From wild relative to relative - making pre-breeding matter

Regional training workshop

Predictive characterization and pre-breeding of crop wild relatives

Pretoria, South Africa

Monday 13th – Thursday 16th April 2015

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"Food is the moral right of all who are born into this world."
– Norman Borlaug,
(March 25, 1914-Sept. 12, 2009),
Nobel laureate and father
of the Green Revolution
breadfortheworld
HAVE FAITH. END HUNGER.
www.bread.org

SOUTH AFRICAN SEED MARKET FOR AGRONOMIC CROPS 2012/13

CROP	Mass (kilogram)		MARKET VALUE BASED ON RETAIL SELLING PRICE [seed price list] R million	Mass (kilogram)		
	Local market	Export market		GMO's (local market)	Hybrids (local and international markets)	Open-pollinated [non-hybrids] (local and international markets)
Barley	6 710 138	0	28.93	0	0	6 710 138
Canola	322 291	400	34.30	0	43 610	279 081
Cotton	44 275	382 500	3.94	405 436	0	426 775
Dry bean	2 870 192	634 107	93.88	0	0	3 504 299
Dry pea	300	128 675	1.04	0	0	128 975
Durum Wheat	172 975	0	0.04	0	0	172 975
Grain sorghum	529 777	267 958	25.42	0	517 045	280 690
Groundnut	2 657 682	43 500	48.06	0	0	2 701 182
Kidney bean	650	0	0.05	0	0	650
OP Maize (white)	2 517 151	1 293 641	46.12	0	0	3 810 792
OP Maize (yellow)	1 091 876	12 115	43.90	0	0	1 103 991
Soya bean	5 789 324	226 300	127.49	2 835 275	0	6 015 624
Sugar beet	0	0	0.00	0	0	0
Sunflower	2 151 705	611 599	209.95	0	1 741 823	1 021 481
Tobacco	12	141	2.80	0	101	52
Wheat	14 837 145	184 325	115.39	0	0	15 021 470
Other Agronomy Crops			3.42			
HYBRID MAIZE: 60K UNITS	60K UNITS	60K UNITS		60K UNITS	60K UNITS	
Yellow hybrid: Commercial market	955 147	20 034	1 721.28	727 924	247 257	0
Yellow hybrid: Smallholder market	1 789	16 648	6.71	0	18 437	0
White hybrid: Commercial market	715 179	55 648	1 755.90	606 005	164 822	0
White hybrid: Smallholder market	5 445	76 774	27.51	320	81 899	0
TOTAL			**R 4 296.12**			

Overview

- **Introduction**
  - **Wheat**
  - **Wheat rusts**
  - **Resistance**
  - **Conventional breeding**
- Wheat pre-breeding
- Case study
- Current and future work

Wheat

Introduction/

- Global wheat production needs to increase
- Stabilize/Increase crop productivity under:
  - Increasingly unstable climate;
  - Less hectares; and
  - Under increase biotic and abiotic stresses
- Breeding and agronomic practices important
- Abiotic: drought, salinity and heat
- Biotic: Fungal diseases most important biotic stressors

Wheat rusts

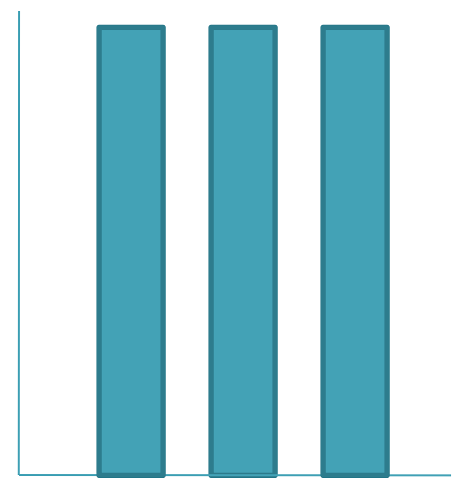
Introduction/

- Wheat rust pathogens
  - *Puccinia graminis* f. sp. *tritici*
  - *Puccinia triticina*
  - *Puccinia striiformis* f. sp. *tritici*
- Causes big crop losses in some seasons
- Breeding for resistance will help in sustaining wheat farming
- Less fungicide application
  - Lowers production costs
  - Decreases environmental impact of production

Resistance breeding

Introduction/

- Vertical resistance
  - Race specific resistance, major gene resistance
  - Gene-for-gene
  - Pathotypes evolve quicker to overcome the resistance



Race- specific resistance

Resistance breeding

Introduction/

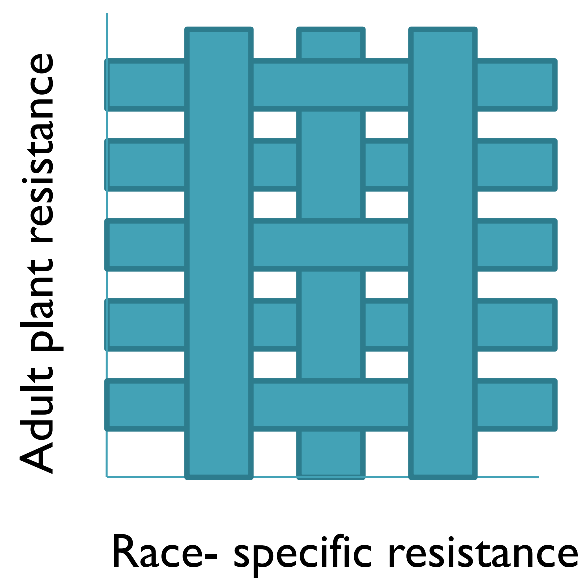
- Vertical resistance
  - Race specific resistance, major gene resistance
  - Gene-for-gene
  - Pathotypes evolve quicker to overcome the resistance
- Horizontal resistance
  - Race non specific , minor gene resistance or durable resistance
  - Minor genes with accumulating effect
  - Resistance more complex for pathotypes to overcome

Adult plant resistance

Resistance breeding

Introduction/

- Vertical resistance
  - Race specific resistance, major gene resistance
  - Gene-for-gene
  - Pathotypes evolve quicker to overcome the resistance
- Horizontal resistance
  - Race non specific , minor gene resistance or durable resistance
  - Minor genes with accumulating effect
  - Resistance more complex for pathotypes to overcome



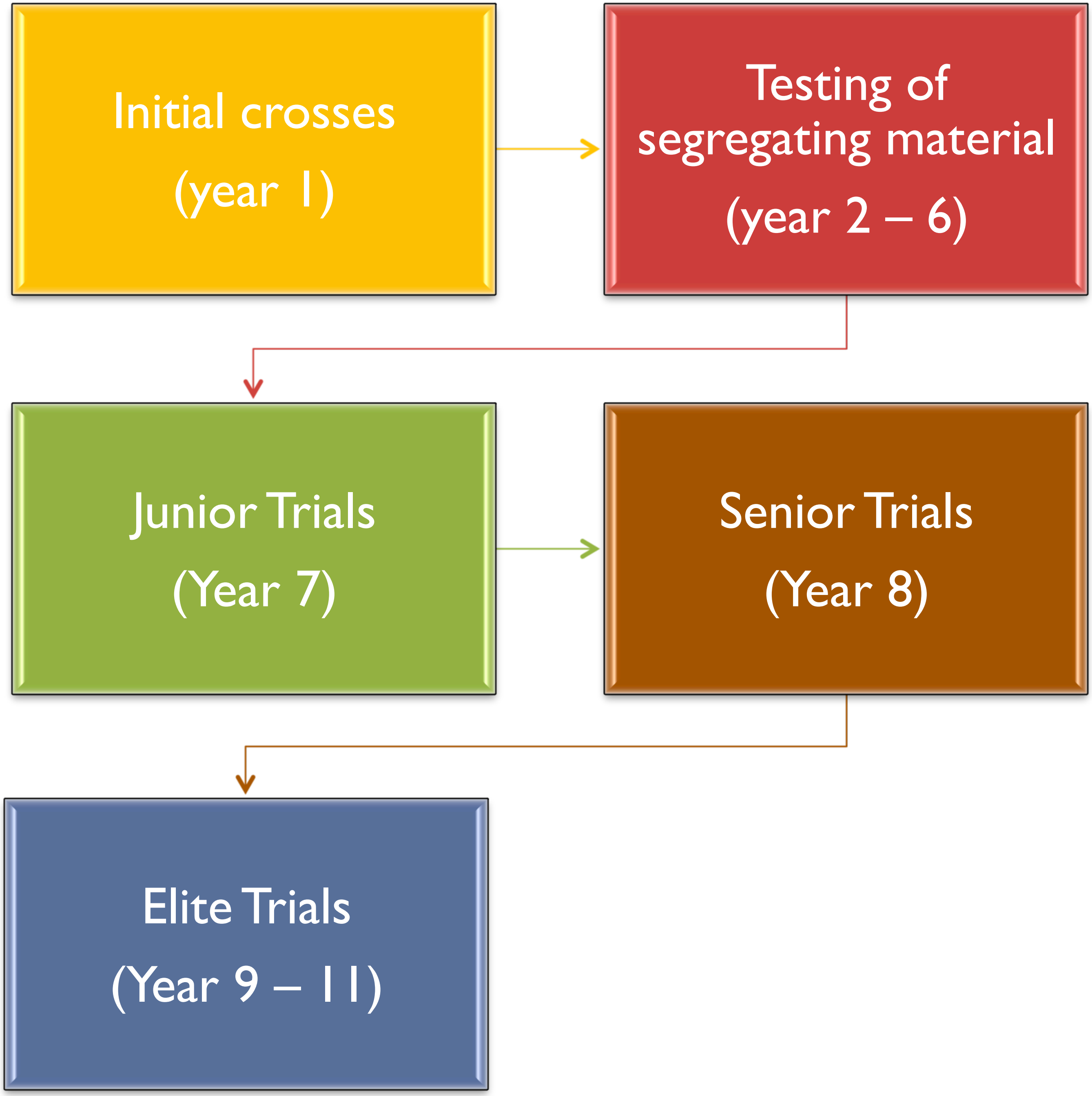
Resistance breeding

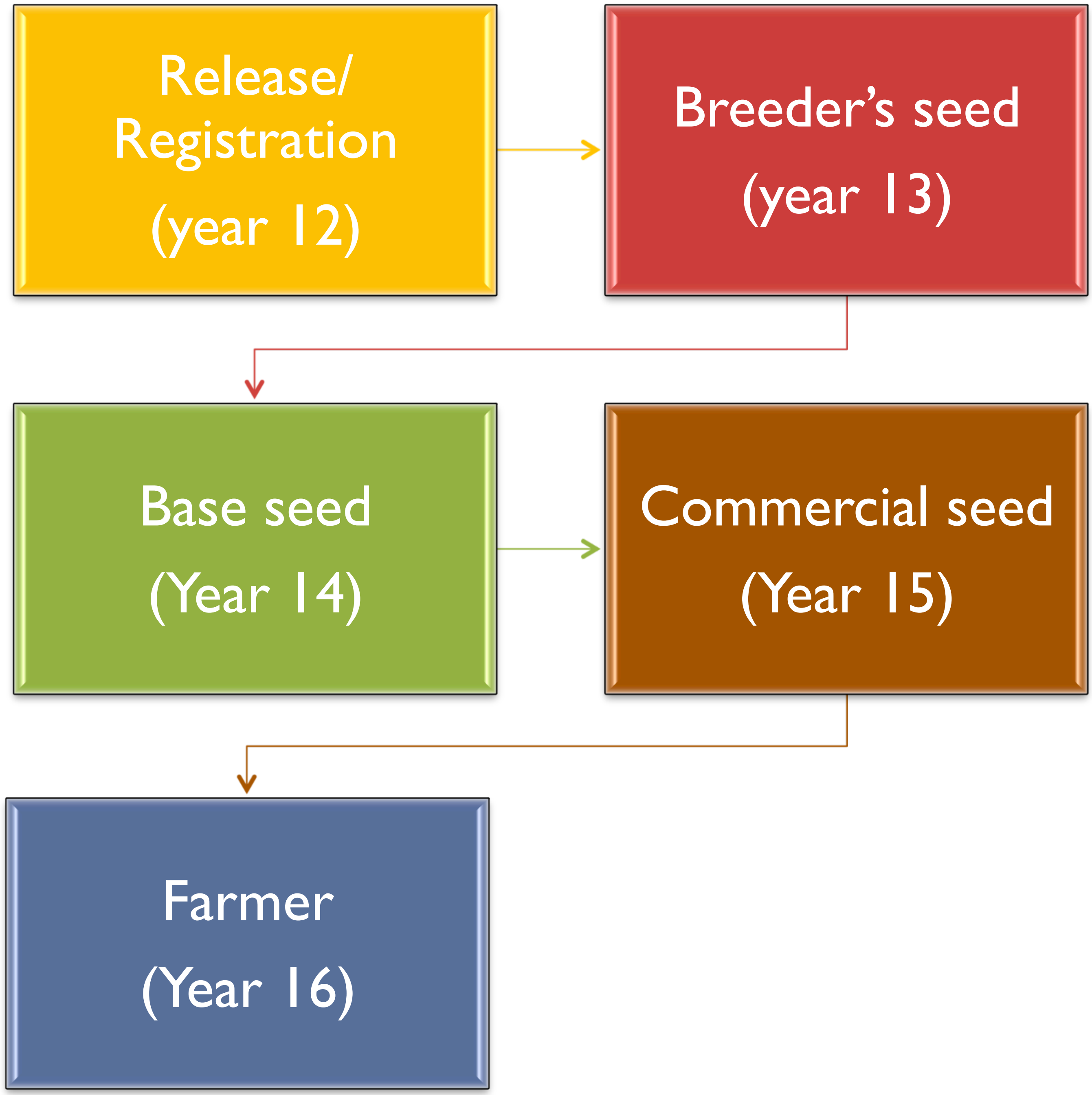
Introduction/

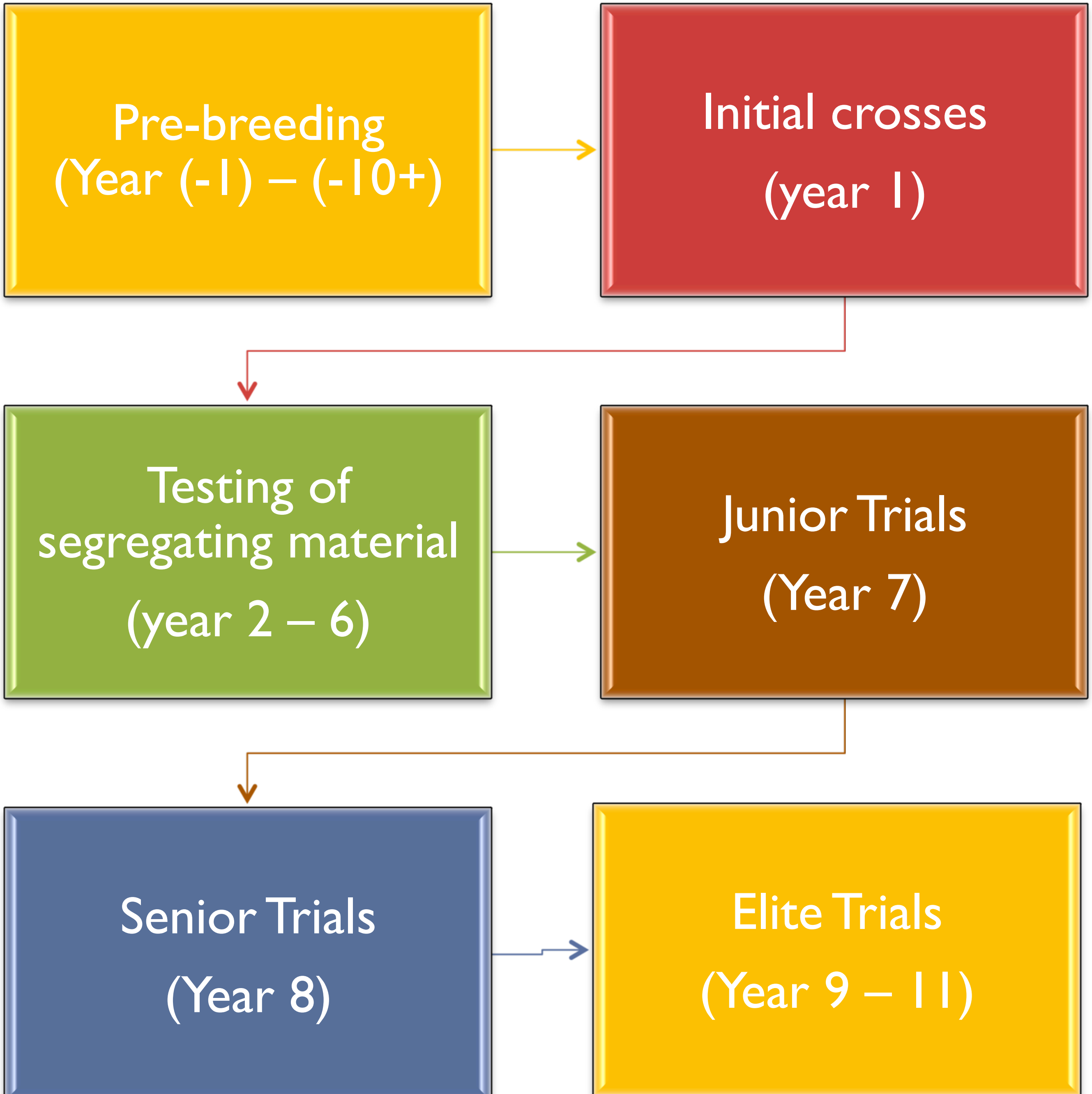
Stem rust	Avirulence genes	Virulence genes
UVPgt60	*Sr13*, *Sr14*, *Sr21*, *Sr22*, *Sr25*, *Sr26*, *Sr27*, *Sr29*, *Sr32*, *Sr33*, *Sr35*, *Sr36*, *Sr37*, *Sr39*, *Sr42*, *Sr43*, *Sr44*, *SrEm*, *SrTmp* and *SrSatu*	*Sr5*, *Sr6*, *Sr7b*, *Sr8a*, *Sr8b*, *Sr9a*, *Sr9b*, *Sr9d*, *Sr9e*, *Sr9g*, *Sr10*, *Sr11*, *Sr16*, *Sr17*, *Sr24*, *Sr30*, *Sr31*, *Sr34*, *Sr38*, *Sr41* and *SrMcN*.

