Remote sensing, phenotyping and wheat improvement

Presented By

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World Food Crops Breeding and Genetics

(Wheat and Oat)

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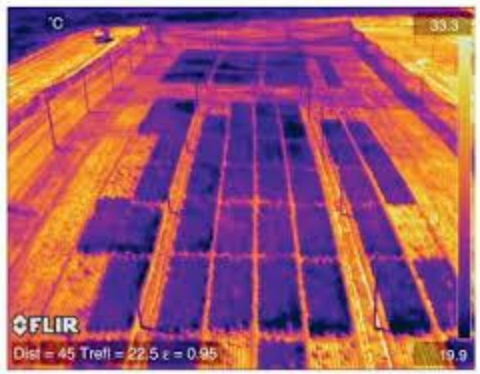


TRENDS in Plant Science

Plant breeding and phenotyping

- Classical breeding approach for yield improvement relies on informed "**numbers game**"
- Crosses are made among potentially complementary parents
- Progeny are assessed visually in segregating populations
- Yield trials as advanced lines to test in the target environments
- Breeders have been successful in yield improvement, using "***yield***" as a selection criteria

- Requires multi year multi location testing

- To avoid or at least reduce this laborious, time consuming, and cumbersome process, breeders need an ***easy, rapid and inexpensive*** indirect selection process to screen genotypes in a ***relatively short time*** before harvesting

- Particularly useful for complex traits such as yield and biomass

- Particularly advantageous if it ***detects high yielding genotypes*** rapidly and efficiently from a ***large number of promising genotypes***

- Use of physiological selection criteria to differentiate grain yield is an indirect breeding approach

- Use of physiology in breeding programs has been limited
  - **Limited understanding of their relationship**
  - **Complex evaluation procedure**

- Canopy temperature well associated with yield of wheat cultivars in irrigated, high radiation environments.

- Carbon isotope discrimination is a useful trait to improve grain yield potential in water-limiting environments.

Spectral reflectance

What is Spectral reflectance?

➢Solar radiation reflected by the plant as measured and calibrated against the light reflected from a white surface

- ➢ Spectral reflectance/vegetative indices may be used to assess ***early biomass and vigor*** of different wheat genotypes under water-limiting conditions
- ➢ Some studies suggested that ***spectral reflectance*** is ***promising remote sensing*** technique for screening genotypes for grain yield

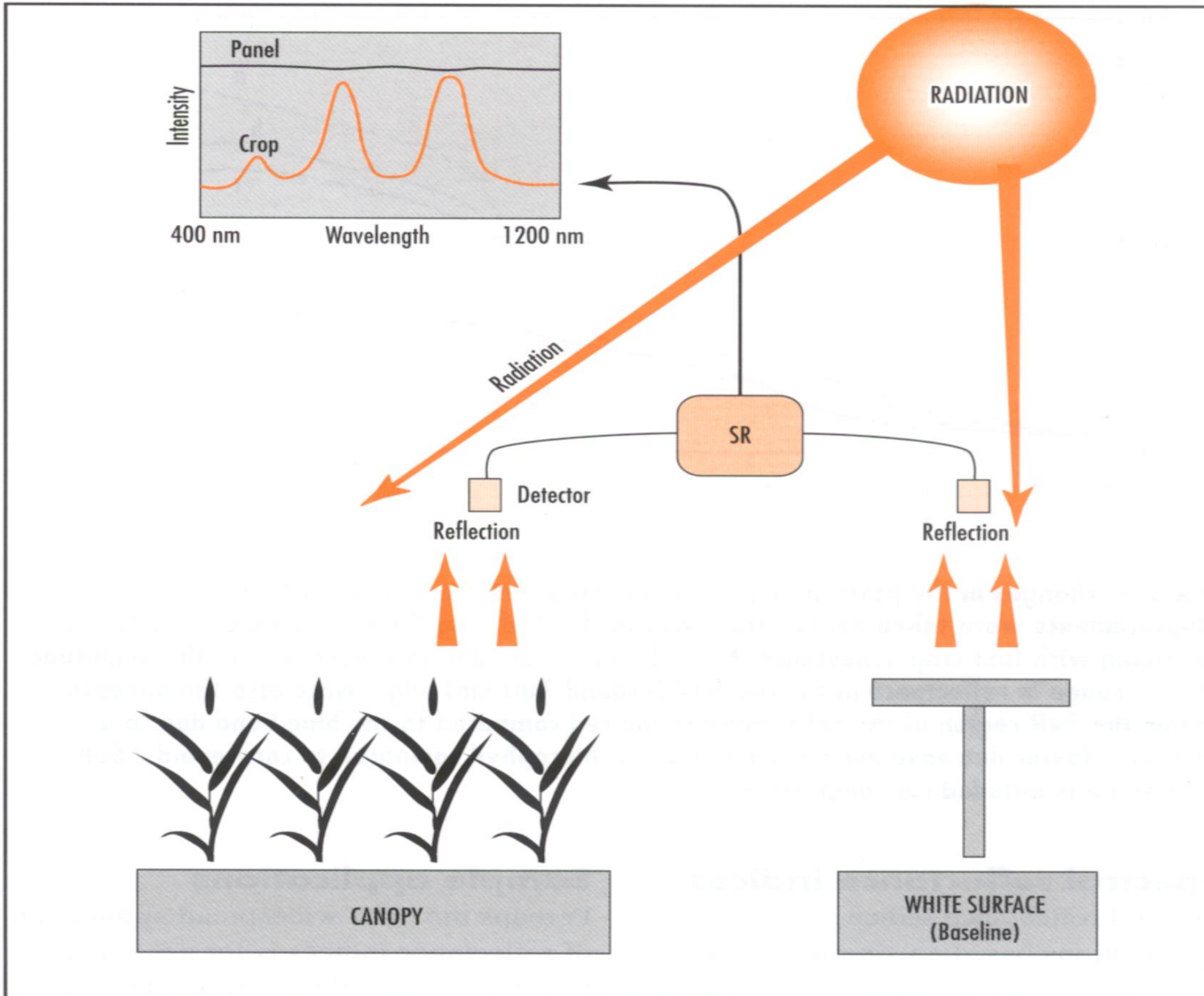


Diagram 3. Spectral reflectance from crop surfaces.

Basic Principles

- Absorption of light at a specific wavelength is associated with specific plant characteristics.
- Reflectance in the visible (VIS) wavelengths (400-700nm) depends on the absorption of light by leaf chlorophyll and associated pigments such as carotenoids and anthocyanins.
- The reflectance in the VIS is low
- Reflectance in the near infrared (NIR) wavelengths (700-1300nm) is high
- Multiple scattering of light by different leaf tissues

- Spectral reflectance indices (SRIs) have been developed on the basis of simple mathematical formulae, such as ratios or differences between the reflectance at given wavelengths

  - **Simple ratio (SR=NIR/VIS)**
  - **Normalized difference vegetation index, NDVI= [(NIR-VIS)/(NIR+VIS)]**

- Used to assess biomass and leaf area index
- SRIs have been used
  - Chlorophyll content, radiation use efficiency, assess drought
  - In-season yield estimation

- Potential use of SRIs to discriminate genotypes for grain yield has been tested under well watered and/or moisture-stressed conditions in
  - durum wheat
  - bread wheat, and
  - soybean
- Association under moisture-stressed conditions was higher
- Under irrigated conditions it was weaker

What we needed ?

