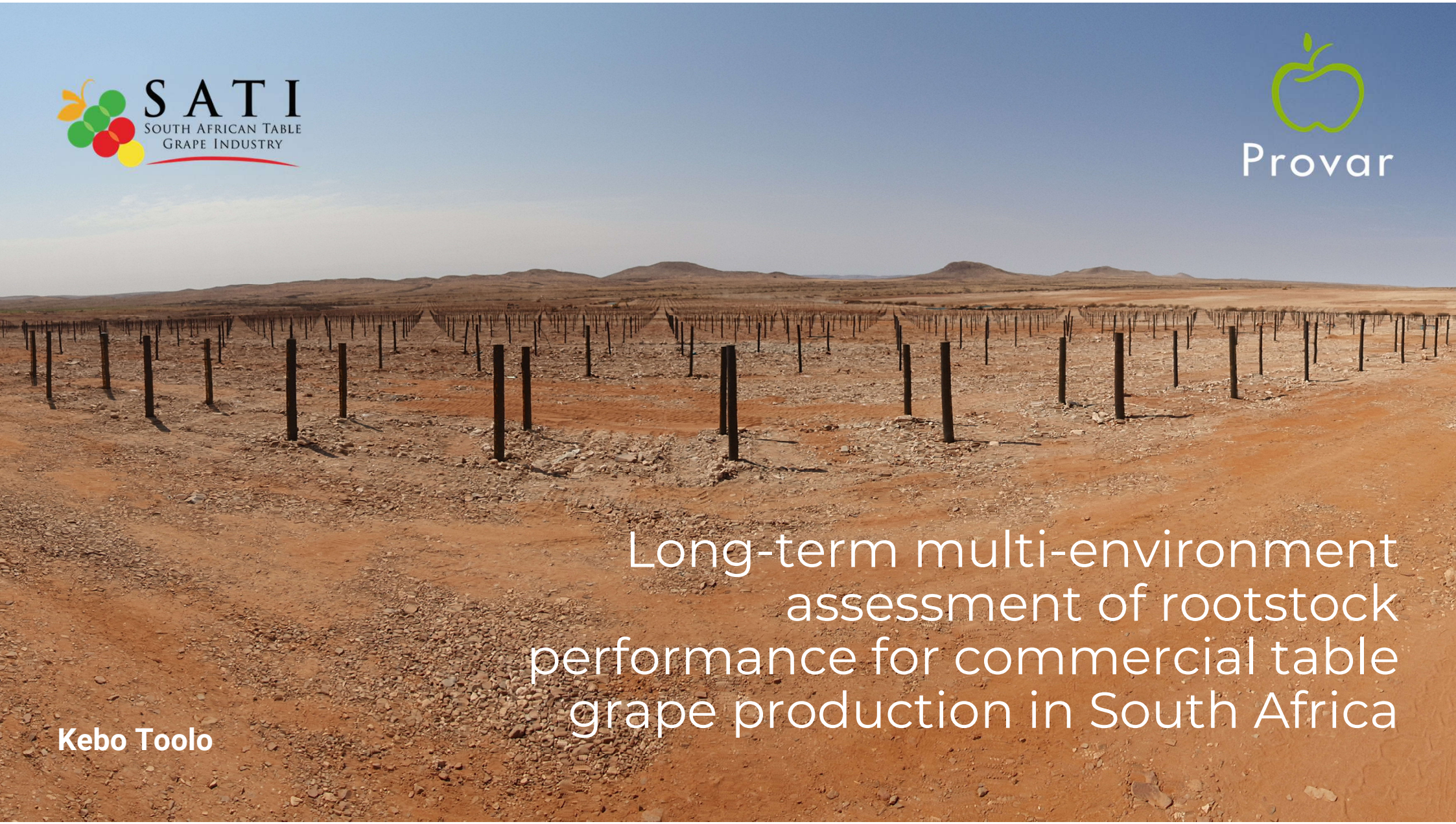

Long-term multi-environment assessment of rootstock performance for commercial table grape production in South Africa

Kebo Toolo

Rootstock Advantages

Provar

Tolerance to soil pests and diseases

Adaptation to specific soil types and climates

Major impact on vineyard profitability and longevity

"The rootstock is the engine of the vine."
- Prof. Eben Archer

Provar

Objectives

Assess rootstock genotype performance on important scion cultivars

Quantify GEI across diverse conditions

- **Climatic**
- **Soil**
- **Management**

Identify superior rootstock genotypes



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Site Information



Kosie van Niekerk Boerdery
(KVNB)

Saron, Berg River

Sugrathirtyfive
(AUTUMNCRISP®)

Alluvial, sandy loam

3.0 × 2.0 m

Drip irrigation

Black sandy soil, loamy fine sand

Micro sprinklers

Drip Irrigation

Gable

Gable with nets

Rootstocks Used

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Rootstock	Parentage	Characteristics
Harmony	*Vitis champinii x Vitis vinifera x Vitis labrusca x Vitis riparia*	High resistance to root-knot and dagger nematodes; low phylloxera resistance. Adapted to warmer areas and sandy soils of moderate fertility. Medium–high vigour; short vegetative cycle.
Paulsen 1103	*V. berlandieri x V. rupestris*	High phylloxera resistance; moderate nematode resistance. Adapted to compact, acidic, clay-calcareous and moderately saline soils; good drought tolerance. High vigour; good colour induction, balanced vines and berry size; tends to delay maturity.
Ramsey	*V. champinii*	Excellent nematode resistance; moderate phylloxera resistance. Adapted to marginal, sandy, infertile and saline soils; excellent drought and salt tolerance. Very high vigour induction.
Richter 110	*V. berlandieri x V. rupestris*	High phylloxera resistance; moderate resistance to root-knot nematodes. Adapted to heavier, dry, gravelly or stony soils and variable soil conditions; excellent drought tolerance. High vigour; good colour induction; delays maturity.
RS-3	*V. champinii x V. riparia x V. rupestris*	Broad resistance to nematodes (including aggressive root-knot biotypes), phylloxera and grapevine fanleaf virus. Adapted to sandy soils; sensitive to excess wetness and salinity. Medium to strong vigour.
RS-9	*V. champinii x V. riparia x V. rupestris*	Broad resistance to nematodes, phylloxera and grapevine fanleaf virus. Adapted to higher-potential soils; suitable for closer plantings. Medium to low vigour induction.
Ruggeri 140	*V. berlandieri x V. rupestris*	High phylloxera resistance; moderate to high resistance to root-knot nematodes. Adapted to dry, lean, superficial, sandy, stony and highly calcareous soils; excellent drought tolerance (poor on wet soils). Very high vigour; short vegetative cycle; delays maturity.
SO4	*V. berlandieri x V. riparia*	High phylloxera resistance; strong resistance to several root-knot nematodes. Wide adaptability; suited to sandy, acidic, clay-limestone and moderately fertile soils; medium drought tolerance. Medium to moderately high vigour; tends to advance ripening.

