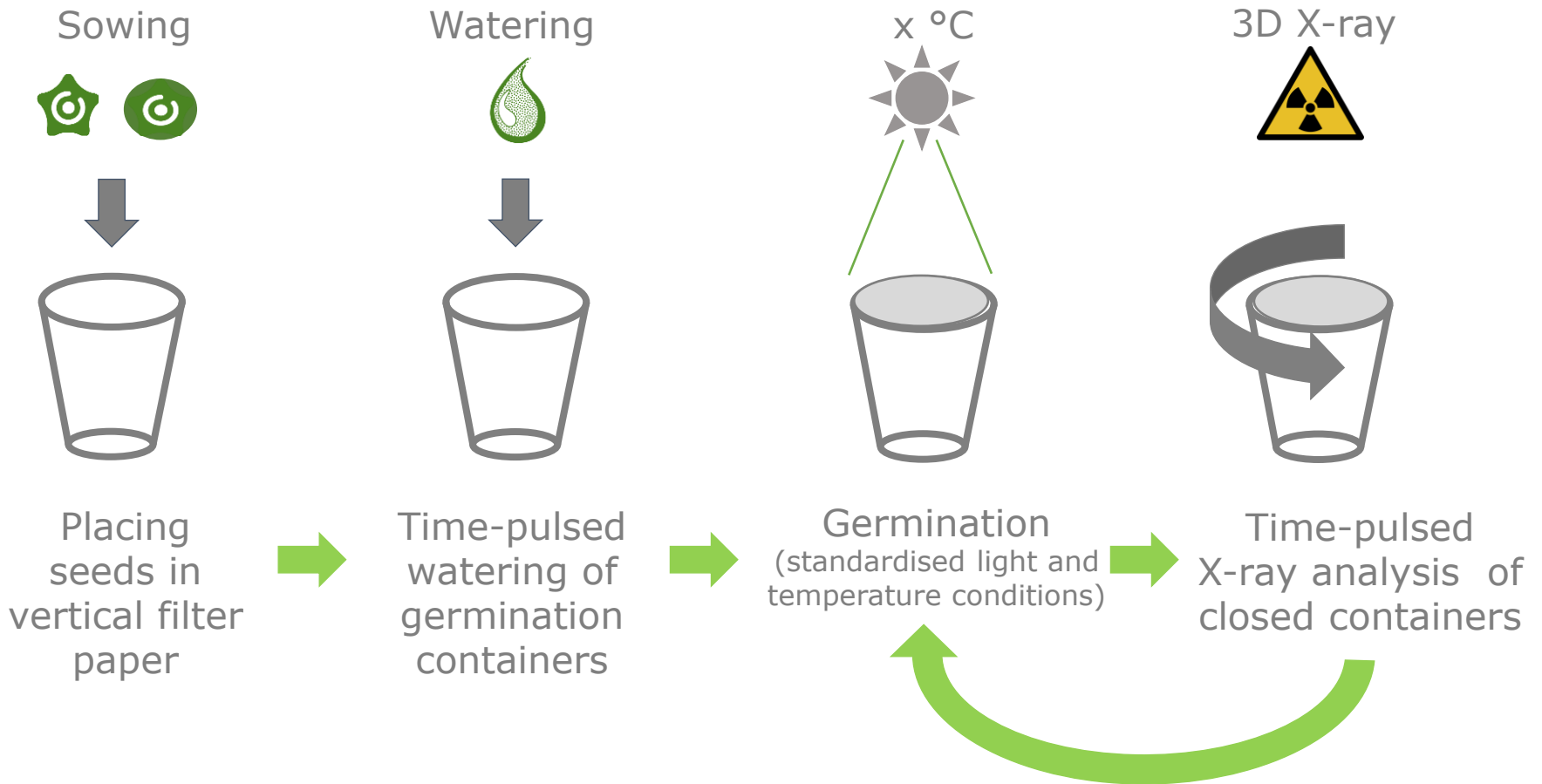
- Labor and cost intensive
- Partly subjective/ difficult to standardize
- No quantitative data on a single plant base
- No information about vigor (biomass production/day)
- No information about uniformity
- No documentation

The **pheno**Test

High-throughput 4D phenotyping
of germinating seeds and seedlings
using 3D x-ray computer tomography

