Cassava Post-harvest Physiological Deterioration (PPD)

-- method, germplasm and plan

Root Quality Lab
Cassava Program

Alliance

Bioversity International

CIAT
International Center for Tropical Agriculture
Since 1967 Science to cultivate change

Postharvest Deterioration of Cassava

Primary deterioration

PPD

Secondary deterioration (microbiological)

Method

Field

3 plants per genotype
Commercial Root size

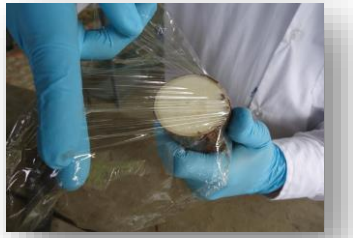
Harvest

10 Roots

Pretreatment to accelerate deterioration

Proximal cut

Distal cut



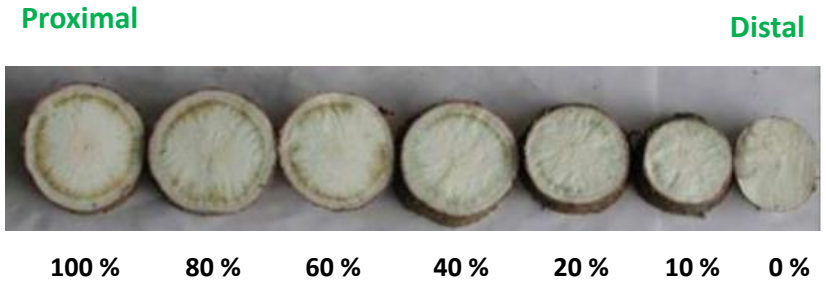
Wrap with plastic film

Tying the plastic film with rubber bands

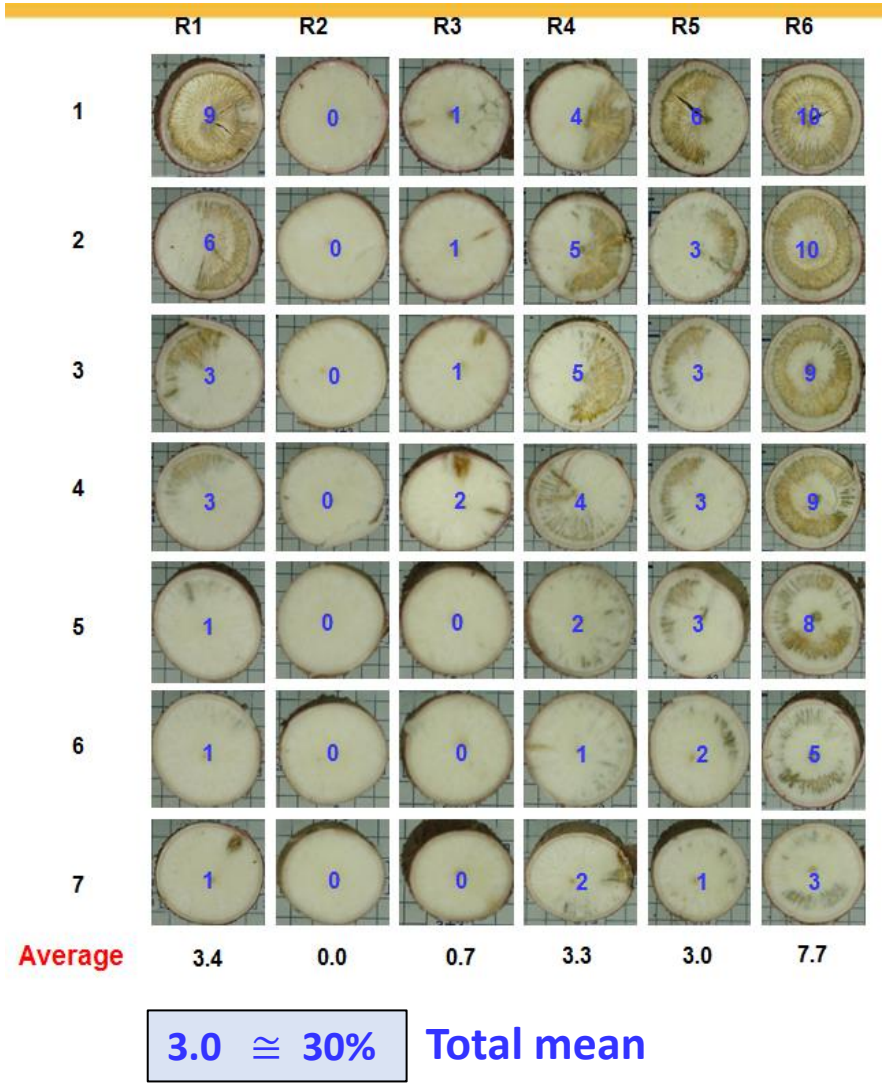
7 days of storage

7 slices (per root); Thickness. 2 cm

PPD Visual scoring



A score from 0 to 10 is assigned to each cut, according to the percentage of surface discoloration (1=10%, 2=20%, etc.). The mean score is calculated for each root.



3.0 ≅ 30% **Total mean**

Marriott, J., B. O. Been, et al. (1978).
Wheatley, C.C. (1982). Thesis Ph. D. University of London. 246 pp.

Sources of PPD tolerance

- **Genebank**
- Wild crossing
- Biofortified cassava

Genebank accessions tolerant to PPD

Genotype	Dry Matter (%) 2019	Dry Matter (%) 2018	Dry Matter (%) 2017	Dry Matter (%) 2016	Dry Matter (%) 2015	Dry Matter (%) 2014	# Environment	Average Dry Matter (%)	PPD (%) 2019	PPD (%) 2018	PPD (%) 2017	PPD (%) 2016	PPD (%) 2015	PPD (%) 2014	# Environment	Average PPD (%)
MEX2	38	30	40	43	40	40	6	38	2		5	10	38	2	5	11
PER183	40	32	40	36	34	31	6	36	5		15	30	0		4	12
ARG73	39	40	42	39			4	40	2	2	28				3	11
MAL3	39	32	40	34	37	38	6	37	22		68		67		3	52

Susceptible

*The genebank accessions was selected based on low PPD and moderate or high dry matter.