Anwar & McKenry (2000-2002), Brooks & Olmo (1997), Ferris et al. (2012), Galet (1988-2000s), Pongrácz (1983), Ramming & McKenry (2003–2004), Smart (2015), SAPO & Vinehealth Australia (2010-2020), Walker et al. (1998, 2009, 2019)

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Rootstock Propagation (2019 – 2025)

Rootstock	% Increase
Harmony	-100
Paulsen 1103	-64
Ramsey	14
Richter 110	-84
RS-3	-100
RS-9	-100
Ruggeri 140	-100
SO4	-100

Seven years. One rootstock!

Randomized Complete Block Design

Provar

4 Blocks

8 Rootstock genotypes each

Harmony
Paulsen 1103
Ramsey
Richter 110
RS-3
RS-9
Ruggeri 140
SO4

Provar

Data Collection

Vegetative characteristics:

Cane mass

Scion: rootstock diameter

Earliness of bud break

Evenness of bud break

Vigour

Canopy density

Reproductive characteristics:

Bunch: shoot

Degree of shatter

Shot berries

Bunch density

Yield per vine

Number of bunches per vine

Avg bunch weight

Avg berry weight

Juice quality:

TSS

TTA

TSS: TTA

Results – MET ANOVA

Characteristic	Main effect		Interaction	
	p Genotype	*p* Environment	*p* G x E	*p* S x E x G
Vegetative				
Cane mass (kg)	< 0,0001	< 0,0001	< 0,0001	0,0002
Scion: rootstock diameter	< 0,0001	< 0,0001	< 0,0001	0,002
Earliness of bud break	0,005	< 0,0001	0,070	0,010
Evenness of bud break	0,703	< 0,0001	0,036	0,567
Vigour	0,329	< 0,0001	0,048	0,003
Canopy density	0,343	0,0001	0,214	0,546
Reproductive				
Bunch: shoot	< 0,0001	< 0,0001	0,035	0,266
Degree of shatter	0,071	< 0,0001	0,074	0,146
Shot berries	0,416	< 0,0001	0,782	0,461
Bunch density	0,236	0,004	0,102	0,513
Yield per vine (kg)	< 0,0001	< 0,0001	0,062	0,002
Number of bunches per vine	0,011	< 0,0001	0,029	< 0,0001
Avg bunch weight (g)	< 0,0001	< 0,0001	0,293	0,000
Avg berry weight (g)	0,0002	< 0,0001	0,0926	0,002
Juice quality				
TSS (°B)	0,016	< 0,0001	0,001	0,001
TTA (g/L)	< 0,0001	< 0,0001	0,024	0,208
TSS: TTA	0,002	< 0,0001	0,067	0,001