phenoTest

Process of germination and acquisition of volume image data



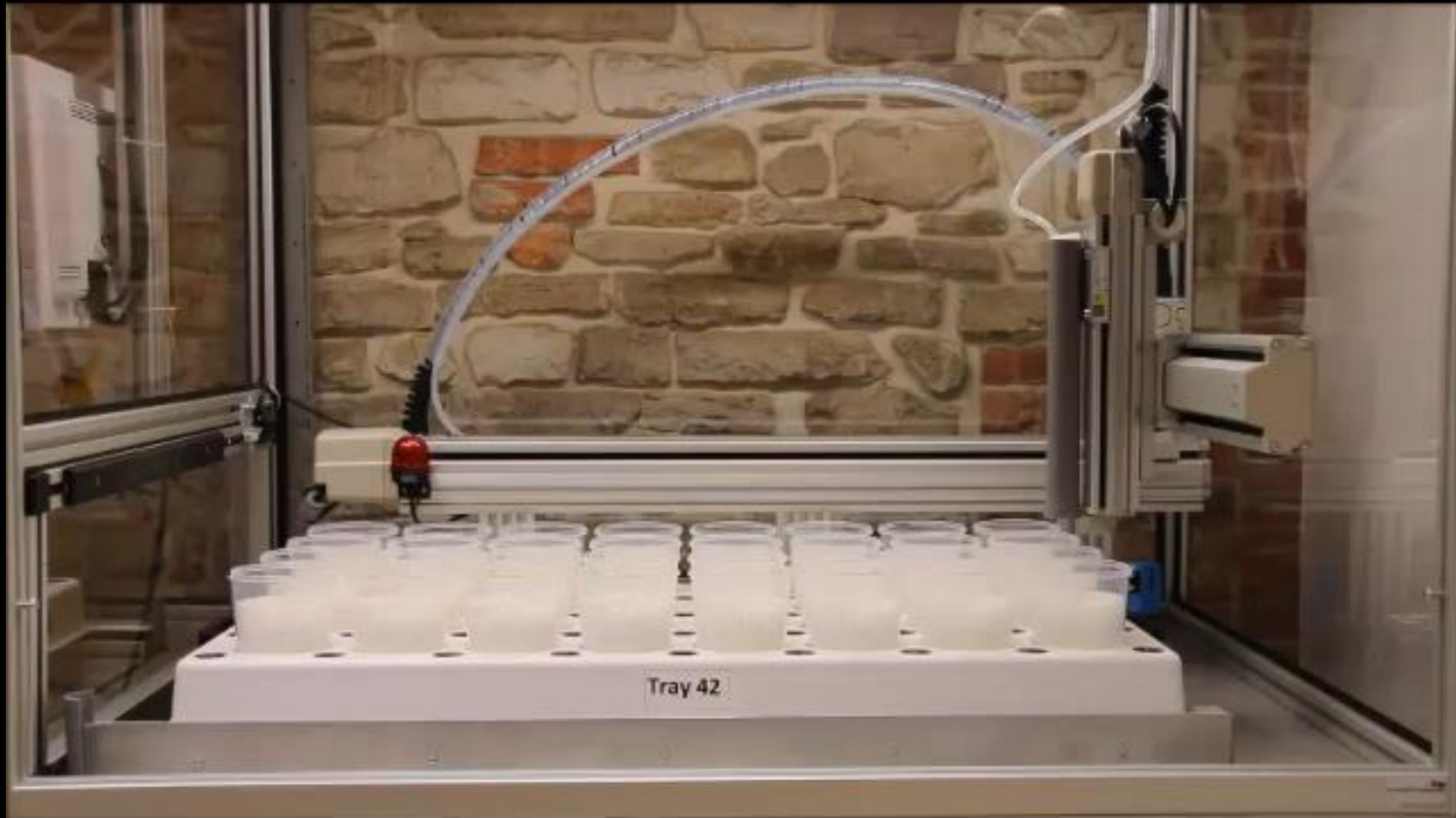
phenoTest

Sowing in conical containers and vertically oriented pleated filter paper



phenoWater

Automated watering and smart trial scheduling



phenoLytics

phenoTest

Standardized light and temperature conditions for germination



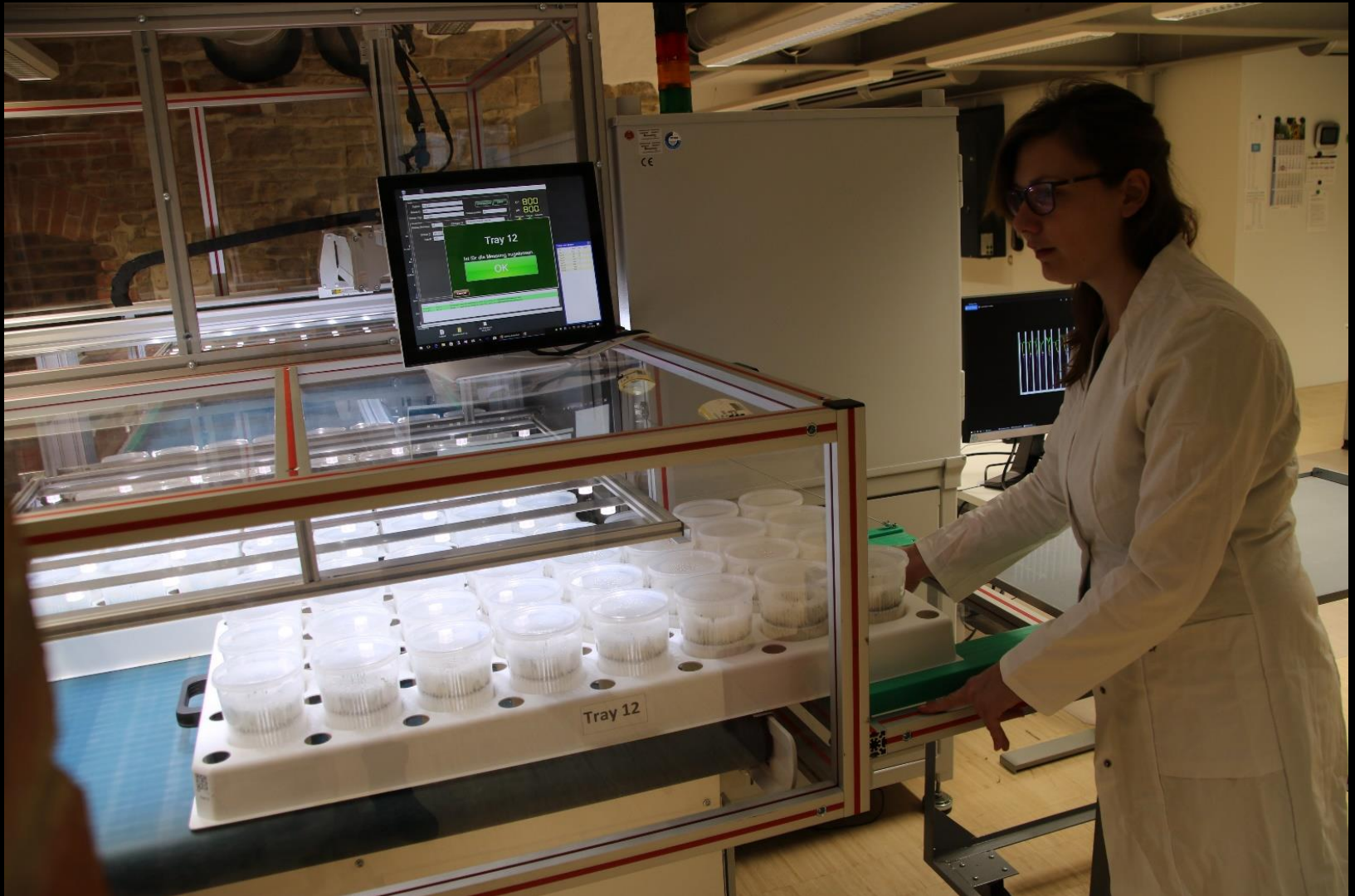
phenoTest

Phenotyping by 3D X-ray tomography



phenoTest

Inserting the trays



phenoTest