Susceptible or resistant accession and population parents

Tolerant accession	Susceptible accession	Unknown
HMC1 (intermediate)	MAL3	SM3134-73
MEX2	VEN77	SM2792-31
ARG73	PER368	
PER183		

Genetic mapping populations for PPD tolerance

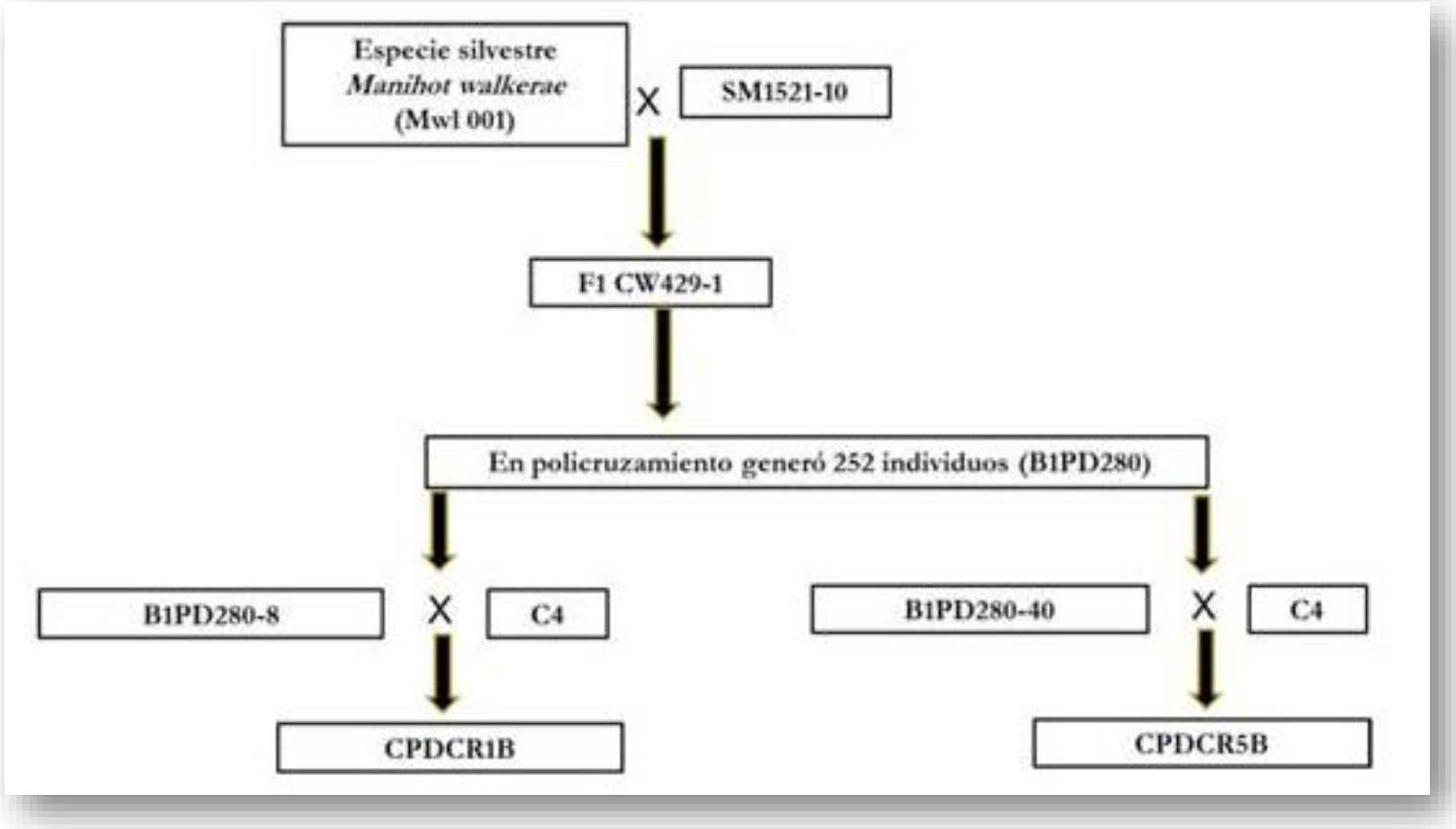
Family	Female_parent	Male_parent	Num.seeds
AM266	HMC1	HMC1	82
GM14287	MEX2	HMC1	61
GM14321	MEX2	MAL3	33
GM14290	PER183	MEX2	29
GM14366	PER183	SM2792-31	164
AM1640	PER183	PER183	~100
GM14635	SM3134-73	ARG73	108

*Multi-parental population is used for linkage mapping and association mapping for PPD tolerance.
Red color shows the parents tolerant to PPD.

Sources of PPD tolerance

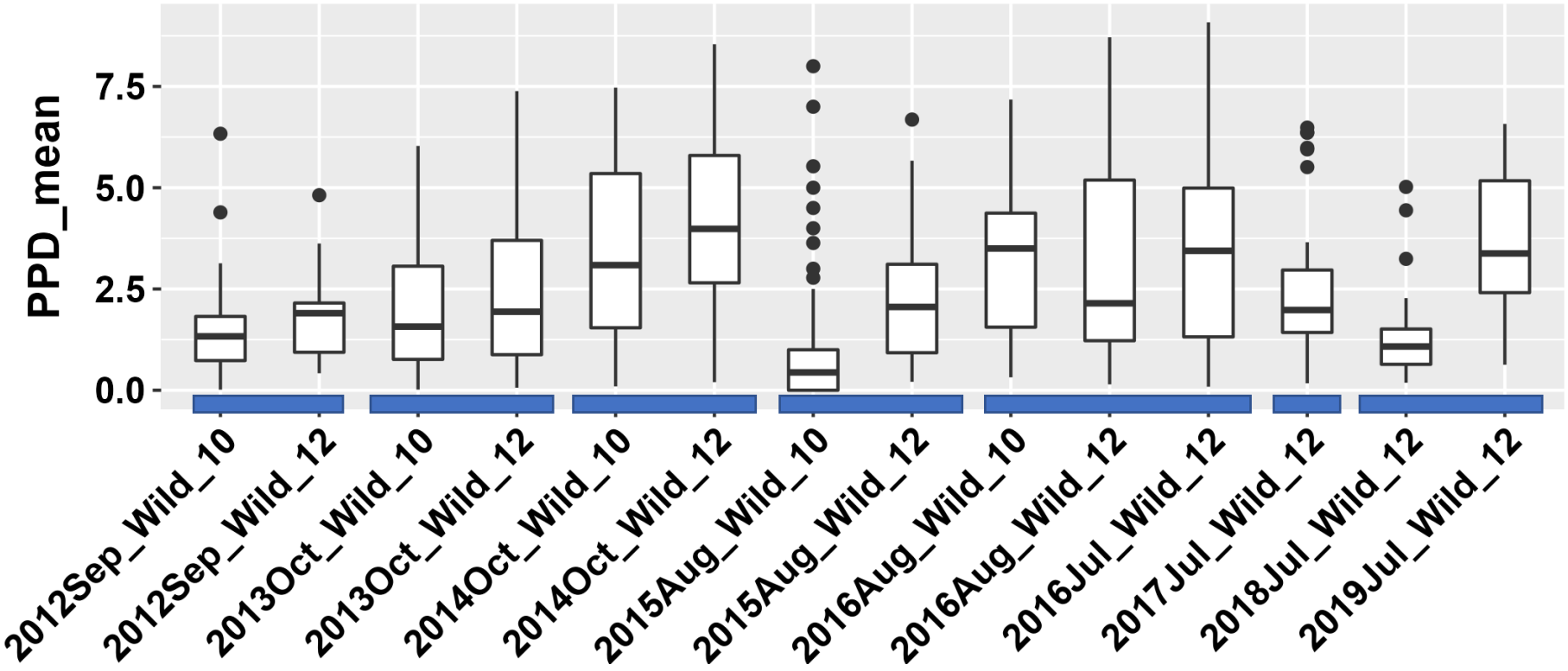
- Genebank
- **Wild crossing**
- Biofortified cassava