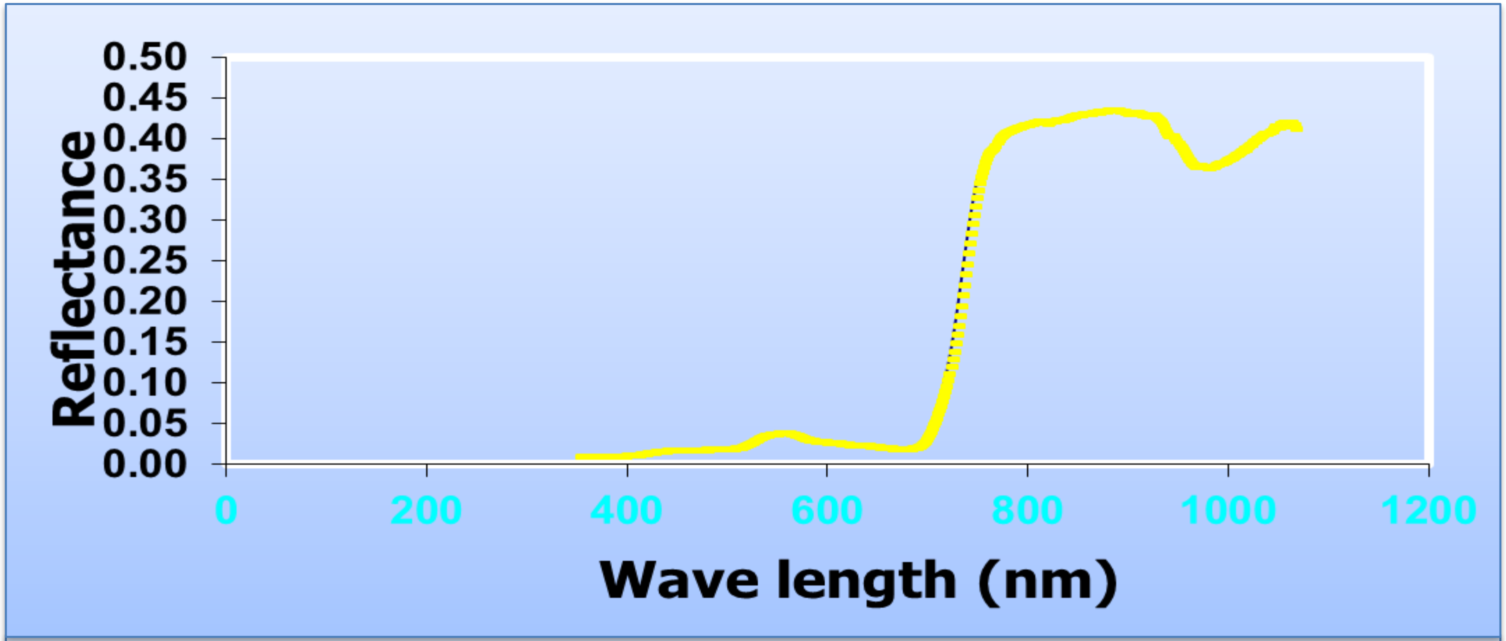
- Needed a wave length
- Shows genetic variations
- Strong genetic correlation
- Heritability is high
- Correlated response in the unselected trait based on selected trait.
- Time and cost involved
- Selection efficiency

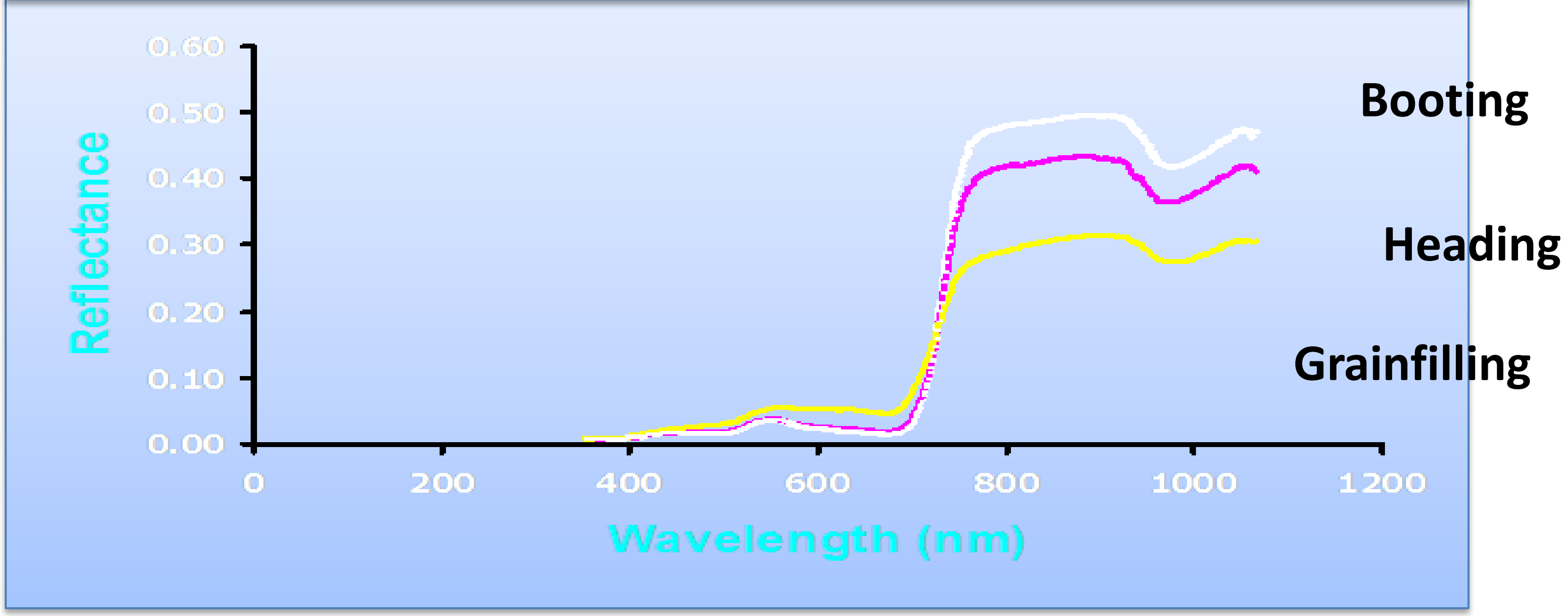
In practice, these combinations are rarely obtained.

Can we find anything ??????