Automated sample supply and exchange for the X-ray analysis

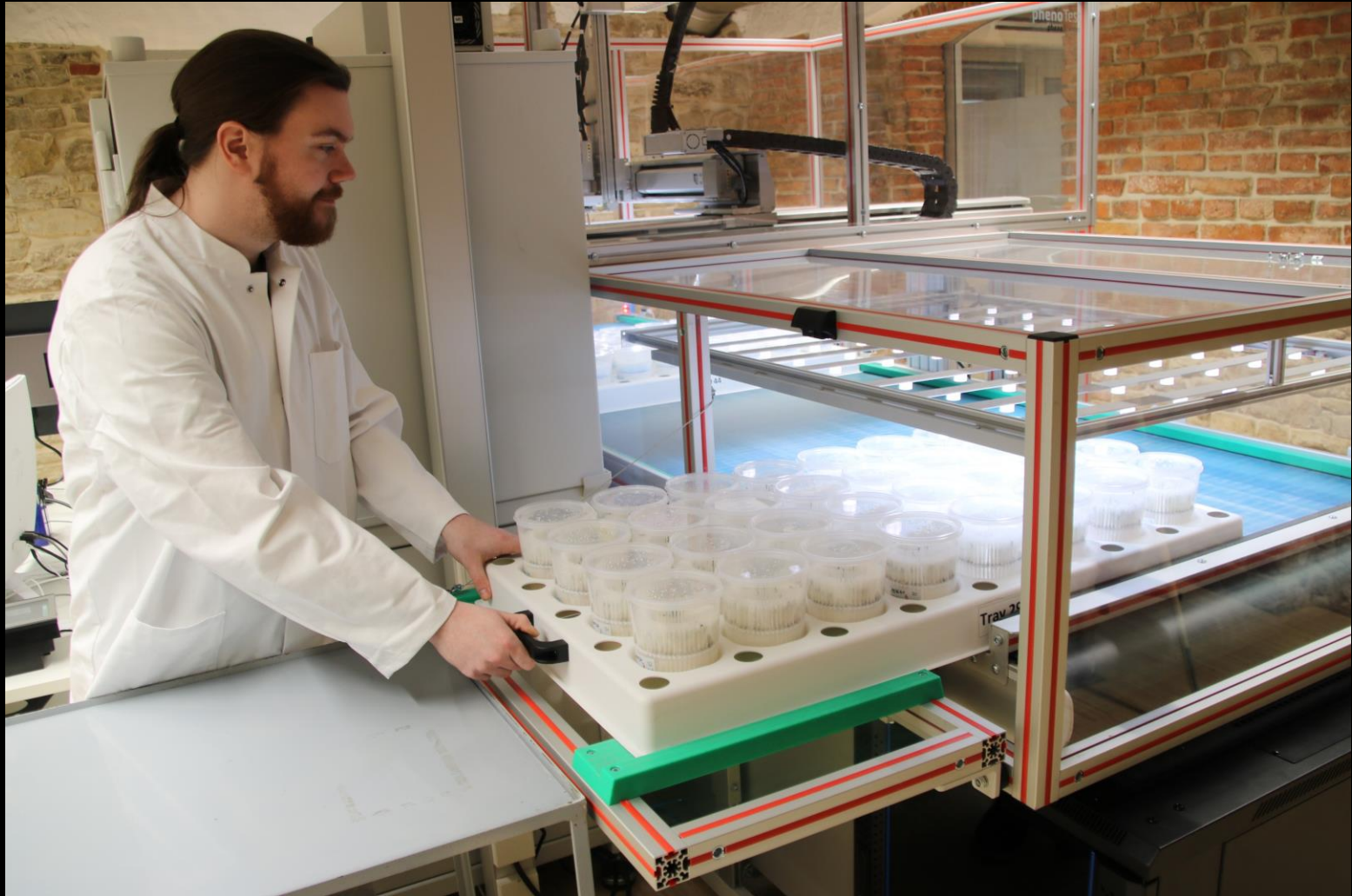


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phenoTest

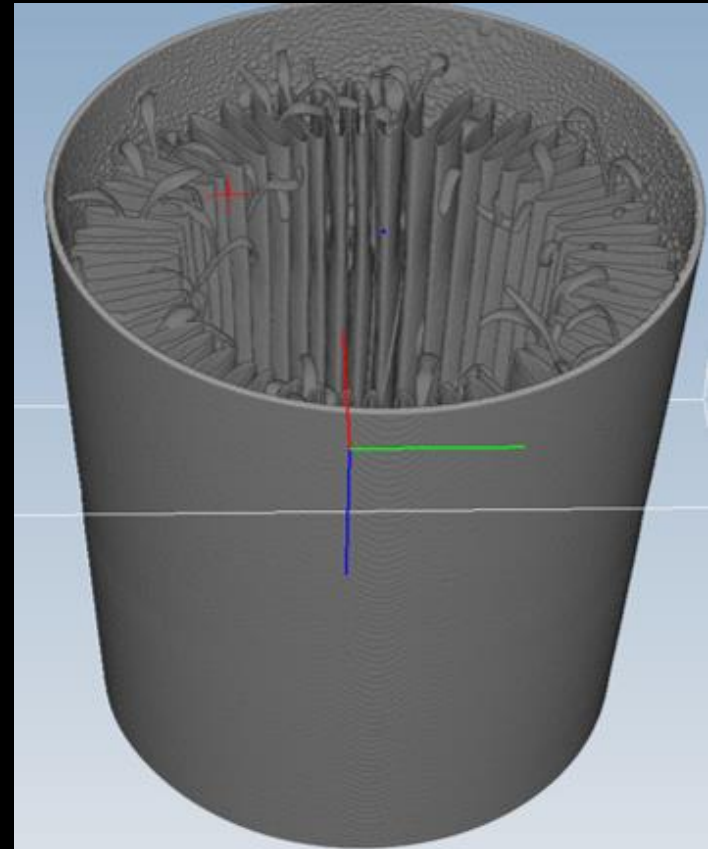
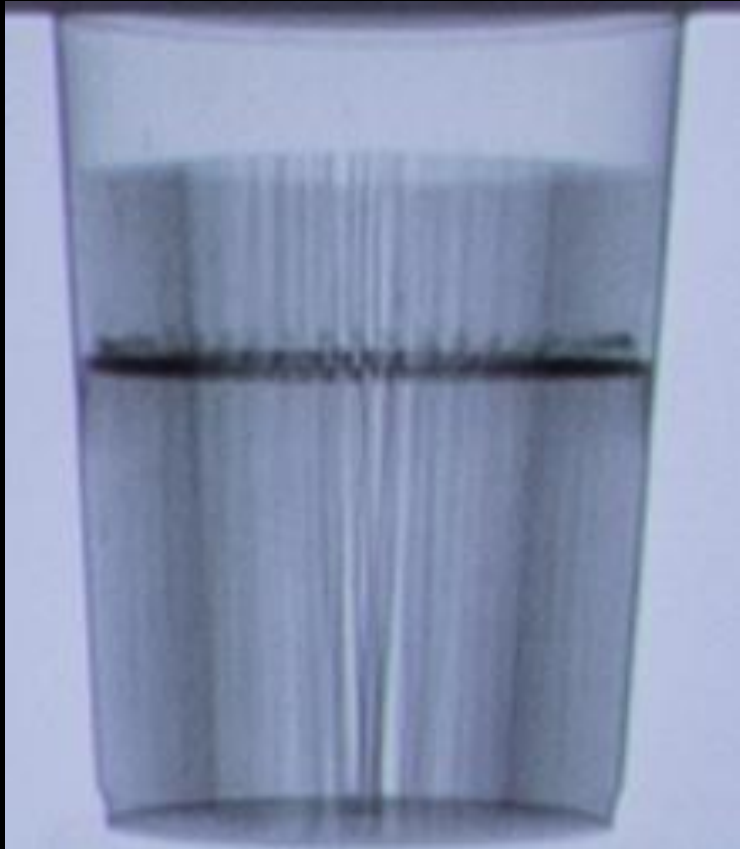
Removing of the trays

- can be fully automated and integrated in the climate chamber



phenoTest

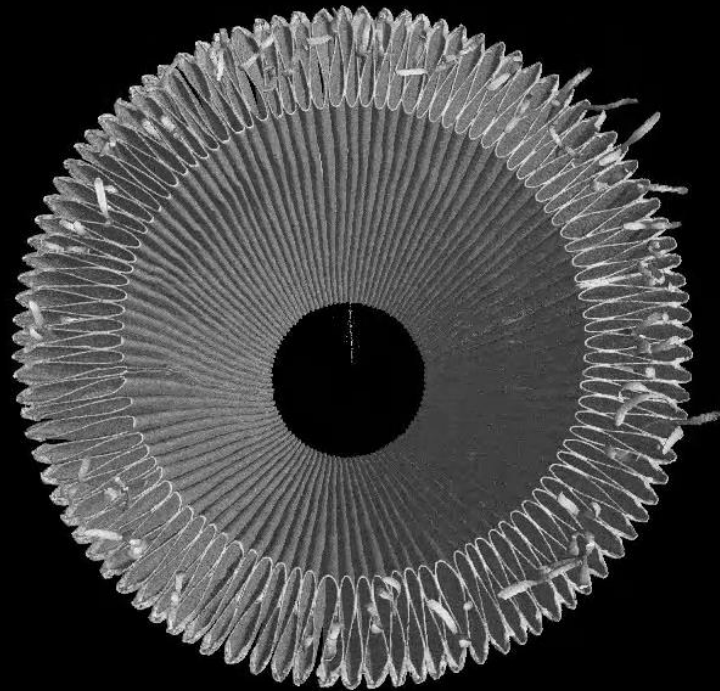
2D x-ray projection versus 3D x-ray reconstruction



phenoTest

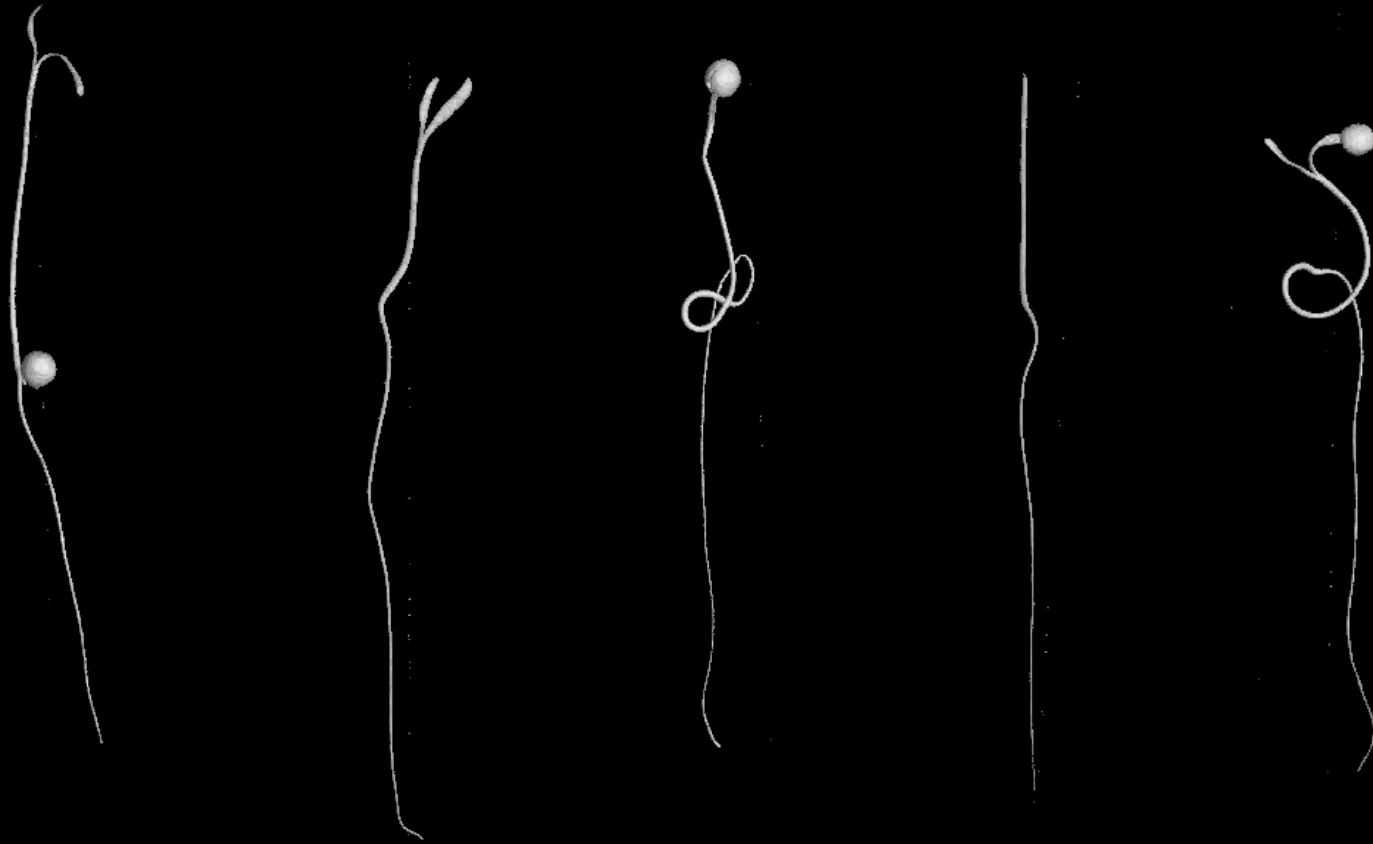
3D reconstruction of the volume from 600 2D images