Populations from wild crosses



**C4 was derived from the cross between TMS30555 (NGA5 in CIAT genebank) and the CMD-resistant clone, TME3, but C4 does not have CMD resistance*

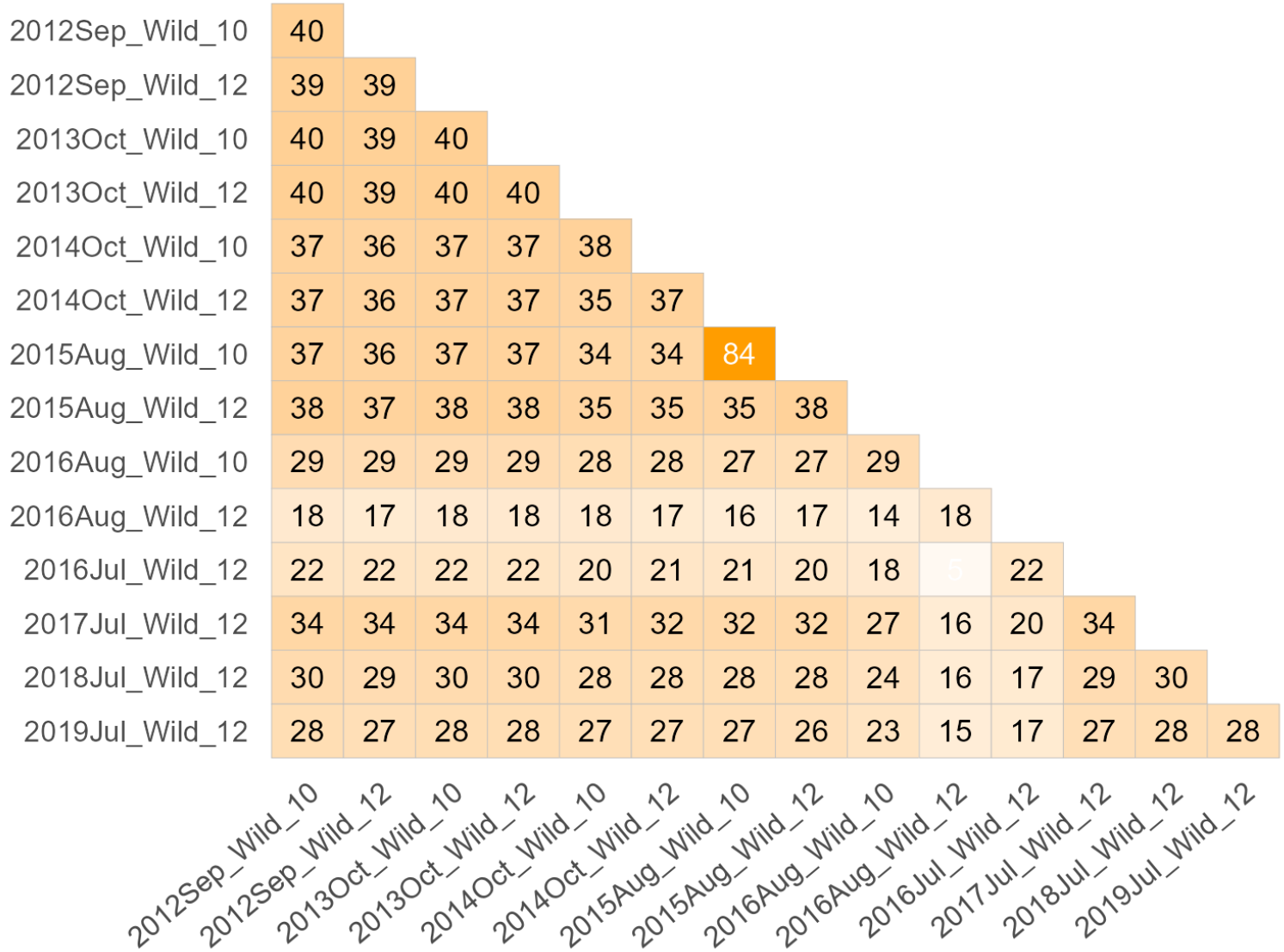
Variation among Environments



trial	number of clones
2012Sep_Wild_10	40
2012Sep_Wild_12	39
2013Oct_Wild_10	40
2013Oct_Wild_12	40
2014Oct_Wild_10	38
2014Oct_Wild_12	37
2015Aug_Wild_10	84
2015Aug_Wild_12	38
2016Aug_Wild_10	33
2016Aug_Wild_12	18
2016Jul_Wild_12	22
2017Jul_Wild_12	34
2018Jul_Wild_12	30
2019Jul_Wild_12	28

Trial name:
planting time_population_months after planting
e.g., 2012Sep_Wild_10, planted in 2012 September, population of wild crosses, 10 months after planting