- Reflectance data were taken using a UV/NIR ASD Spectroradiometer (350-1060 nm)
- Data were collected at different growth stages booting, heading, and grainfilling
- Spectral readings were collected at 50 cm above the canopy
- Four readings were taken from different places within each plot
- Mean of four readings was used for analysis


Libretto 80CT





Typical reflectance pattern of different wavelengths by plants

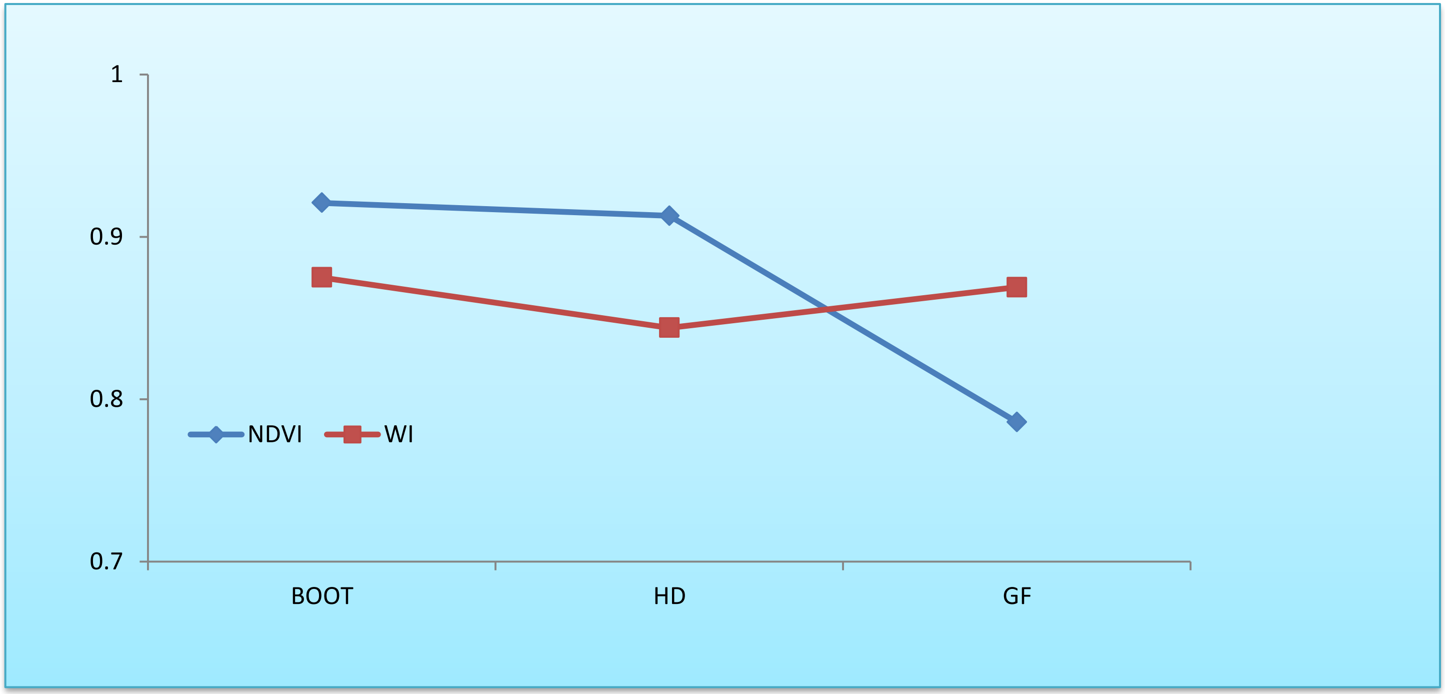
Spectral Indices

- Different indices were calculated based on the different references
- Five indices were calculated based on combinations of wavelengths (750, 850, 900, 970, and 1000 nm)

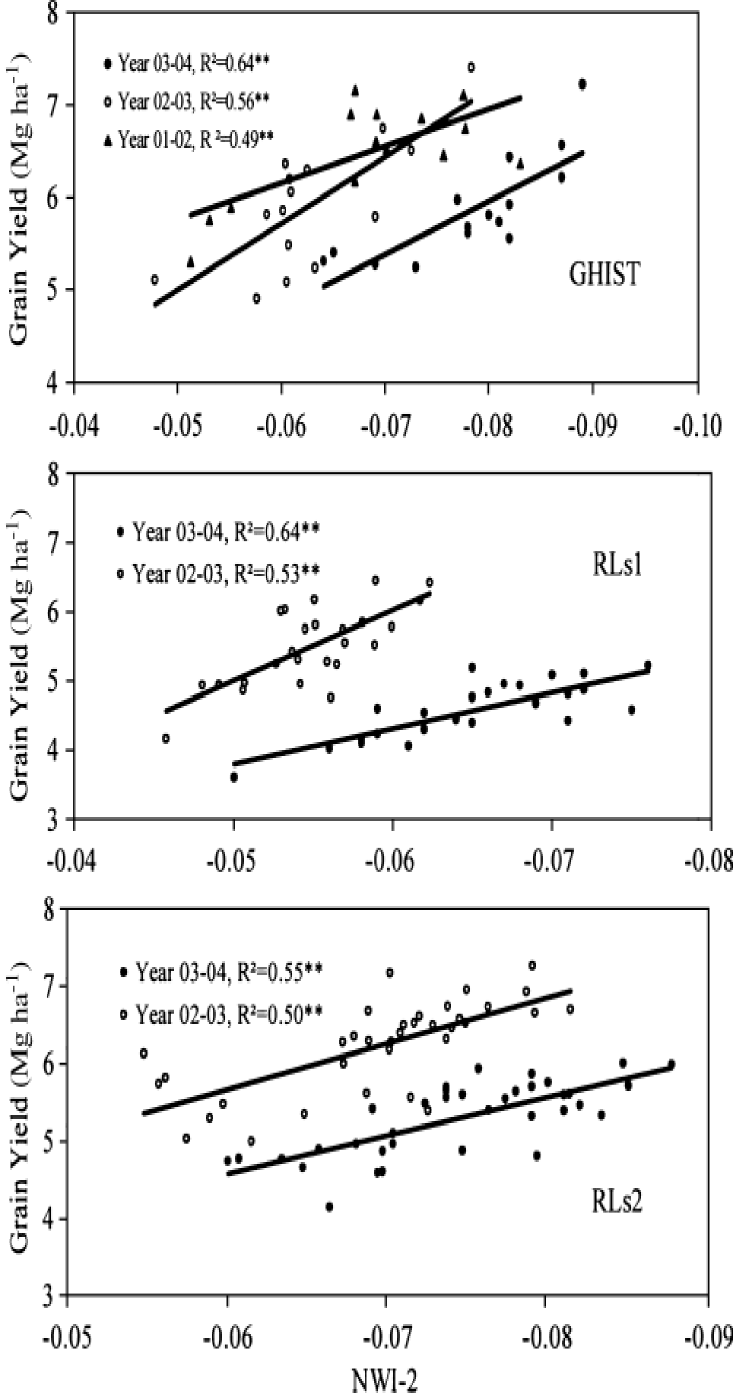
  - Water index, WI = R_{900}/R_{970}
  - Red normalized difference vegetation index, RNDVI = $(R_{780}-R_{670})/(R_{780}+R_{670})$
  - $SR=R_{780}/R_{680}$

- Two newly calculated normalized water indices were calculated as follows:

  - Normalized water index-1, NWI-1 = $(R_{970}-R_{900})/(R_{970}+R_{900})$
  - Normalized water index-2, NWI-2 = $(R_{970}-R_{850})/(R_{970}+R_{850})$
  - NWI-3= $(R_{970}-R_{920})/(R_{970}+R_{920})$
  - NWI-4= $(R_{970}-R_{880})/(R_{970}+R_{880})$