Genotypic differences without interactions

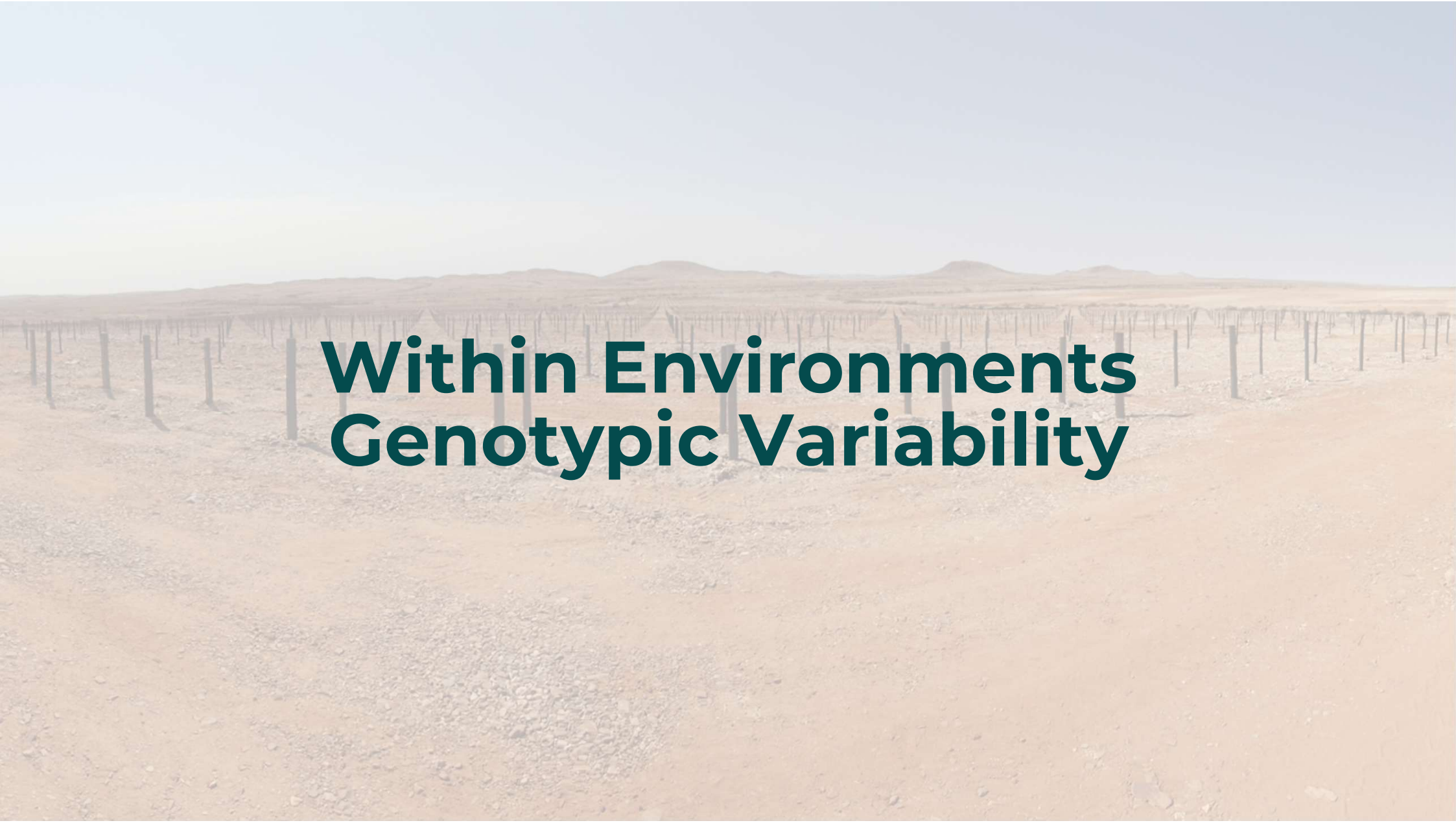
AMMI and GGE on the highlighted

GGE on the highlighted

Provar

Genotypic Differences Without Interactions

Rootstock	Earliness of bud break		Yield per vine (kg)		Avg bunch weight (g)		Avg berry weight (g)		TSS: TTA	
Harmony	3,408	cd	11,709	cde	471,750	bc	6,439	cd	57,351	bcd
Paulsen 1103	3,364	d	12,785	abc	481,470	bc	6,712	abc	55,944	cd
Ramsey	3,650	abc	13,634	ab	510,130	ab	6,745	ab	57,101	bcd
Richter 110	3,333	d	12,984	abc	459,560	cd	6,588	abc	58,112	abc
RS-3	3,783	a	12,468	bcd	497,510	abc	6,526	bc	59,939	a
RS-9	3,678	ab	10,453	e	423,760	d	6,194	d	59,277	ab
Ruggeri 140	3,392	cd	11,089	de	476,620	bc	6,786	ab	55,924	cd
SO4	3,425	bcd	14,243	a	535,090	a	6,869	a	55,132	d
LSD	0,264		1,543		39,172		0,296		2,532	
p-value	0,005		< 0,0001		< 0,0001		0,000		0,002	


Within Environments
Genotypic Variability

Begin Boerdery

Sweet Celebration™

Provar

Rootstock	Cane mass (kg)		Scion: rootstock diameter		Earliness of bud break		Bunch density		Yield per vine (kg)		Avg bunch weight (g)		Avg berry weight (g)		TTA (g/L)		TSS: TTA	
Harmony	1,678	bc	0,873	cd	3,833	bc	66,667	b	10,674	d	403,320	c	6,428	c	0,391	ab	54,920	ab
Paulsen 1103	1,755	bc	0,907	cd	3,958	bc	60,417	b	12,628	abc	485,380	ab	7,213	a	0,402	a	51,100	b
Ramsey	2,189	a	1,110	a	4,208	ab	83,333	a	13,440	ab	456,590	abc	7,319	a	0,376	abc	54,668	ab
Richter 110	1,181	d	1,078	ab	4,042	abc	56,250	b	13,394	ab	435,820	bc	6,928	ab	0,361	bc	56,279	ab
RS-3	1,402	cd	0,787	d	4,208	ab	69,792	ab	11,959	bcd	456,060	abc	6,609	bc	0,348	c	59,191	a
RS-9	1,368	cd	0,958	bc	4,375	a	66,667	b	10,565	d	419,490	c	6,647	bc	0,344	c	60,540	a
Ruggeri 140	1,853	ab	1,070	ab	3,708	c	65,625	b	11,444	cd	457,990	abc	7,300	a	0,400	a	50,603	b
SO4	1,688	bc	1,110	a	3,667	c	57,292	b	13,903	a	493,310	a	7,341	a	0,402	a	50,731	b
LSD	0,397		0,121		0,401		15,298		1,932		55,094		0,455		0,038		6,526	
p-value	0,001		< 0,0001		0,012		0,035		0,008		0,037		0,001		0,010		0,025	

Buffelskraal Boerdery

Sable Seedless®

Rootstock	Scion: rootstock diameter		Bunch: shoot	
Harmony	0,811	c	0,822	bc
Paulsen 1103	0,800	c	0,887	ab
Ramsey	0,964	ab	0,810	bc
Richter 110	0,941	ab	0,991	a
RS-3	0,855	bc	0,896	ab
RS-9	0,890	abc	0,725	c
Ruggeri 140	0,920	abc	0,784	bc
SO4	0,980	a	0,890	ab
LSD	0,126		0,117	
p-value	0,045		0,005	

Denau Boerdery

Crimson Seedless

Rootstock	Cane mass (kg)		Scion: rootstock diameter		Earliness of bud break		Bunch density		Avg berry weight (g)	
Harmony	3,219	abc	0,866	d	3,375	bc	75,000	a	6,538	a
Paulsen 1103	2,978	bc	0,948	bc	3,417	bc	81,250	a	6,205	ab
Ramsey	3,635	a	0,952	abc	3,750	ab	68,750	ab	5,895	bc
Richter 110	2,392	d	1,012	ab	3,333	bc	66,667	ab	6,078	b
RS-3	3,444	ab	0,901	cd	4,208	a	55,208	bc	6,263	ab
RS-9	3,298	abc	0,961	abc	3,958	a	45,833	c	5,631	c
Ruggeri 140	3,153	abc	0,931	cd	3,167	c	76,042	a	6,156	ab
SO4	2,757	cd	1,023	a	3,292	bc	73,958	a	6,253	ab
LSD	0,549		0,071		0,537		18,095		0,397	
p-value	0,003		0,003		0,006		0,009		0,006	