Leaf rust	Avirulence genes	Virulence genes
UVPrt9	*Lr2a*, *Lr2b*, *Lr3bg*, *Lr15*, *Lr16*, *Lr17* and *Lr26*	*Lr1*, *Lr2c*, *Lr3a*, *Lr3ka*, *Lr10*, *Lr11*, *Lr14a*, *Lr20* and *Lr30*
UVPrt13	*Lr3a*, *Lr3bg*, *Lr3ka*, *Lr11*, *Lr16*, *Lr20* and *Lr30*	*Lr1*, *Lr2a*, *Lr2b*, *Lr2c*, *Lr10*, *Lr14a*, *Lr15*, *Lr17*, *Lr24* and *Lr26*

Stripe rust	Avirulence genes	Virulence genes
6E22A-	*Yr1*, *Yr3a*, *Yr4a*, *Yr4b*, *Yr5*, *Yr9*, *Yr10*, *Yr15*, *Yr27*, *YrA*, *YrCle*, *YrCv*, *YrHVII*, *YrMor*, *YrSd*, *YrSp* and *YrSu*	*Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr17*and *Yr25*


Initial crosses
(year 1)
Testing of segregating material
(year 2 – 6)
Junior Trials
(Year 7)
Senior Trials
(Year 8)
Elite Trials
(Year 9 – 11)


Release/
Registration
(year 12)
Breeder's seed
(year 13)
Base seed
(Year 14)
Commercial seed
(Year 15)
Farmer
(Year 16)


Pre-breeding
(Year (-1) – (-10+)
Initial crosses
(year 1)
Testing of segregating material
(year 2 – 6)
Junior Trials
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Senior Trials
(Year 8)
Elite Trials
(Year 9 – 11)

Pre-breeding
(Year (-1) – (-10+))

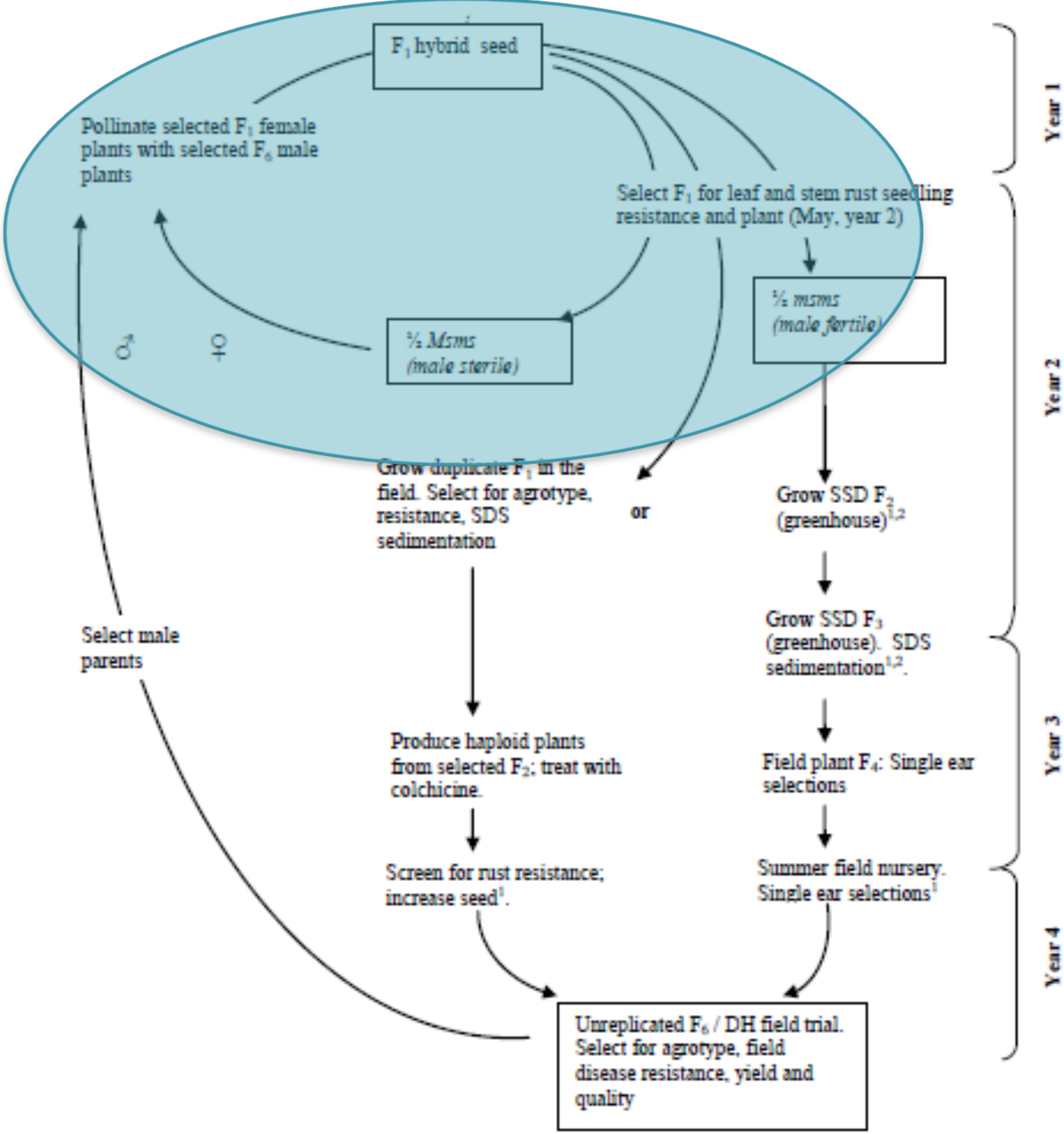
Overview

- Introduction
- **Wheat pre-breeding**
  - **MS-MARS**
  - **Doubled haploids**
  - **MAS**
- Case study
- Current and future work

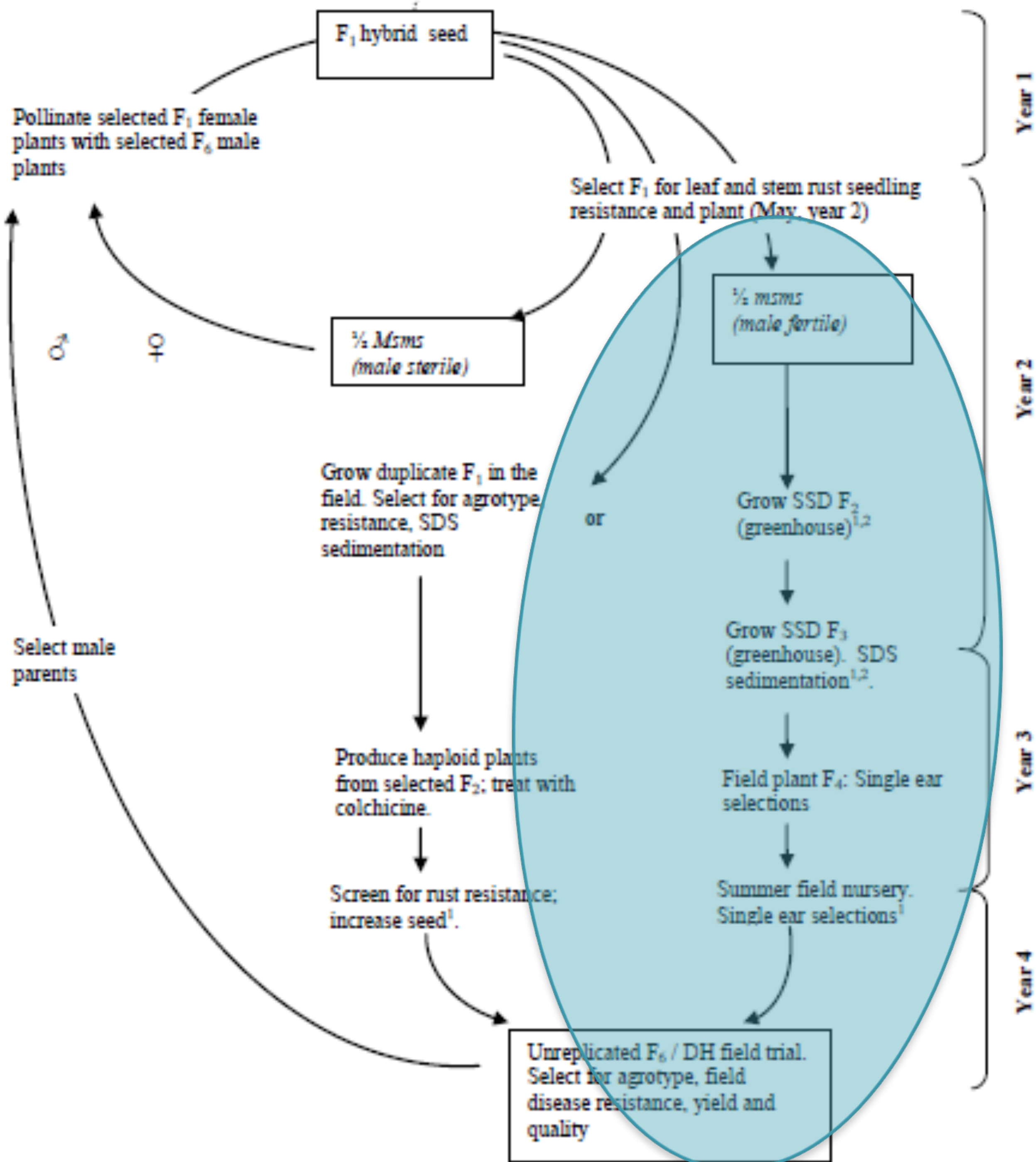
Introduction

Wheat pre-breeding/

- MS-MARS
- Since 1998
- WCT funding
- Concentrate mainly on rust resistance
  - Specific genes via MAS
  - APR
- Distribute rust resistance material
  - Nurseries (since 2006)
  - Lines together with molecular info and phenotype info



F1 hybrid seed
Pollinate selected F1 female plants with selected F6 male plants
Select F1 for leaf and stem rust seedling resistance and plant (May, year 2)
½ Msms (male sterile)
½ msms (male fertile)
♂
♀
Grow duplicate F1 in the field. Select for agrotype, resistance, SDS sedimentation
or
Grow SSD F2 (greenhouse)1,2
Grow SSD F3 (greenhouse). SDS sedimentation1,2.
Select male parents
Produce haploid plants from selected F2; treat with colchicine.
Field plant F4: Single ear selections
Screen for rust resistance; increase seed1.
Summer field nursery. Single ear selections1
Unreplicated F6 / DH field trial. Select for agrotype, field disease resistance, yield and quality
Year 1
Year 2
Year 3
Year 4



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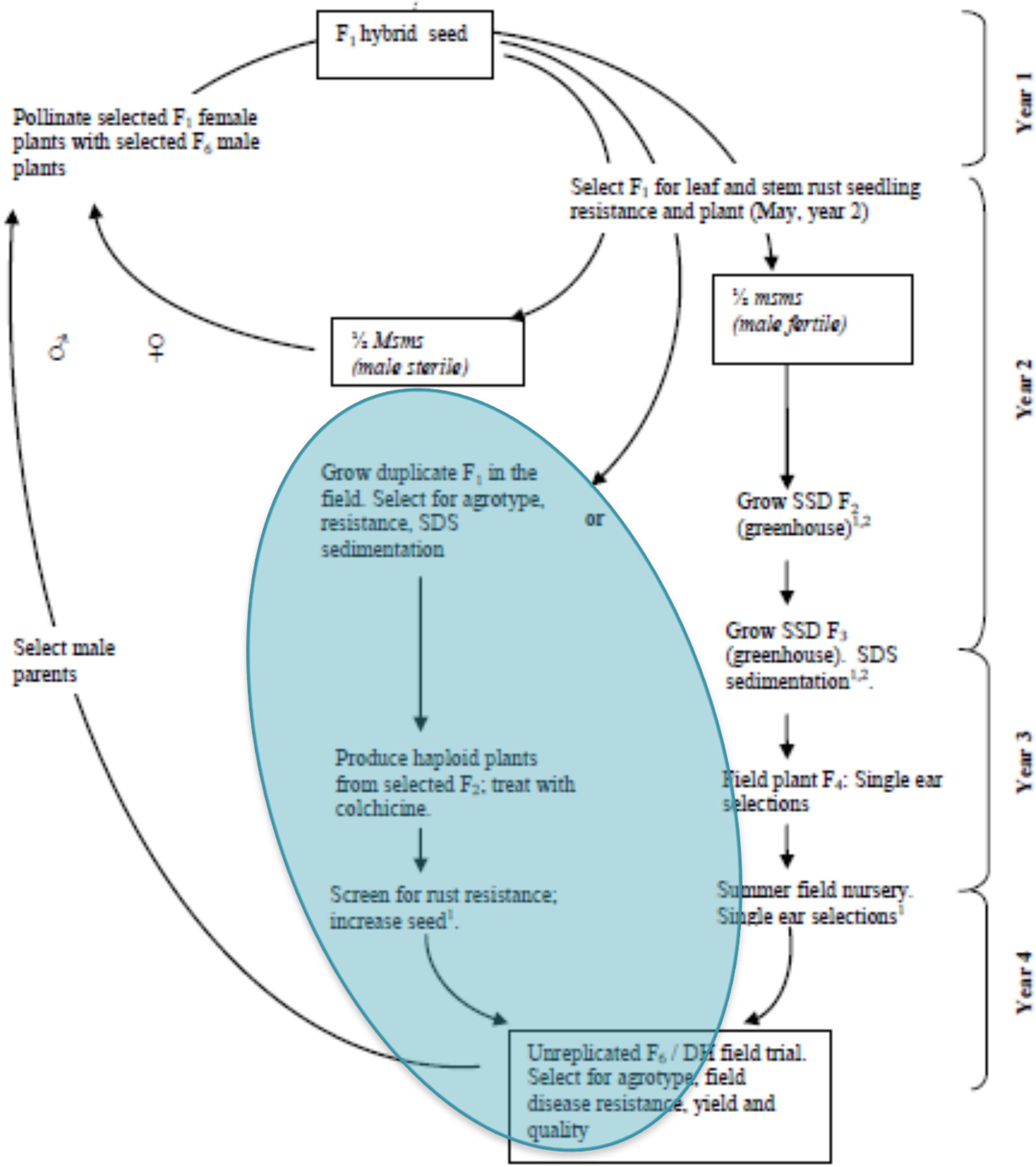
Year 1
Year 2
Year 3
Year 4


SU-PBL



F_1 hybrid seed
Year 1
Pollinate selected F_1 female plants with selected F_6 male plants
Select F_1 for leaf and stem rust seedling resistance and plant (May, year 2)
½ *msms* (*male fertile*)
½ *Msms* (*male sterile*)
♂
♀
Year 2
Grow duplicate F_1 in the field. Select for agrotype, resistance, SDS sedimentation
or
Grow SSD F_2 (greenhouse)[1,2]
Grow SSD F_3 (greenhouse). SDS sedimentation[1,2].
Select male parents
Produce haploid plants from selected F_2; treat with colchicine.
Field plant F_4: Single ear selections
Year 3
Screen for rust resistance; increase seed[1].
Summer field nursery. Single ear selections[1]
Year 4
Unreplicated F_6 / DH field trial. Select for agrotype, field disease resistance, yield and quality

Doubled haploids

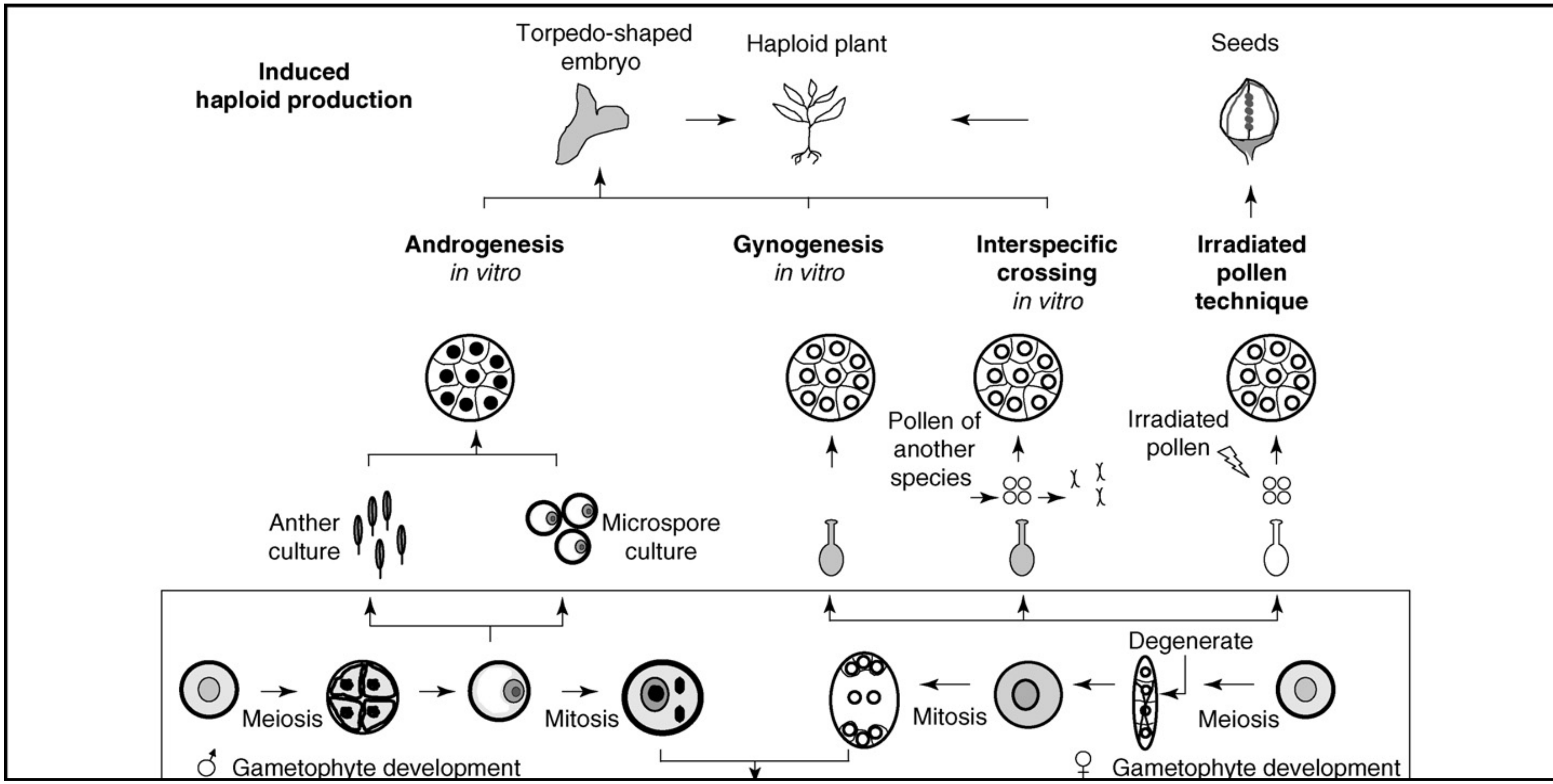
Wheat pre-breeding/

- Doubled haploid production is the most time efficient route to homozygosity in plants.
- There are three reasons for using this technology in SA context:
  - Most efficient route of fixing desirable traits into specific lines
  - Facilitates hybrid breeding
  - Doubled haploids can be applied in MAS
- There are three methods of doubled haploid production in wheat
  - Wide crosses
  - Anther culture
  - Microspore culture