Szene



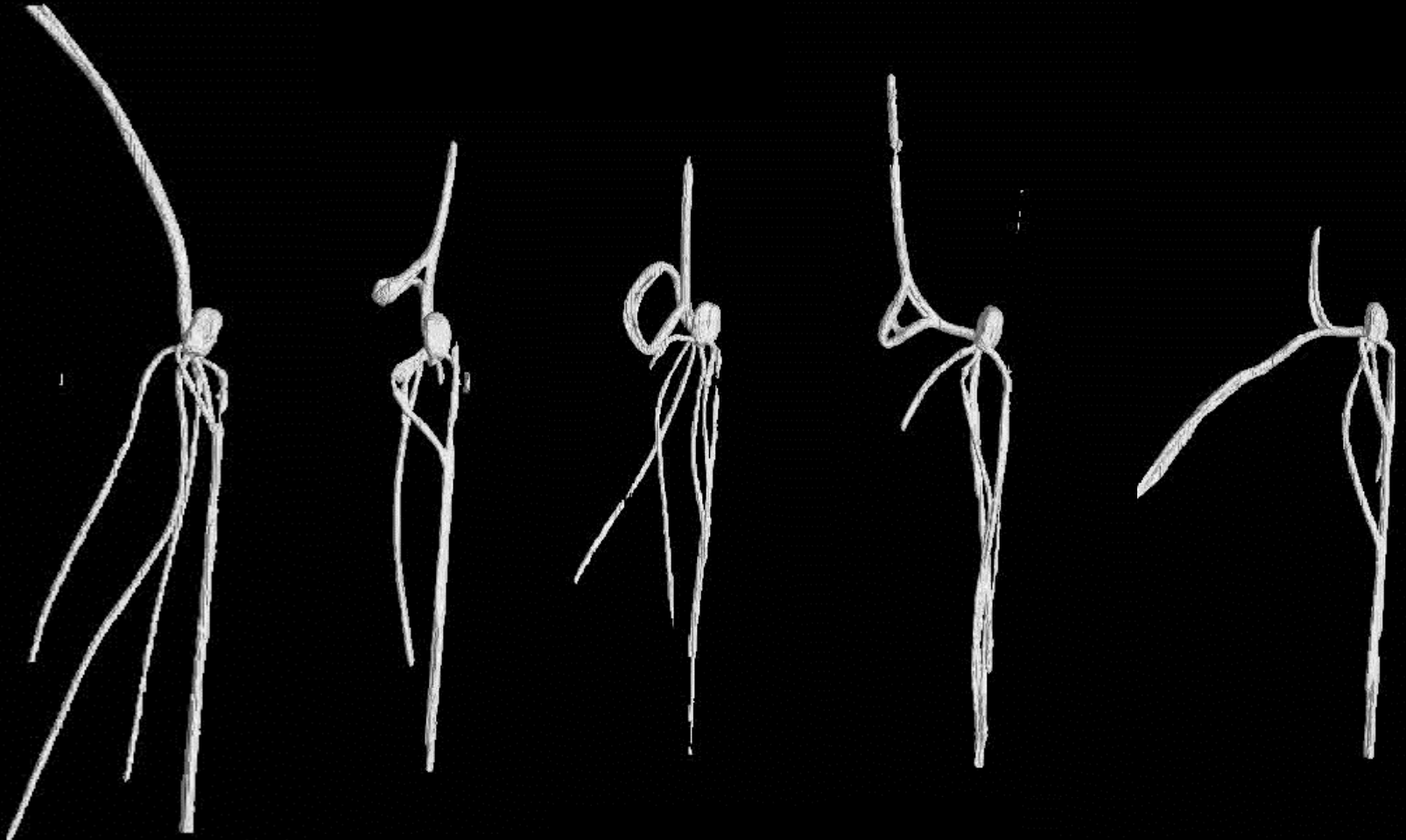
phenoTest

Isolation and segmentation of the seedlings from the filter paper
Example sugar beet



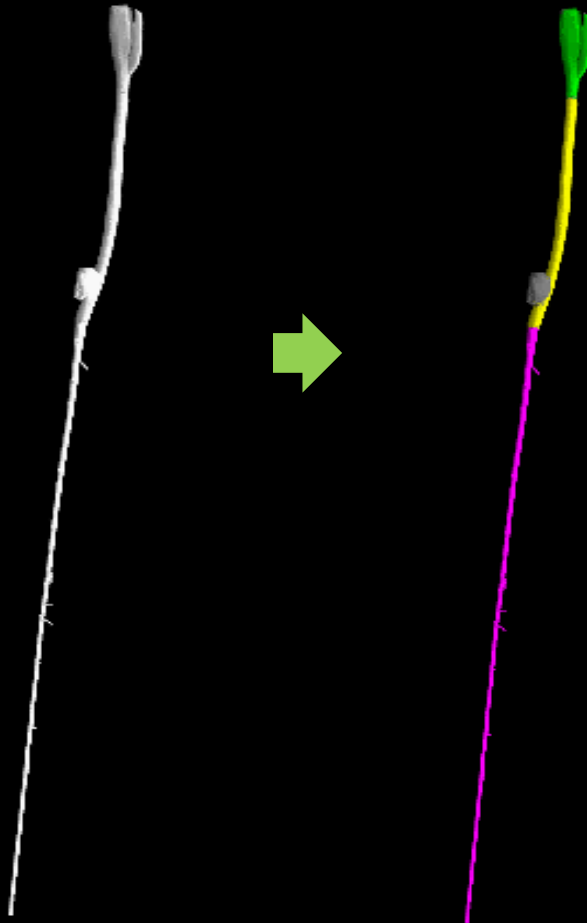
phenoTest

Isolation and segmentation by an AI-based algorithm- Wheat



phenoTest

Automated image processing and measurement of the different organs of each individual plant



Length, volume,
direction of growth:

- Root
- Hypocotyl
- Cotyledons
- etc

phenoTest

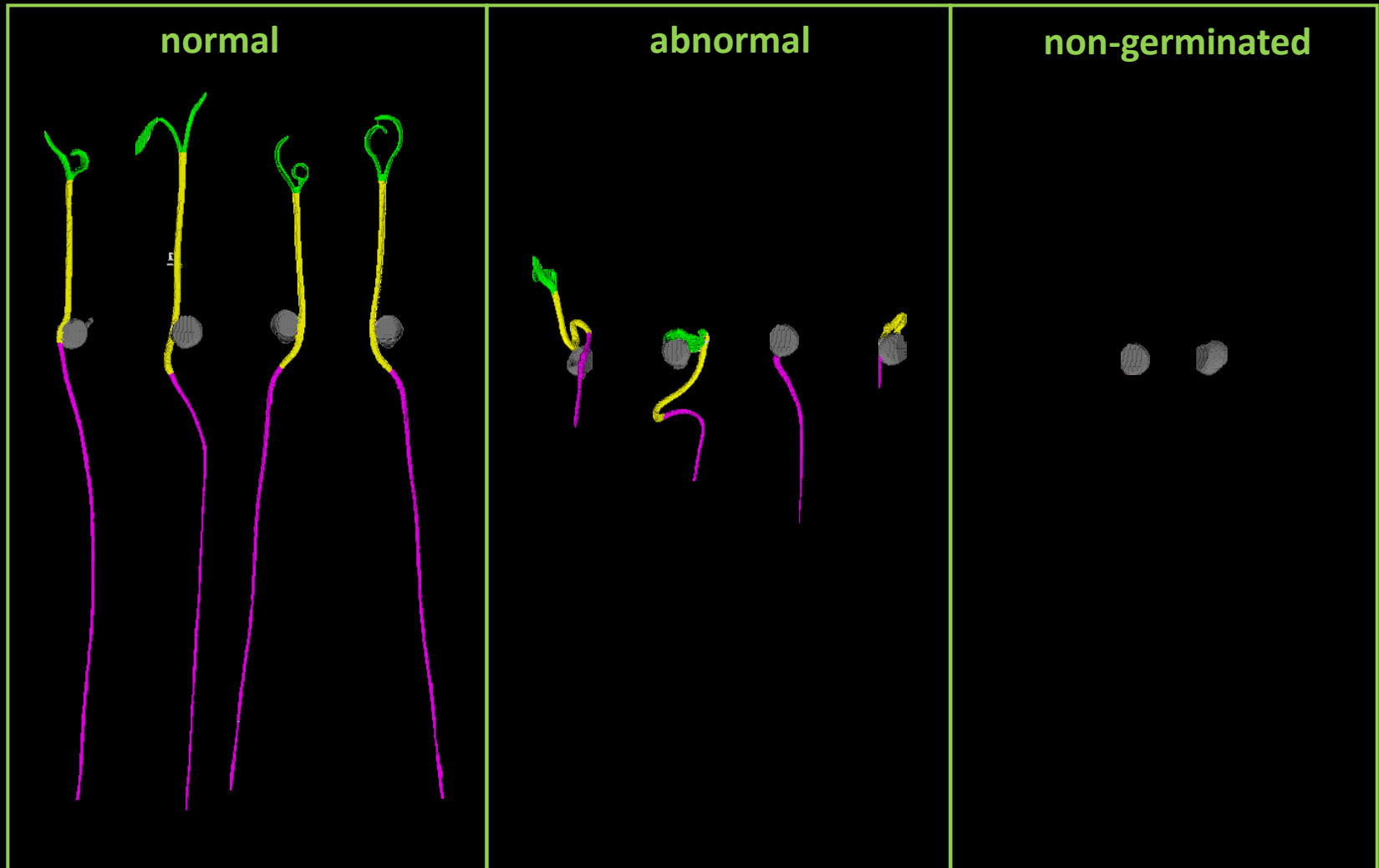
Quantitative and standardized data file output for each seedling

Partie	Samen- /Keimling- Nr.	Segment ation failed 7d	Removed by user 7d	Germinat ed 7d	Above belows 7d	Numb. cotyl. 7d	Total length mm 7d	Root length mm 7d	Hyp. length mm 7d	Cotyl. 1 length mm 7d	Cotyl. 2 length mm 7d	Total vol. found mm3 7d	Total vol. seg. Mm3 7d	Seed- Remaind er vol. seg. Mm3 7d	Root vol. mm3 7d	Hyp. vol. mm3 7d	Cotyl. 1 vol. mm3 7d	Cotyl. 2 vol. mm3 7d
RC2000180_P22	1	false	false	true	false	1,00	40,07	14,43	18,38	7,25	0,00	35,48	34,23	8,39	10,20	10,24	5,39	0,00
RC2000180_P22	2	false	false	true	false	0,00	75,10	55,11	19,99	0,00	0,00	46,05	44,84	11,77	17,37	15,69	0,00	0,00
RC2000180_P22	3	false	false	true	false	0,00	78,37	66,56	11,81	0,00	0,00	40,15	38,80	11,52	17,76	9,51	0,00	0,00
RC2000180_P22	4	false	false	true	false	0,00	45,64	34,20	11,44	0,00	0,00	32,88	31,40	9,68	12,07	9,65	0,00	0,00
RC2000180_P22	5	false	false	true	false	0,00	41,07	32,92	8,15	0,00	0,00	37,80	36,91	14,34	13,22	9,36	0,00	0,00
RC2000180		false	false	true	false	1,00	61,21	39,11	17,12	4,98	0,00	42,18	38,31	9,70	12,97	11,78	3,86	0,00
RC2000180		false	false	true	false	0,00	42,03	25,94	16,09	0,00	0,00	37,26	36,44	9,78	12,59	14,07	0,00	0,00
RC2000180		false	false	true	false	0,00	90,13	66,09	24,04	0,00	0,00	41,63	39,45	5,71	17,01	16,74	0,00	0,00
RC2000180		false	false	true	false	0,00	53,15	40,96	12,19	0,00	0,00	50,72	48,40	12,67	25,93	9,80	0,00	0,00
RC2000180		false	false	true	false	0,00	68,68	53,59	15,09	0,00	0,00	36,22	34,79	8,55	8,56	17,69	0,00	0,00
RC2000180		false	false	true	false	1,00	87,67	64,86	17,85	4,95	0,00	46,54	45,66	8,83	16,87	14,39	5,57	0,00
RC2000180		false	false	true	false	0,00	49,30	18,25	31,05	0,00	0,00	39,82	39,50	13,61	3,82	22,07	0,00	0,00
RC2000180		false	false	true	false	0,00	49,36	46,70	2,66	0,00	0,00	33,40	32,56	10,29	16,78	5,49	0,00	0,00
RC2000180		false	false	true	false	0,00	22,48	10,16	12,32	0,00	0,00	30,28	29,81	11,26	10,40	8,14	0,00	0,00
RC2000180		false	false	true	false	0,00	73,30	48,31	24,99	0,00	0,00	47,05	45,88	9,98	16,66	19,23	0,00	0,00
RC2000180		false	false	true	false	2,00	93,77	67,42	19,80	6,55	4,22	45,32	44,26	0,00	21,48	16,62	3,87	2,29
RC2000180		false	false	true	false	0,00	65,37	43,68	21,69	0,00	0,00	44,32	43,69	10,26	16,08	17,35	0,00	0,00
RC2000180		false	false	true	false	1,00	49,38	21,81	22,57	5,00	0,00	45,10	43,92	11,40	10,89	16,59	5,04	0,00
RC2000180		false	false	true	false	3,00	95,71	65,77	16,06	13,89	7,63	43,89	42,94	5,49	16,46	13,19	4,24	2,70
RC2000180		false	false	true	false	1,00	70,33	49,79	15,64	4,90	0,00	31,62	31,51	0,00	14,90	11,45	5,16	0,00
RC2000180		false	false	true	false	1,00	90,07	65,96	19,22	4,89	0,00	50,67	48,63	10,01	20,46	14,14	4,02	0,00
RC2000180		false	false	true	false	0,00	79,04	62,52	16,51	0,00	0,00	42,55	42,07	9,54	14,37	18,16	0,00	0,00
RC2000180		false	false	true	false	0,00	46,76	42,40	4,35	0,00	0,00	31,59	30,99	13,01	15,89	2,09	0,00	0,00
RC2000180		false	false	true	false	0,00	66,40	61,50	4,90	0,00	0,00	37,63	36,58	10,89	19,20	6,50	0,00	0,00
RC2000180		false	false	true	false	1,00	74,09	57,80	12,92	3,36	0,00	29,01	28,87	0,00	15,92	8,26	4,69	0,00
RC2000180		false	false	true	false	0,00	38,13	30,36	7,78	0,00	0,00	39,95	37,87	13,47	14,99	9,41	0,00	0,00
RC2000180		false	false	true	false	0,00	85,57	66,84	18,73	0,00	0,00	46,99	45,41	15,68	19,38	10,36	0,00	0,00
RC2000180		false	false	true	false	2,00	84,60	65,45	12,32	6,84	5,10	49,26	47,66	13,51	17,13	8,36	4,46	4,20
RC2000180		false	false	true	false	0,00	80,19	73,24	6,95	0,00	0,00	37,81	36,84	6,96	21,40	8,48	0,00	0,00
RC2000180		false	false	true	false	0,00	73,58	66,74	6,85	0,00	0,00	40,32	39,26	7,77	23,70	7,78	0,00	0,00
RC2000180		false	false	true	false	0,00	66,21	48,59	17,63	0,00	0,00	47,13	45,58	11,84	15,71	18,03	0,00	0,00
RC2000180		false	false	true	false	2,00	90,80	68,69	15,59	6,52	1,38	39,77	39,31	0,00	19,88	10,78	7,89	0,76