KVNB

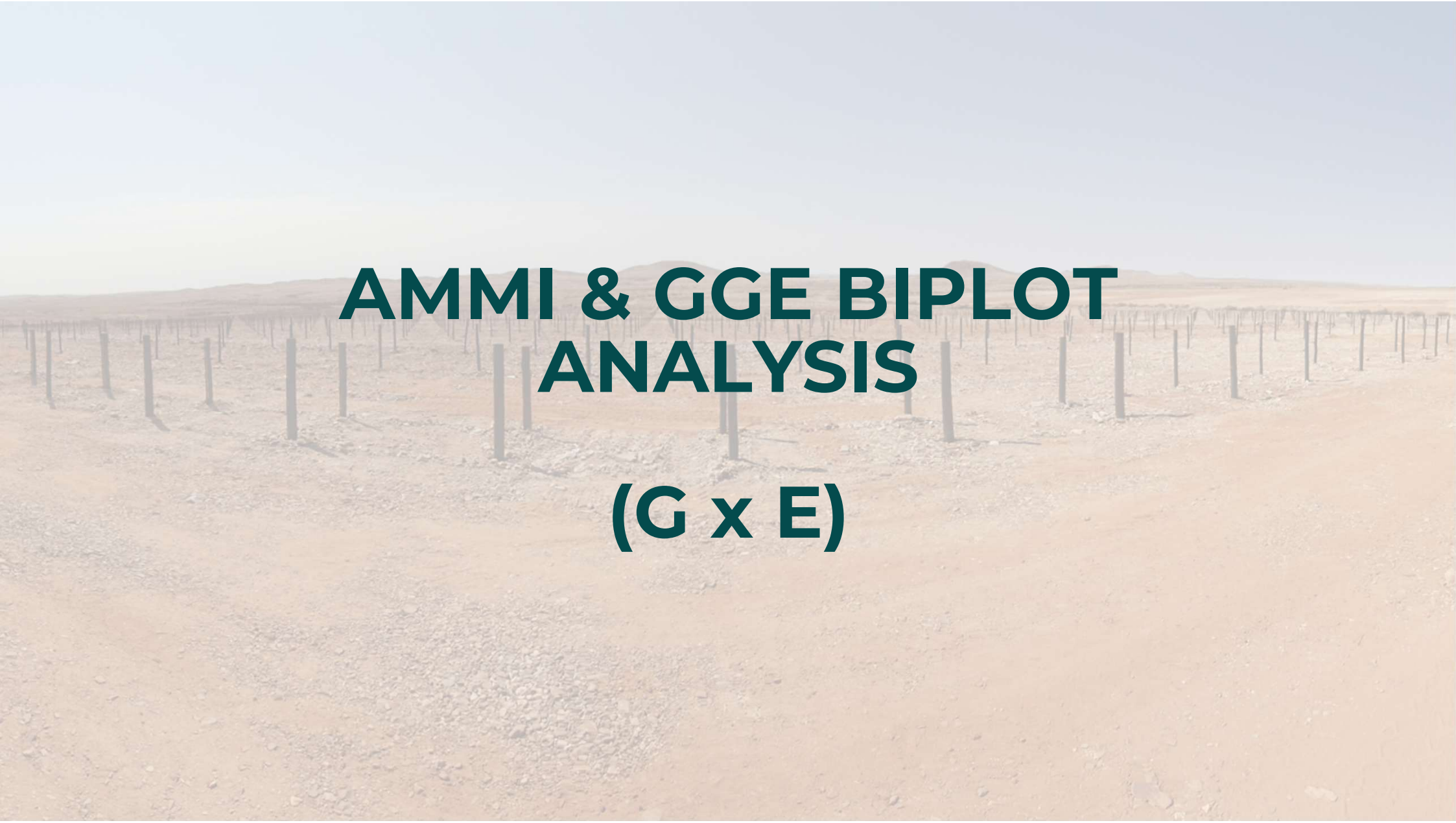
AUTUMNCRISP®

Rootstock	Cane mass (kg)		Scion: rootstock diameter		Yield per vine (kg)	
Harmony	2,728	a	0,979	cde	16,459	ab
Paulsen 1103	1,726	d	0,893	e	13,308	b
Ramsey	2,199	bc	1,166	b	18,003	a
Richter 110	1,799	d	1,020	cd	16,436	ab
RS-3	1,671	d	0,909	de	15,707	ab
RS-9	1,750	d	1,092	bc	12,935	b
Ruggeri 140	1,971	cd	1,012	cd	12,888	b
SO4	2,394	ab	1,299	a	18,391	a
LSD	0,374		0,119		4,094	
p-value	< 0,0001		< 0,0001		0,045	

Yarona

Thompson Seedless

Rootstock	Cane mass (kg)	Scion: rootstock diameter	Earliness of bud break	Bunch: shoot	Degree of shatter	Yield per vine (kg)	Number of bunches per vine	Avg bunch weight (g)	Avg berry weight (g)	TSS (°B)
Harmony	2,142 a	1,002 b	4,042 b	0,670 b	66,667 ab	8,128 bc	20,625 bc	305,730 bc	4,142 ab	22,700 ab
Paulsen 1103	1,141 bcd	0,933 b	3,864 bc	0,704 ab	73,864 ab	9,581 ab	25,000 ab	328,080 b	4,123 ab	21,291 e
Ramsey	1,600 ab	1,035 b	4,417 a	0,803 a	66,667 ab	12,118 a	30,500 a	414,800 a	4,500 a	21,867 cde
Richter 110	1,095 bcd	1,248 a	3,833 bc	0,696 ab	46,875 c	4,490 c	16,364 c	236,840 c	3,655 bc	23,427 a
RS-3	0,962 cd	0,986 b	4,125 ab	0,659 b	82,292 a	9,325 ab	28,136 a	326,100 b	3,932 ab	21,736 de
RS-9	0,647 d	1,043 b	4,000 b	0,532 c	57,292 bc	8,065 bc	28,583 a	238,900 c	3,263 c	21,179 e
Ruggeri 140	1,419 bc	1,024 b	4,417 a	0,728 ab	66,667 ab	7,507 bc	20,333 bc	343,050 ab	4,492 a	22,246 bcd
SO4	0,873 d	1,309 a	3,583 c	0,717 ab	65,625 ab	10,425 ab	31,909 a	328,900 b	4,164 ab	22,559 bc
LSD	0,543	0,113	0,363	0,107	18,221	3,845	7,484	78,783	0,583	0,788
p-value	0,000	< 0,0001	0,001	0,003	0,028	0,023	0,003	0,002	0,003	0,000



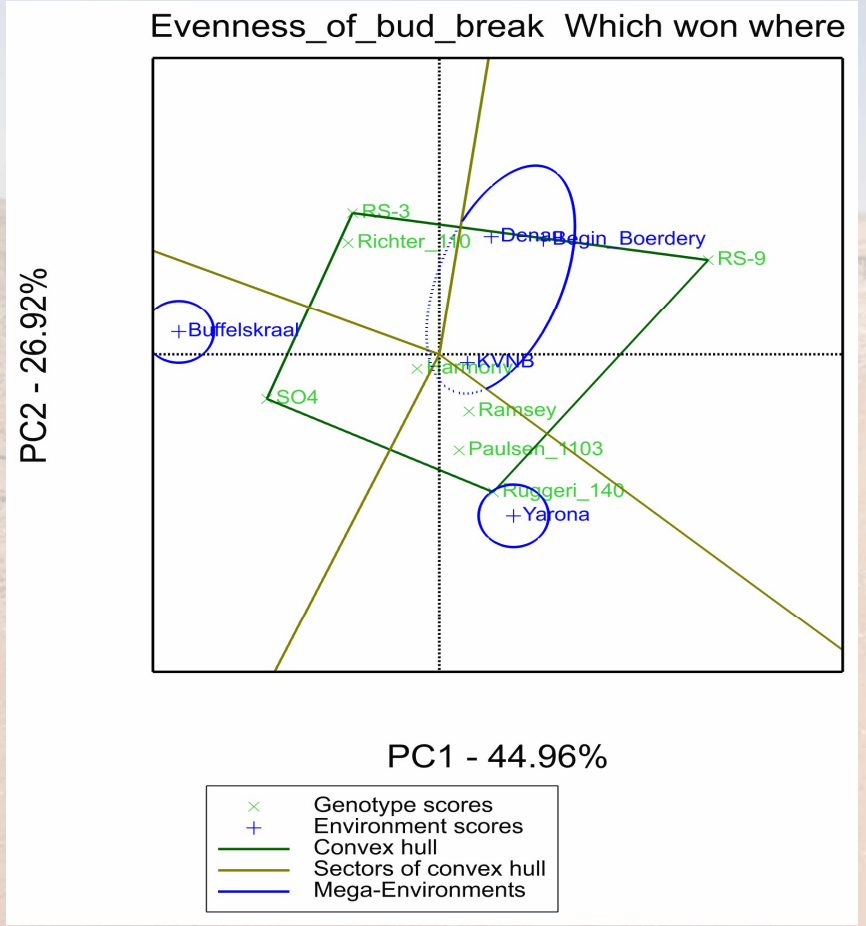
AMMI & GGE BIPLOT ANALYSIS

(G x E)