Doubled haploids

Wheat pre-breeding/

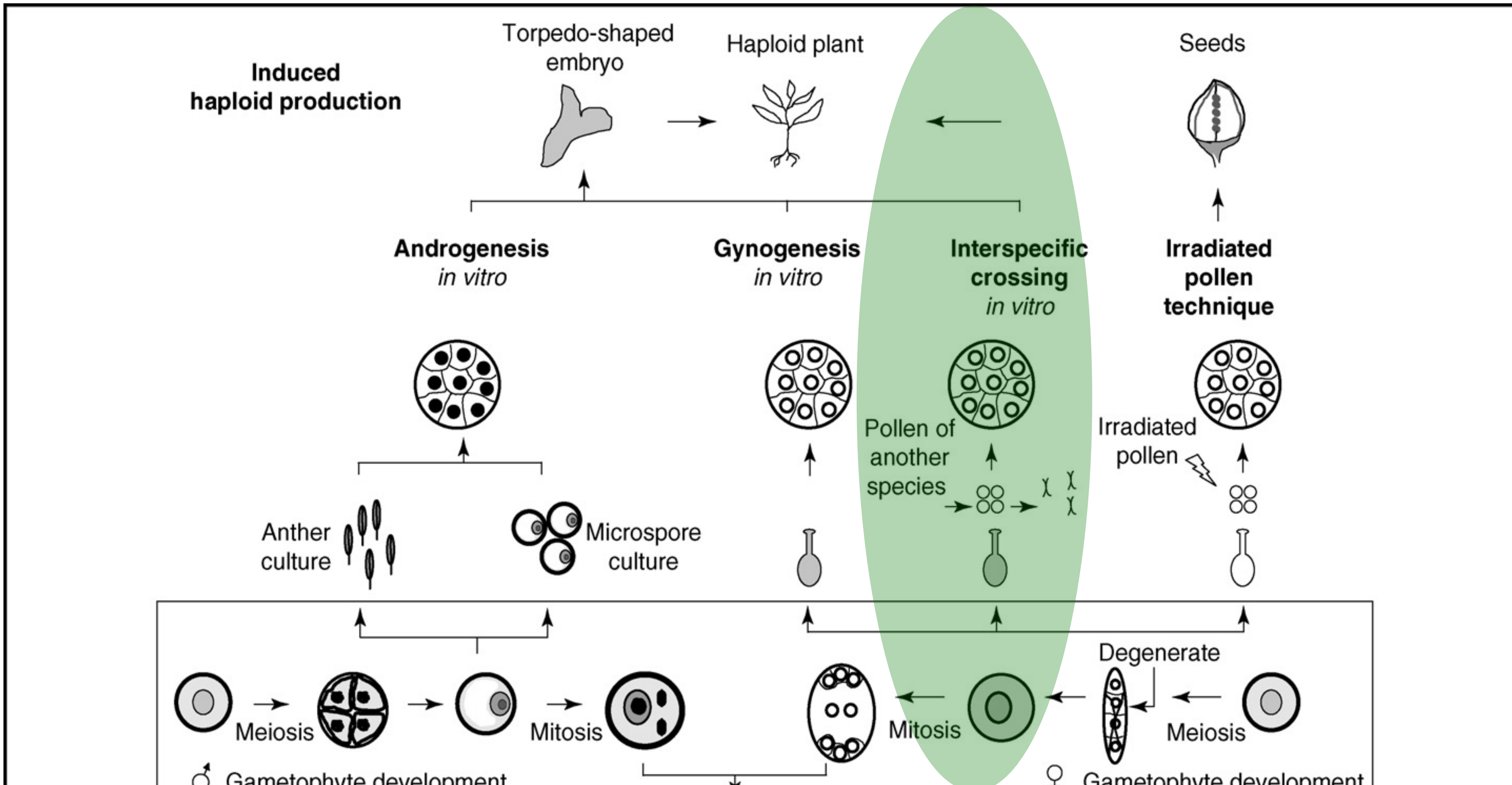
Pathways for doubled haploid induction.



Wide-crossing

Wheat pre-breeding/Doubled haploids

Pathways for doubled haploid induction.



Wide-crossing

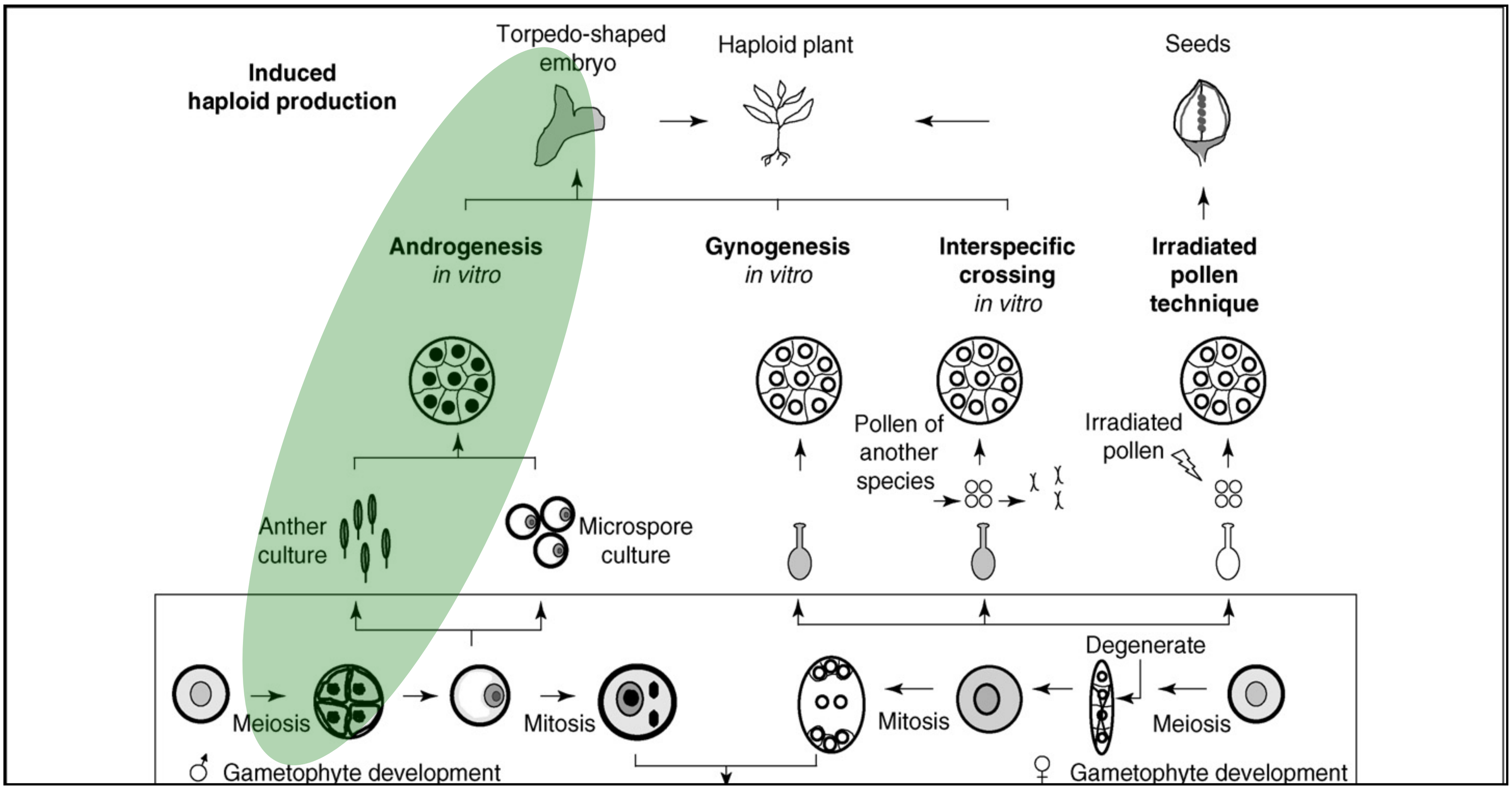
Wheat pre-breeding/Doubled haploids

1. Pollination by genetically distant male pollinator at uni-nucleated stage
2. Eg. Maize pollinating wheat
3. Fundamental genetic incompatibility
4. Elimination of the male genetic material
5. Haploid embryos that are produced are rescued
6. Cultured *in vitro* to produce haploid plants
7. Acclimated to *ex vivo* environment
8. Colchicine treatments
9. Doubled haploid seeds produced

Anther culture

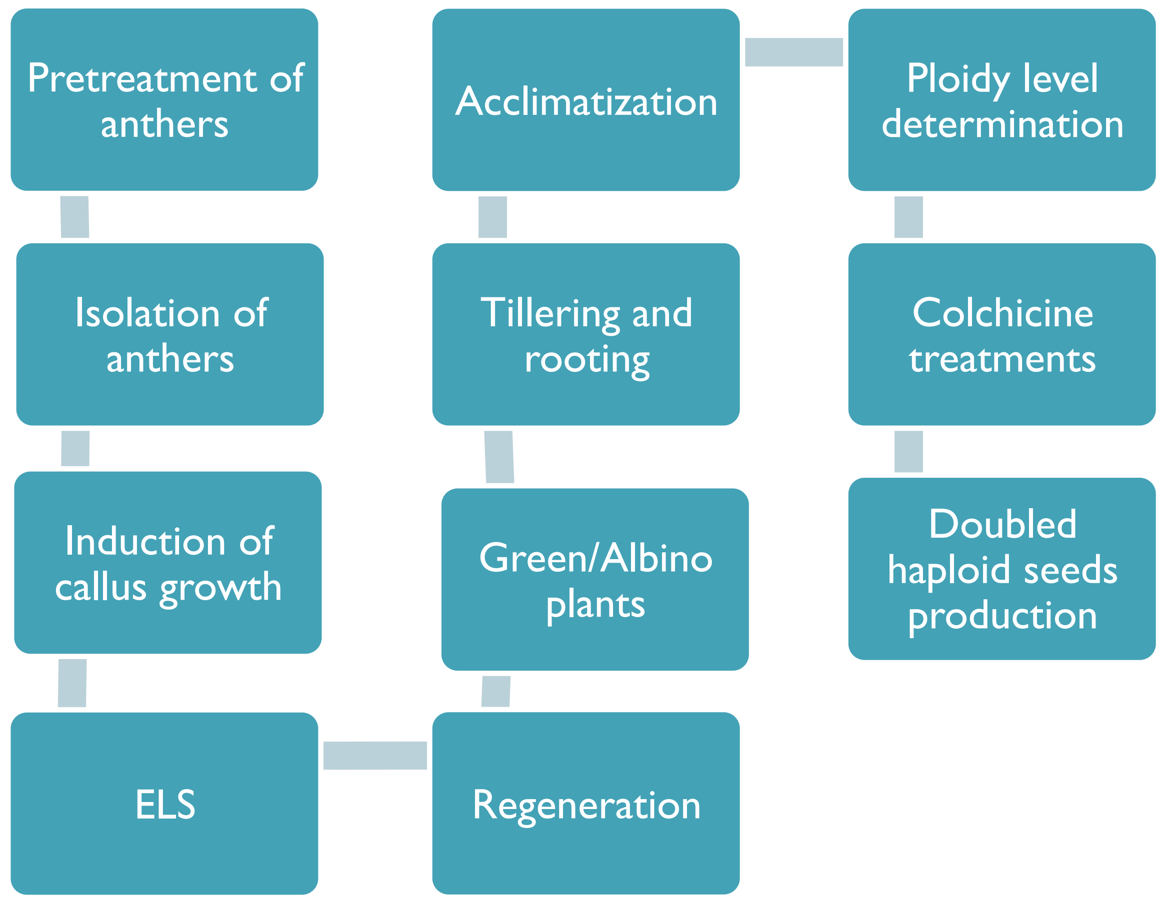
Wheat pre-breeding/Doubled haploids

Pathways for doubled haploid induction.