Connection between trials

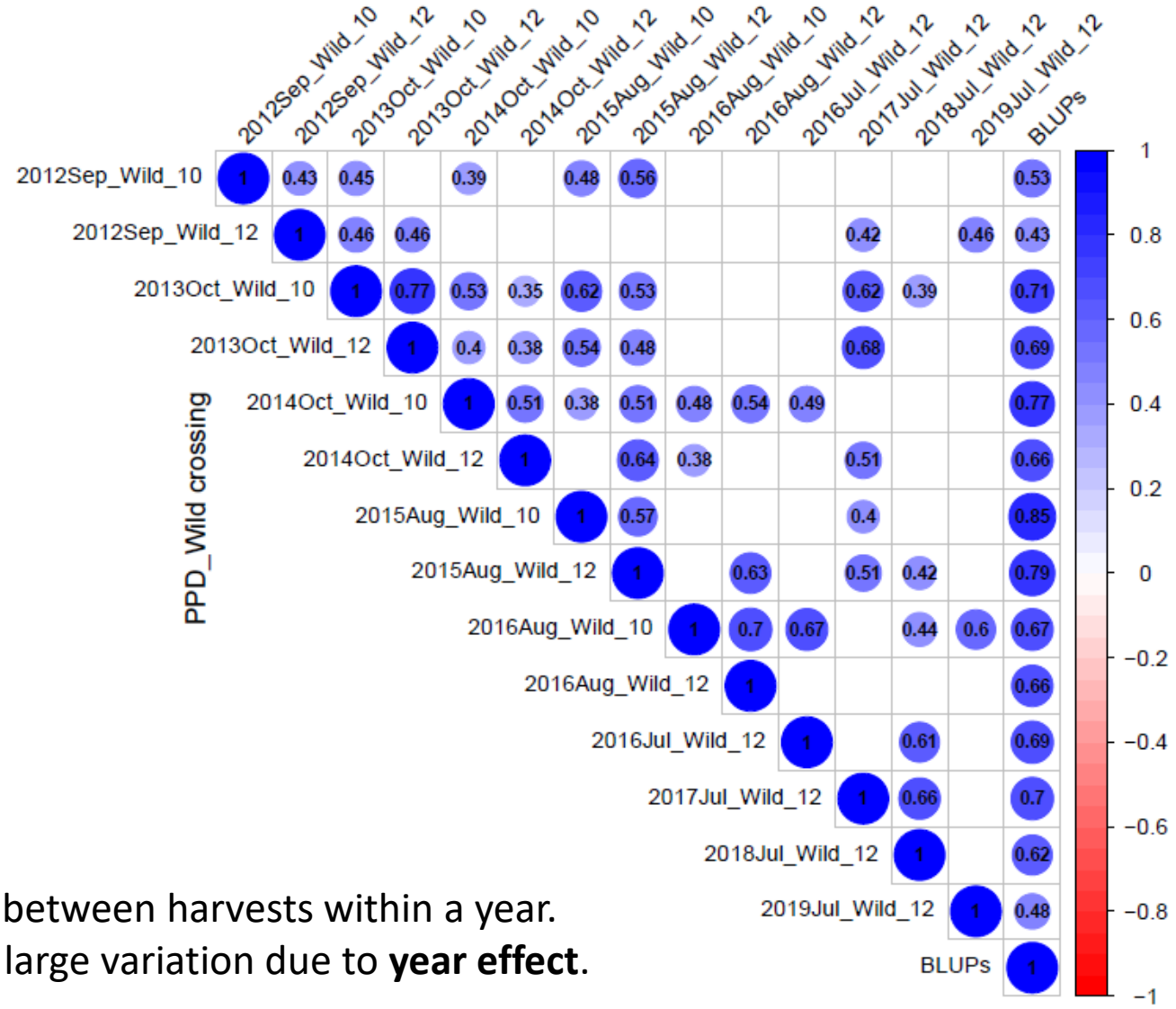


PPD Evaluation in Multiple Environments

H^2 is 0.67
14 environments
7 years

	Genotype	2012Sep_Wild_10	2012Sep_Wild_12	2013Oct_Wild_10	2013Oct_Wild_12	2014Oct_Wild_10	2014Oct_Wild_12	2015Aug_Wild_10	2015Aug_Wild_12	2016Aug_Wild_10	2016Aug_Wild_12	2016Jul_Wild_12	2017Jul_Wild_12	2018Jul_Wild_12	2019Jul_Wild_12	BLUPs
R	PER183	1.23	1.98	3.21	2.14	0.10	0.74		0.27	0.55	0.15	0.09	1.52	0.58	0.63	0.98
	CPDCR5B-036	0.74	0.99	0.27	0.06		1.31	0.03	0.21	2.14		1.02	1.46			1.03
	CPDCR5B-069A	0.56	2.00	0.02	0.66	0.80	2.27		0.86	1.10	0.49		0.84	1.07		1.06
	CPDCR1B-080	0.61	0.51	0.67	1.33	1.49	2.65	0.26	1.17	0.78		0.84	0.17	0.65	2.06	1.07
	CPDCR5B-102	0.66	0.75	0.35	0.63	0.15	3.17	0.32	0.94	1.53		1.04				1.07
	CPDCR5B-055	2.47	1.83	0.84	0.68	1.00		0.80	1.17			1.04				1.51
	B1PD280-040	0.40	1.32	1.58	0.41	0.59	2.32		2.04							1.54
	CPDCR1B-052	1.82	0.69	1.44	0.94	2.48	3.71	0.38	0.70	1.13		3.02	0.70	0.75	1.96	1.55
	AM206-5	1.80	0.42	0.32	0.59	1.42	0.30	0.07	0.26	4.77	0.29	5.10	0.42	1.63	5.94	1.58
	CPDCR5B-041	1.89	2.54	0.80	0.68	1.99	3.63	1.21	0.67	2.33						1.78
	COL22	1.63	2.06	3.44	3.69	1.11	1.15	0.88	1.60	1.42	1.02	1.24	3.10	0.38	3.19	1.85
	CPDCR1B-075	0.01	2.03	0.60	1.01	0.99	3.98	0.54	0.27	4.05			2.38			1.86
	CPDCR1B-065	0.39	0.90	1.34	1.67	4.44	3.25	1.00	0.97	1.75	1.30		2.00	0.69	2.43	1.87
	CPDCR5B-053	0.80	2.19	0.71	0.17			0.36	0.40				2.87	1.72		1.88
	HMC-1	0.42	0.64	3.02	4.42	1.71	4.47	0.74		1.72	1.20	1.55	2.70	0.69	1.00	2.00
	CPDCR5B-096	1.73	1.80	0.61	0.56	2.21	3.94	0.37	2.38	3.78	1.79		3.65	1.49	1.34	2.08
	B1PD280-008	0.37	0.70	0.44	2.71	1.82	5.80	0.67	1.24	3.61	1.74		2.25	0.19	2.94	2.08
	CPDCR1B-046	1.14	1.94	2.56	3.78	3.60	0.88	4.50	0.57				1.24	0.69	5.12	2.36
	CPDCR1B-048	1.09	1.89	2.08	2.08	3.96	5.21	1.21	3.07	2.21		3.38	0.51	0.67	2.82	2.39
	CPDCR1B-026	1.27	1.38	1.82	3.74	4.52	4.41	0.50	1.38	3.57		4.66	1.79	0.23	2.79	2.60
	CPDCR1B-078	1.22	2.12	1.34	3.86	3.32	4.52	0.61	0.92		4.62					2.63