AMMI + GGE – Evenness of Bud Break

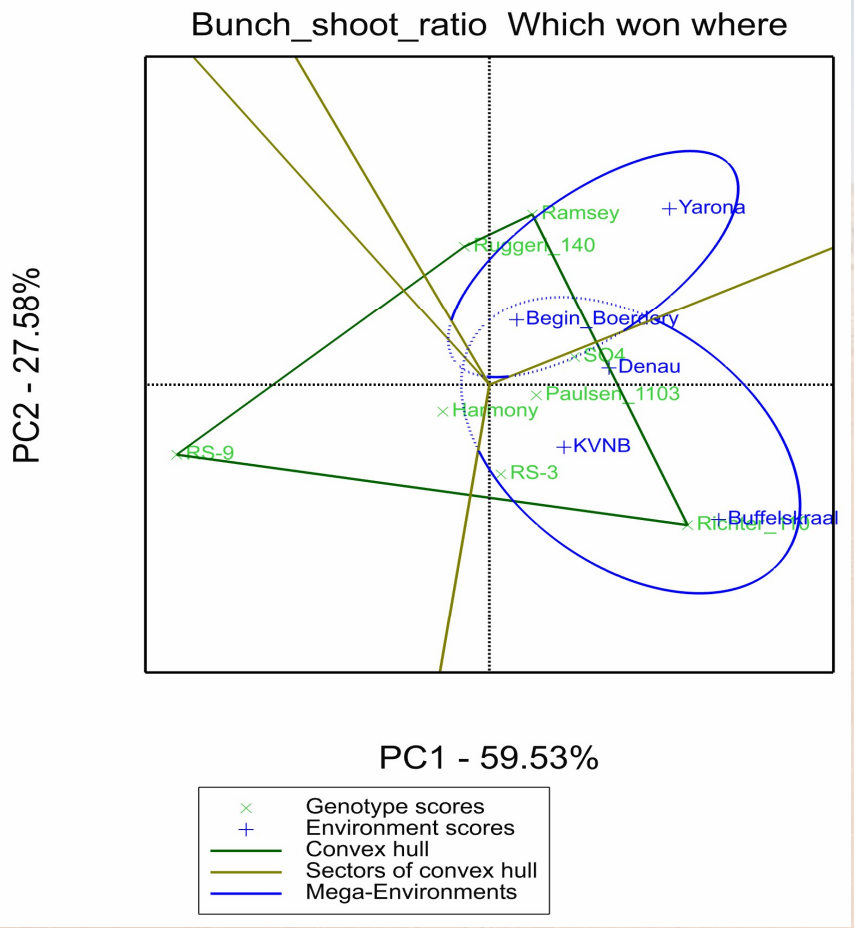
Evenness of bud break		
Genotype	**Mean**	**ASV**
Harmony	**3,369**	**0,158**
Ramsey	**3,492**	**0,242**
Paulsen 1103	**3,425**	**0,334**
Ruggeri 140	**3,494**	**0,543**
Richter 110	**3,394**	**0,667**
RS-3	**3,638**	**0,695**
SO4	**3,471**	**0,9707**
RS-9	**3,460**	**1,708**
G x E *p* value		**0,036**
IPCA 1 *p*		**0,006**
IPCA 2 *p*		**0,103**

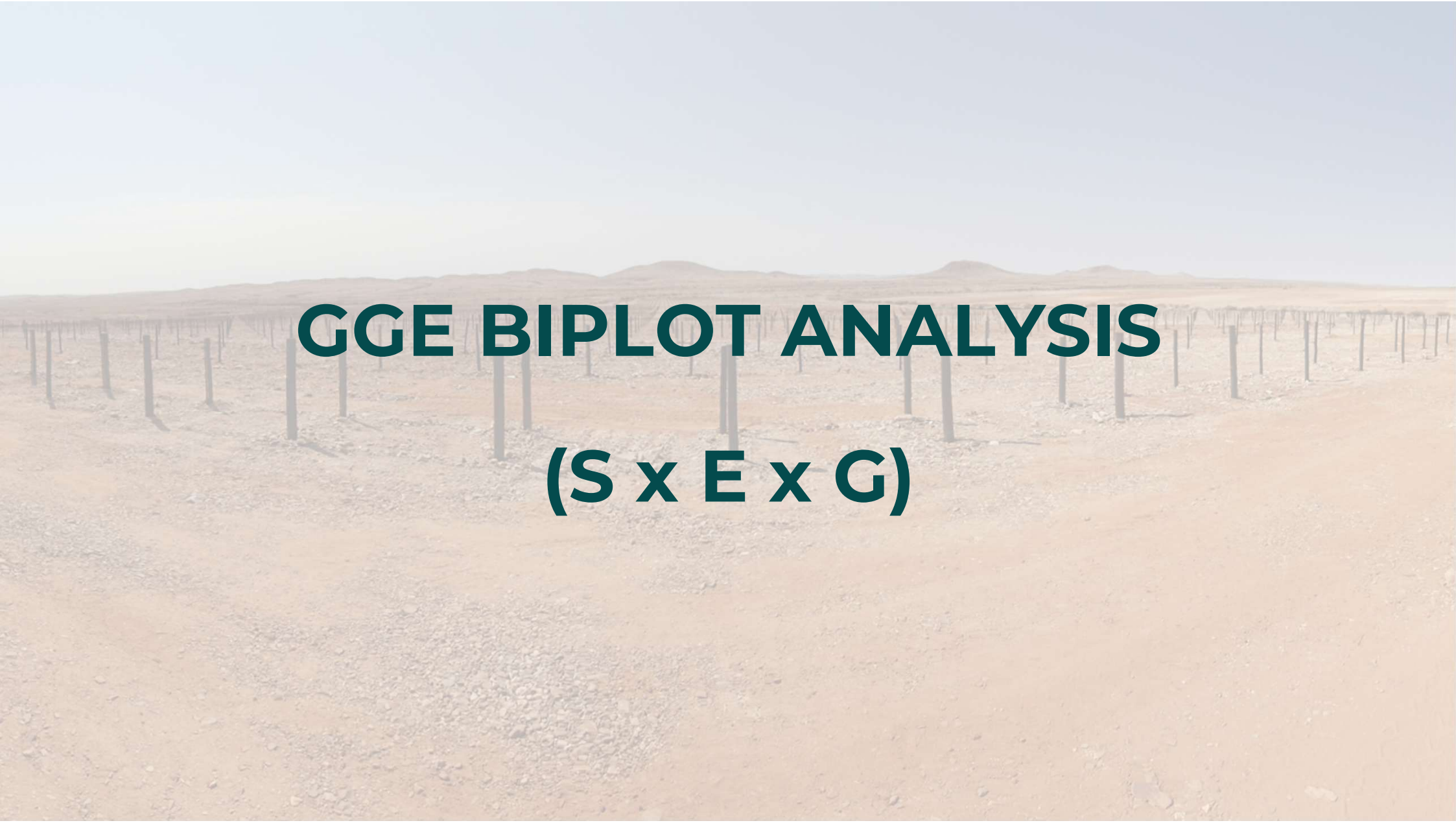
Evenness of bud beak rating: 5 = even, 1 = uneven.