Anther culture

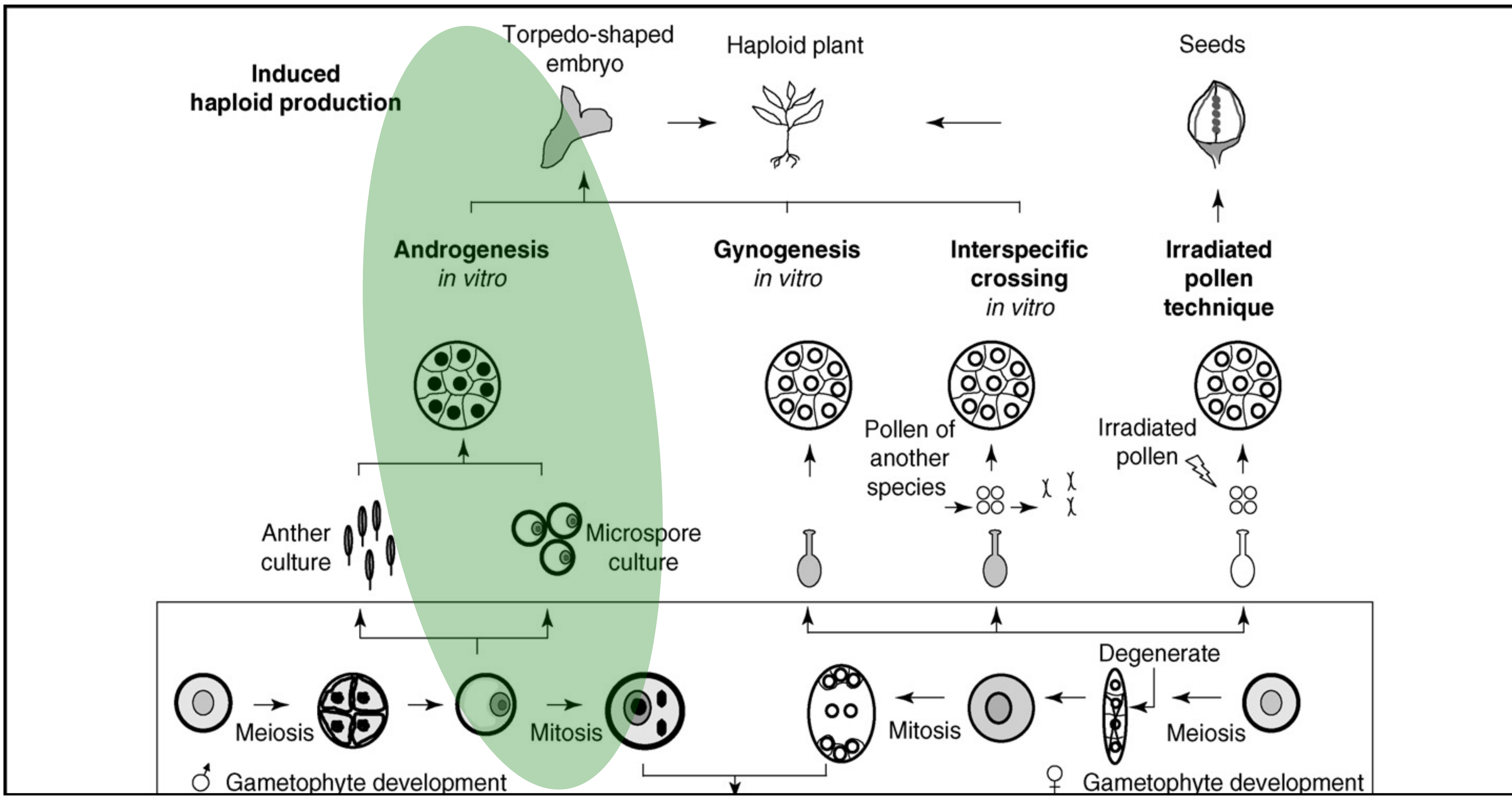
Wheat pre-breeding/Doubled haploids



Microspores

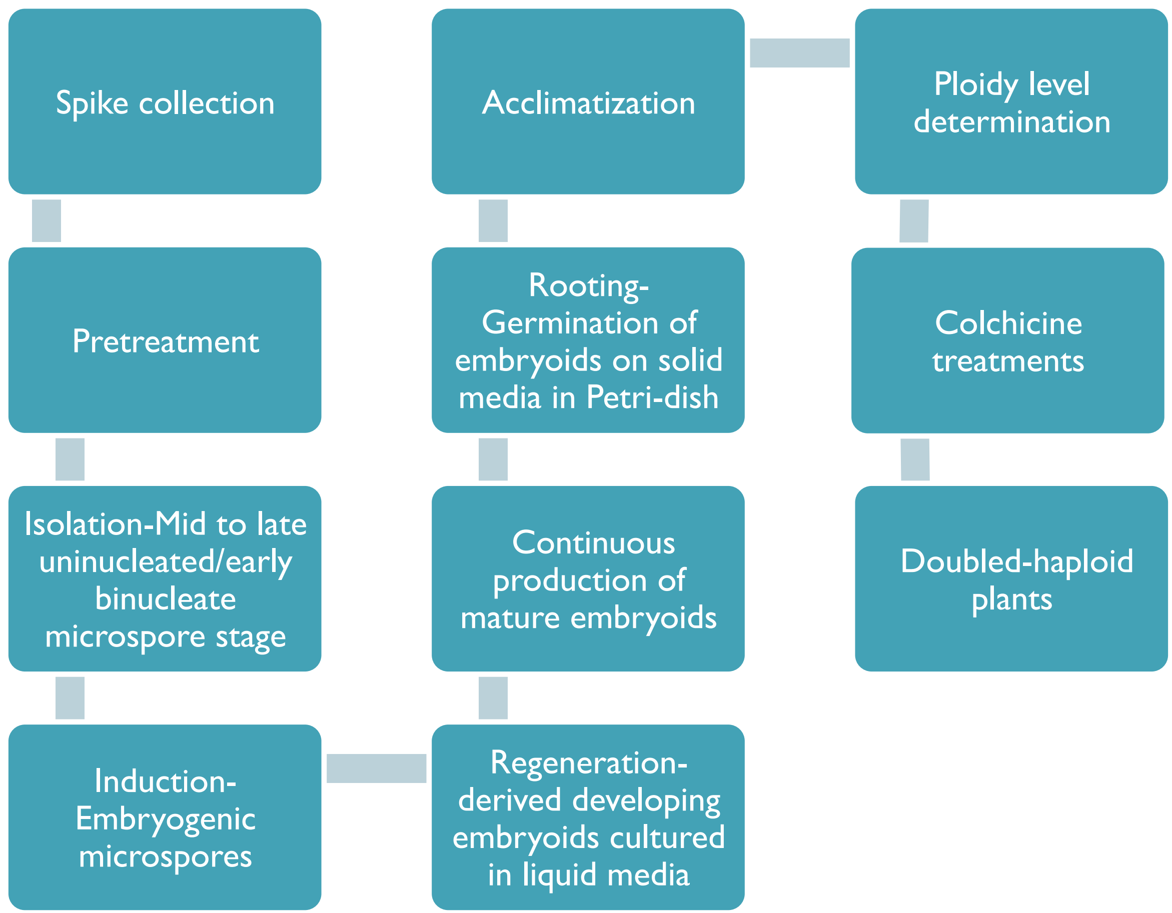
Wheat pre-breeding/Doubled haploids

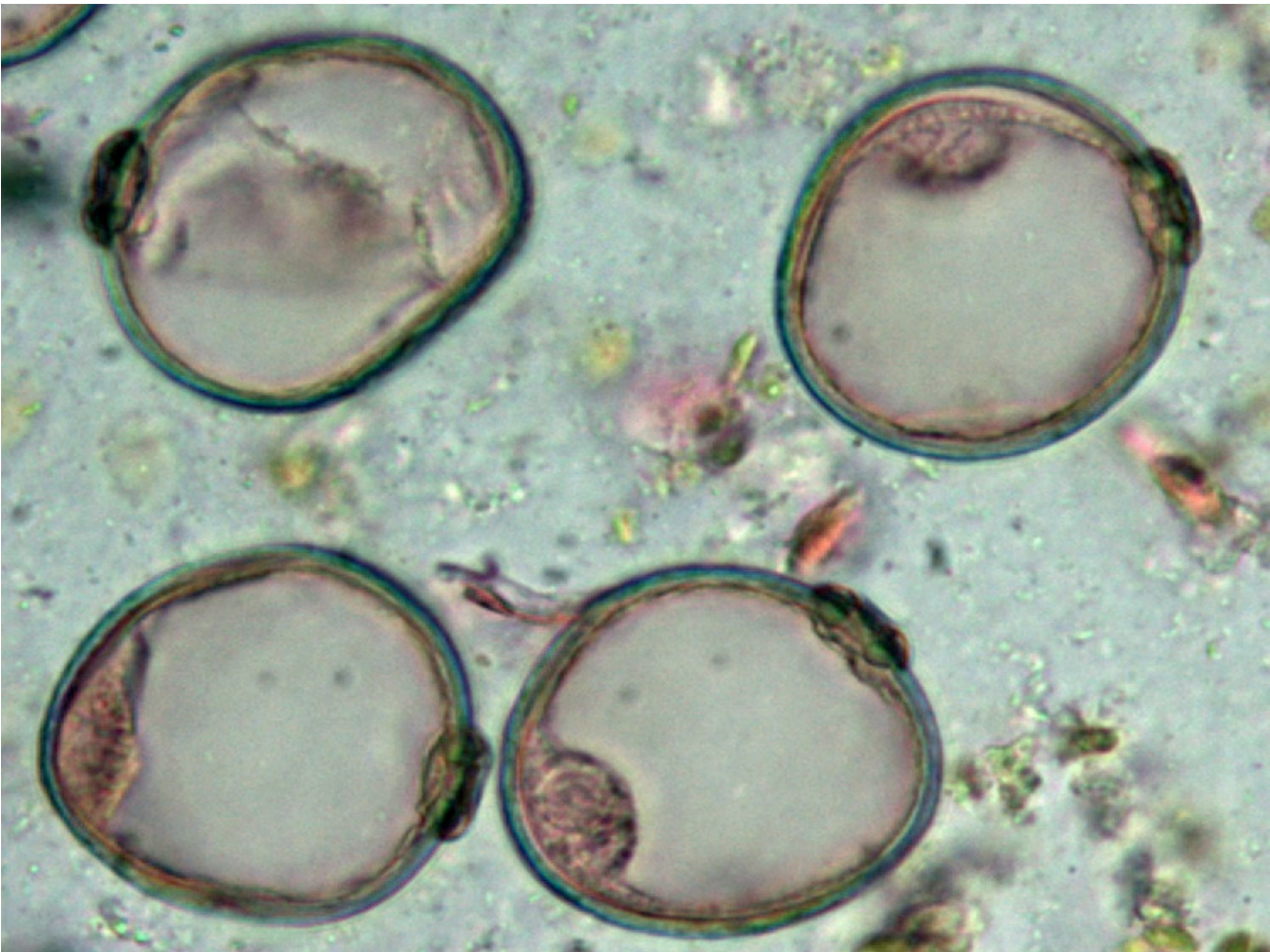
Pathways for doubled haploid induction.