Changes of two SRIs in different growth stages



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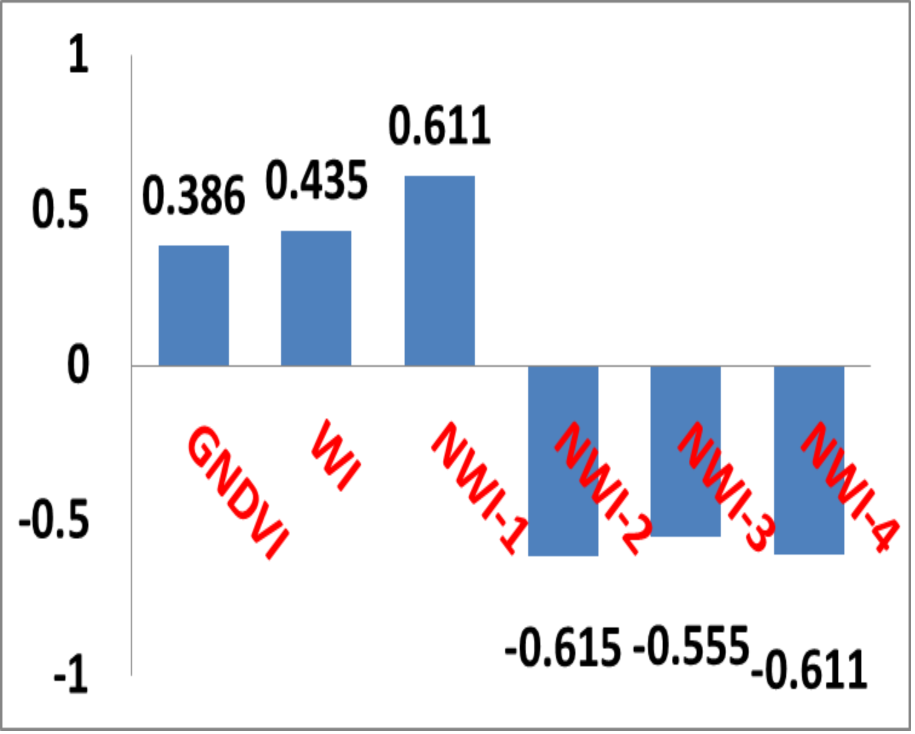
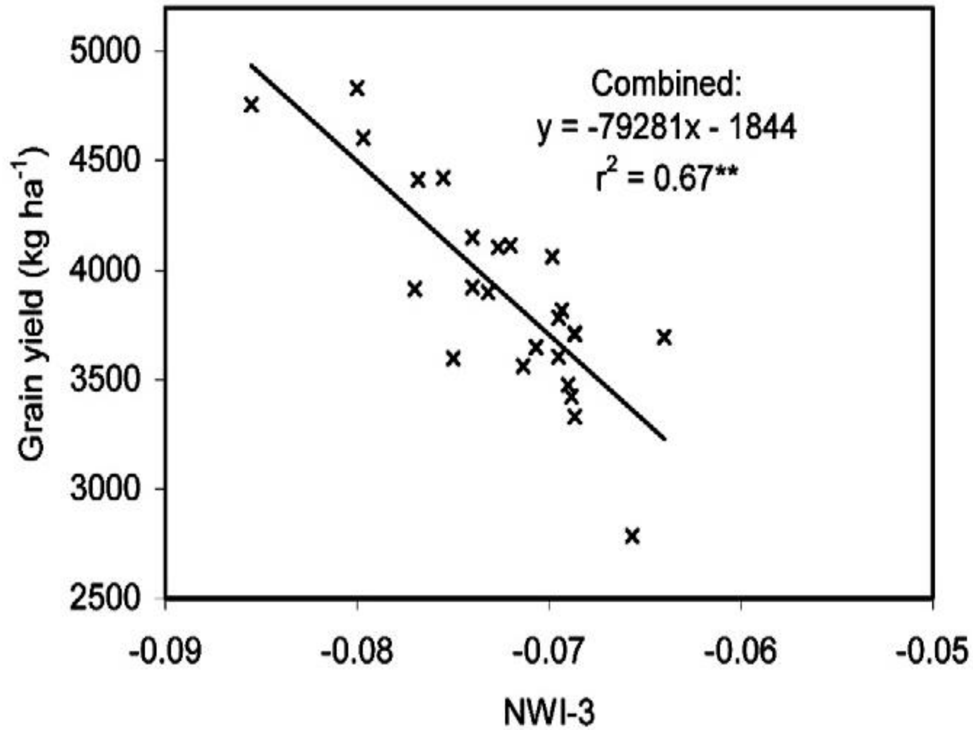
	B+H	B+G	H+G	B+H+G
NDVI	0.54	0.537	0.536	0.576
NWI1	-0.66	-0.65	-0.71	-0.741
NWI2	-0.65	-0.64	-0.71	-0.743

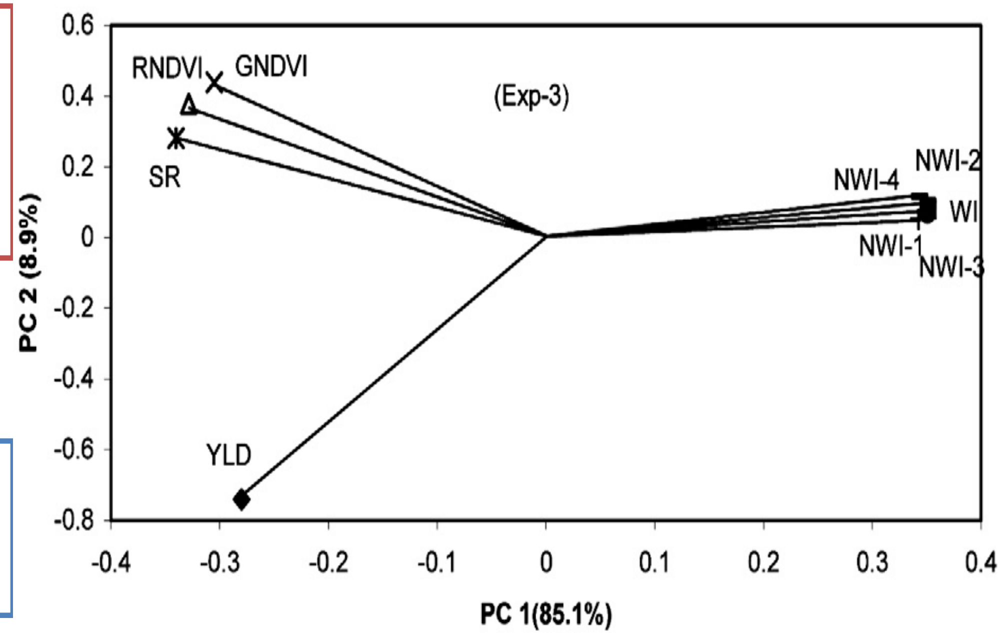
Mean association between grain yield and SRIs in different growth stages across experiments at CIMMYT