AMMI + GGE – Bunch: Shoot

Bunch: shoot		
Genotype	**Mean**	**ASV**
Harmony	**0,624**	**0,052**
SO4	**0,671**	**0,058**
Paulsen 1103	**0,643**	**0,129**
RS-3	**0,627**	**0,244**
Ruggeri 140	**0,640**	**0,317**
RS-9	**0,551**	**0,328**
Ramsey	**0,648**	**0,348**
Richter 110	**0,691**	**0,396**
G x E *p* value		**0,035**
IPCA 1 *p*		**0,006**
IPCA 2 *p*		**0,030**





GGE BIPLOT ANALYSIS

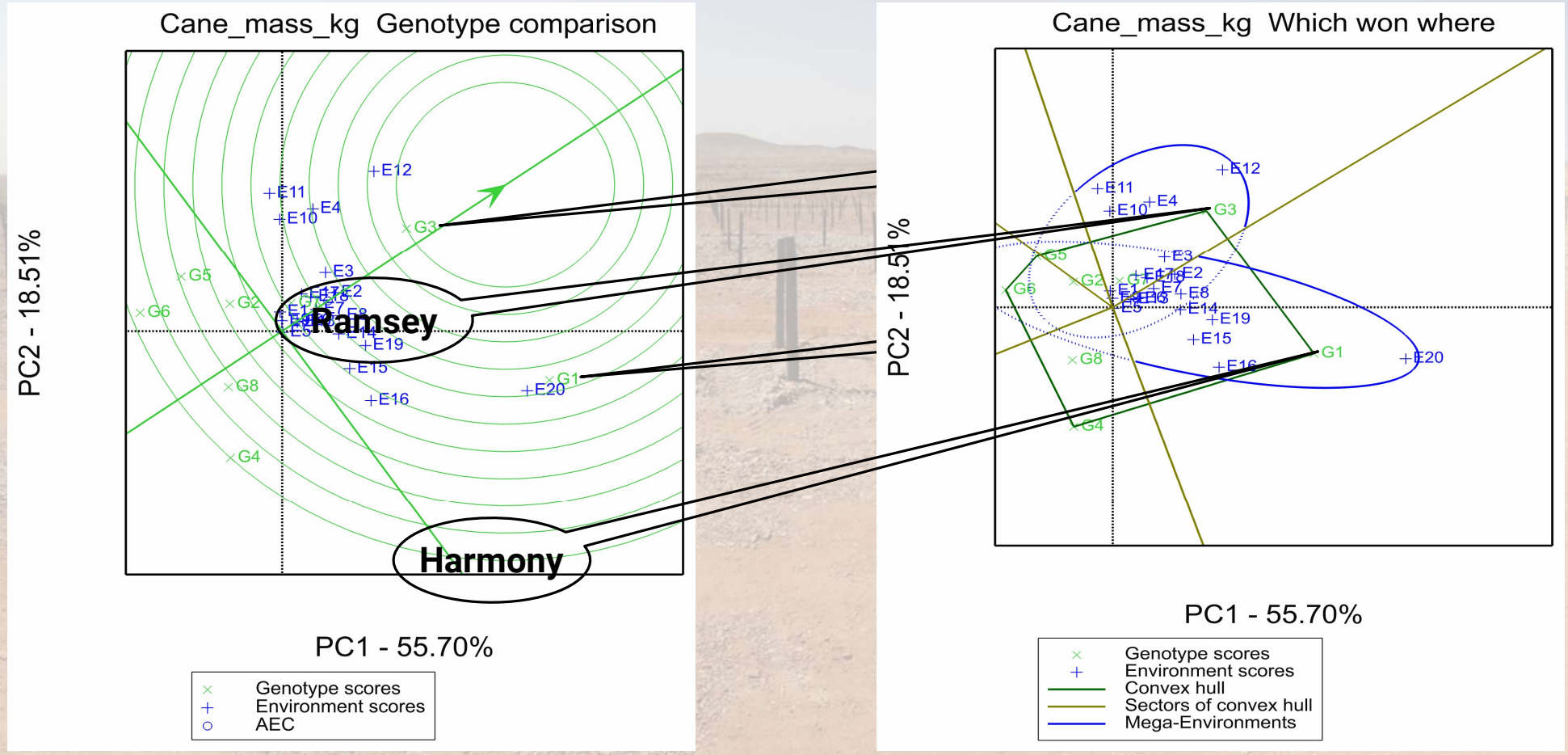
(S x E x G)

