10.1071/FP15182_AC

© CSIRO 2016

Supplementary Material: *Functional Plant Biology*, 2016, 43(2), 173–188.

Supplementary Material

Wheats developed for high yield on stored soil moisture have deep vigorous root systems

Sarah M. Rich[A,B], *Anton P. Wasson*[A,H], *Richard A. Richards*[A], *Trushna Katore*[C], *Renu Prashar*[D], *Ritika Chowdhary*[E], *D. C. Saxena*[D], *H. M. Mamrutha*[E], *Alec Zwart*[F], *S. C. Misra*[C], *S. V. Sai Prasad*[D], *R. Chatrath*[E], *Jack Christopher*[G] *and Michelle Watt*[A]

[A]CSIRO Agriculture Flagship, GPO Box 1600, Canberra, ACT 2601, Australia.

[B]School of Plant Biology, Faculty of Natural and Agricultural Sciences, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia.

[C]Agharkar Research Institute, Agarkar Road, Pune, 411 004, India.

[D]Indian Agricultural Research Institute, Regional Wheat Research Station, Indore, 452 001, India.

[E]Indian Directorate of Wheat Research, Karnal, 132 001, India.

[F]CSIRO Data 61, GPO Box 664, Canberra, ACT 2601, Australia.

[G]University of Queensland, Queensland Alliance for Agricultural and Food Innovation, Leslie Research Centre, PO Box 2282, Toowoomba, Qld 4350, Australia.

[H]Corresponding author. Email: anton.wasson@csiro.au

Table S1. List of genotypes and trials (as listed in Table 2) which they were sown

Physiological group (geographic for Australian lines, 'northern' vs 'south and western'; management background for the Indian lines, 'irrigated' vs 'rainfed') and C306 background is also listed

Genotype	Physiological group	Trials	C306	Genotype	Physiological group	Trials	C306	Genotype	Physiological group	Trials	C306
Beaufort	Australian North	4,6,7		DBW 14	Indian Irrigated	1,4		A 9-30-1	Indian Rainfed	1,4,6,7	
Bounty	Australian North	4,5		DBW 16	Indian Irrigated	2,4,6		AKDW 2997-16	Indian Rainfed	3,4	
Gregory	Australian North	4,5,6,7		DBW 17	Indian Irrigated	2,3,4,5,7		B. Yellow	Indian Rainfed	3,4,5	
Hartog	Australian North	4,5		HD 2733	Indian Irrigated	4		C 306 (Aust. seed)	Indian Rainfed	4,5	YES
Hunter	Australian North	4,5		HI 1531	Indian Irrigated	2,4,5,6		C306	Indian Rainfed	2,3,4,5,6,7	YES
Impala	Australian North	4		HI 8638	Indian Irrigated	4		COW (W) -1	Indian Rainfed	3,4,6	
Janz	Australian North	4,5,6,7		HS 240	Indian Irrigated	4		Dhawardry	Indian Rainfed	4,6,7	
Kennedy	Australian North	4,6,7		HUW 234	Indian Irrigated	3,4,5,6		DL 153-2	Indian Rainfed	4	
Livingstone	Australian North	4		HW 2045	Indian Irrigated	1,4,6,7		HD 2189	Indian Rainfed	4,5	
Orion	Australian North	4		K 9107	Indian Irrigated	4		HD 2781	Indian Rainfed	4,5	YES
Spitfire	Australian North	4		LOK -1	Indian Irrigated	1,3,4,5		HD 2888	Indian Rainfed	2,4,6	YES
Stampede	Australian North	4,5		NI 5439	Indian Irrigated	1,2,4,6,7		HD 4672	Indian Rainfed	2,3,4,5,6	
Ventura	Australian North	4		NIAW 34	Indian Irrigated	2,4,6		HI 1500	Indian Rainfed	4,6,7	
Axe	Australian South & West	4		NW 2036	Indian Irrigated	4		HI 8627	Indian Rainfed	4,5,6	
Bolac	Australian South & West	4,5		PBW 343	Indian Irrigated	1,4		HS 277	Indian Rainfed	1,2,4,5,6,7	
Chara	Australian South & West	4		PBW 373	Indian Irrigated	4		HS 420	Indian Rainfed	4,6,7	
Derrimut	Australian South & West	4		PBW 550	Indian Irrigated	4		HW 2004	Indian Rainfed	1,2,3,4,5,6,7	YES
Espada	Australian South & West	4		RAJ 3765	Indian Irrigated	4		HW 2044	Indian Rainfed	4	
H45	Australian South & West	4		RAJ 4083	Indian Irrigated	4		K 8027	Indian Rainfed	4	
Lincoln	Australian South & West	4		UP 2338	Indian Irrigated	2,4,6		MACS 1967	Indian Rainfed	4	
Mace	Australian South & West	4,5		VL 738	Indian Irrigated	4		MACS 6145	Indian Rainfed	4,6	YES
Magenta	Australian South & West	4,5		VL 804	Indian Irrigated	4		PBW 175	Indian Rainfed	1,4,5	
Scout	Australian South & West	4		WH 1021	Indian Irrigated	3,4		PBW 396	Indian Rainfed	4	
Westonia	Australian South & West	4, 6, 7		6674p	Other	4		VL 616	Indian Rainfed	4,5	