Babar et al. 2006, Crop Science, 46: 578-588





Mean association between grain yield and SRIs in different experiments at Stillwater, Ok



Prasad et al. 2007, Crop Science, 47:1416–1425

	Overall mean GC across three years across three experiments at CIMMYT	Overall mean GC across three years across three experiments at Stillwater, Oklahoma
NDVI	**0.586**	**0.63**
NWI-1	**-0.889**	**-0.875**
NWI-2	**-0.893**	**-0.805**
NWI-3		**-0.935**
NWI-4		**-0.895**

Average GC between between SRIs and grain yield within individual three random populations under irrigated conditions, mean overall PC in parenthesis

Babar et al, 2006; Prasad et al. 2007

	Heritability	Realized heritability
NDVI	0.604	0.411
NWI-1	0.717	0.696
NWI-2	0.748	0.733
Yield	0.636	0.629

Average broad-sense and realized heritability of SRIs and grain yield in three different populations

Babar et al., 2007, AJAR, 58:432-442;
Prasad et al, 2007, Crop Science, 47:1416–1425

	R	*CR*	*CR/R*
NDVI	0.689	0.394	0.598
WI	0.691	0.603	0.919
NWI-1	0.688	0.607	0.924
NWI-2	0.702	0.617	0.939
Yield	0.658	-	-

Mean *R*, *CR*, and *CR/R* of SRIs and yield in three populations

Babar et al., 2007, AJAR, 58:432-442;
Prasad et al, 2007, Crop Science, 47:1416–1425

Selection Efficiency

	NDVI	NWI-1	NWI-2
Yield per se	5.97	5.97	5.97
Based on SRIs	5.67	5.76	5.78
Difference (%)	5.9	3.7	3.4

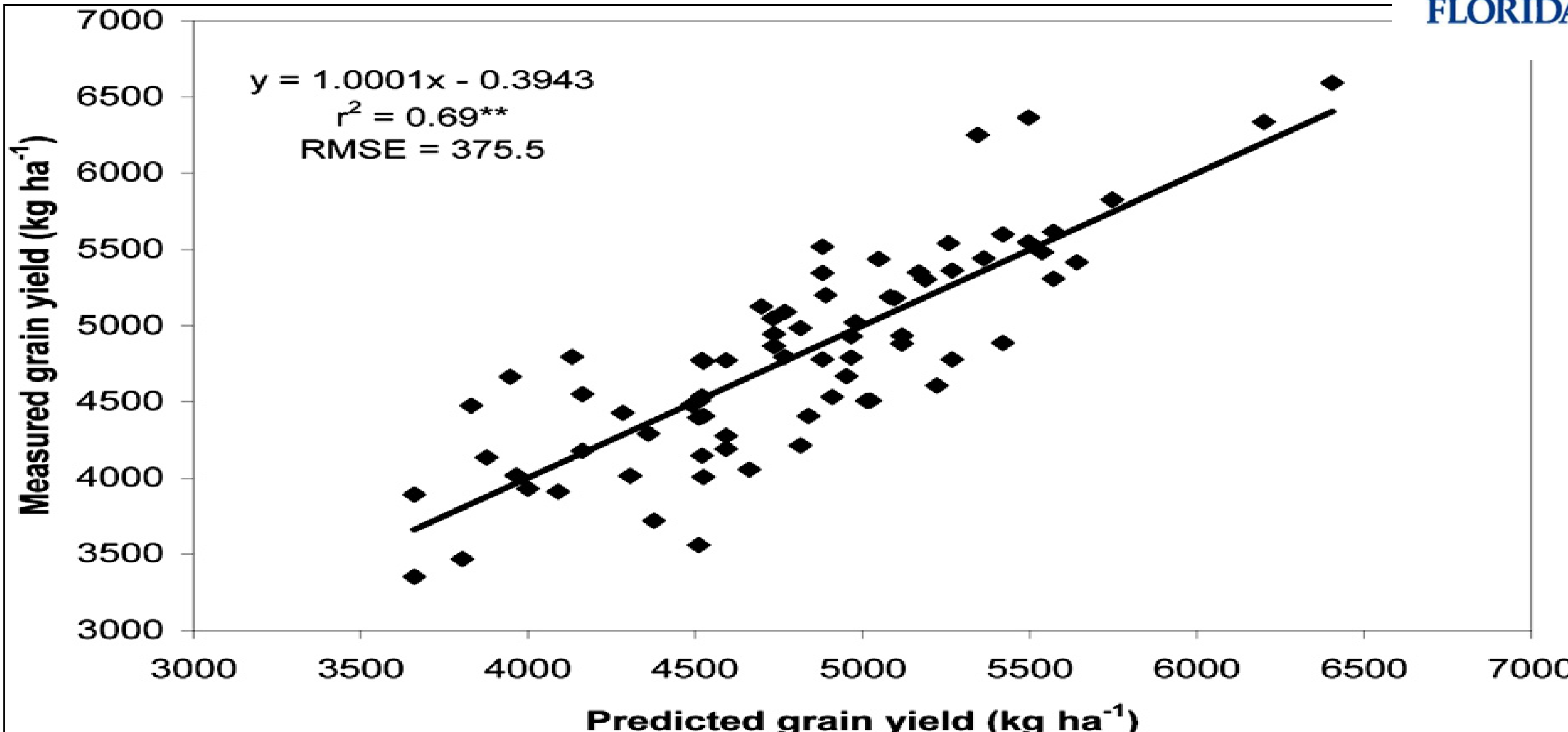
Mean difference between the mean grain yield of 20% top yielding genotypes based on SRIs and yield per se in three populations

Babar et al., 2007, AJAR, 58:432-442;
Prasad et al, 2007, Crop Science, 47:1416–1425

	NDVI	NWI-2	Combined
GHIST	56%	67%	78%
RLs1	57%	67%	76%
RLs2	47%	60%	60%
RLs3	54%	69%	85%

Mean percentage of selected genotypes among 20% highest yielding genotypes across three years in four experiments

Babar et al., 2007, AJAR, 58:432-442;
Prasad et al, 2007, Crop Science, 47:1416–1425