S x E x G – GGE Biplots References

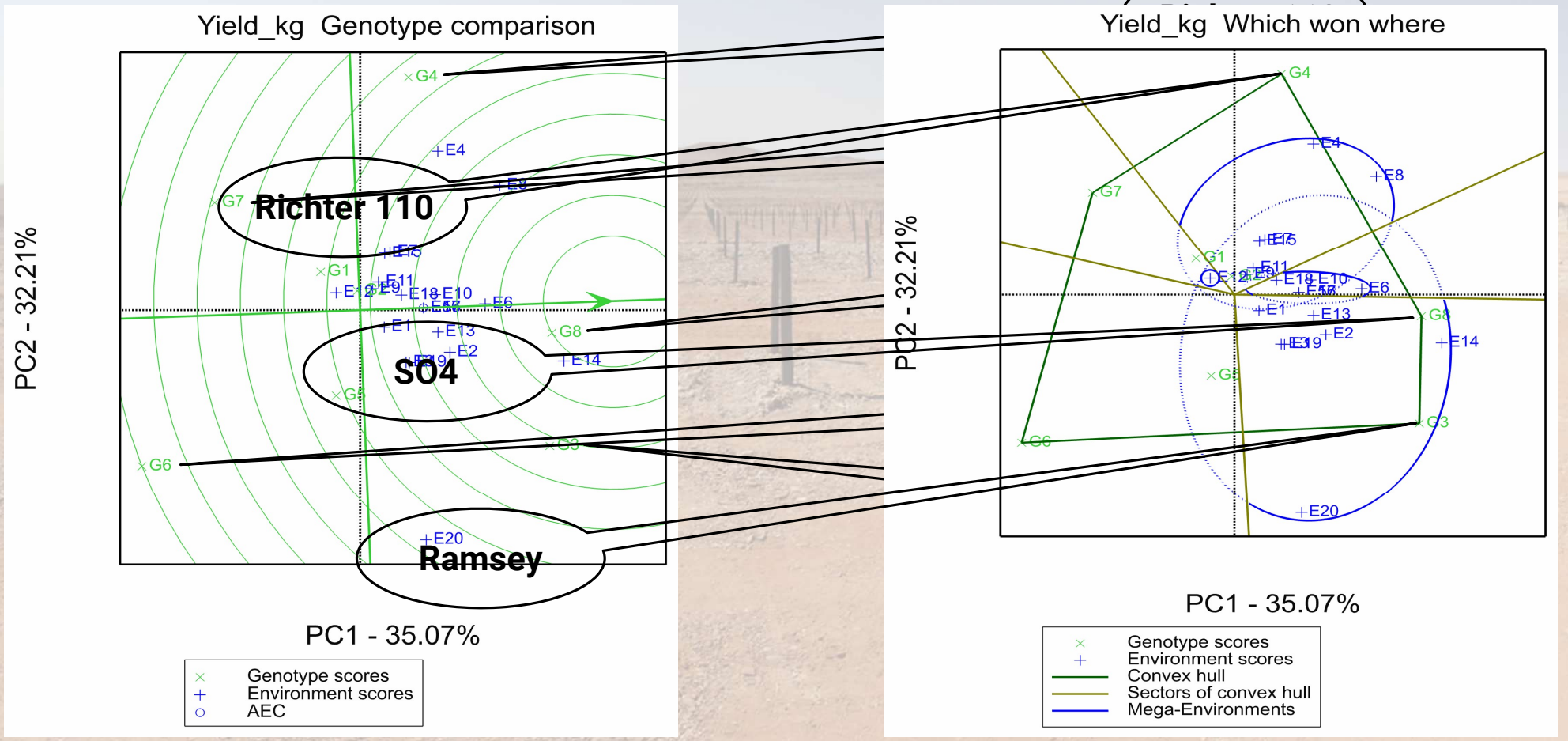
Season	Site/Environment	Code
2020_2021	Begin Boerdery	E1
2021_2022	Begin Boerdery	E2
2022_2023	Begin Boerdery	E3
2024_2025	Begin Boerdery	E4
2020_2021	Buffelskraal Boerdery	E5
2021_2022	Buffelskraal Boerdery	E6
2022_2023	Buffelskraal Boerdery	E7
2024_2025	Buffelskraal Boerdery	E8
2020_2021	Denau Boerdery	E9
2021_2022	Denau Boerdery	E10
2022_2023	Denau Boerdery	E11
2024_2025	Denau Boerdery	E12
2020_2021	KVNB	E13
2021_2022	KVNB	E14
2022_2023	KVNB	E15
2024_2025	KVNB	E16
2020_2021	Yarona	E17
2021_2022	Yarona	E18
2022_2023	Yarona	E19
2024_2025	Yarona	E20

Rootstock	Code
Harmony	G1
Paulsen 1103	G2
Ramsey	G3
Richter 110	G4
RS-3	G5
RS-9	G6
Ruggeri 140	G7
SO4	G8