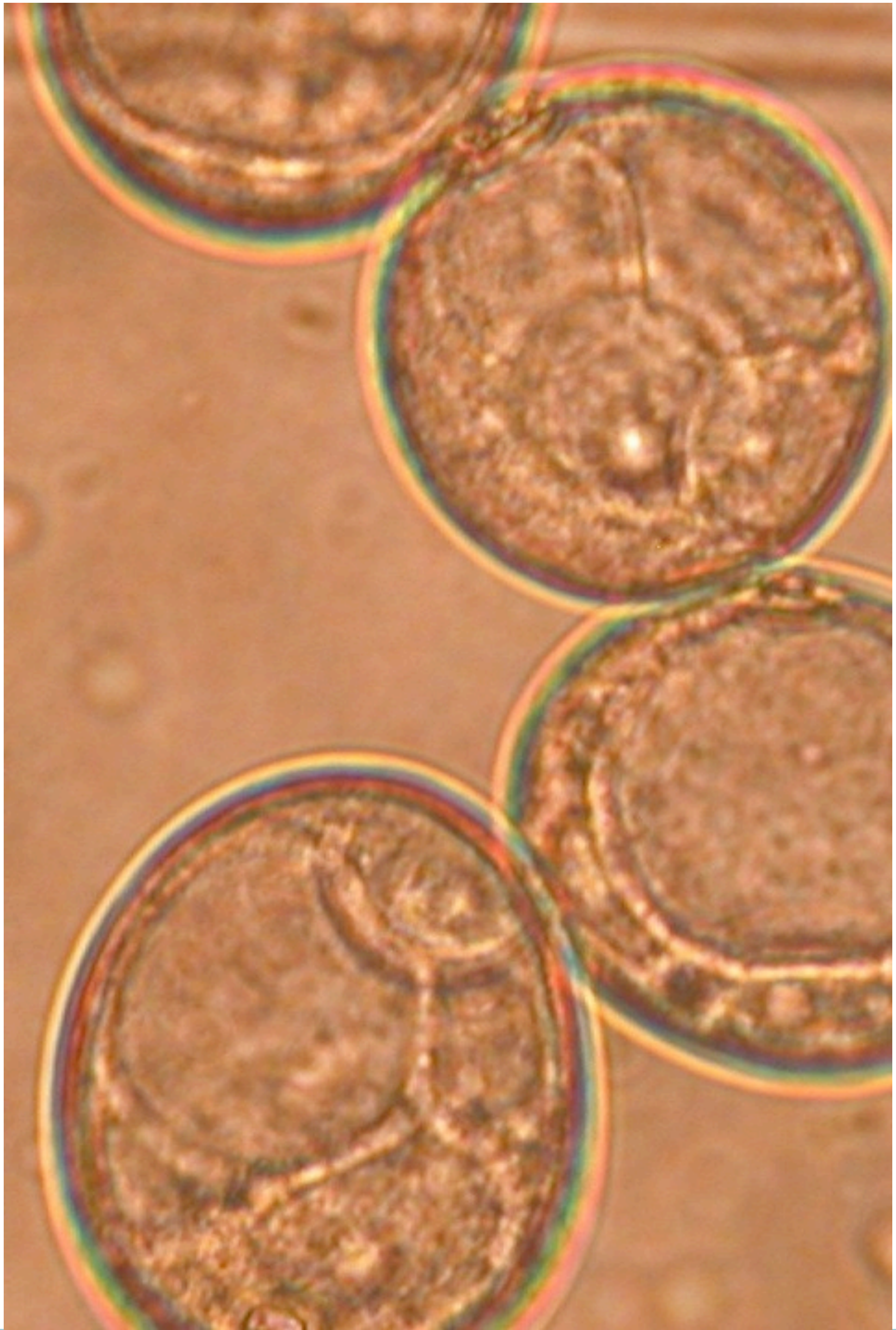


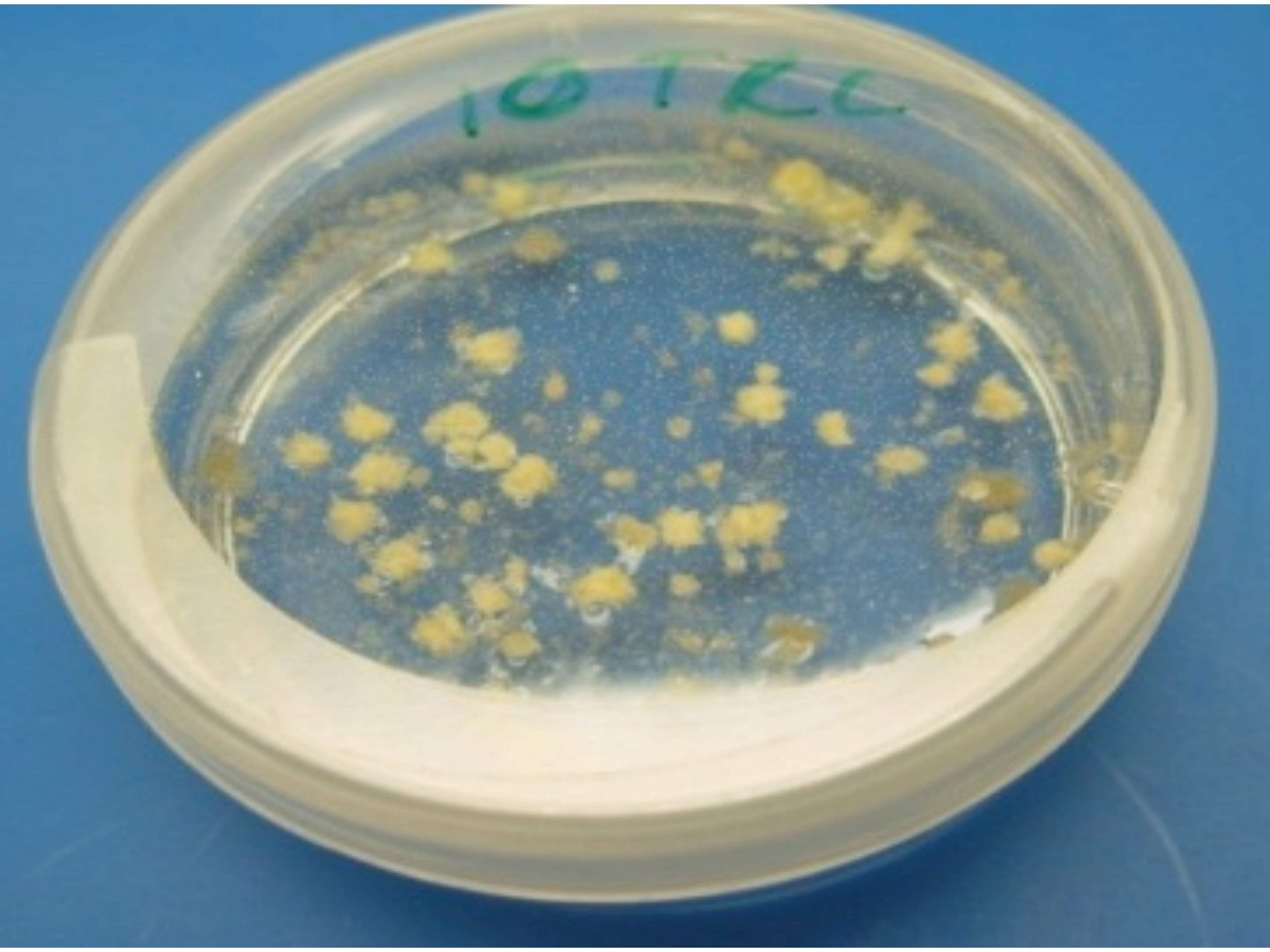
Microspores

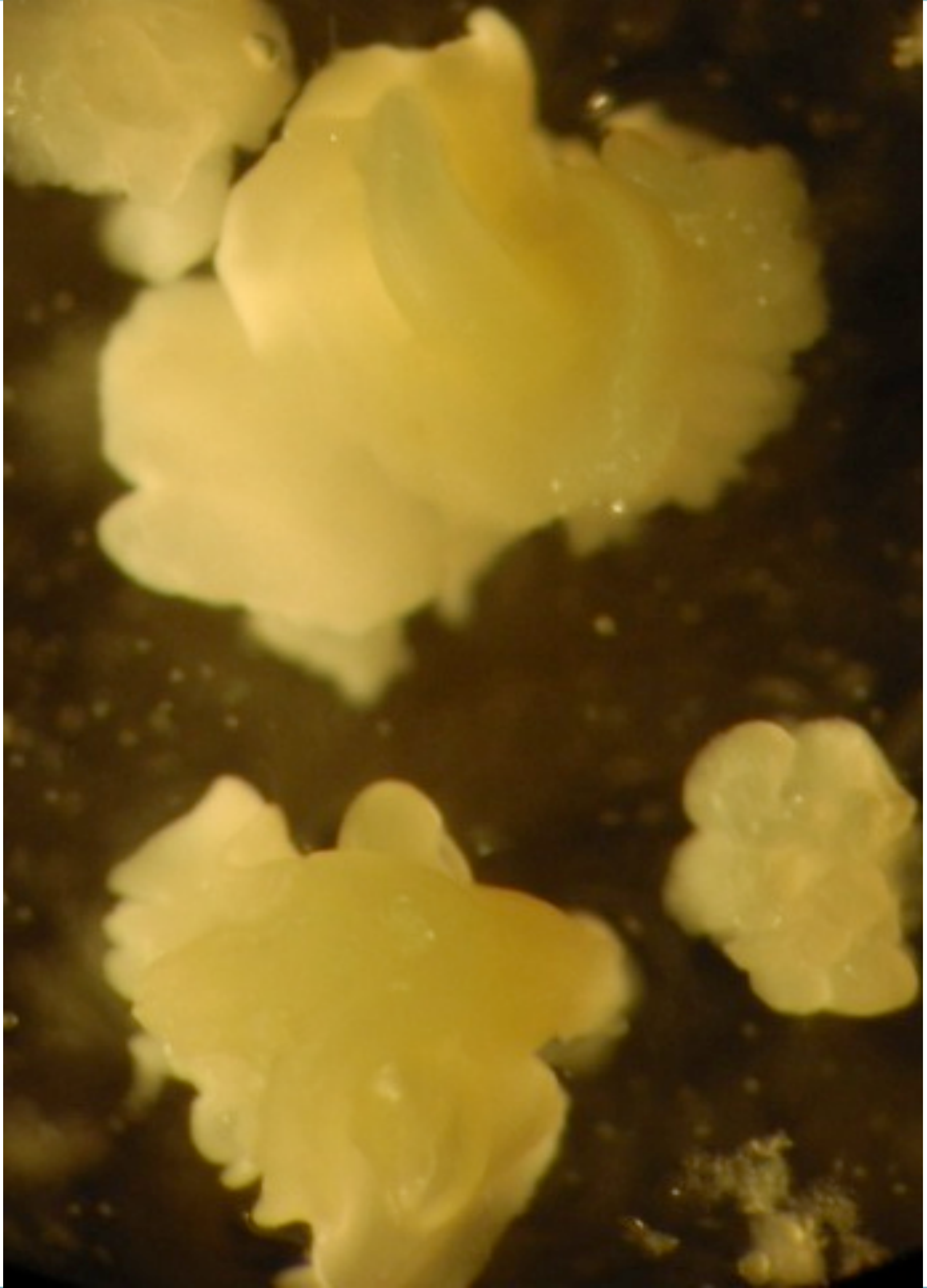
Wheat pre-breeding/Doubled haploids

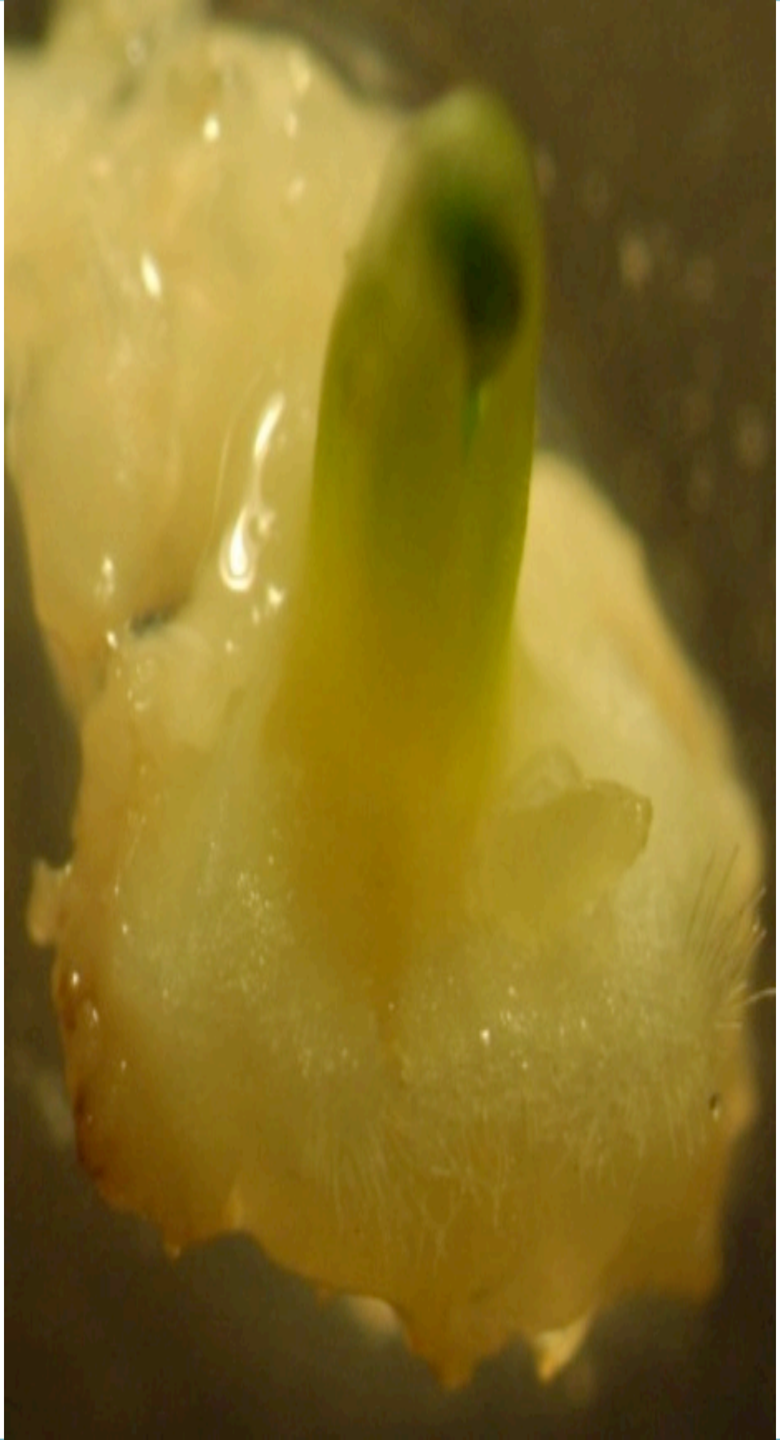


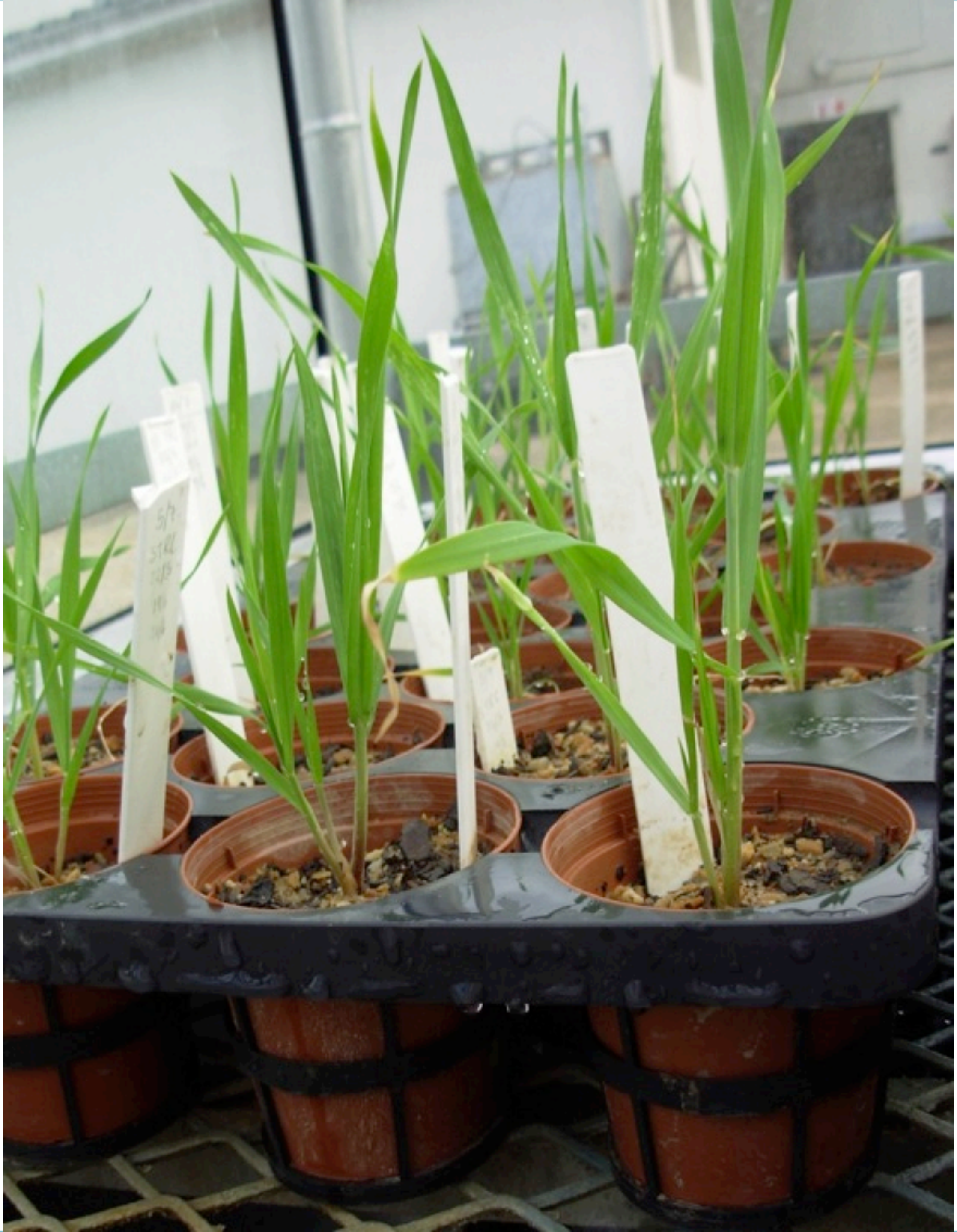


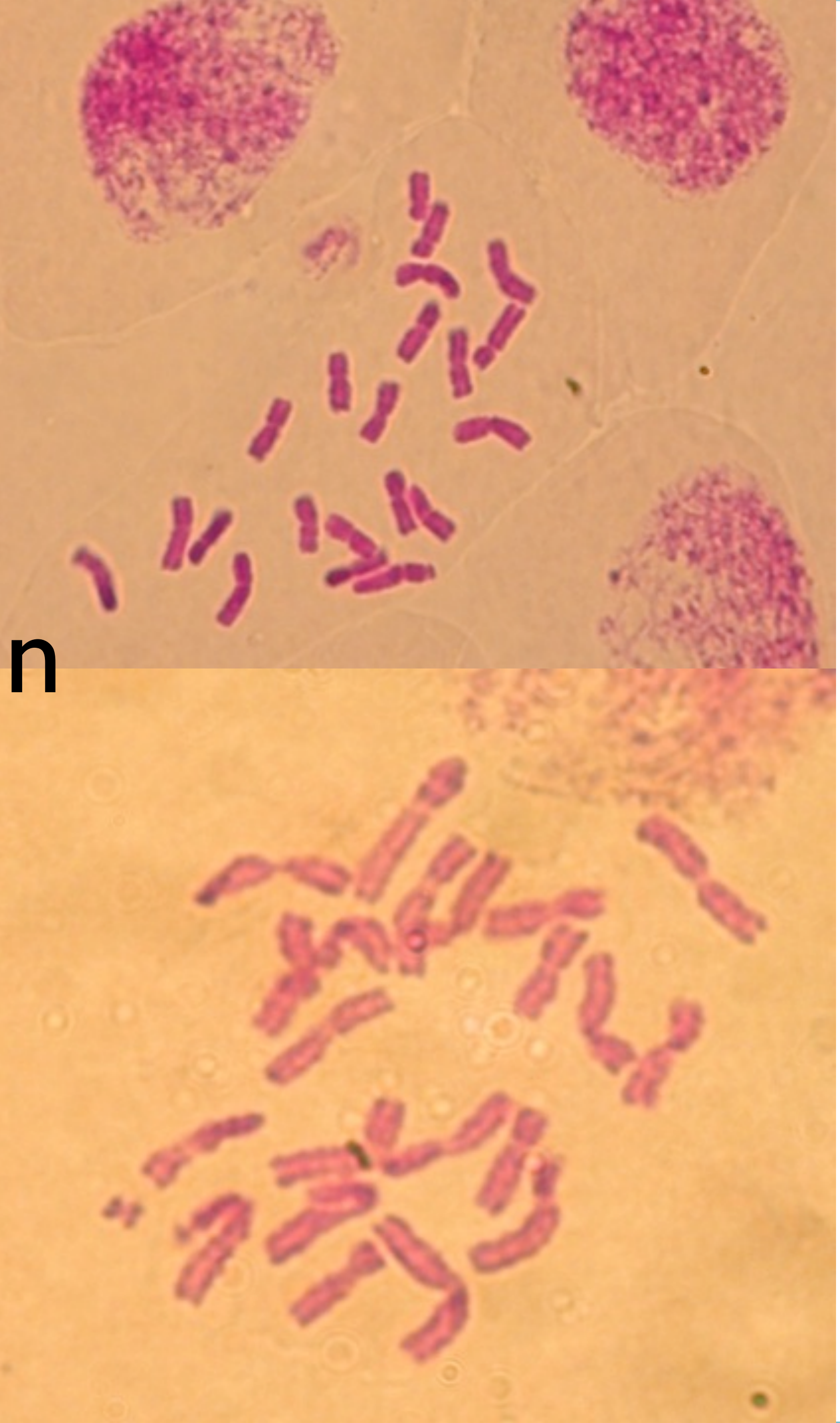








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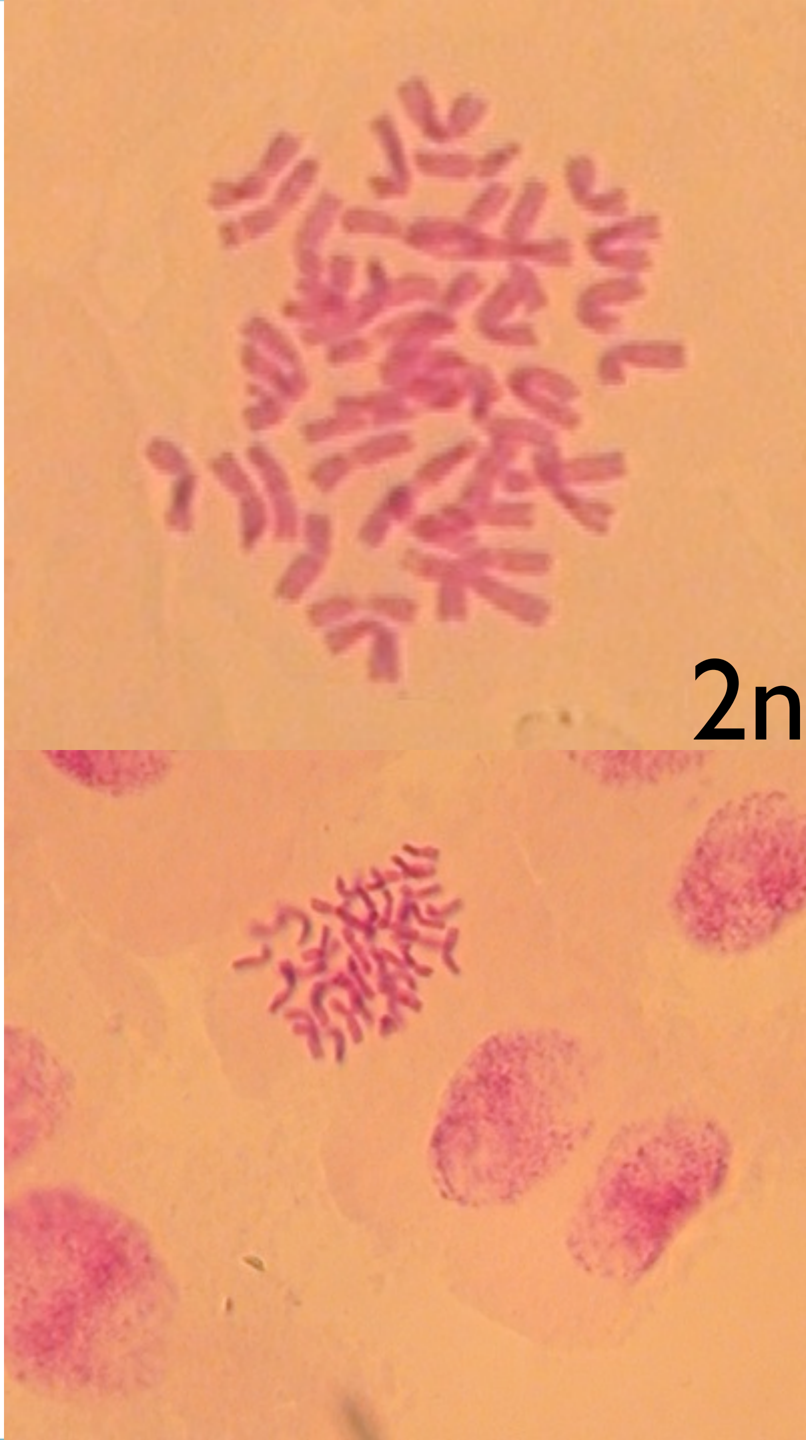
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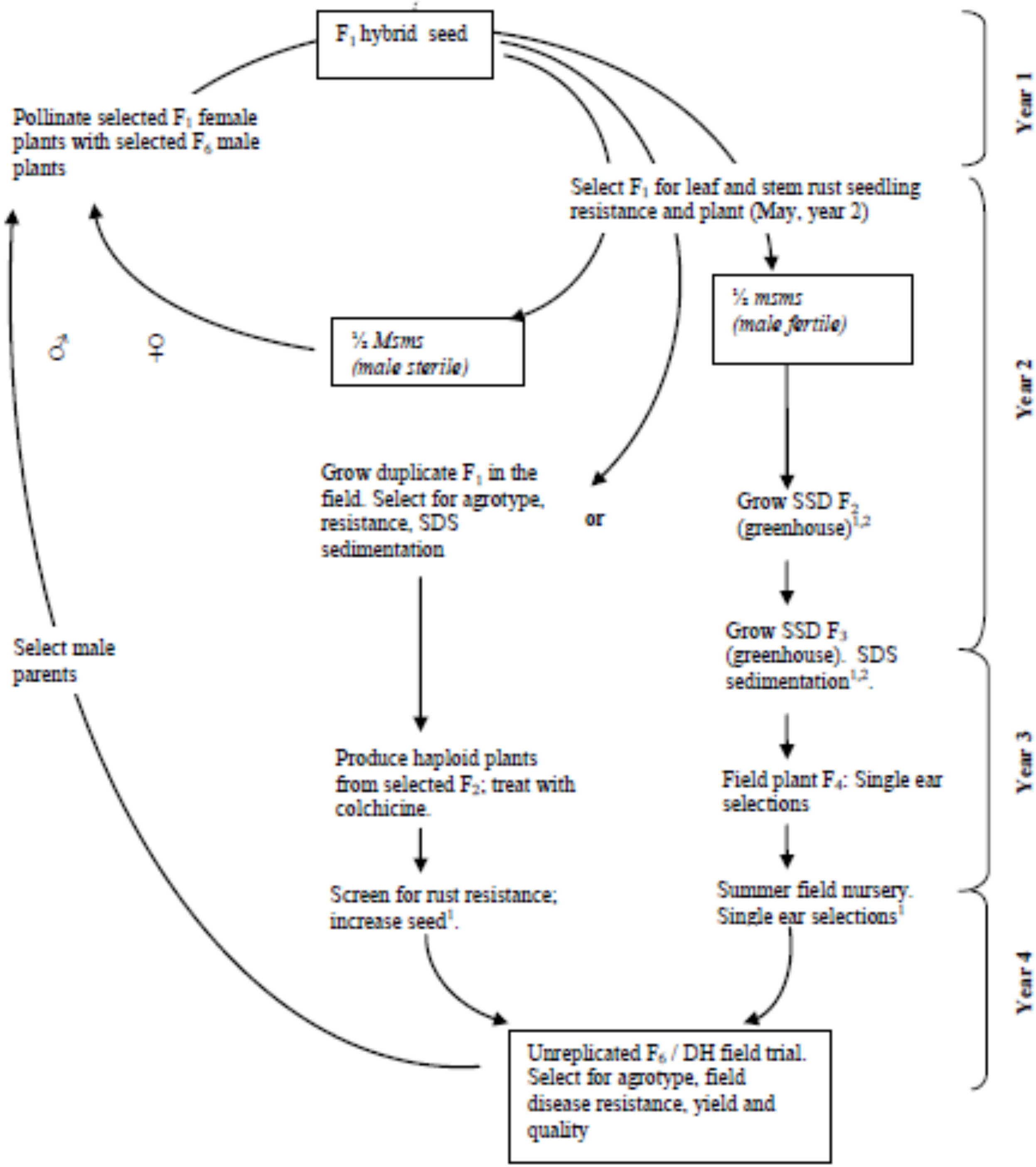
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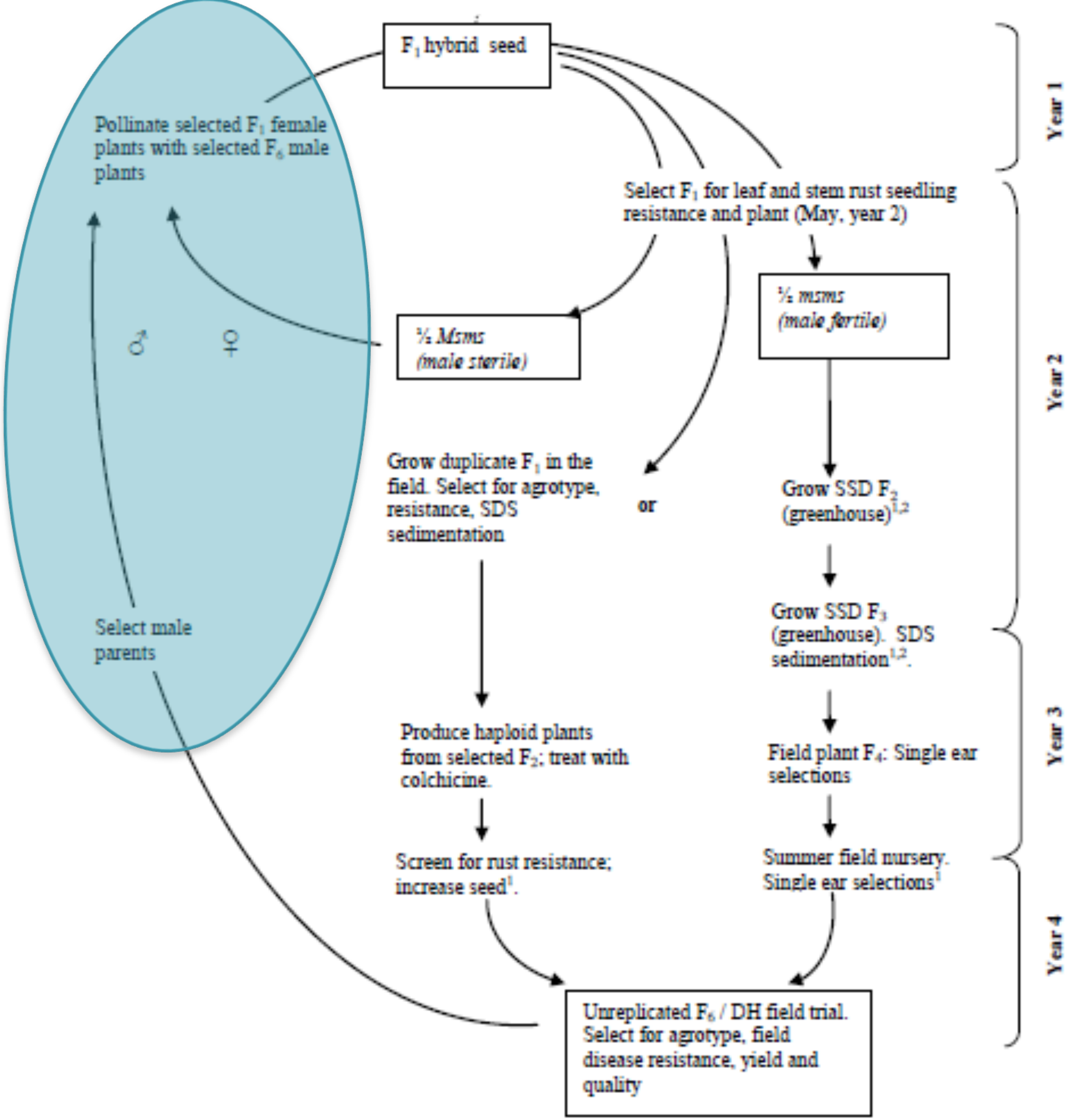
Year 1
Year 2
Year 3
Year 4