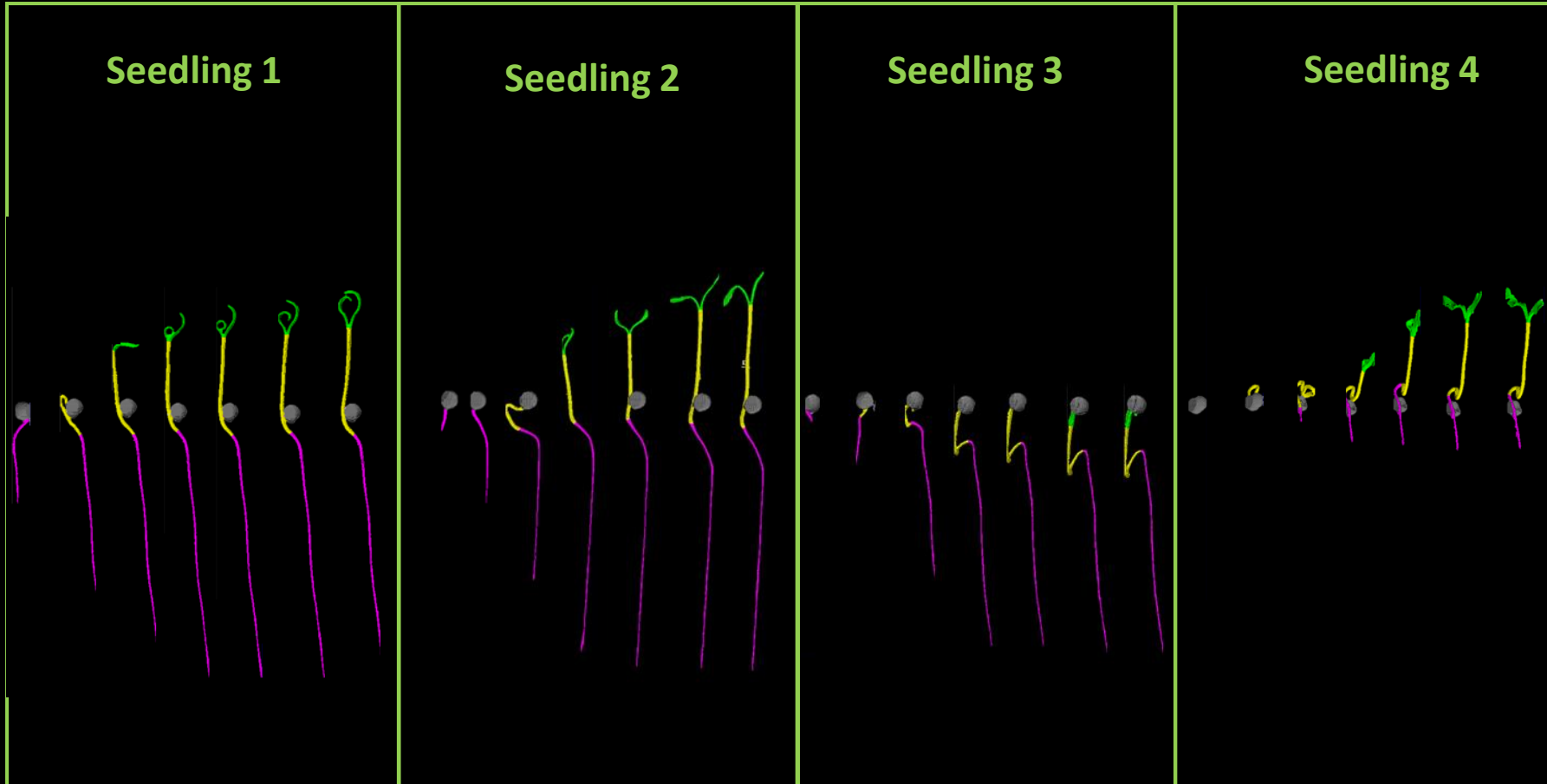
phenoTest

Automated classification into qualitative classes



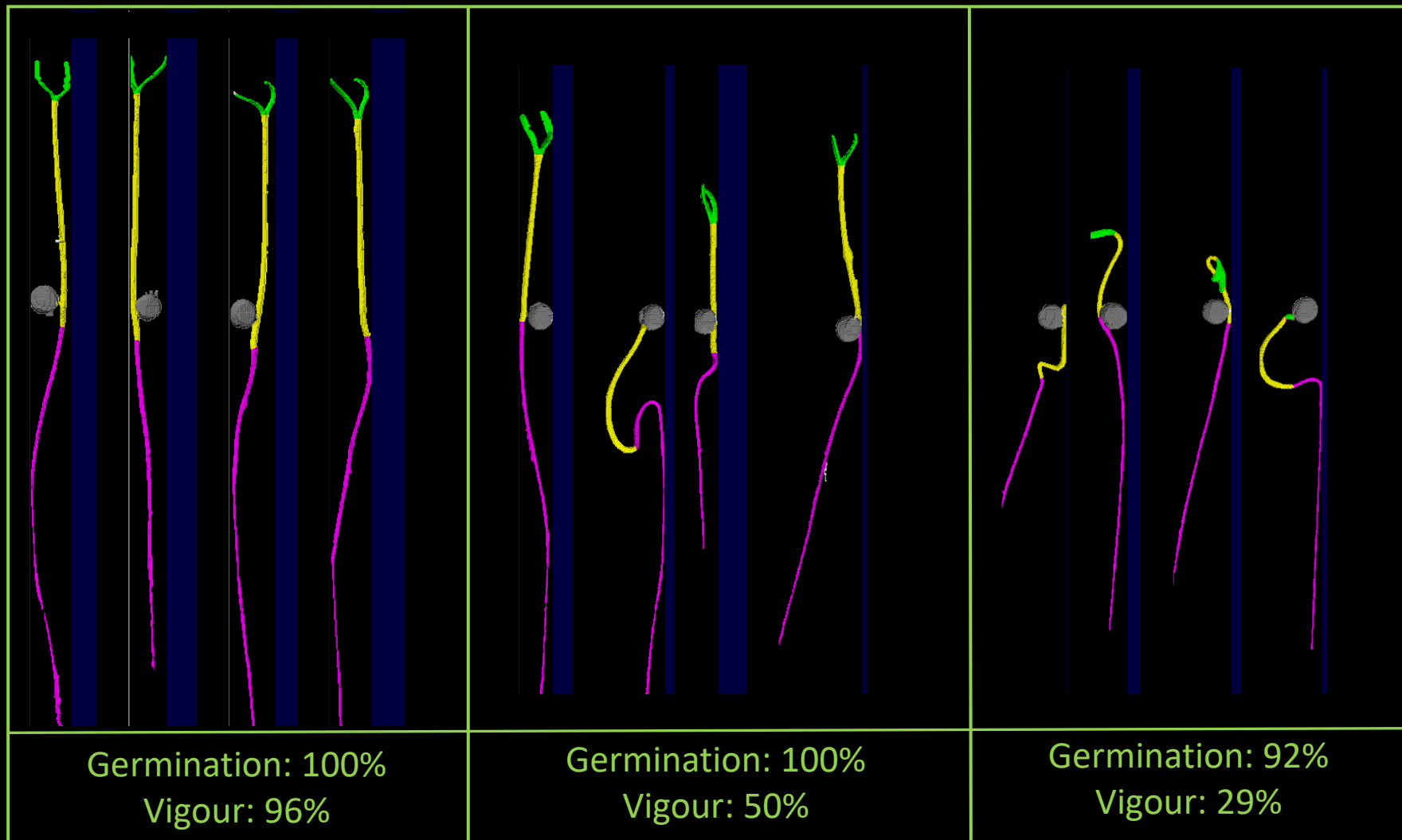
phenoTest

3D-phenotyping over time = 4D-phenotyping



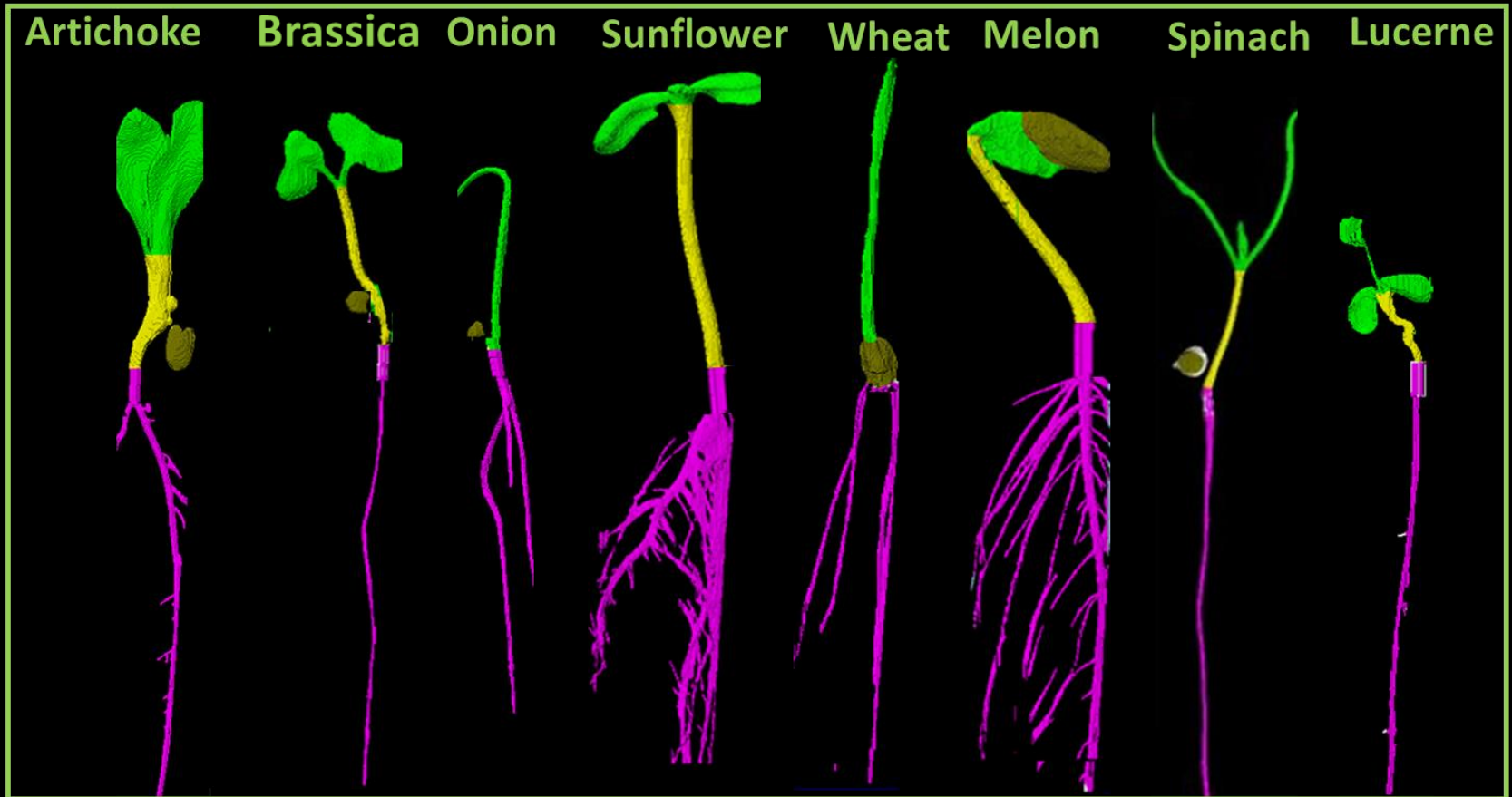
phenoTest

Quantifying vigor of seed lots



The phenoTest

A universally applicable tool for all crops

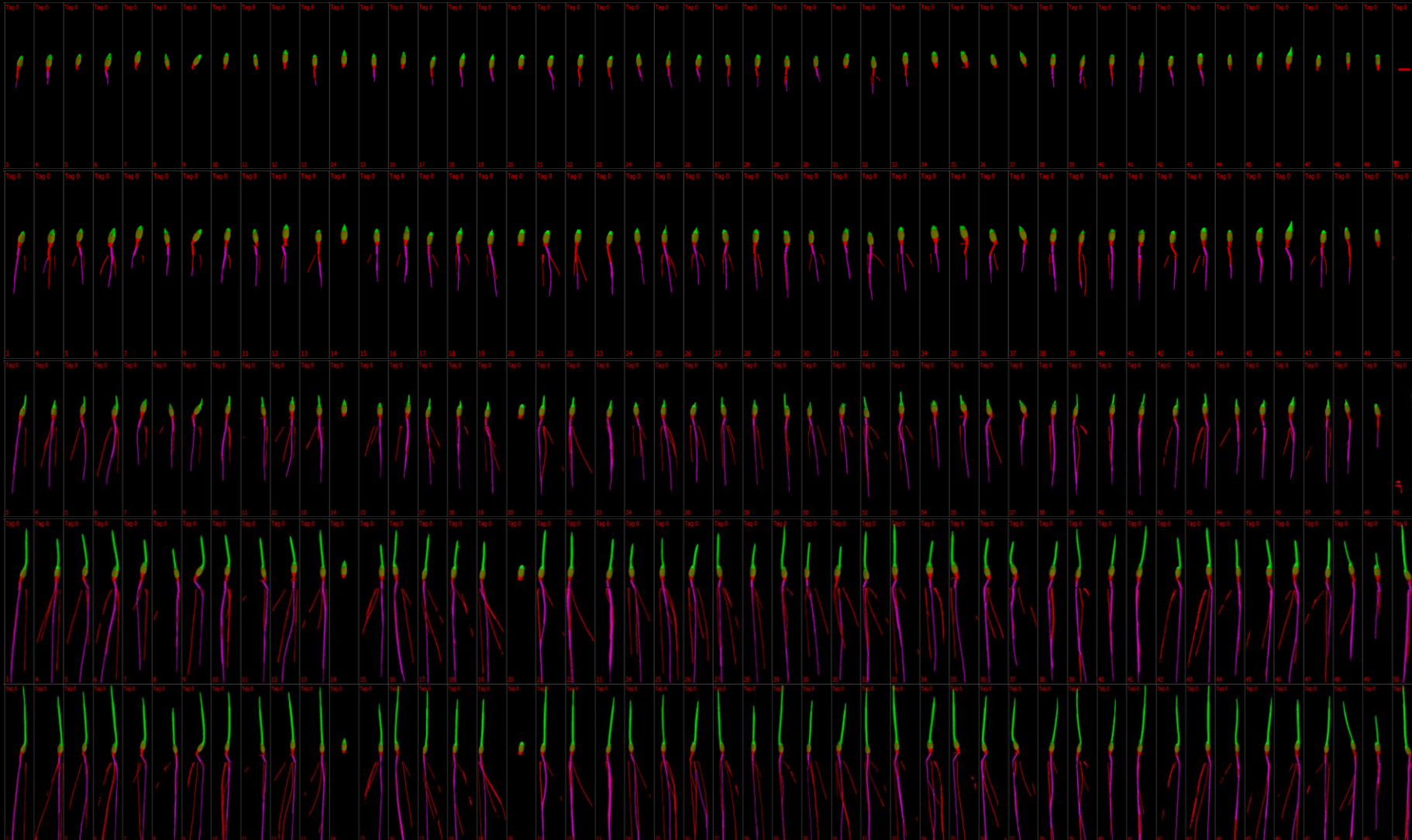


.... etc.

phenoLytics

phenoTest

Display segmentations of barley per day



The phenoTest-

A universal and automated germination and vigor test for all crops

- Fully-automated, high-throughput (24/7 operation possible)
- Reduced labor dependency and operation costs
- Standardized and globally reproducible across labs
- Quantified and documented measurements for each individual seedling
- Quantitative data of all plant organs of each individual seedling
- Big data acquisition for statistic analyses and retrospective adaptation