	CPDCR1B-064	0.51	0.45	1.73	1.64	4.97	7.61	0.67	4.00	1.56		4.62	1.51	0.64	2.34	2.70
	CPDCR5B-016	2.64	0.71	0.77	1.21	0.36		2.50	5.67	3.57	8.40		2.52	0.63	1.41	2.94
	CPDCR5B-043	1.74	1.90	1.73	0.46	5.63	0.20	0.71	3.13		8.63		1.41			2.99
	CPDCR1B-019	1.09	2.83	2.91	2.63	3.67	3.98	1.29	2.61			6.23	2.21			3.01
	CPDCR1B-062	1.62	2.22	1.09	3.38	5.43	3.92	1.02	5.05	3.50		2.88	1.37	0.41	6.17	3.04
	CPDCR1B-054	1.35	1.98	3.42	2.09	5.43	6.85	0.67	2.48	3.68		4.00	1.96	1.47	3.04	3.05
	CPDCR1B-028	0.70	1.33	1.57	1.63	4.21	6.49	0.90		6.45		3.51	1.78	0.36	5.45	3.10
	CPDCR5B-109	1.71	2.02	1.30	2.71	2.46	4.35	0.70	2.47	4.71		9.08	1.92	1.43	3.82	3.12
S	C4	4.39		2.58	1.37	2.78	7.44	0.62	3.41		3.56			1.51	5.44	3.20
	CPDCR1B-027	1.31	1.62	0.73	1.22	5.40	3.79	0.29	1.43	7.18	8.71		1.86	2.28	4.15	3.28
	CPDCR1B-043	1.70	0.90	1.59	1.80	6.39	8.28	1.82	2.69		5.23		3.00	1.29	3.30	3.48
	CPDCR1B-034	1.85	3.62	3.50	2.51	6.65	4.32	0.64	2.08	5.45		7.00	1.29			3.51
	CPDCR1B-015	2.50	2.66	3.43	2.84	5.21	7.04	1.11	3.53	3.01	2.23		6.37	1.51	5.32	3.59
S	CM523-7	1.84	4.82	4.17	7.39	2.86	5.34	1.34	2.23	3.52	2.06	4.68	6.36	1.35	6.58	3.75
	CPDCR1B-013	1.42	2.22	4.69	4.81		1.64	1.62	2.77			8.52	5.51	3.24	3.90	3.83
	CPDCR5B-013					6.36										3.84
	CPDCR1B-068	1.25	1.98	1.47	4.59	2.40	7.84	0.80	4.19	4.76	5.07		5.99	4.44	5.40	3.91
	CPDCR1B-074	6.33	3.52	4.15	5.11	7.47	5.65	3.64	5.17	4.37		2.45	2.86	1.09	4.00	4.17
	CPDCR1B-008	2.41	0.97	6.03	6.61	6.90	8.54	2.78	4.82	4.63	6.80		5.95	1.88	4.46	4.98
	CPDCR1B-076	3.13	2.72	5.95	5.37	5.86	8.03	5.53	6.68			6.54	6.48	5.02	3.46	5.41

Correlation between trials



* **Significant correlation** between harvests within a year.
* PPD tolerance showed large variation due to **year effect**.

Best clones tolerant to PPD (Jorge Luna)

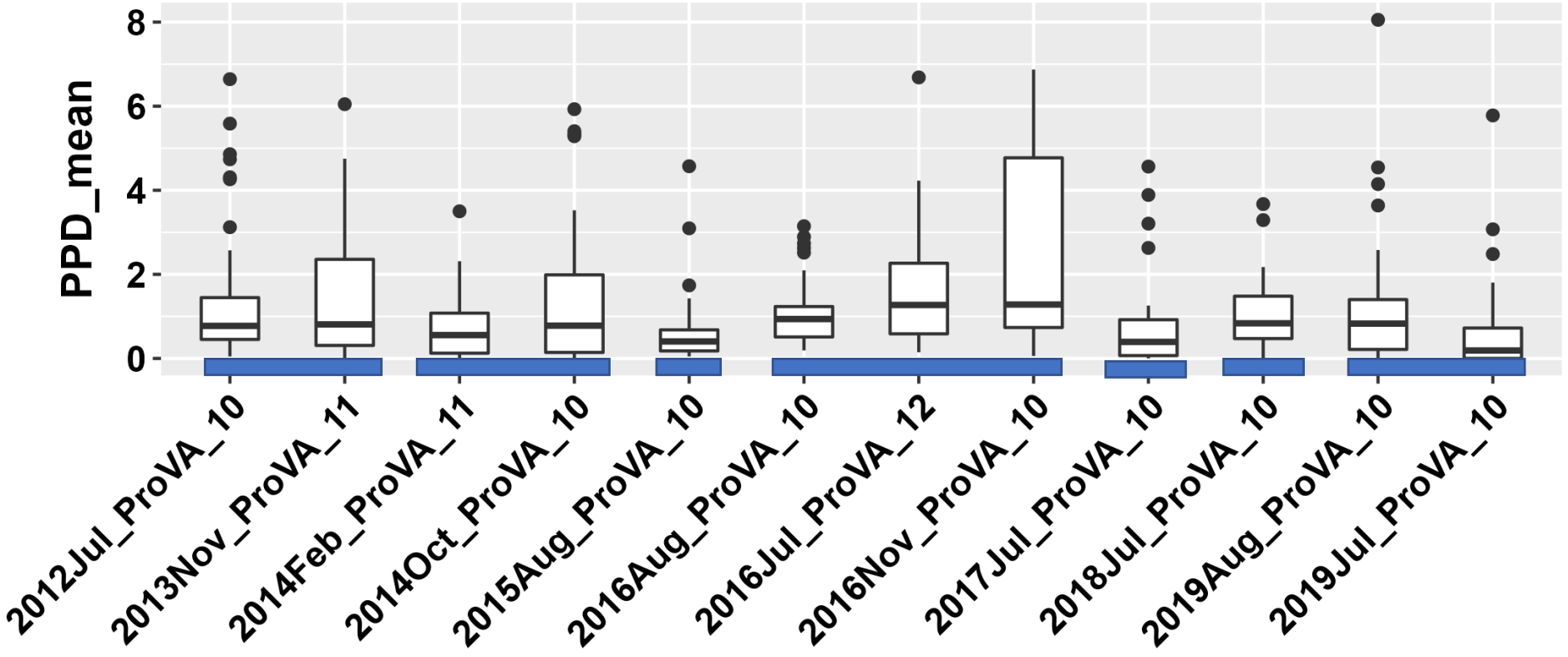
Genotype	# years	Average Dry Matter (%)	# Years	Average PPD (%)
B1PD280-040	7	35	7	12
CPDCR1B-080	7	37	7	9.2
CPDCR5B-036	7	37	7	8.7
CPDCR5B-053	7	37.4	7	9
CPDCR5B-055	7	37.2	7	12.2
CPDCR5B-069A	7	31.7	7	8.9
CPDCR5B-102	7	32	7	9