Resistance genes & MAS

Wheat pre-breeding/

- *Lr24/Sr24*
  - Transferred from *Agropyron elongatum*
  - On chromosome 3D
  - Virulence in South Africa
- *Sr31/Lr26/Yr9*
  - Transferred from Rye
  - On chromosome 1B
  - Virulence in South Africa
- *Lr37/Sr38/Yr17*
  - Transferred from *Triticum ventricosum*
  - On chromosome 2AS
  - Virulence in South Africa
- *Sr2*
  - Transferred from tetraploid emmer wheat
  - On chromosome 3BL
  - Gene provides durable resistance to all stem rust pathotypes.
  - Need to be accompanied by other resistance genes to provide sufficient resistance
- *Lr34/Yr18*
  - On chromosome 7DS
  - Provides durable resistance to all leaf and stripe rust pathotypes.
  - Need to be accompanied by other resistance genes to provide sufficient resistance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Year 1
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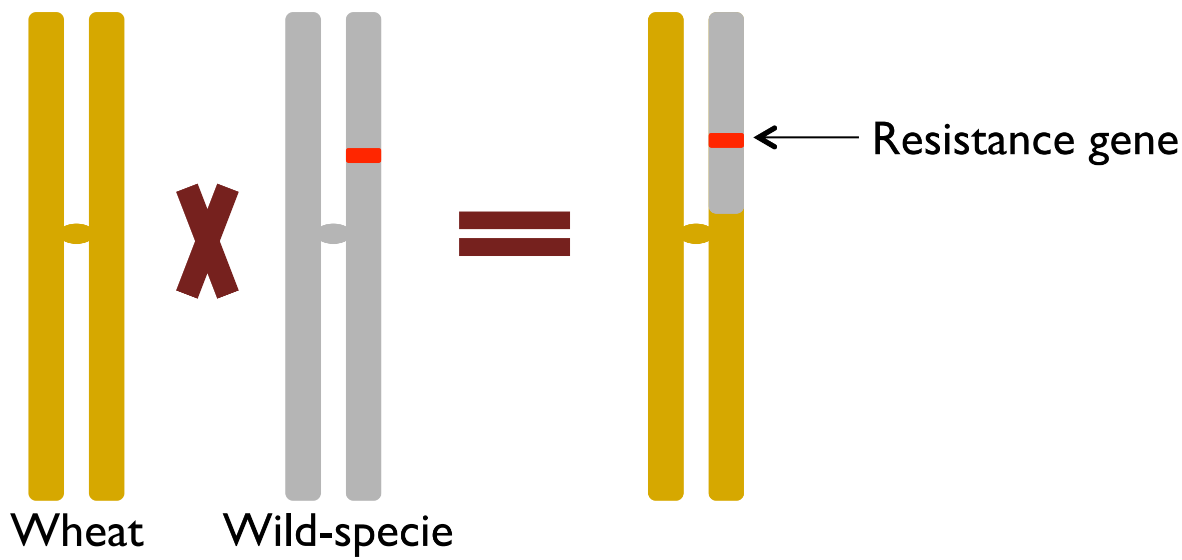
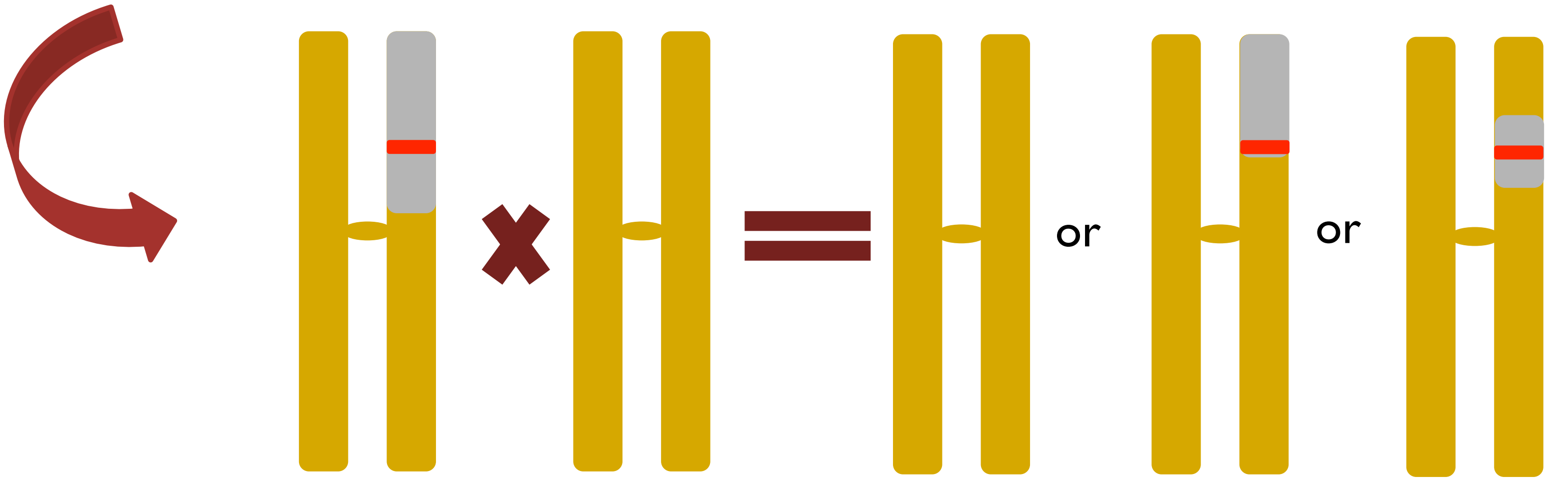
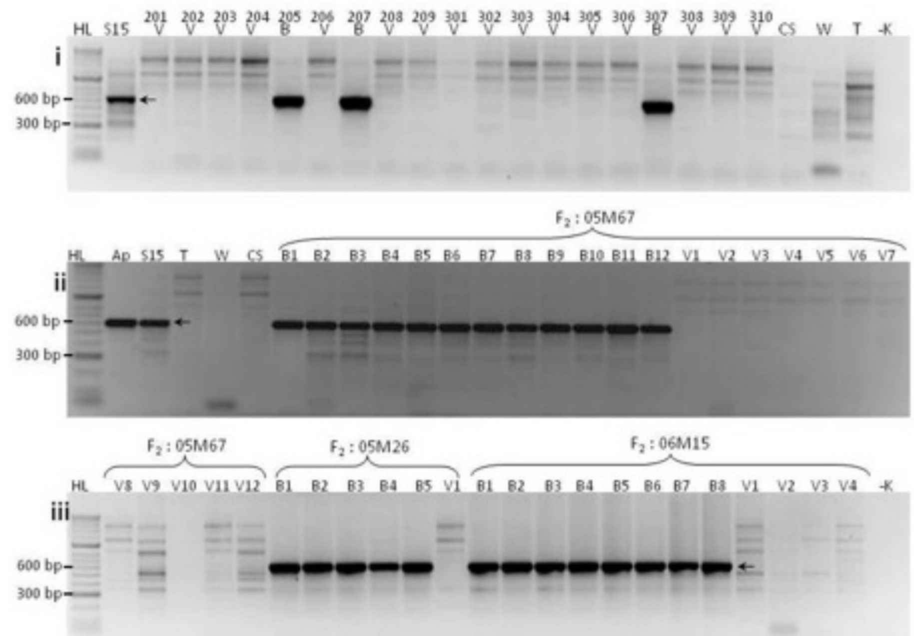
Novel Wild-species Resistance sources

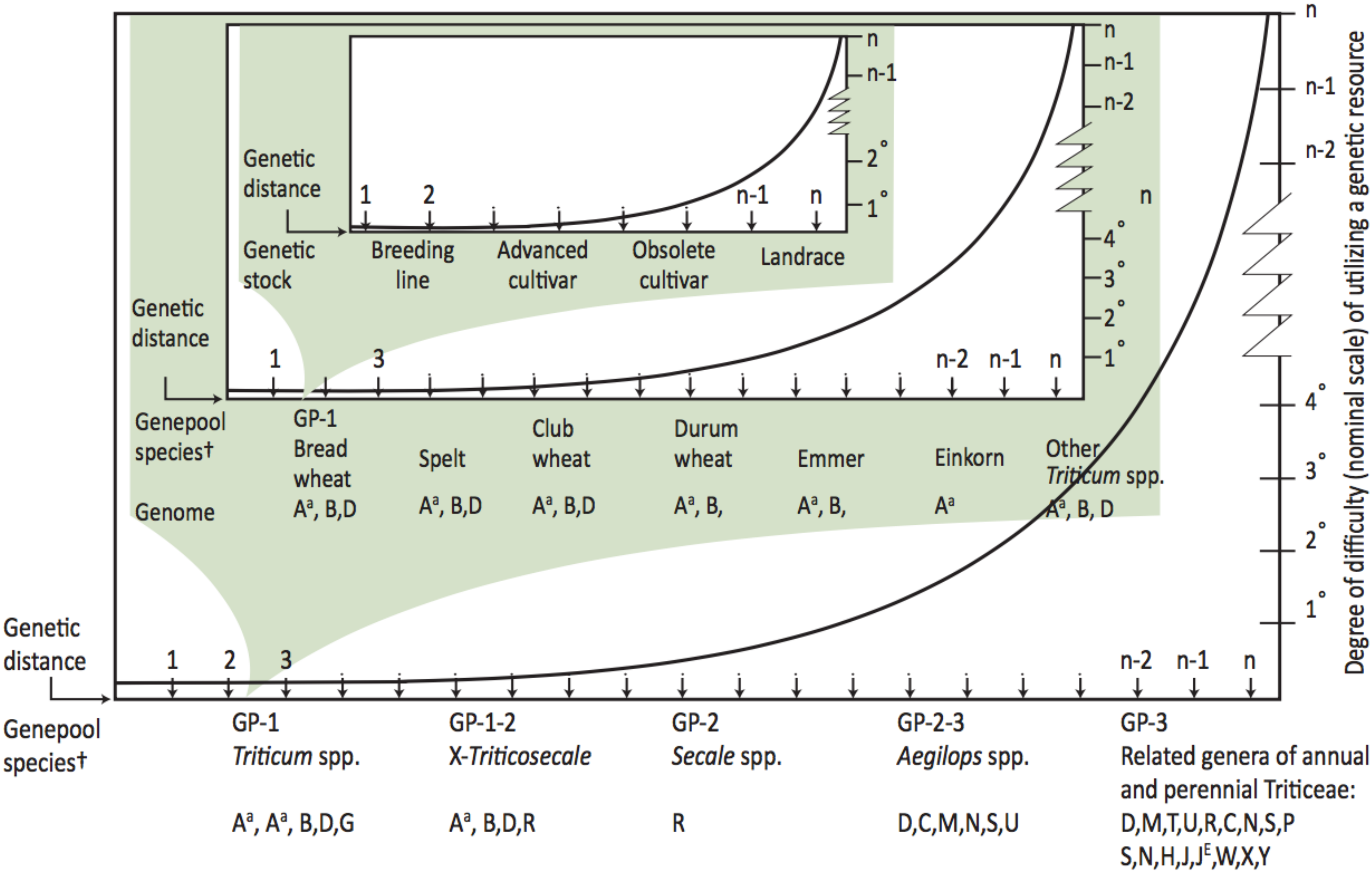
Wheat pre-breeding/

- Wild-species good source of novel resistance genes
- Transfer between wheat and wild-specie relatives possible




or
or


HL S15 201 202 203 204 205 206 207 208 209 301 302 303 304 305 306 307 308 309 310 CS W T -K
i
600 bp
300 bp
F2 : 05M67
HL Ap S15 T W CS B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 B12 V1 V2 V3 V4 V5 V6 V7
ii
600 bp
300 bp
F2 : 05M67
F2 : 05M26
F2 : 06M15
HL V8 V9 V10 V11 V12 B1 B2 B3 B4 B5 V1 B1 B2 B3 B4 B5 B6 B7 B8 V1 V2 V3 V4 -K
iii
600 bp
300 bp



Genetic distance
1
2
n-1
n
Genetic stock
Breeding line
Advanced cultivar
Obsolete cultivar
Landrace
n
n-1
2°
1°
Genetic distance
1
3
n-2
n-1
n
Genepool species†
GP-1 Bread wheat
Spelt
Club wheat
Durum wheat
Emmer
Einkorn
Other *Triticum* spp.
Genome
Aª, B,D
Aª, B,D
Aª, B,D
Aª, B,
Aª, B,
Aª
Aª, B, D
n
n-1
n-2
n
4°
3°
2°
1°
Genetic distance
1
2
3
n-2
n-1
n
Genepool species†
GP-1 *Triticum* spp.
GP-1-2 X-*Triticosecale*
GP-2 *Secale* spp.
GP-2-3 *Aegilops* spp.
GP-3 Related genera of annual and perennial Triticeae:
Aª, Aª, B,D,G
Aª, B,D,R
R
D,C,M,N,S,U
D,M,T,U,R,C,N,S,P S,N,H,J,J^E,W,X,Y
n
n-1
n-2
4°
3°
2°
1°
Degree of difficulty (nominal scale) of utilizing a genetic resource

T. kotschyi: Lr54/Yr37 (2DL)

Wheat pre-breeding/Novel Wild-species Resistance sources

T. sharonense: Lr56/Yr38 (6A)

Wheat pre-breeding/Novel Wild-species Resistance sources

T. peregrinum (UUSS): *Lr59*

Wheat pre-breeding/Novel Wild-species Resistance sources

T. neglecta: Lr62/Yr42 (6A)

Wheat pre-breeding/Novel Wild-species Resistance sources

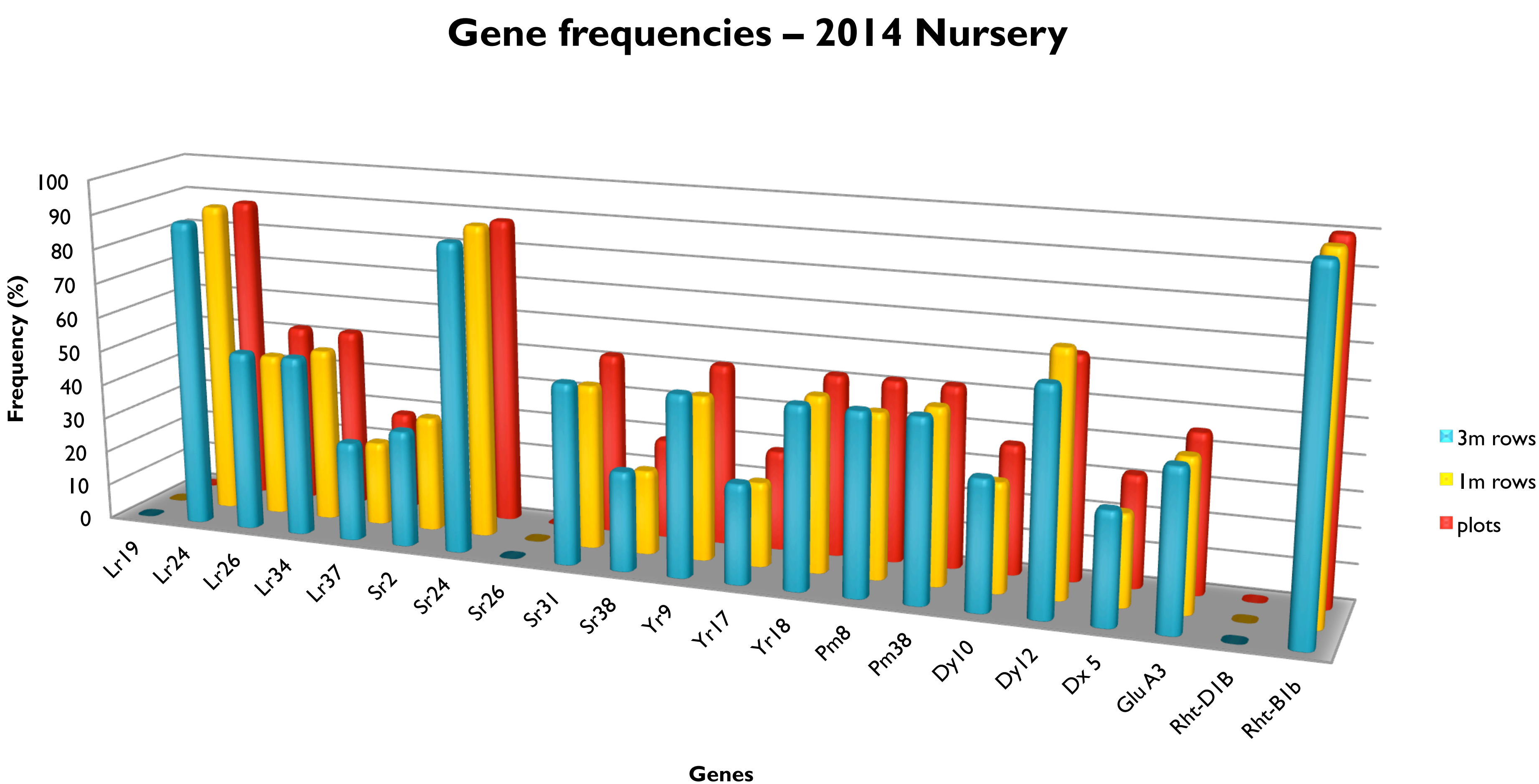
MAS

Wheat pre-breeding/Novel Wild-species Resistance sources

Resistance translocation	Primer	Primer sequence	Ta (ºC)	Amplified fragment size (bp)
Lr53/Yr35	S8N1-OF	5'-CACGTTGGTAACTGAACATT-3'	48	500
	S8N1-OR	5'-CTCACGTTGGACTTAAA-3'		
Lr54/Yr37	S14 275F	5'-CATGCAGAAAACGACACACC-3'	60	297
	S14 252R	5'-GGTAAGTGGTCAGGCGTTGT-3'		
Lr56/Yr38	S8N1-OF	5'-CACGTTGGTAACTGAACATT-3'	48	500
	S8N1-OR	5'-CTCACGTTGGACTTAAA-3'		
Lr59	S15 T3F	5'-GTCACTTGCTTGAATTTAATG-3'	52	622
	S15 T3R	5'-TCCATAGCTGGTAGCTAGATG-3'		
Lr62/Yr42	Opw 7.2F	5'-CAGGAGCATAGTCATACTTGGG-3'	60	700
	Opw 7.2R	5'-CTGGACGTCAACAATGGC-3'		