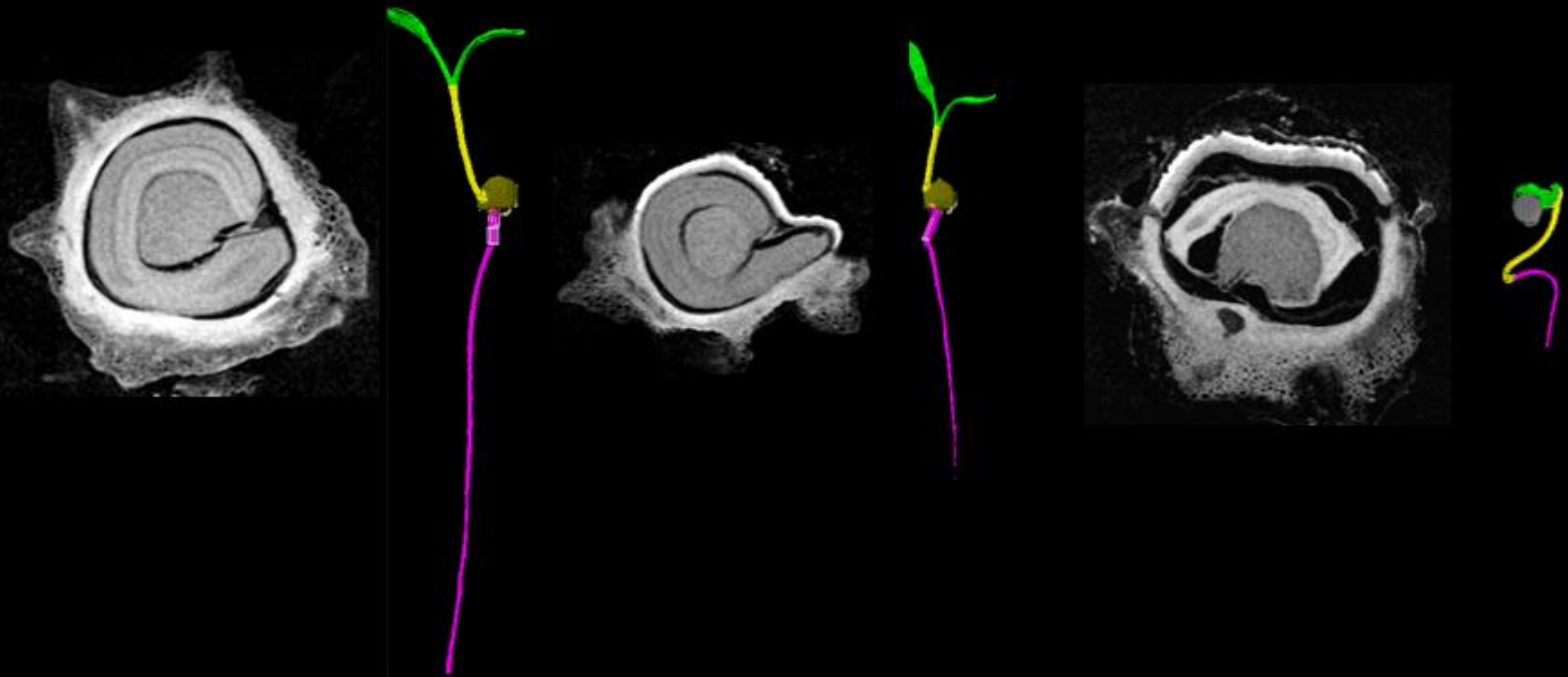
Combining

phenoCheck and **phenoTest**

to define relevant seed parameters for
high germination, vigor and yield

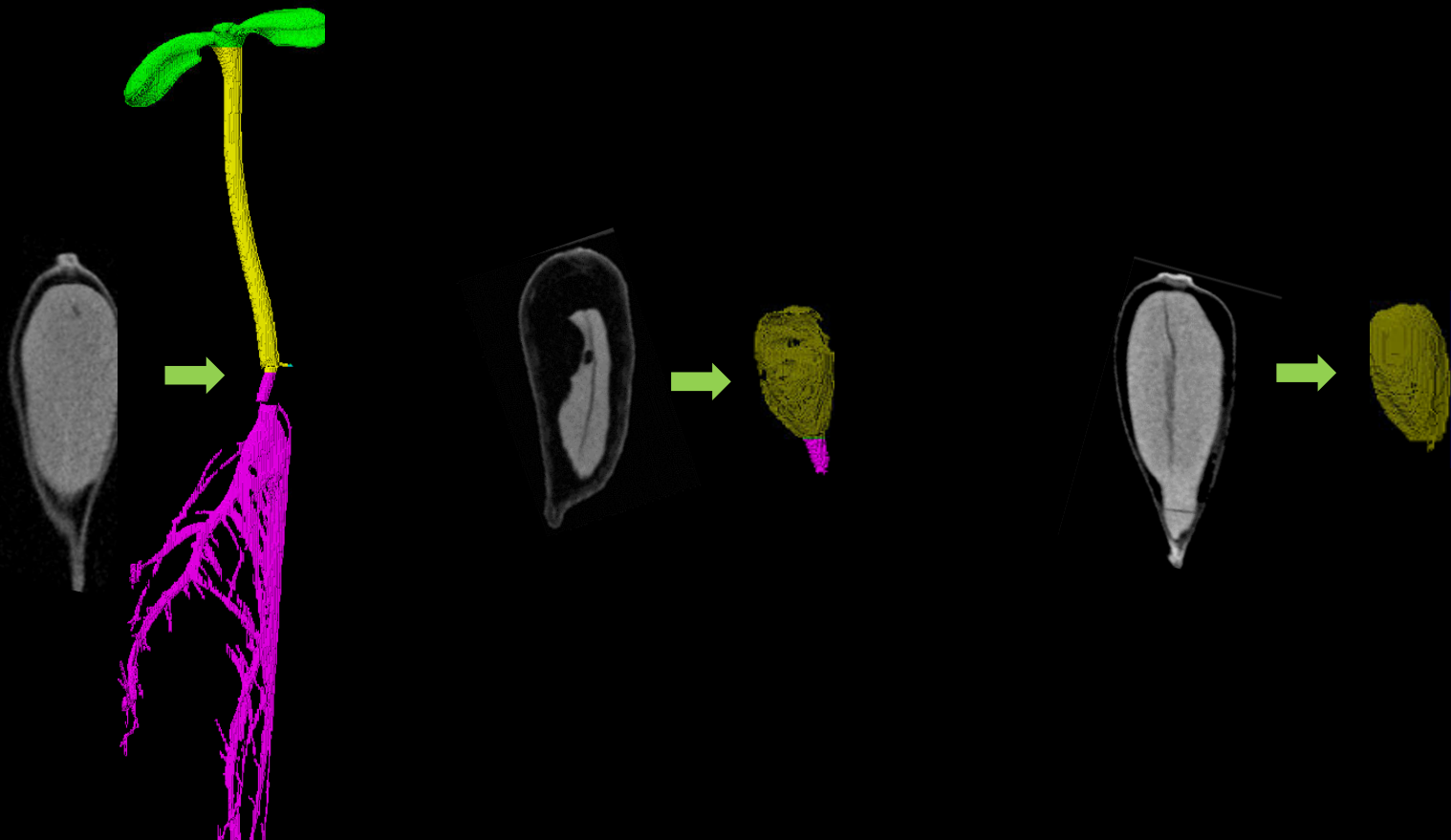
Combining phenoCheck and phenoTest – The missing link in seed analyses:

Automated 1:1 comparison
of seed to seedling quality in high-throughput



Combining phenoCheck and phenoTest – The missing link in seed analyses:

Automated 1:1 comparison
of seed to seedling quality in high-throughput



phenoCheck and phenoTest-

Enabling tools to optimize all processes

- Automated seed analysis/ germination and vigor testing
- Breeding
- Multiplication
- Seed processing
- Seed treatment
- Seed priming and pelleting
- Seed storage and packaging
- Others....



phenoLytics

.... seeds go digital

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