Wyalkatchem	Australian South & West	4,5		Babax	Other	4		VL 829	Indian Rainfed	4,5,6	
Yitpi	Australian South & West	4,5		CV100	Other	4,5		WH 147	Indian Rainfed	1,3,4	
30276	Other	4		CV98	Other	4		NIL3-14	Other	4,5,6,7	
30374	Other	4		Gladius	Other	4		Seri	Other	4,5	
38-19	Other	4,5		Lan 8	Other	4		Speedee	Other	4	
				LAN1	Other	4		Syn 29589	Other	4,5,6,7	

Table S2. Predicted values and standard errors from a model of Biomass, Yield, and Harvest Index for all Australian trials

Genotype Name	Biomass (g)			Yield (g)			Harvest index		
	2012 hillplots	2013 hillplots	2013 mini-plots	2012 hillplots	2013 hillplots	2013 mini-plots	2012 hillplots	2013 hillplots	2013 mini-plots
30276	258 + 16	325 + 14	360 + 20	72.2 + 7.8	100.3 + 5.8	95.8 + 9.1	0.29 + 0.02	0.31 + 0.02	0.27 + 0.02
30374	225 + 16			69.6 + 7.8			0.30 + 0.02		
33404	259 + 16			61.9 + 7.0			0.23 + 0.02		
38-19	84 + 17			23.4 + 7.8			0.29 + 0.02		
6674p	184 + 17			62.8 + 7.8			0.37 + 0.02		
A 9-30-1	159 + 16	216 + 14	306 + 20	30.4 + 5.6	61.5 + 5.8	79.2 + 9.1	0.19 + 0.02	0.28 + 0.02	0.26 + 0.02
AKDW 2997-16	132 + 16			27.3 + 6.0			0.21 + 0.02		
Axe	158 + 18			55.9 + 7.8			0.36 + 0.03		
B. Yellow	185 + 16			30.7 + 6.4			0.17 + 0.02		
Babax	180 + 16			59.2 + 7.0			0.30 + 0.02		
Beaufort	210 + 16	235 + 15	359 + 20	54.2 + 8.9	61.6 + 5.8	115.4 + 9.1	0.28 + 0.03	0.26 + 0.02	0.32 + 0.02
Bolac	179 + 17			40.9 + 6.4			0.25 + 0.02		
C 306	194 + 16	323 + 14	351 + 20	56.6 + 6.4	117.4 + 5.8	118.5 + 9.1	0.31 + 0.02	0.36 + 0.02	0.34 + 0.02