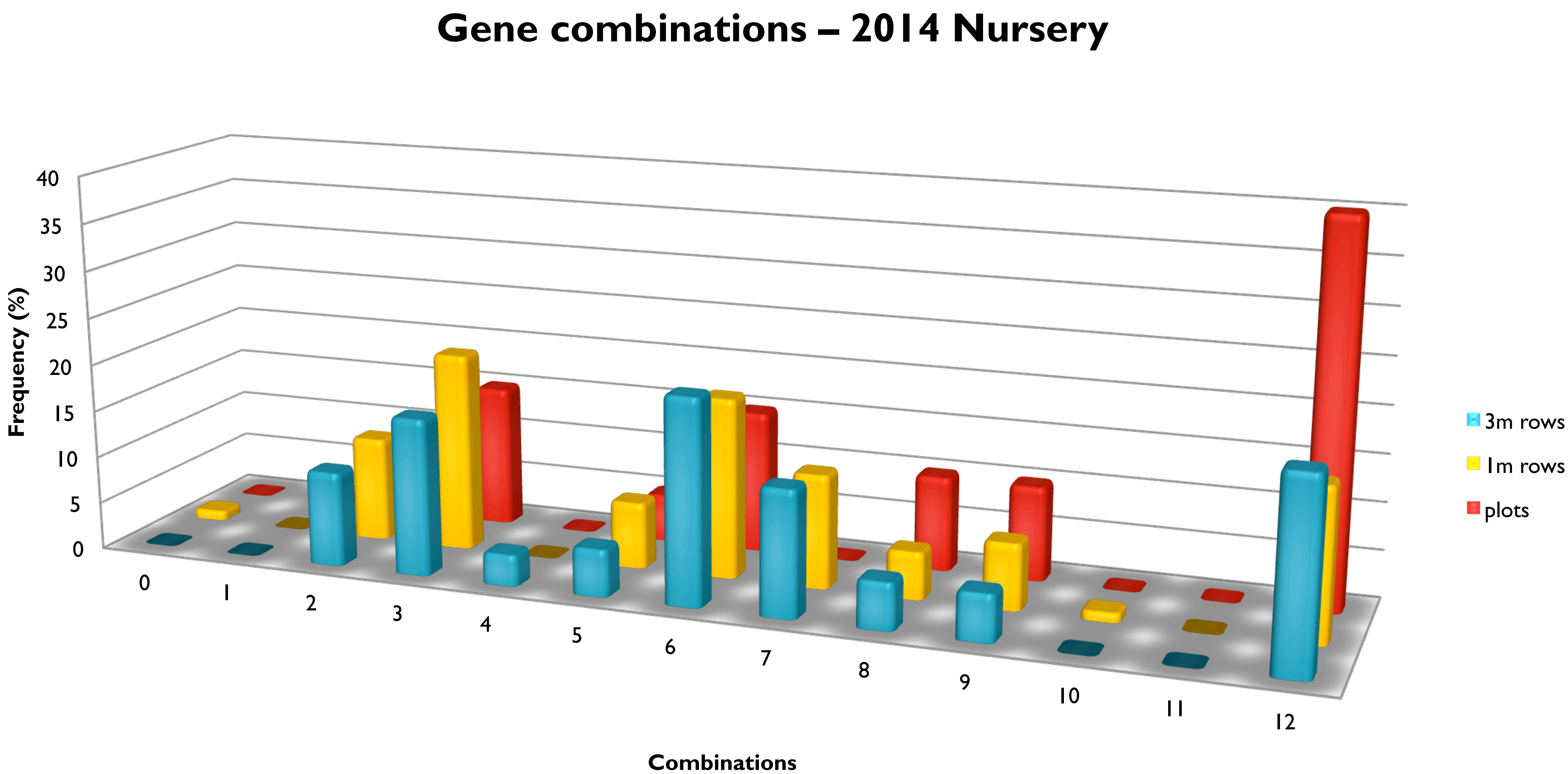
Distribution of resistant material

Wheat pre-breeding/



Distribution of resistant material

Wheat pre-breeding/



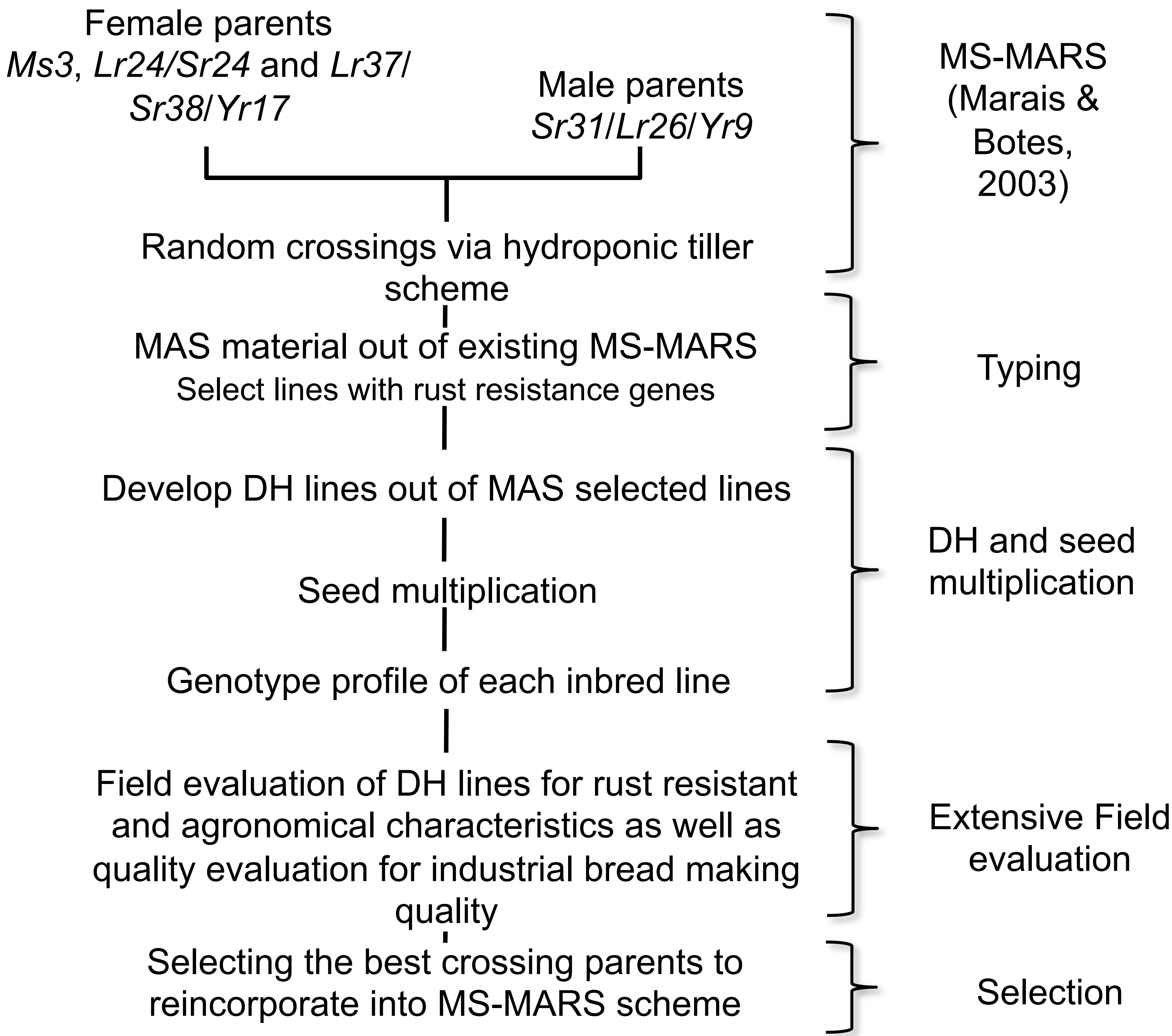
Distribution of resistant material

Wheat pre-breeding/

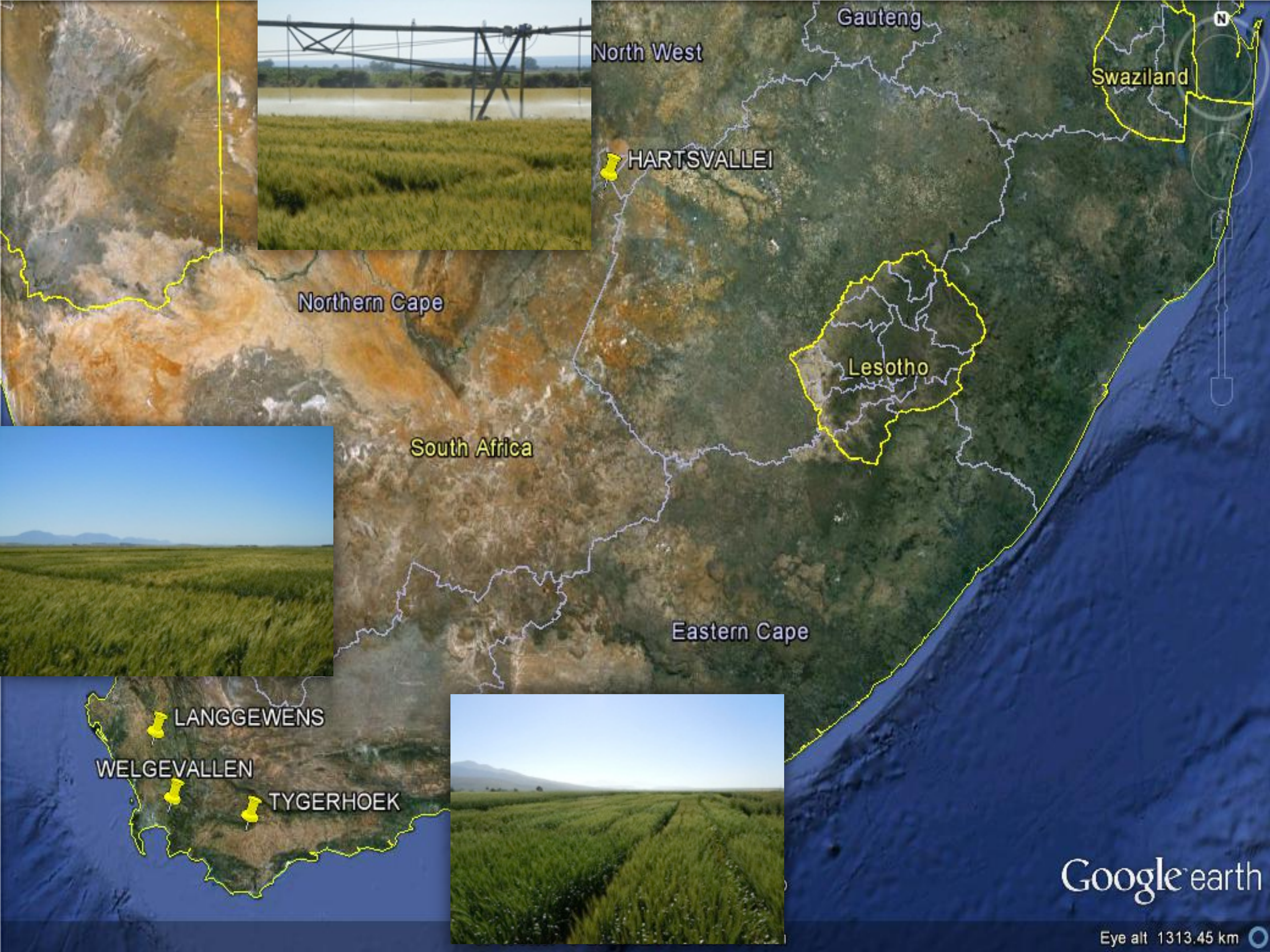
8th SU-PBL Nursery Molecular Data (2013)																					
Entries	Disease Resistance															Quality				Height	
	Lr19	*Lr24*	*Lr26*	*Lr34*	*Lr37*	*Sr2*	*Sr24*	*Sr26*	*Sr31*	*Sr38*	*Yr9*	*Yr17*	*Yr18*	*Pm8*	*Pm38*	*Dy10*	*Dy12*	*Dx 5*	*Glu A3*	*Rht-D1B*	*Rht-B1b*
13US1M001	0	1	0	1	0	1	1	0	0	0	0	0	1	0	1	1	0	1	0	0	1
13US1M002	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1
13US1M003	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	0	1
13US1M004	0	1	0	1	0	1	1	0	0	0	0	0	1	0	1	0	1	0	0	0	1
13US1M005	0	0	1	1	0	0	0	0	1	0	1	0	1	1	1	0	1	0	1	0	1
13US1M006	0	1	1	0	0	1	1	0	1	0	1	0	0	1	0	0	1	0	0	0	1
13US1M007	0	1	1	0	0	1	1	0	1	0	1	0	0	1	0	0	1	0	0	0	1
13US1M008	0	1	1	0	0	0	1	0	1	0	1	0	0	1	0	0	1	0	0	0	1
13US1M009	0	1	1	0	0	1	1	0	1	0	1	0	0	1	0	1	0	1	1	0	1
13US1M010	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	1
13US1M011	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	1	0	1
13US1M012	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1
13US1M013	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1
13US1M014	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	0	1	0	0	0	1
13US1M015	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	0	1	0	0	0	1
13US1M016	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	0	0	1	0	1
13US1M017	0	1	1	0	0	0	1	0	1	0	1	0	0	1	0	1	0	1	1	0	1
13US1M018	0	1	1	1	0	0	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1
13US1M019	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	0	1	0	1	0	1
13US1M020	0	1	1	0	0	0	1	0	1	0	1	0	0	1	0	1	0	1	0	0	1

Overview

- Introduction
- Wheat pre-breeding
- **Case study**
  - **MAS**
  - **DH and seed multiplication**
  - **Field evaluation**
    - **Baking quality evaluation**
    - **Rust screening**
    - **Data analysis**
- Current and future work



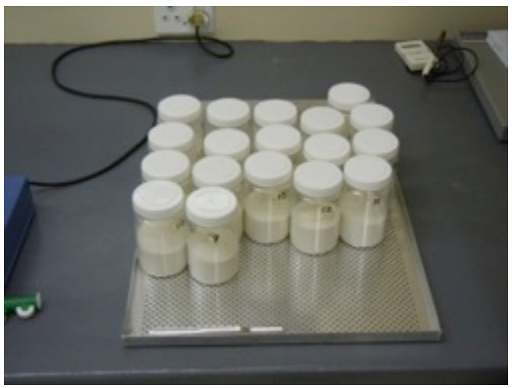
Female parents
Ms3, *Lr24/Sr24* and *Lr37*/*Sr38*/*Yr17*
Male parents
Sr31/*Lr26*/*Yr9*
Random crossings via hydroponic tiller scheme
MAS material out of existing MS-MARS
Select lines with rust resistance genes
Develop DH lines out of MAS selected lines
Seed multiplication
Genotype profile of each inbred line
Field evaluation of DH lines for rust resistant and agronomical characteristics as well as quality evaluation for industrial bread making quality
Selecting the best crossing parents to reincorporate into MS-MARS scheme
MS-MARS (Marais & Botes, 2003)
Typing
DH and seed multiplication
Extensive Field evaluation
Selection


Gauteng
North West
Swaziland
HARTSVALLEI
Northern Cape
Lesotho
South Africa
Eastern Cape
LANGGEWENS
WELGEVALLEN
TYGERHOEK
Google earth
Eye alt 1313.45 km

Quality evaluation

Case Study/

Flour quality



Rheological quality

Baking quality

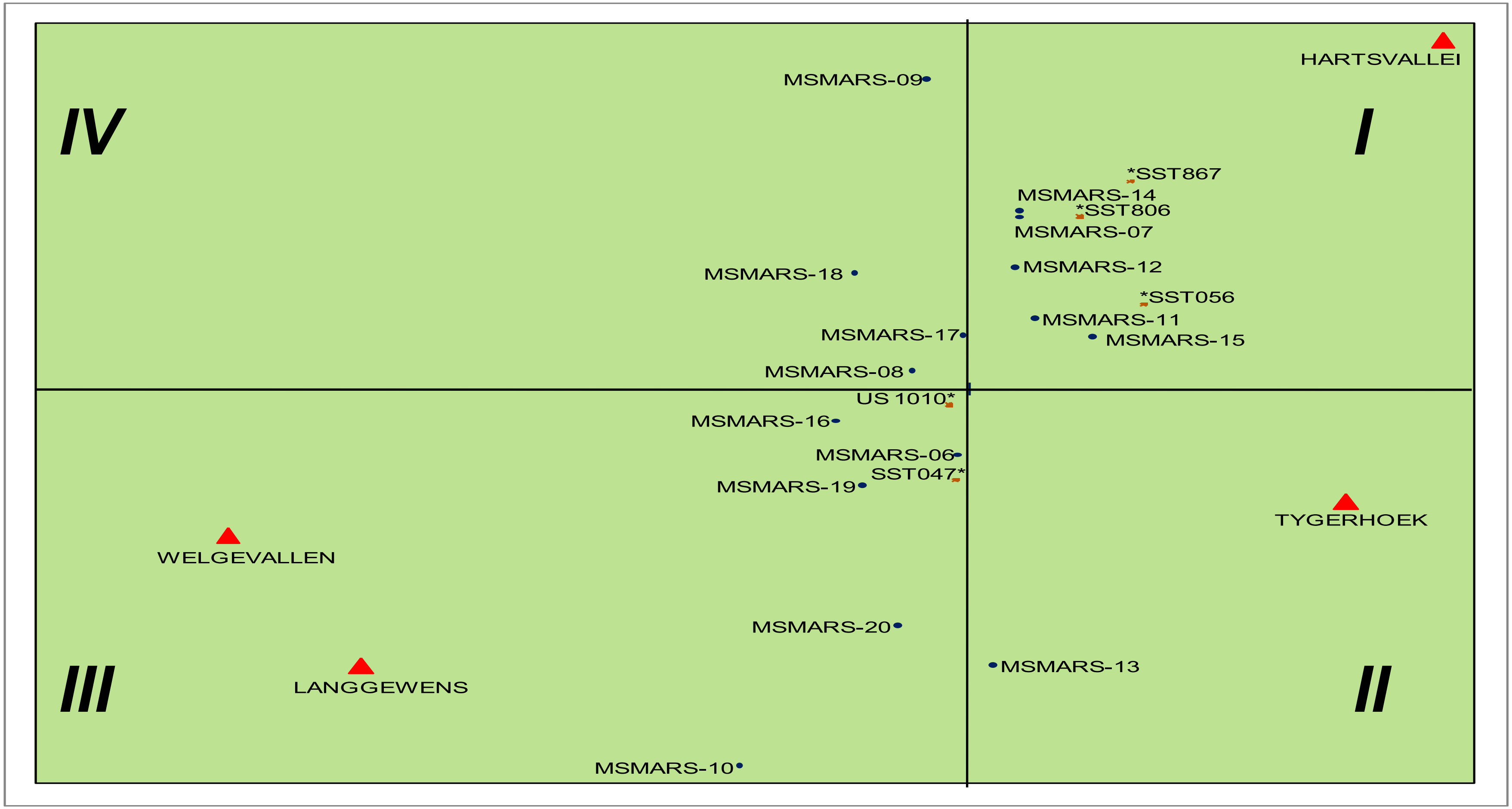
Quality evaluation

Case Study/

Name	Deviation from SST806	Quality	Quality deviations
MS-MARS-15	0	Above Average	No deviation from SST806
MS-MARS-19	0	Above Average	No deviation from SST806
MS-MARS-08	1	Average	Problem with VOL
MS-MARS-09	1	Average	-Problem with HLM
MS-MARS-18	1	Average	Problem with EX
MS-MARS-20	1	Average	Problem with HLM
MS-MARS-13	2	Average	Very good EX and PROT. Problem with FL and ABS