Selected four clones for genetic studies and breeding
Make crosses between these and other tolerant clones

Sources of PPD tolerance

- Genebank
- Wild crossing
- **Biofortified cassava**

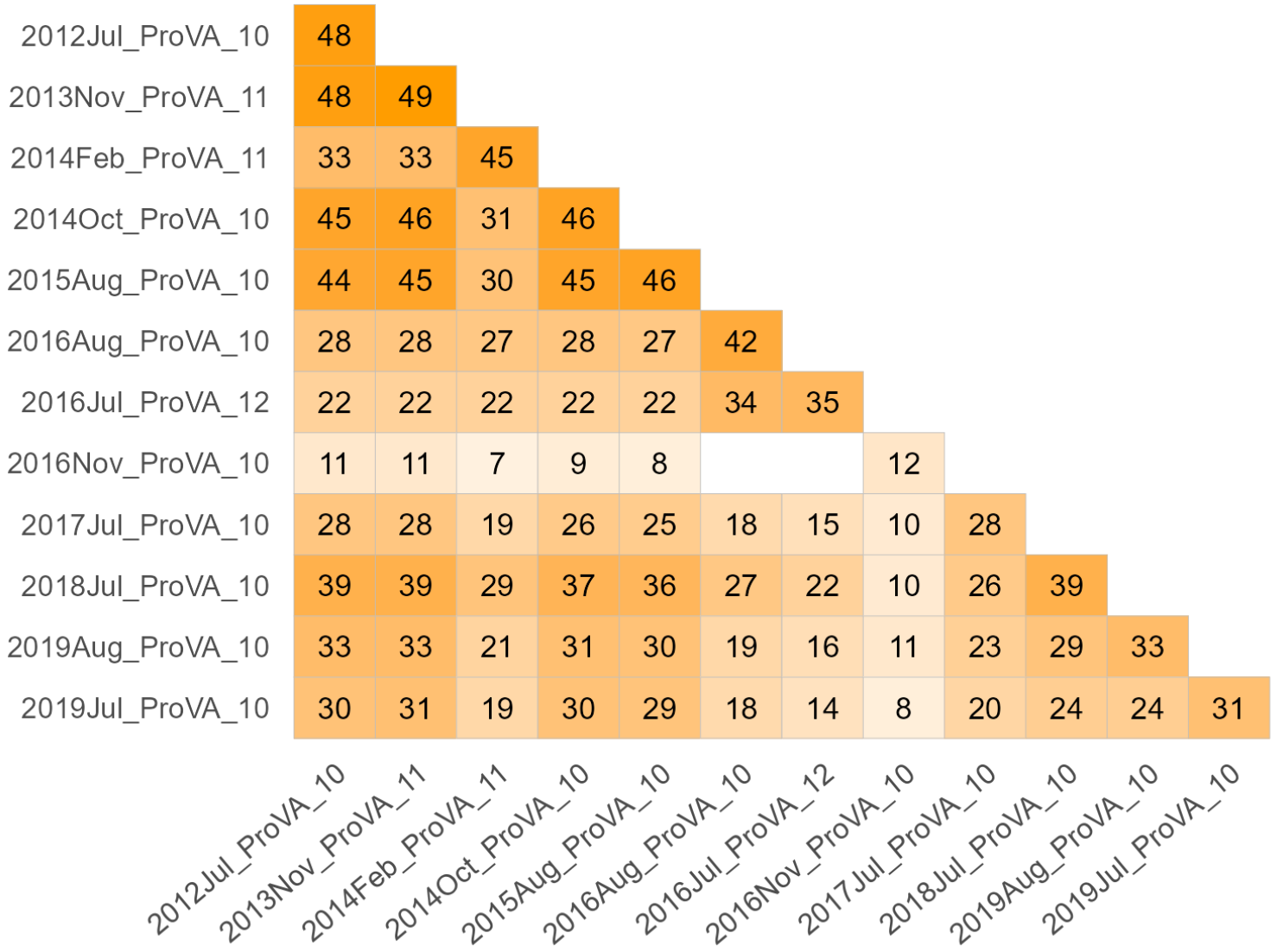
Variation among Environments



trial	number of clones
2012Jul_ProVA_10	48
2013Nov_ProVA_11	49
2014Feb_ProVA_11	45
2014Oct_ProVA_10	46
2015Aug_ProVA_10	46
2016Aug_ProVA_10	42
2016Jul_ProVA_12	35
2016Nov_ProVA_10	12
2017Jul_ProVA_10	28
2018Jul_ProVA_10	39
2019Aug_ProVA_10	33
2019Jul_ProVA_10	31

Trial name:
planting time_population_months after planting
e.g., 2012Sep_Wild_10, planted in 2012 September, population of pro-Vitamin A, 10 months after planting