C306	241 + 16			72.4 + 8.9			0.29 + 0.03		
Chara	216 + 16			61.3 + 7.8			0.28 + 0.02		
COW (W) - 1	229 + 16	239 + 14	379 + 20	67.0 + 6.0	89.3 + 5.8	145.7 + 9.1	0.30 + 0.02	0.37 + 0.02	0.38 + 0.02
CV100	152 + 17			59.1 + 7.0			0.35 + 0.02		
CV98	181 + 16			59.9 + 7.8			0.32 + 0.02		
DBW 14	143 + 17			53.6 + 6.0			0.37 + 0.02		
DBW 16	212 + 17	227 + 14		78.1 + 6.4	87.8 + 5.8		0.36 + 0.02	0.39 + 0.02	
DBW 17	185 + 17	194 + 14	322 + 20	69.3 + 6.4	83.2 + 5.8	136.3 + 9.1	0.39 + 0.02	0.43 + 0.02	0.42 + 0.02
Derrimut	211 + 16			63.6 + 8.9			0.32 + 0.03		
Dhawardry	188 + 16	261 + 14	344 + 20	47.4 + 6.4	83.9 + 5.8	104.8 + 9.1	0.25 + 0.02	0.32 + 0.02	0.30 + 0.02
DL 153-2	223 + 16			33.0 + 15.3			0.20 + 0.04		
EGA Bounty	182 + 16			67.5 + 7.0			0.35 + 0.02		
EGA Gregory	206 + 16	249 + 14	357 + 20	60.3 + 6.4	78.8 + 5.8	120.0 + 9.1	0.29 + 0.02	0.31 + 0.02	0.33 + 0.02
EGA Stampede	190 + 16			68.1 + 7.0			0.34 + 0.02		
Espada	211 + 17			64.2 + 7.8			0.28 + 0.03		

GBA Hunter	194 + 17			69.0 + 6.4			0.35 + 0.02		
Gladius	206 + 17			58.7 + 7.8			0.31 + 0.02		
H45	196 + 16			42.8 + 8.9			0.21 + 0.03		
Hartog	189 + 17			47.9 + 7.0			0.27 + 0.02		
HD 2189	178 + 17			67.3 + 5.6			0.37 + 0.02		
HD 2733	210 + 16			71.5 + 5.6			0.34 + 0.02		
HD 2781	183 + 17			50.3 + 6.4			0.28 + 0.02		
HD 2888	203 + 16	280 + 14	315 + 20	59.1 + 6.0	83.5 + 5.8	69.9 + 9.1	0.27 + 0.02	0.30 + 0.02	0.22 + 0.02
HD 4672	198 + 16	306 + 14		63.3 + 6.0	124.1 + 5.8		0.31 + 0.02	0.40 + 0.02	
HI 1500	208 + 16	347 + 15	349 + 22	55.6 + 7.8	124.6 + 5.8	115.4 + 9.1	0.26 + 0.02	0.36 + 0.02	0.33 + 0.02
HI 1531	175 + 16	314 + 14		60.5 + 6.4	123.6 + 5.8		0.35 + 0.02	0.39 + 0.02	
HI 8627	237 + 16	315 + 14		55.8 + 6.0	120.5 + 5.8		0.24 + 0.02	0.38 + 0.02	
HI 8638	218 + 16			54.5 + 6.4			0.27 + 0.02		
HS 240	193 + 16			43.7 + 8.9			0.25 + 0.03		
HS 277	212 + 17	261 + 15	333 + 20	34.8 + 6.4	81.5 + 5.8	108.3 + 9.1	0.15 + 0.02	0.30 + 0.02	0.32 + 0.02
HS 420	178 + 17	256 + 14	367 + 20	53.7 + 7.0	89.2 + 5.8	125.5 + 9.1	0.31 + 0.02	0.35 + 0.02	0.34 + 0.02