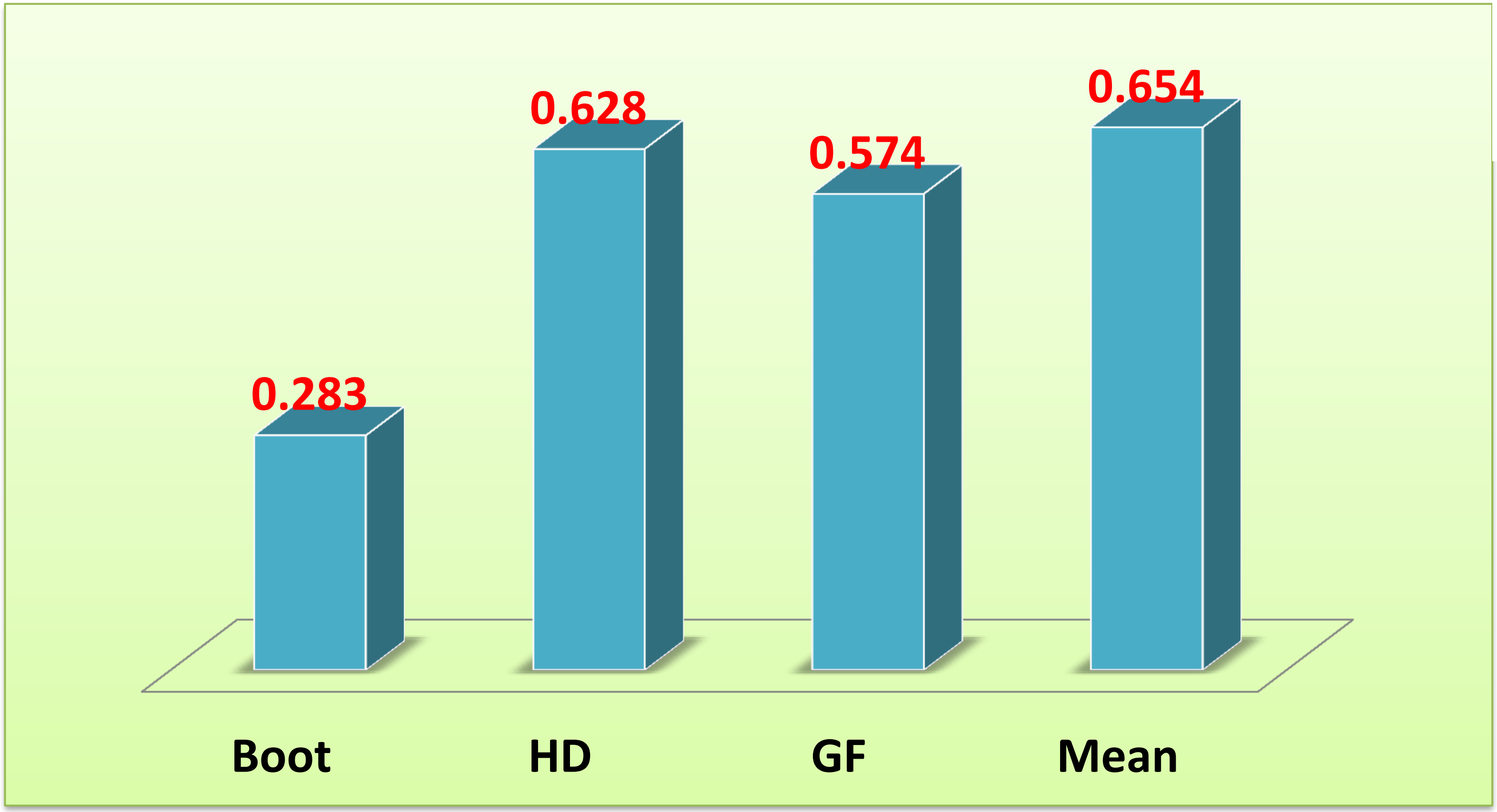
Relationship betw^{n} measured and predicted grain yield based on the linear equation using (NWI-3) as the predictor, estimated using the mean values of three growth stages

Prasad et al, 2007, Crop Science, 47:1416–1425

SRIs	BM	Grains m^{-2}
NDVI	0.572	0.537
NWI-1	0.725	0.653
NWI-2	0.735	0.641

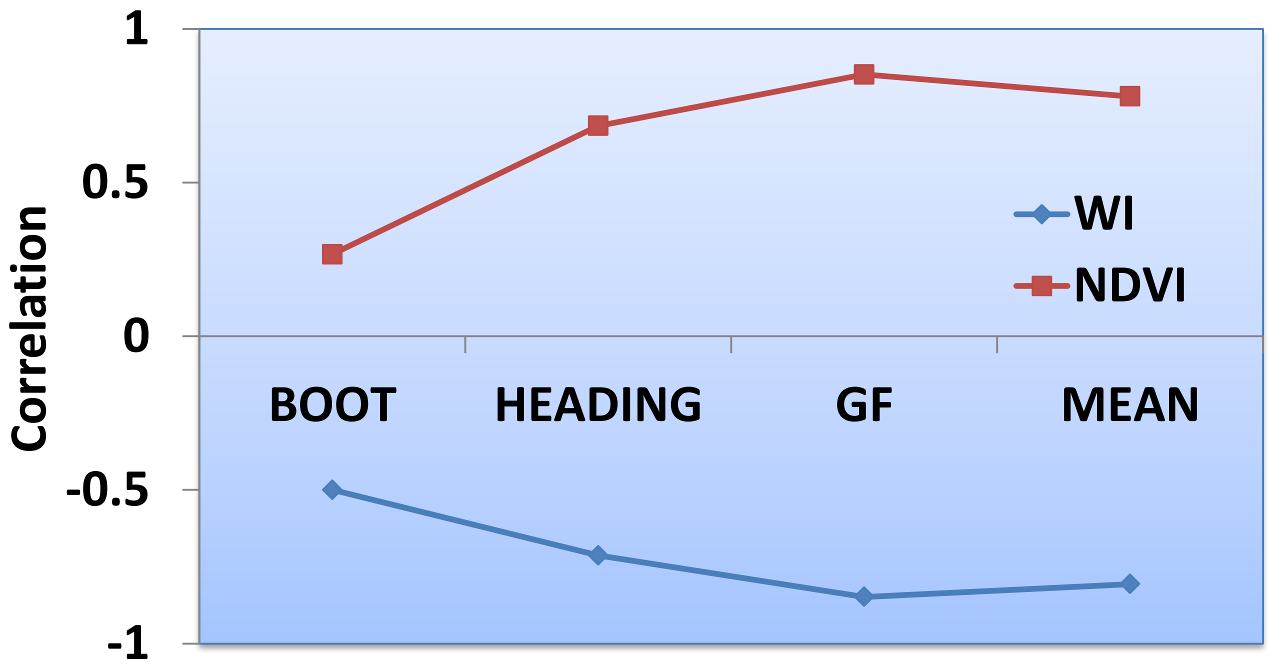
Mean association between grains/m^2 and biomass at maturity in four different experiments

Babar et al, 2006; Prasad et al. 2007



Mean correlations between grain yield and water content at different GS in three experiments

Babar et al, 2006



Mean correlations between water content and SRIs at different growth stages in three experiments