Connection between trials



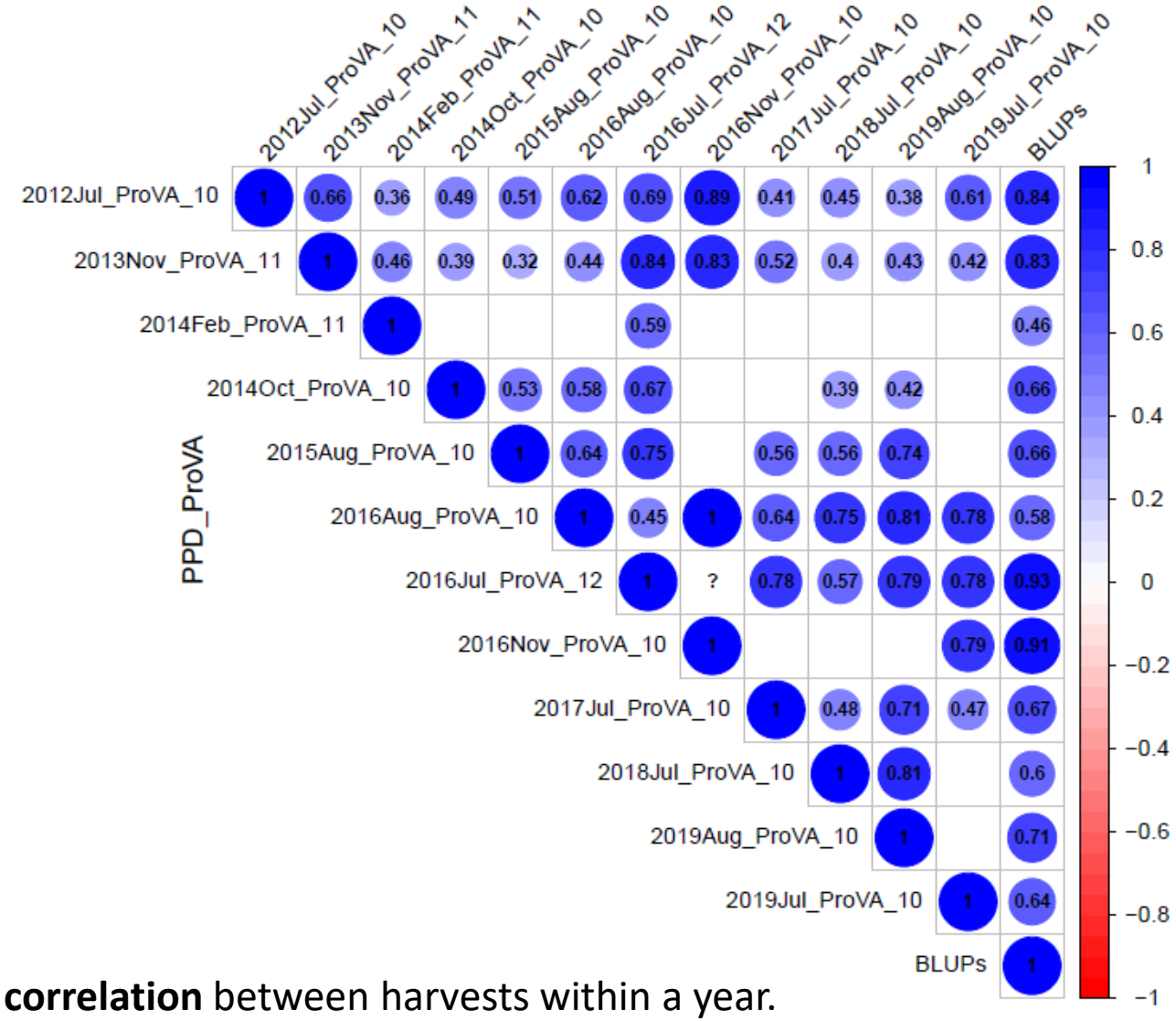
	Genotype	2012Jul_ProVA_10	2013Nov_ProVA_11	2014Feb_ProVA_11	2014Oct_ProVA_10	2015Aug_ProVA_10	2016Aug_ProVA_10	2016Jul_ProVA_12	2016Nov_ProVA_10	2017Jul_ProVA_10	2018Jul_ProVA_10	2019Aug_ProVA_10	2019Jul_ProVA_10	BLUPs
	GM905-52	0.31	0.14	0.00	0.75	0.07	0.19	0.15		0.00	0.05		0.00	0.22
	GM3732-5	0.05	0.05	0.28	0.05	0.05	0.25	0.69		0.36	0.13	0.39	0.02	0.26
	GM3732-54							0.15						0.29
	GM3736-20	0.21	0.33	0.75	0.14	0.15	0.51	0.23		0.05	1.48			0.32
	GM3732-36	0.24	0.14	0.00	0.07	0.24								0.33
	GM3736-29	0.45	0.31		0.07	0.10	0.96	0.26		0.16	1.48	0.00		0.34
	GM3736-72						0.84	0.27						0.36
	GM905-57	0.52	0.21	0.03	0.43	0.10	1.19	0.28		0.02	0.40	0.20	0.45	0.37
	GM3732-37						1.00	0.28						0.38
	GM3732-17	0.79	0.00		0.19	0.45	0.20	0.25			0.52	1.02	0.00	0.40
	GM3732-30	0.61	0.05	0.57	0.07		0.92		0.06	0.60	0.55	0.21	0.06	0.43
	GM3732-27	0.31	0.20	0.50	0.10	0.38	1.55				0.39			0.43
	GM3732-21	0.48	0.77	0.56	0.00	0.14	0.78	0.67			0.71	0.21		0.46
	GM3736-44	0.37	0.44		0.24	1.31	0.21			0.03	0.40	0.09	0.48	0.46
	GM3736-73	0.54	0.76	0.13	0.05	0.21	1.24	0.53	0.27	0.07	1.31	0.14		0.46
	GM3736-74			0.67			0.19	0.64						0.48
	GM3736-53	0.62	0.93		1.09	0.76				0.03	0.02	0.36		0.65
	GM3732-22	0.42	0.10	0.11	1.43	1.06	1.11			0.51			0.19	0.65
	GM3732-14	0.43	0.21	0.63	0.43	0.14	0.50	2.26		0.20	0.57	1.38	0.00	0.65
	GM3736-5	1.07	0.07	0.03	0.14	0.43	0.77	1.69			1.02			0.66
	GM3736-16	1.07	0.00	1.08	0.05	0.55	1.04				1.63		0.00	0.66
	GM3732-20	1.33	0.56	0.92	0.03	0.24								0.68
	GM3736-75			0.43			0.59	1.08						0.69
	GM3736-40						0.21							0.73
	GM3736-34	1.17	1.62		0.46	1.10			0.11	1.15		0.11	0.03	0.79
	GM3736-26	1.41	0.55		1.64	0.26	0.29	1.25		0.17	1.57		0.00	0.80
	GM3736-70	0.29	1.51	0.94	0.59	0.12			1.04	0.77	0.31	0.81	0.68	0.80
	GM3736-66			0.00										0.80
	COL22		0.57		0.66	1.43							0.19	0.81
	GM3732-6						2.89	0.74						0.81
	GM3736-18	0.76	0.69	1.46	0.00	0.49			0.91		0.70	1.40	0.32	0.81
	GM3736-2	0.37	0.88	0.00	0.98	0.52	1.37	1.05			1.88	2.21		0.82
	HMC-1	0.71	0.31		2.93	0.43						0.88	0.00	0.83
	GM3736-15						0.21	1.42						0.83
	GM3736-30					0.07								0.83
	GM3732-29			0.12										0.85
	GM3736-69			0.17										0.87
	GM3736-71						1.49	1.21						0.87
	GM3736-51	0.85	1.07	0.11	0.98	0.90	0.64	2.18		0.06	0.50	1.17	0.29	0.88
	GM3736-25	0.59	2.37	1.10	1.39	0.21	0.78	1.54			0.00		0.00	0.91
	GM3736-63			0.28										0.91
R	PER183	1.54	0.64		2.50	0.32						0.44	0.00	0.92
	GM3736-78	1.23	2.36	0.47	0.81	0.17	0.52	1.27		0.70	0.27	0.11		0.95
	GM3736-83	1.41	0.16		3.52	0.65					0.54	0.83	0.00	0.97
	GM3732-13	2.02	0.81		1.17	0.07				0.57	0.79			0.97
	GM3736-82	0.85	1.88	0.00	1.07	1.12			0.89	0.27	1.20	1.23	0.76	1.03
	GM3736-6			0.75										1.09
	GM3736-49						0.96	1.82						1.10
	GM3736-32			0.85										1.13
	GM3736-11			0.89										1.15
	GM3736-54	0.67	3.33	3.50	0.08	0.26	0.29				0.70	0.57		1.16
	GM3736-28			1.09										1.23
	GM3732-32						1.53							1.28
	GM3732-18						2.52	2.02						1.37
	GM905-60	0.45	1.05	0.26	2.15	0.26	2.10	2.30			3.29	4.54	0.63	1.42
	AM206-5	3.12	2.21		0.68	0.26							0.86	1.43
	GM3732-4						2.63	2.27						1.50
	GM3732-15	2.02	1.98	1.38	5.29	0.69	1.18	2.00		0.98	1.14	0.07	0.00	1.53
	GM3736-24	0.92	4.52	0.26	0.98	0.26					1.37			1.54
	GM3736-79	1.71	2.22		5.93	0.45			1.71	0.43	1.14	0.46		1.55
	GM3736-1	0.36	4.55	0.29	2.06	0.12	0.84	4.20		0.21	1.22	1.59	0.08	1.63
	GM3736-21	1.07	2.90	1.94	1.95	0.43	1.05	3.64		3.21	0.84	0.91	0.66	1.65
	GM3736-9	0.64	1.31	0.24	0.57	1.17	1.21	4.23		4.56	1.77	4.15	1.14	1.67
	GM3736-3			2.31										1.70
	GM3736-13								4.34					1.85
	GM3736-64	4.31	2.45						1.52	0.90	2.17	1.45	2.48	1.90
	GM3736-27			1.42			2.73	3.00						1.92
	GM3736-50	2.57	2.73	2.11	2.14	1.74	0.84	2.97			1.88			1.93
S	CM523-7	0.76	0.31		5.33	3.10						3.64	3.07	1.93
	GM3736-37						1.09	3.76						2.03
	GM3736-42	5.59	2.86	1.41					6.57	0.00	1.18	0.06		2.17
	GM3736-52	4.26	3.17	0.82										2.27
	GM3736-61	4.86	4.75		2.00	0.48			6.07	1.26	1.57	2.58	1.46	2.65
	GM3736-67	4.74	3.36	0.05	2.43	0.57			6.87	2.63	0.44	1.00	5.78	2.68
	GM3736-14	6.64	6.05	2.26	5.40	4.57	3.15	6.68		3.89	3.67	8.05	1.80	4.48