HUW 234	166 + 16	295 + 15		42.9 + 6.0	97.1 + 5.8		0.27 + 0.02	0.34 + 0.02	
HW 2004	231 + 16	305 + 14	356 + 20	55.6 + 7.0	101.4 + 5.8	119.9 + 9.1	0.27 + 0.02	0.33 + 0.02	0.33 + 0.02
HW 2044	183 + 17			60.9 + 6.4			0.34 + 0.02		
HW 2045	172 + 17	287 + 14	378 + 20	48.3 + 6.0	99.4 + 5.8	137.2 + 9.1	0.28 + 0.02	0.35 + 0.02	0.36 + 0.02
Impala	218 + 17			62.9 + 6.4			0.27 + 0.02		
Janz	157 + 17	222 + 14	354 + 20	48.0 + 7.8	54.0 + 5.8	105.9 + 9.1	0.28 + 0.03	0.24 + 0.02	0.30 + 0.02
K 8027	212 + 16			66.4 + 6.0			0.32 + 0.02		
K 9107	192 + 16			58.2 + 5.6			0.31 + 0.02		
Kennedy	190 + 17	253 + 14	334 + 20	65.1 + 8.9	96.3 + 6.1	122.9 + 9.1	0.34 + 0.03	0.38 + 0.02	0.37 + 0.02
Lan 8	184 + 16			58.0 + 7.0			0.26 + 0.02		
LAN1	178 + 17			48.3 + 7.8			0.25 + 0.02		
Lincoln	177 + 16			56.0 + 7.8			0.29 + 0.02		
Livingstone	208 + 16			66.9 + 7.8			0.32 + 0.02		
LOK -1	227 + 16			72.4 + 6.4			0.33 + 0.02		
Mace	198 + 18			68.9 + 7.8			0.35 + 0.02		
MACS 1967	176 + 16			39.5 + 5.6			0.22 + 0.02		

MACS 6145	208 + 16	260 + 15		61.5 + 6.4	84.7 + 5.8		0.29 + 0.02	0.31 + 0.02	
Magenta	223 + 16			63.6 + 8.9			0.33 + 0.03		
NI 5439	221 + 16	328 + 14	336 + 20	77.4 + 5.6	120.2 + 5.8	116.1 + 9.1	0.35 + 0.02	0.37 + 0.02	0.35 + 0.02
NIAW 34	209 + 16	262 + 14		75.3 + 6.0	97.1 + 5.8		0.35 + 0.02	0.37 + 0.02	
NIL3-14	210 + 16	263 + 14	376 + 20	60.5 + 6.0	80.1 + 5.8	118.6 + 9.1	0.30 + 0.02	0.31 + 0.02	0.32 + 0.02
NW 2036	195 + 16			53.5 + 7.0			0.29 + 0.02		
Orion	212 + 16			54.4 + 8.9			0.27 + 0.03		
PBW 175	181 + 17			46.2 + 6.4			0.28 + 0.02		
PBW 343	213 + 16			76.8 + 6.4			0.34 + 0.02		
PBW 373	227 + 16			71.9 + 5.6			0.32 + 0.02		
PBW 396	228 + 17			47.7 + 7.0			0.22 + 0.02		
PBW 550	205 + 17			76.2 + 6.4			0.37 + 0.02		
RAJ 3765	164 + 16			48.9 + 6.0			0.31 + 0.02		
RAJ 4083	190 + 16			65.1 + 6.0			0.36 + 0.02		
Scout	192 + 16			47.9 + 7.0			0.26 + 0.02		
Seri	187 + 17			58.6 + 7.0			0.31 + 0.02		

Speedee	232 + 16			71.6 + 6.4			0.31 + 0.02		
Spitfire	211 + 16			70.4 + 7.0			0.37 + 0.02		
Syn 29589	196 + 17	284 + 15	367 + 20	62.3 + 7.0	98.0 + 5.8	127.4 + 9.1	0.31 + 0.02	0.34 + 0.02	0.35 + 0.02
UP 2338	193 + 16	253 + 14		53.7 + 6.0	91.7 + 5.8		0.28 + 0.02	0.36 + 0.02	
Ventura	207 + 17			62.0 + 8.9			0.32 + 0.03		
VL 616	206 + 16			54.9 + 6.0			0.29 + 0.02		
VL 738	216 + 16			64.8 + 6.0			0.30 + 0.02		
VL 804	220 + 17			50.1 + 7.8			0.22 + 0.02		
VL 829	213 + 17	224 + 14		56.2 + 6.0	64.2 + 5.8		0.31 + 0.02	0.28 + 0.02	
Westonia	212 + 16	251 + 14	375 + 20	69.9 + 7.8	96.1 + 5.8	138.4 + 9.1	0.30 + 0.02	0.38 + 0.02	0.37 + 0.02
WH 1021	192 + 16			58.9 + 5.6			0.31 + 0.02		
WH 147	144 + 16			40.0 + 6.0			0.30 + 0.02		
Wyalkatchem	179 + 16			59.9 + 6.4			0.35 + 0.02		
Yitpi	189 + 16			56.2 + 7.0			0.28 + 0.02		