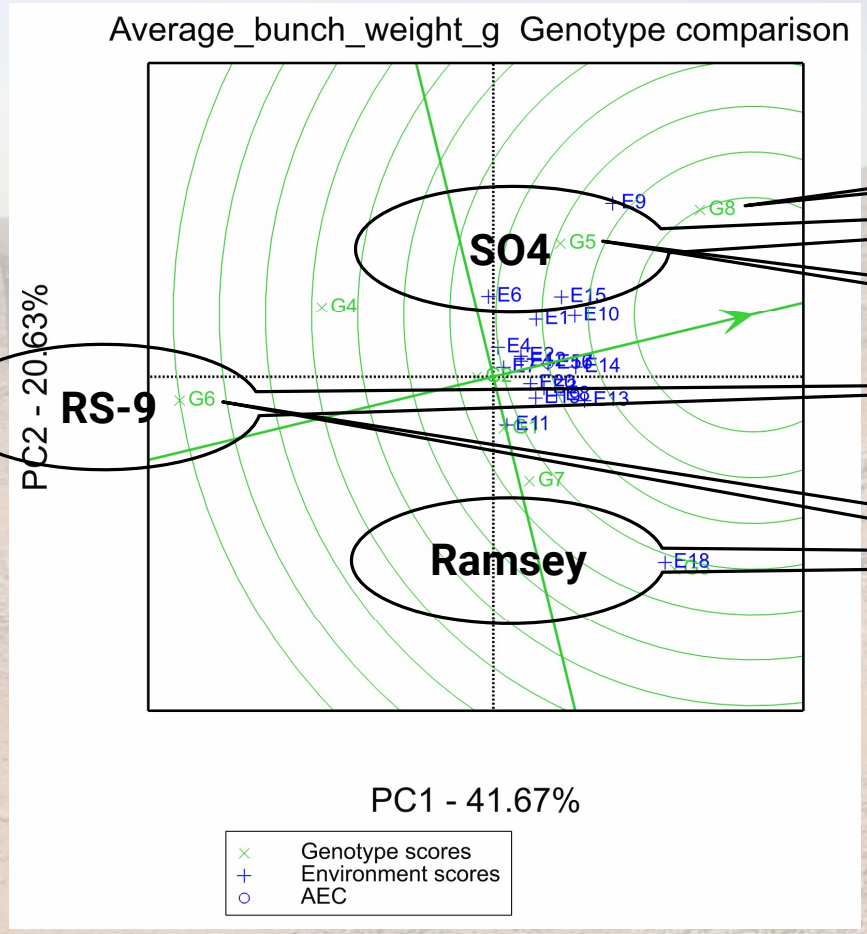
GGE – Cane Mass

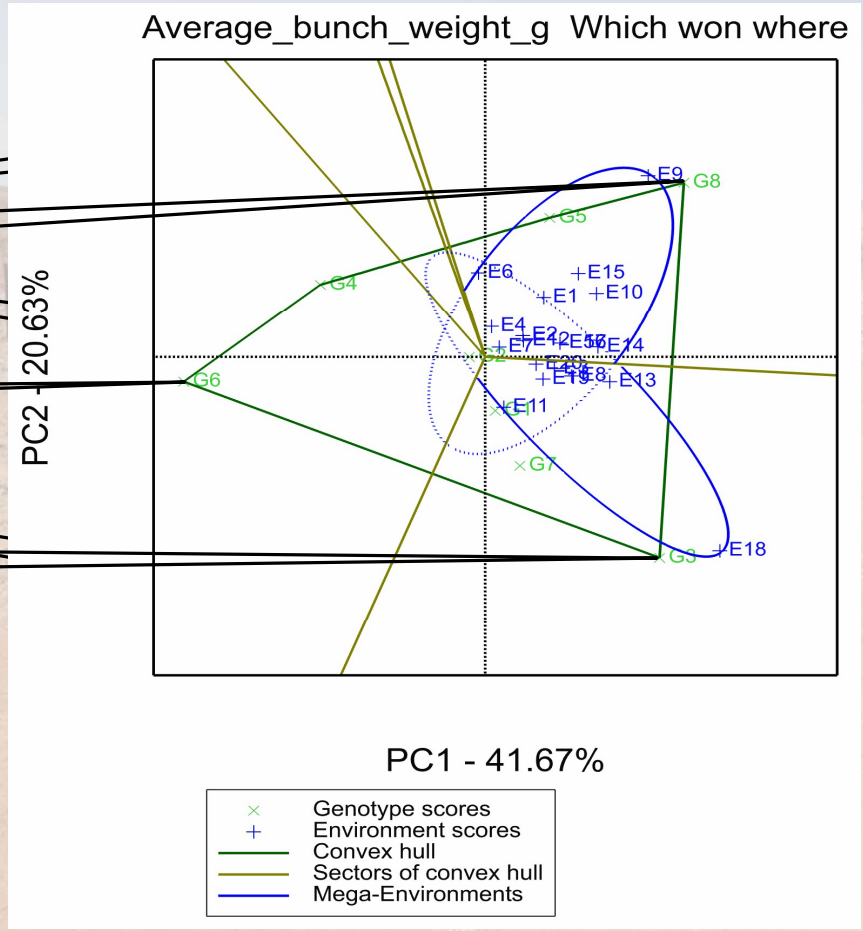


GGE – Yield Per Vine



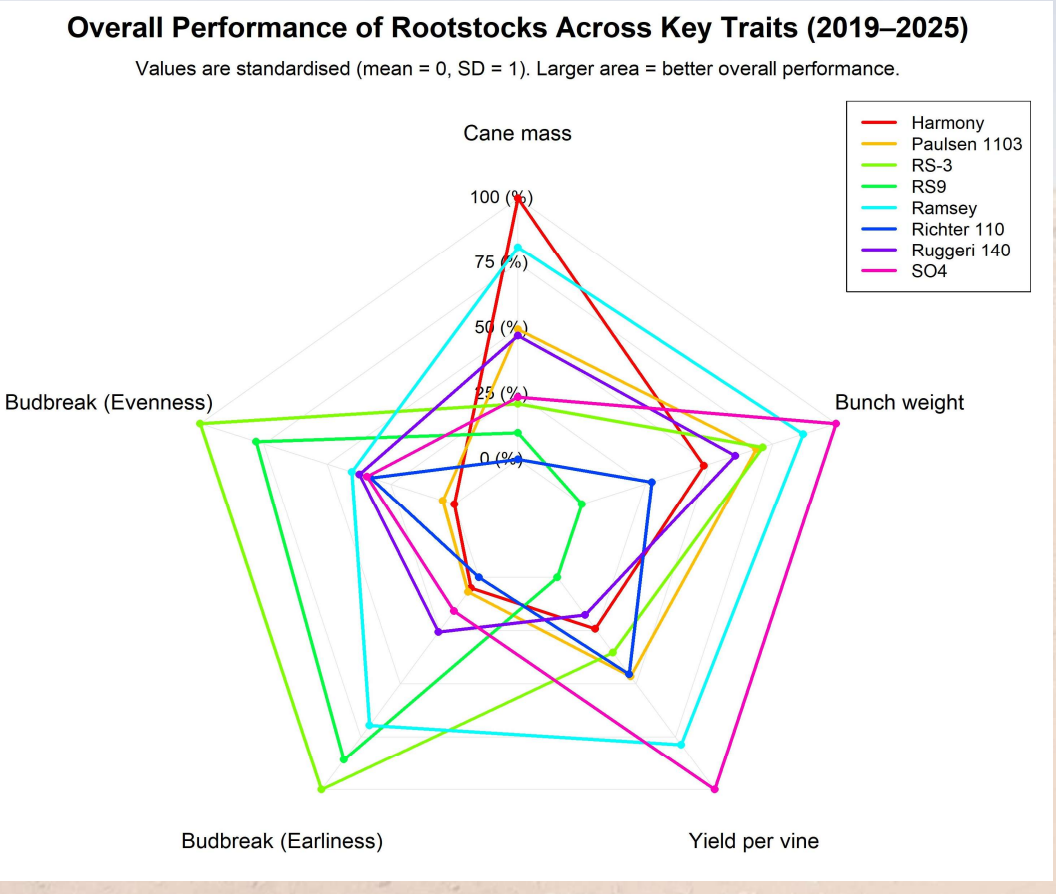
GGE – Avg Bunch Weight





Overall Performance

Genotype	Comment
Ramsey	Vegetative Powerhouse. Early bud break; high yield but site-specific.
SO4	Yield-driven. Moderate in the rest of the traits.
Richter 110	Niche Specialist. High yield potential but unstable.
Ruggeri 140	Reproductive Specialist. High bunch count that doesn't fully convert to yield.
RS-3	Early Riser. Induces even bud break but weak growth and yield.
RS-9	Underperformed across most metrics.



Recommendations

- **Multi-environment evaluation on S × E × G is essential for de-risking rootstock selection, as performance is highly context dependent.**
- **Ramsey can be utilized for rapid vineyard establishment, high vegetative vigour, or where adaptability across variable environments is required.**
- **SO4 should be considered for yield stability and commercial tonnage where consistent reproductive performance is key.**
- **Rootstock choice must align with scion compatibility, soil/climate constraints, biotic pressures (e.g., nematodes) and production goals.**
- **SO4 warrants further investigation as a high-yielding table grape rootstock.**



THANK YOU

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