PPD Evaluation in Multiple Environments

H^2 is 0.72
13 environments
7 years

Biofortified cassava, in general, showed good PPD tolerance

Correlation between trials



* **Significant correlation** between harvests within a year.
* PPD tolerance showed large variation due to **year effect**.

Best clones tolerant to PPD (Jorge Luna)

Genotype	# years	Average Dry Matter (%)	Average PPD (%)	Beta carotene (µg/g FW; NIRS)
GM3732-14	7	34.5	3.9	3.9
GM3732-21	7	34.6	4.4	8
GM3732-27	7	37.7	5.1	5.1
GM3732-36	7	34.15	1.4	4.2
GM3736-44	7	42.8	3.8	5.1
GM905-57	7	40	3.5	6.4

Selected three clones for further genetic studies and breeding
Make crosses between these and other tolerant clones

Data analysis plan:

Jorge Luna, Sandra and Lizbeth will upload the data to CassavaBase – **Oct 21**
Luis Fernando will analyze all the agronomy, quality, and PPD data -- **Oct 30**
----> need to pay attention to the correlation between PPD and DM

Schedule a meeting on **Nov 01** to discuss the results and plan the manuscript writing.

Workplan (Jorge Luna will coordinate the activities):

Previous population

1. **Sequence/genotype** the two wild crossing families and progenitors

New population:

2. **Sequence/genotype** the new families from **Nelson**, progenitors, and R and S accessions
3. **Screen** the new populations for PPD and other traits
4. **RNA-Seq** and **Metabolism** of progenitors, and R and S accessions

Protocol development:

5. **Room** with controlled temperature and humidity for PPD screening – CtEH proposal
6. **Chamber** for physiological monitoring – CtEH proposal
7. **Prediction** model for objectively scoring PPD – collaboration with Michael, NaCRRI, and IITA
8. Estimate PPD development under **farmers' storage condition**

We also need to pay attention to **starch stability after harvesting under storage**