Table S3. Pseudo-ANOVA table for fixed effects from a linear mixed model for shoot parameters (Table S2)

Fixed factor	Degrees of freedom	Biomass	Yield	Harvest index
Genotype	89	<0.001***	<0.001***	<0.001***
Trial	2	<0.001***	<0.001***	<0.001***
Genotype:Trial	47	<0.001***	<0.001***	<0.001***
LSD (mean)		44	19.2	0.05

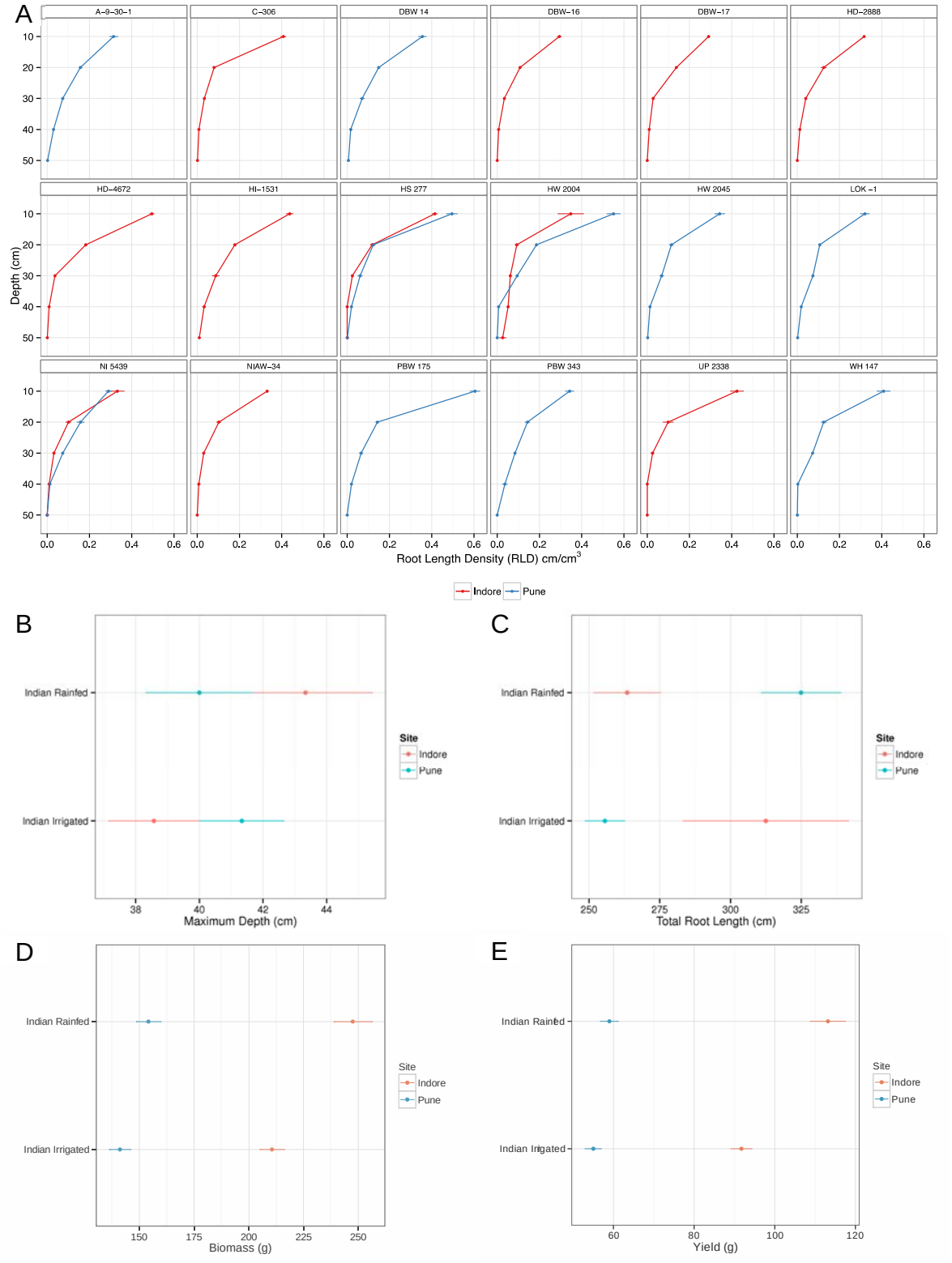

Fig. S1. (A) Root length density (cm/cm^3) plotted against depth (cm – reverse axis). The plot is faceted by genotype and the lines show data from two sites, Pune (blue) and Indore (red) in the 2010-11 season. Error bars show the standard error of the mean from three replicated cores from individual hill-plots. (B) The mean maximum depth (cm), (C) total root length (cm), (D) biomass (g), (E) and Yield (g) of rainfed and irrigated Indian wheats at Indore (red) and Pune (Blue).