AMMI-Biplot

Case Study/



MLFT

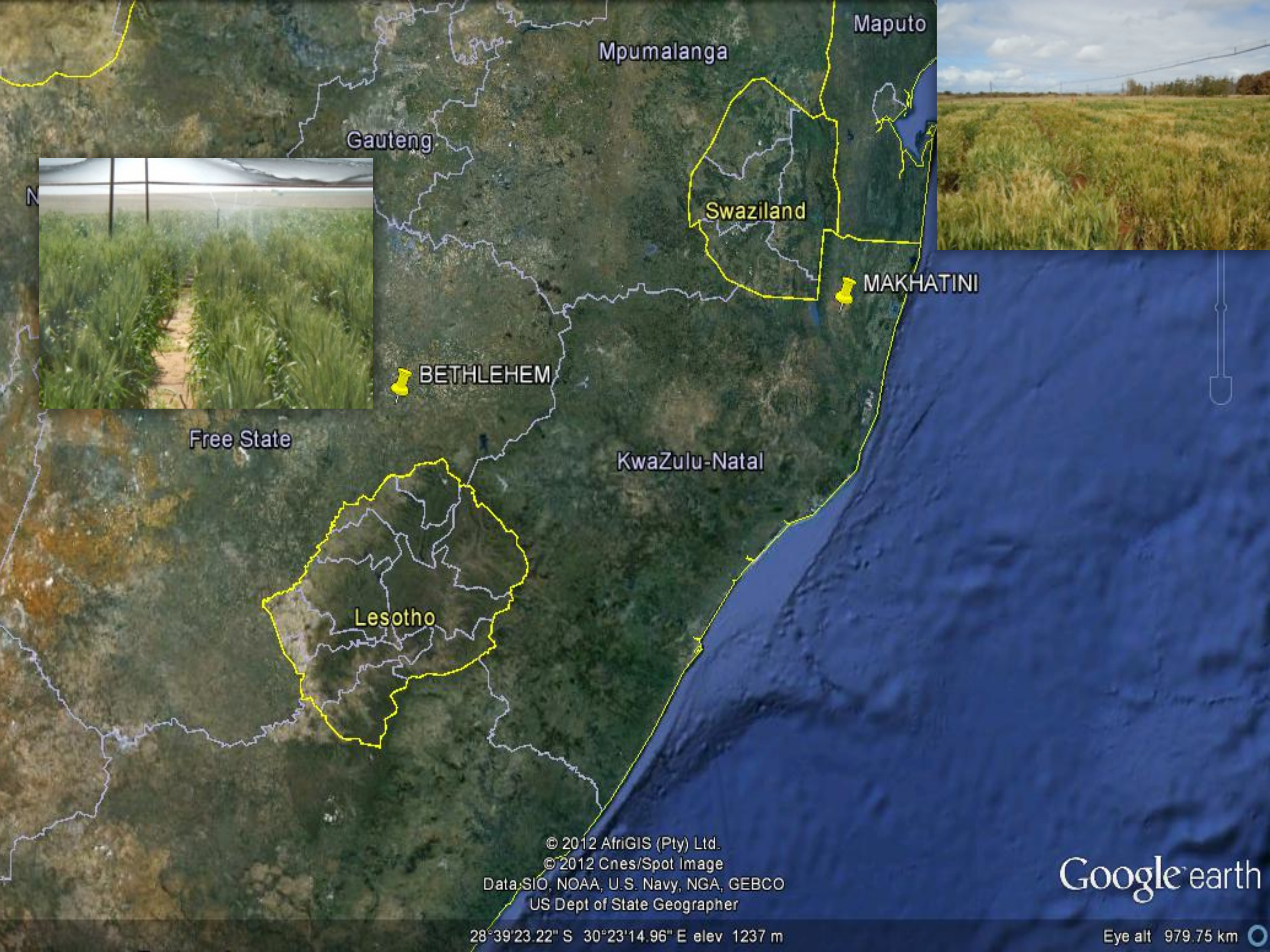
Case Study/

Group	Name	Adaptability and stability characteristic
1	SST056 MS-MARS-11 MS-MARS-12 MS-MARS-15	Very well adapted to low and high potential environments in South Africa
2	SST867 SST806 MS-MARS-07 MS-MARS-14	Adapted to low and high potential environments in South Africa
3	MS-MARS-13	Very well adapted to the dryland high potential environments in South Africa
4	MS-MARS-08 MS-MARS-17 MS-MARS-18	Adapted only to high potential environments in South Africa
5	MS-MARS-10 MS-MARS-20	Adapted to low potential environments in South Africa
6	MS-MARS-09	Adapted only to high potential irrigation environment in South Africa
7	US1010	Stable
8	SST047 MS-MARS-06 MS-MARS-16 MS-MARS-19	Poor performing and not very well adapted or stable

Field rust screening

Case study/

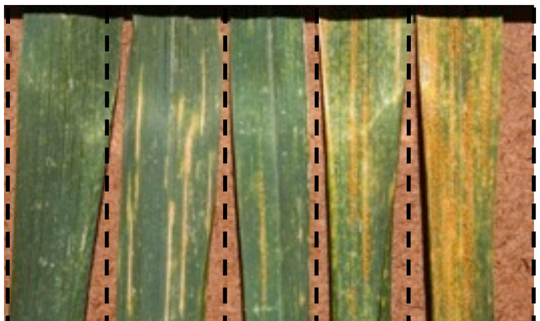
- Each of the lines were screened for adult plant resistance against the following rust pathotypes:
  - Stem rust – UVPgt60
    - Virulent for *Sr24*, *Sr31* and *Sr38*
  - Leaf rust – UVPrt13
    - Virulent for *Lr24* and *Lr26*
  - Stripe rust – 6E22A-
    - Virulent for *Yr17*


Maputo
Mpumalanga
Gauteng
Swaziland
MAKHATINI
BETHLEHEM
Free State
KwaZulu-Natal
Lesotho
© 2012 AfriGIS (Pty) Ltd.
© 2012 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
Google earth
28°39'23.22" S 30°23'14.96" E elev 1237 m
Eye alt 979.75 km

Field rust screening

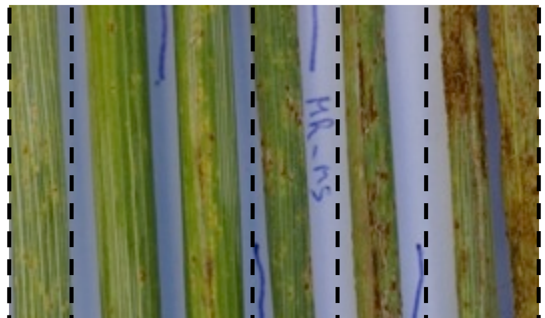
Case study/

Stripe rust



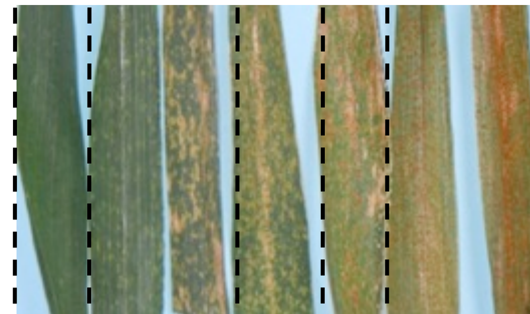
R R-MR **MR** MS **S**

Stem rust

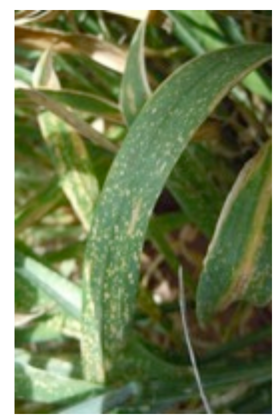


R R-MR **MR** MS **S**

Leaf rust



R R-MR **MR** MS **S**



Field rust screening

Case study/

Group	Name	*Sr2*	*Lr34/Yr18*	*Sr24/Lr24*	*Sr31/Lr26/Yr9*	*Sr38/Lr37/Yr17*
1	SST 047	-	-		-	
2	SST 806	-	-	-	-	-
	SST 867	-	-	-	-	-
	US 1010	-	-	-	-	-
3	MS-MARS-06	-	-	-		-
4	MS-MARS-08	-				
5	MS-MARS-07	-				-
	MS-MARS-10	-				-
	MS-MARS-14	-				-
	MS-MARS-20	-				-
6	MS-MARS-09	-			-	-
	MS-MARS-17	-			-	-
7	SST 056	-			-	
	MS-MARS-11	-			-	
	MS-MARS-15	-			-	
8	MS-MARS-12	-	-			-
	MS-MARS-13	-	-			-
	MS-MARS-16	-	-			-
9	MS-MARS-18	-	-		-	-
	MS-MARS-19	-	-		-	-

Conclusion

Case study/

Evaluation	Specific characteristic	MS-MARS lines
General yield adaptability and stability	Low and high potential	MS-MARS-07, 11, 12, 14 & 15
	Low potential	MS-MARS-13
Bread quality	Above average	MS-MARS-15 & 19
	Average	MS-MARS-08, 09, 13, 18 & 20
Rust resistance	Minor genes for the three rust pathogens	MS-MARS-15 & 18
	Minor genes for two rust pathogens	MS-MARS-07 & 09

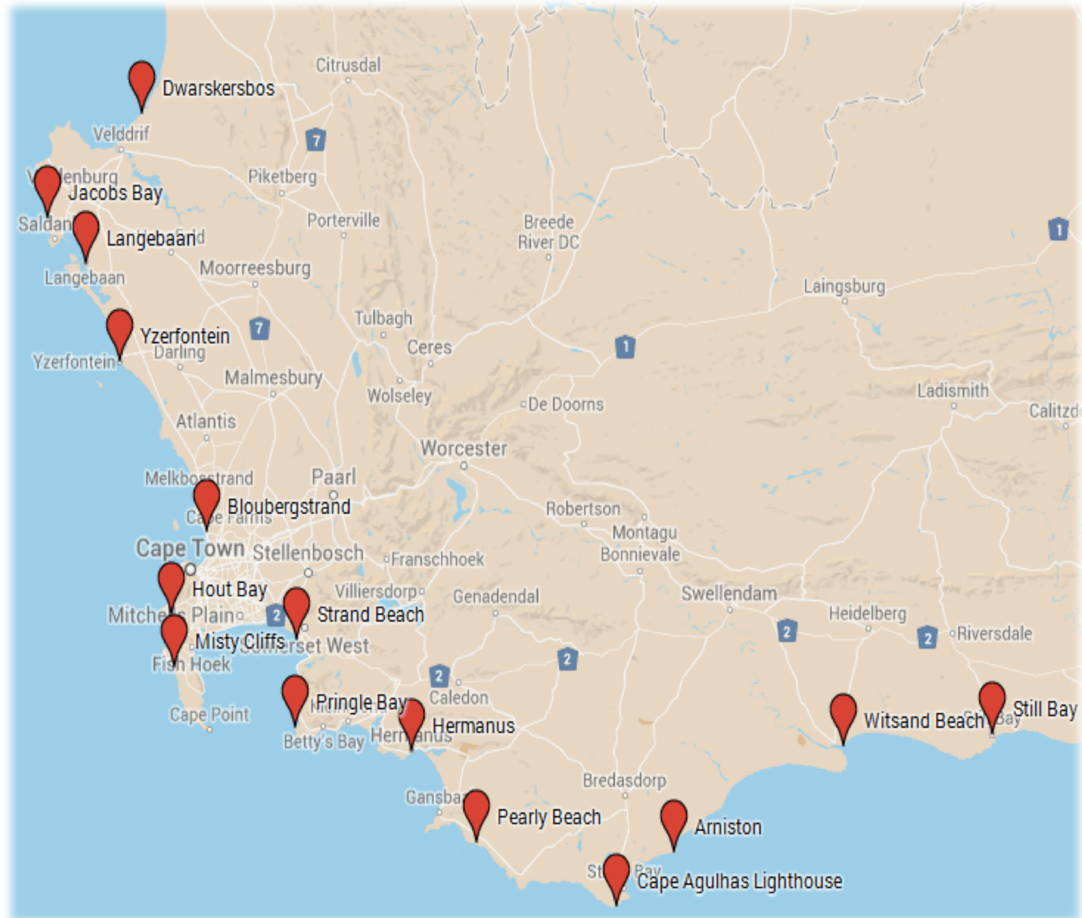
Conclusions

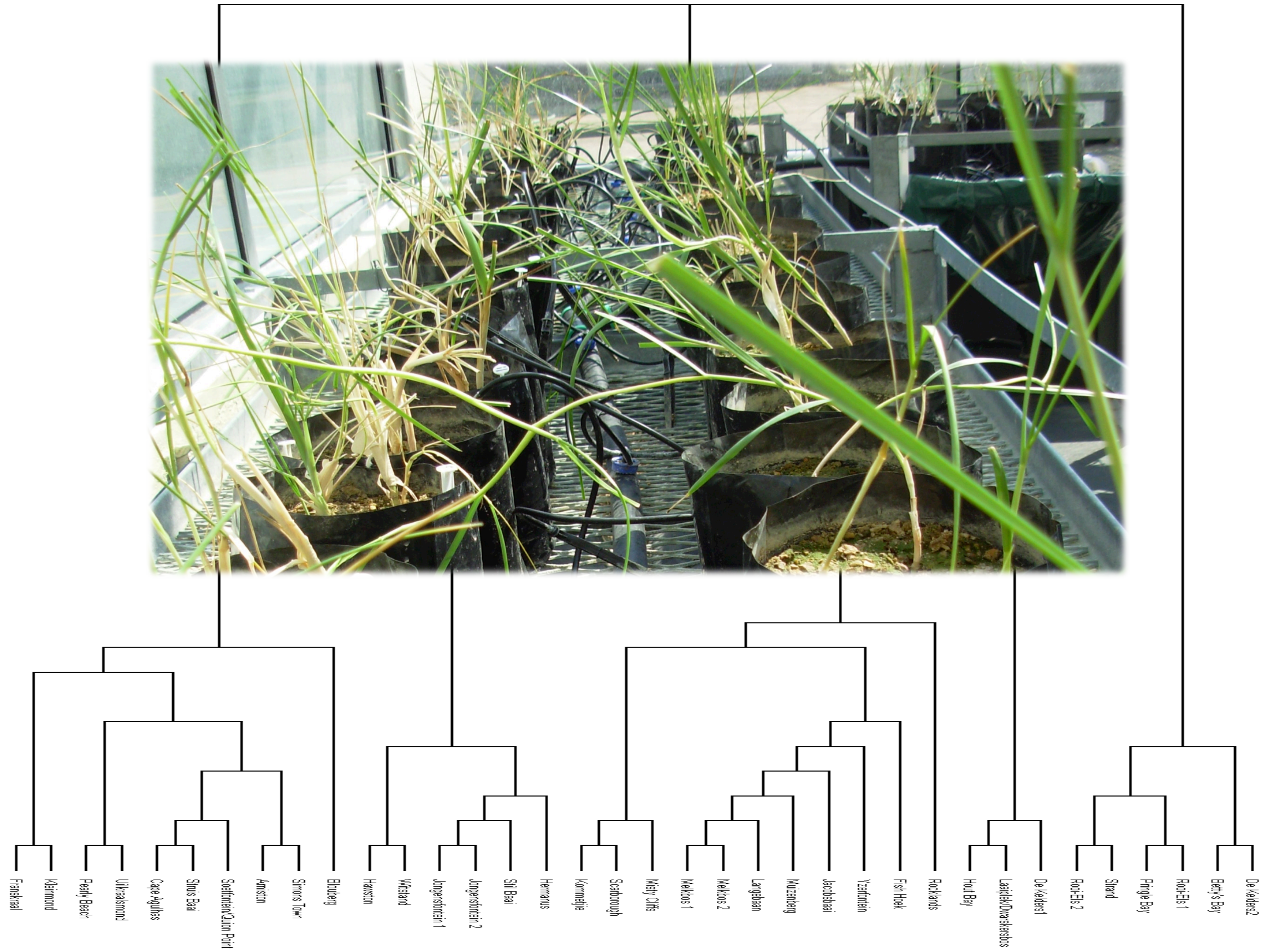
Case study/

- Breeding strategy relies on:
  - Mode of reproduction
  - Traits to be improved
  - Time available
  - Resources
- MS-MARS scheme applied to most crops and traits regardless of the mode of reproduction or nature of the traits (qualitative and quantitative) to be improved
- DHs assist in shortening the generations needed for obtaining pure breeding material (one vs. six generations).
- Requires costly resources in the form of highly skilled labour and equipment
- Innovative approach to combine MAS and a biotechnology tool such as DHs

Salinity tolerance

Current activities/




Franskraal
Kleinmond
Pearly Beach
Uilkraalsmond
Cape Agulhas
Struis Baai
Soetfontein/Quion Point
Arniston
Simons Town
Blouberg
Hawston
Witsand
Jongensfontein 1
Jongensfontein 2
Stil Baai
Hermanus
Kommetjie
Scarborough
Misty Cliffs
Melkbos 1
Melkbos 2
Langebaan
Muizenberg
Jacobsbaai
Yzerfontein
Fish Hoek
Rocklands
Hout Bay
Laaiplek/Dwarskersbos
De Kelders1
Rooi-Els 2
Strand
Pringle Bay
Rooi-Els 1
Betty's Bay
De Kelders2

Physiological traits

Future activities/

- Expanding current MS-MARS based pre-breeding activities to national platform
- Funded by GrainSA, DST and industry
- All of the SA wheat breeding programs involved
- Primary aim is improvement of yield
- Physiological traits of primary interest
- UAV based high throughput phenotyping to be implimented
- Move towards phenomics approach

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SU-PBL staff and students (Past and present):

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