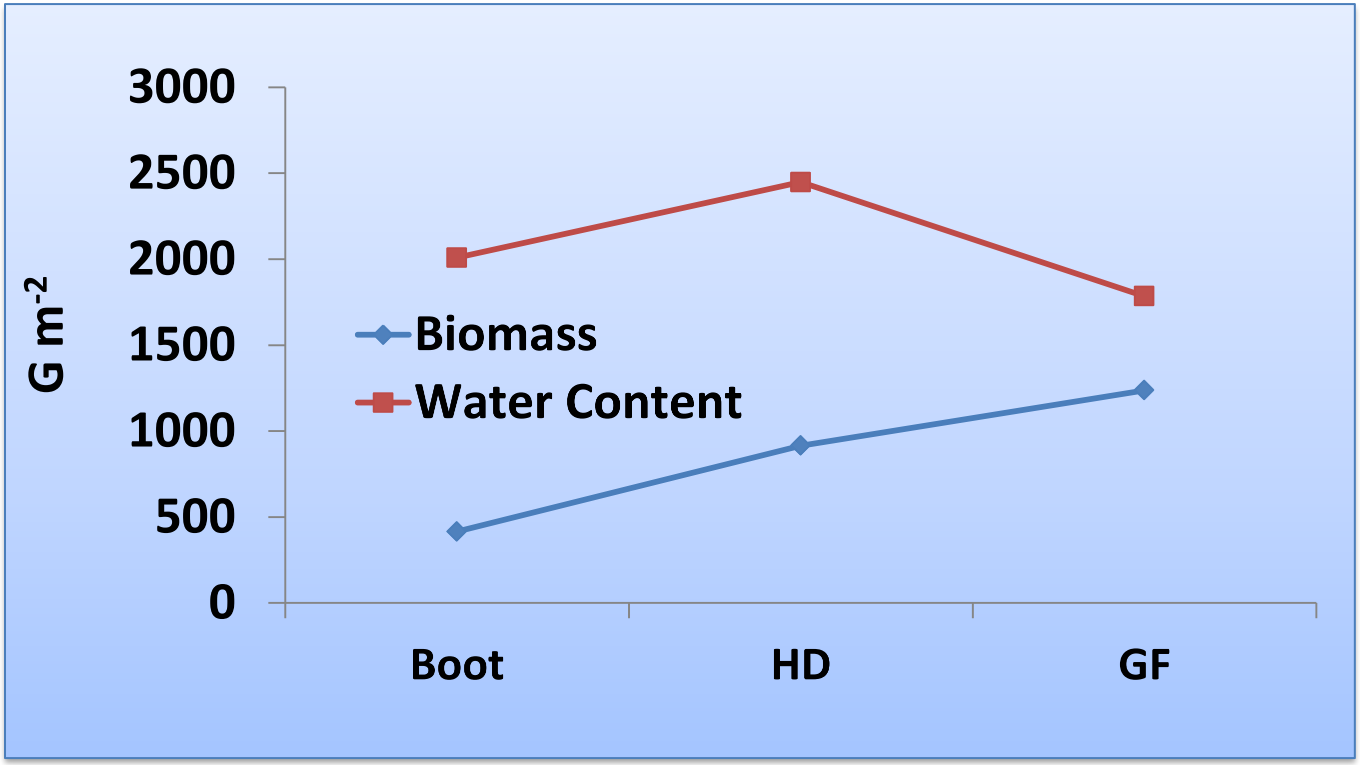
Babar et al, 2006

Spectral Reflectance to estimate in-season genetic variation for and Biomass, canopy temperature and chlorophyll content

	NDVI	NWI-1	NWI-2
Boot	0.158	-0.580	-0.645
HD	0.600	-0.657	-0.656
GF	0.619	-0.648	-0.663
Mean	0.633	-0.764	-0.761
GCORR	0.585	-0.765	-0.778

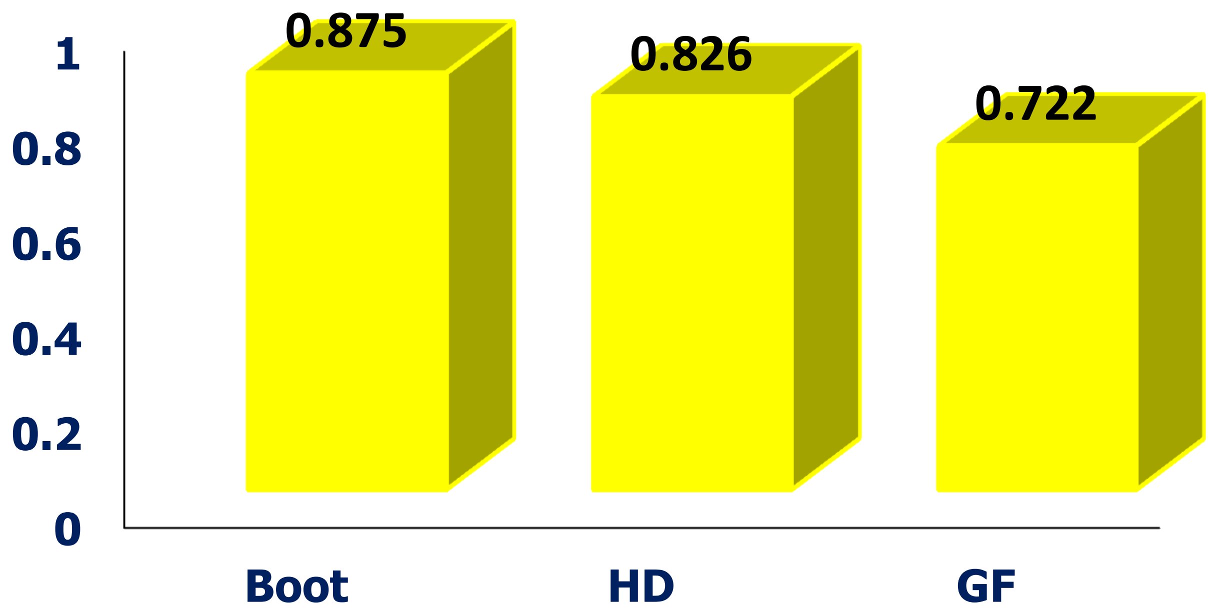
Mean PC and GC between biomass and SRIs in three growth stages in three experiments

Babar et al., 2006b, Crop Science, 46:1046–1057;
Prasad et al, 2009, CJPS, 89: 485-496



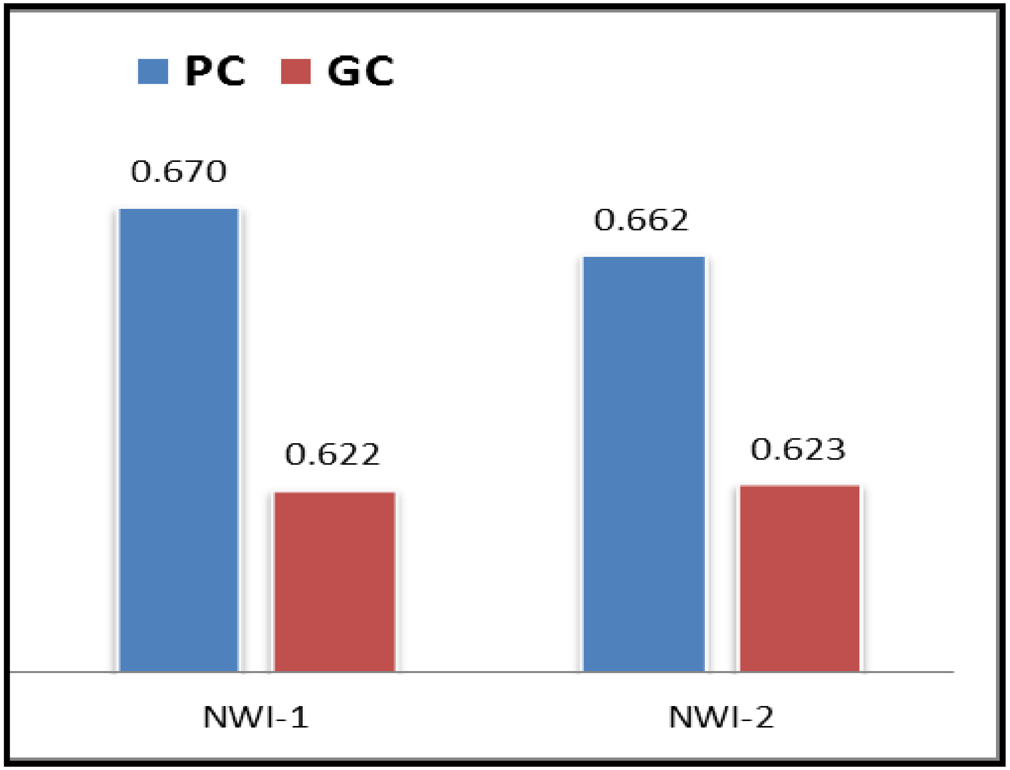
Changes in biomass and water content in different growth stages