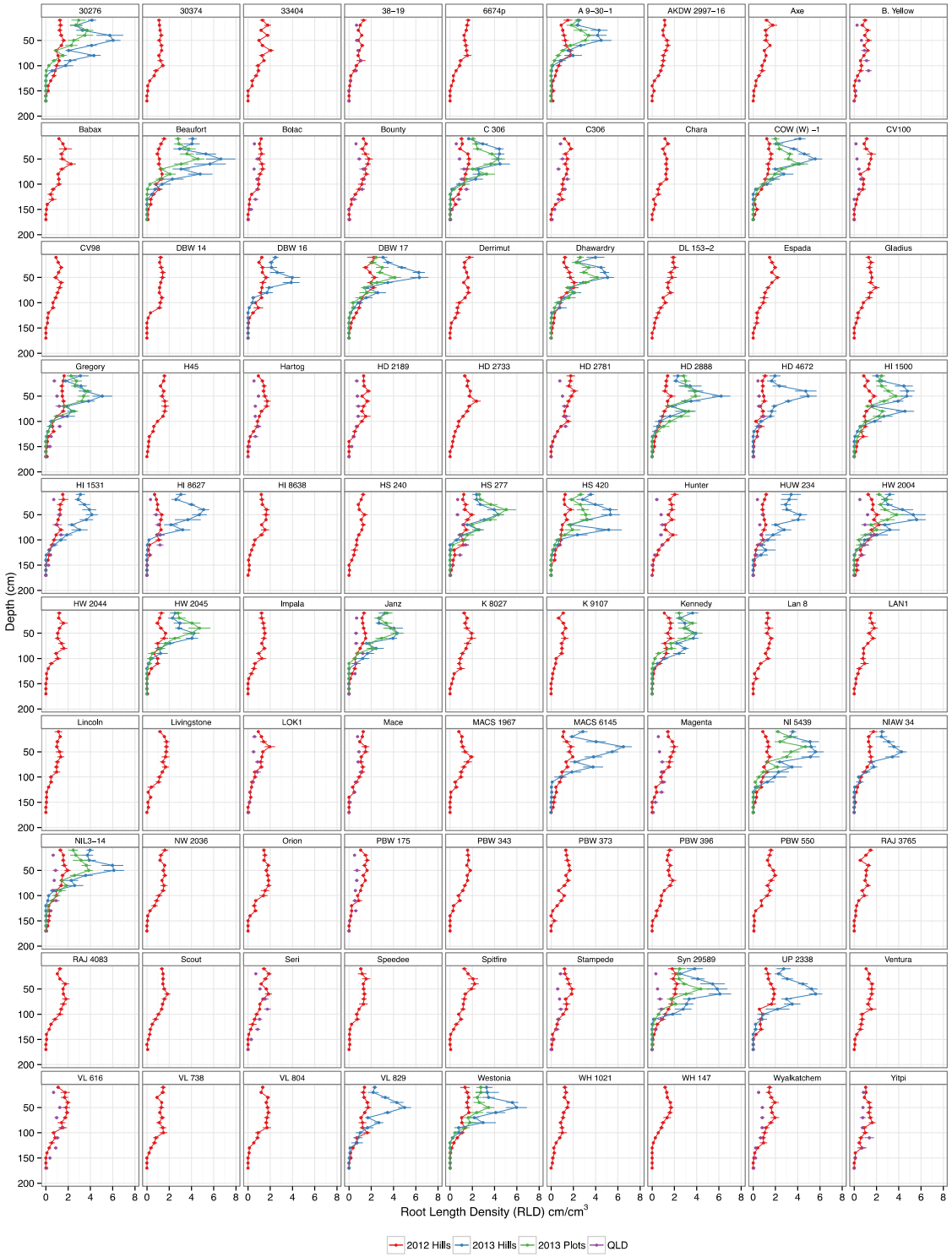

Fig. S2. An expanded version of Fig. 3 showing the root length density of all sampled genotypes. Root length density (cm/cm^3) is plotted against depth (cm – reverse axis). The plot is faceted by genotype and the lines show data from four trials at three sites and two seasons. Hill-plot data is shown from the Leeton in 2012 (red) and 2013 (blue) and from Gatton in Queensland in 2012 (purple). Mini-plot data is shown from Leeton Experimental Station in 2013 (green). Error bars show the standard error of the mean from eight replicated cores in the hill-plots and five replicated mini-plots with two cores/plot.

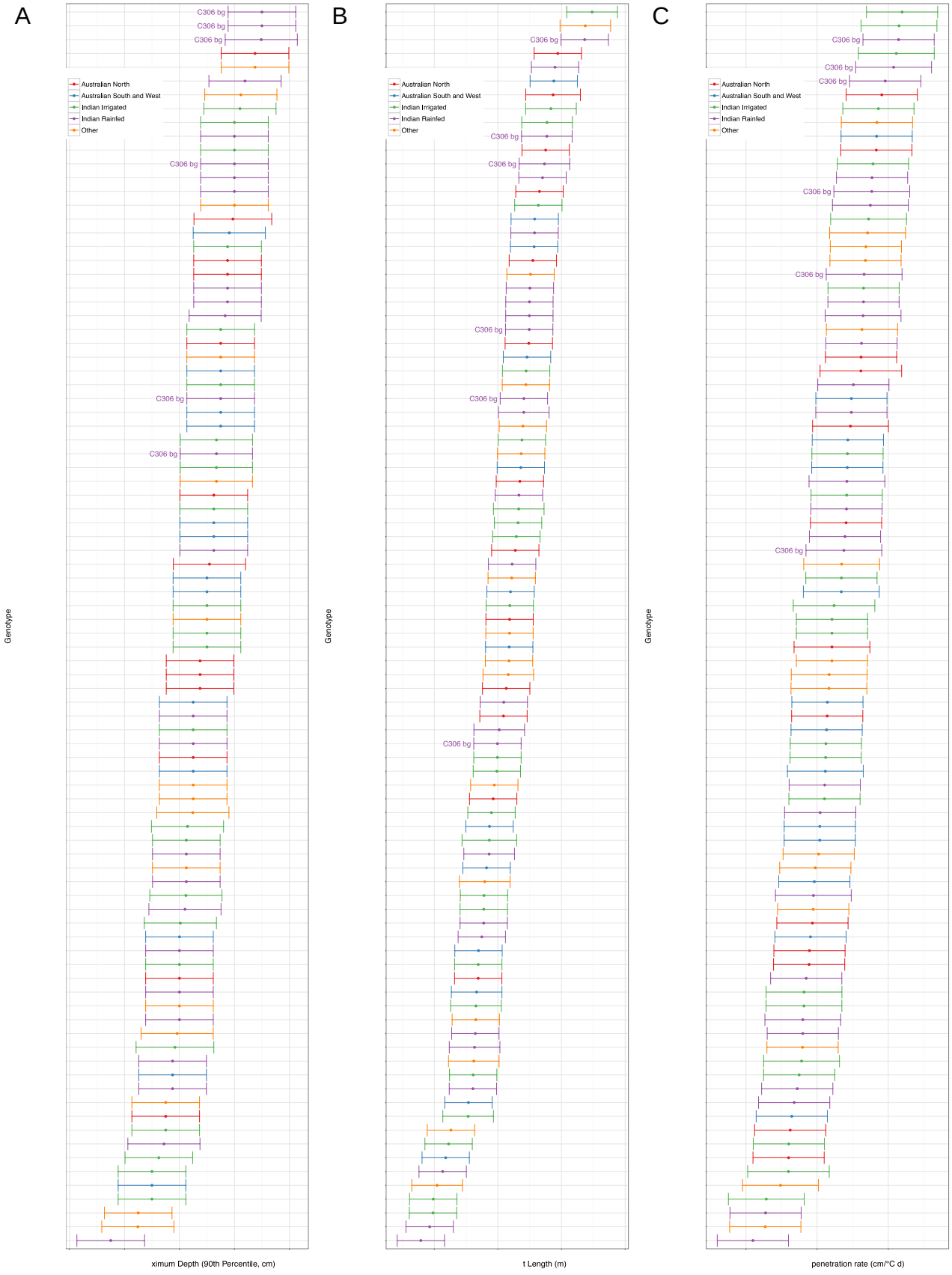

Fig. S3. Genotype means from hill-plots in 2012 for maximum depth (90th percentile; A), total root length (B) and root penetration rate (C). The means and standard errors were derived from a linear mixed model that treated genotype as a fixed effect and replicate as a random effect. The points are coloured according to the class to which the genotype

belongs. The genotype C306, and those with C306 in the pedigree, are highlighted with a “C306 bg” label in red (“bg” for background).

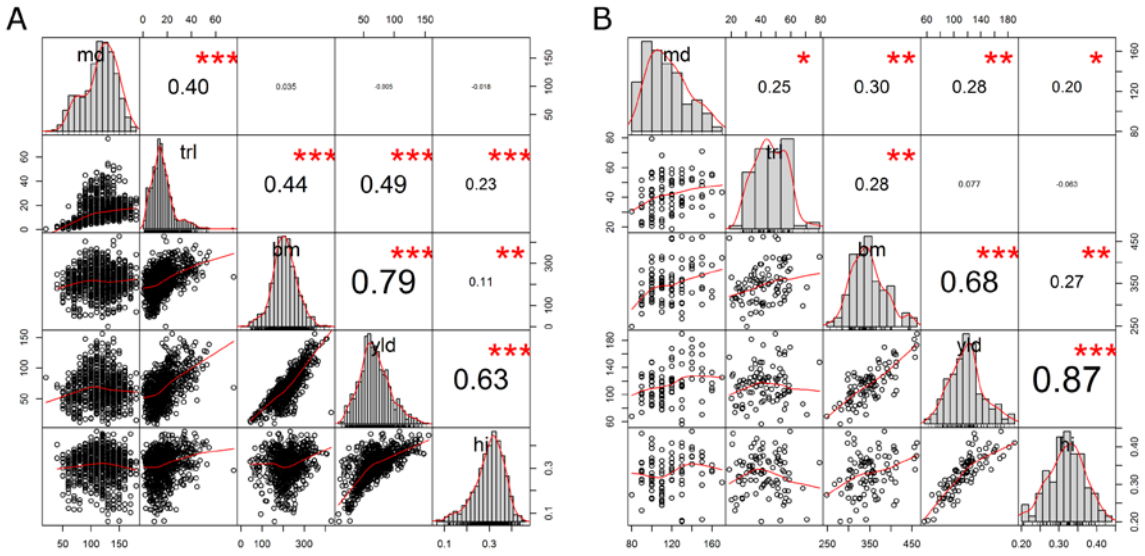

Fig. S4. Correlation matrix plots for root and shoot traits in (A) Yanco hillplots (2012, 2013) and (B) Yanco miniplots (2013). The traits are on the diagonal: md – maximum depth (cm); trl – total root length (m); bm – biomass (g); yld – yield (g); hi – harvest index. The histograms show the distribution of the measured values. The spearman rank correlation was used. The upper triangle shows the absolute value of the correlation (r_s) with the text scaled accordingly and with the significance (*P*-value) represented as stars (in red): 0 '***' 0.001 '**' 0.01 '*' 0.05. The lower triangle shows bivariate scatterplots with a fitted line. Axes are displayed at the end of each row and column, on alternate opposite sites. The traits maximum depth (90th percentile) and root penetration rate are not shown as they are strongly correlated with maximum depth.