Babar et al., 2006b, Crop Science, 46:1046–1057



Average correlations between water content and biomass at three GS in three experiments

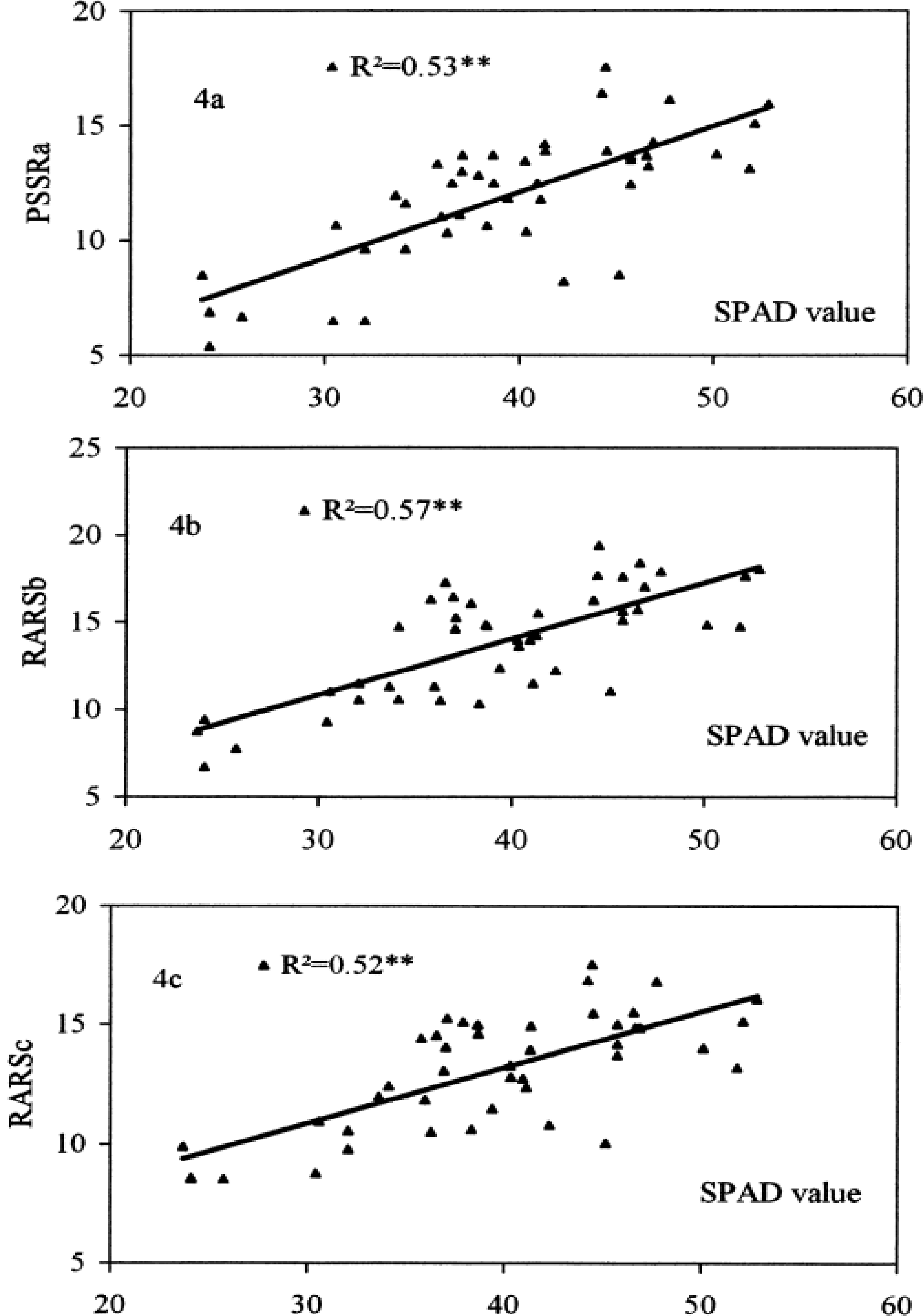
Babar et al., 2006b, Crop Science, 46:1046–1057



The phenotypic and genetic correlations between CT and WI, NWI-1, and NWI-2 at three different growth stages in three different experiments in two different years.

Babar et al., 2006b, Crop Science, 46:1046–1057

Relationship between chlorophyll content (SPAD values) and pigment specific simple ratio-chlorophyll a (PSSRa), ratio analysis of reflectance spectra-chlorophyll b (RARSb), and ratio analysis of reflectance spectra-carotenoids (RARSc) across 3 yr in experiment



Babar et al., 2006b, Crop Science, 46:1046–1057;

Spectral Reflectance and Water Limiting Environments

Babar et al., 2006c, Euphytica, 150: 155–172

	HD	GF	MEAN	GCORR
NDVI	0.278	0.463	0.498	0.511
WI	-0.567	-0.603	-0.713	-0.753
NWI-1	-0.564	-0.619	-0.714	-0.763
NWI-2	-0.600	-0.619	-0.732	-0.761

Mean correlations between yield and SRIs in three GS, over GS and GC in three experiments and years under 2-Irrig

Babar et al., 2006c, Euphytica, 150: 155–172

	HD	GF	MEAN	GCORR
NDVI	0.396	0.254	0.312	0.359
WI	-0.702	-0.569	-0.727	-0.815
NWI-1	-0.710	-0.571	-0.734	-0.792
NWI-2	-0.734	-0.548	-0.731	-0.810

Mean correlations between yield and SRIs in two GS, mean over GS, and GC in two experiments under 1-Irrig.

Babar et al., 2006c, Euphytica, 150: 155–172

SELECTION EFFICIENCY

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	2-Irrig	1-Irrig
25% selection based on yield per se	5.29 (t/ ha)	4.73 (t/ha)
25% selection based on NWI-2	5.12 (t/ha)	4.61(t/ha)
Difference (%)	3.21	2.5

Average highest yield (25%) based on yield per se compared to average yield of the highest (25%) based on NWI-2 and the mean difference in two moisture environments

Babar et al., 2006c, Euphytica, 150: 155–172

	Selected Genotypes (12.5%)		Selected Genotypes (25%)	
	Based on mean of GS	Based on selection in different GS	Based on mean of GS	Based on selection in different GS
2-Irrig.	47	55	61	77
1-Irrig	50	63	63	81

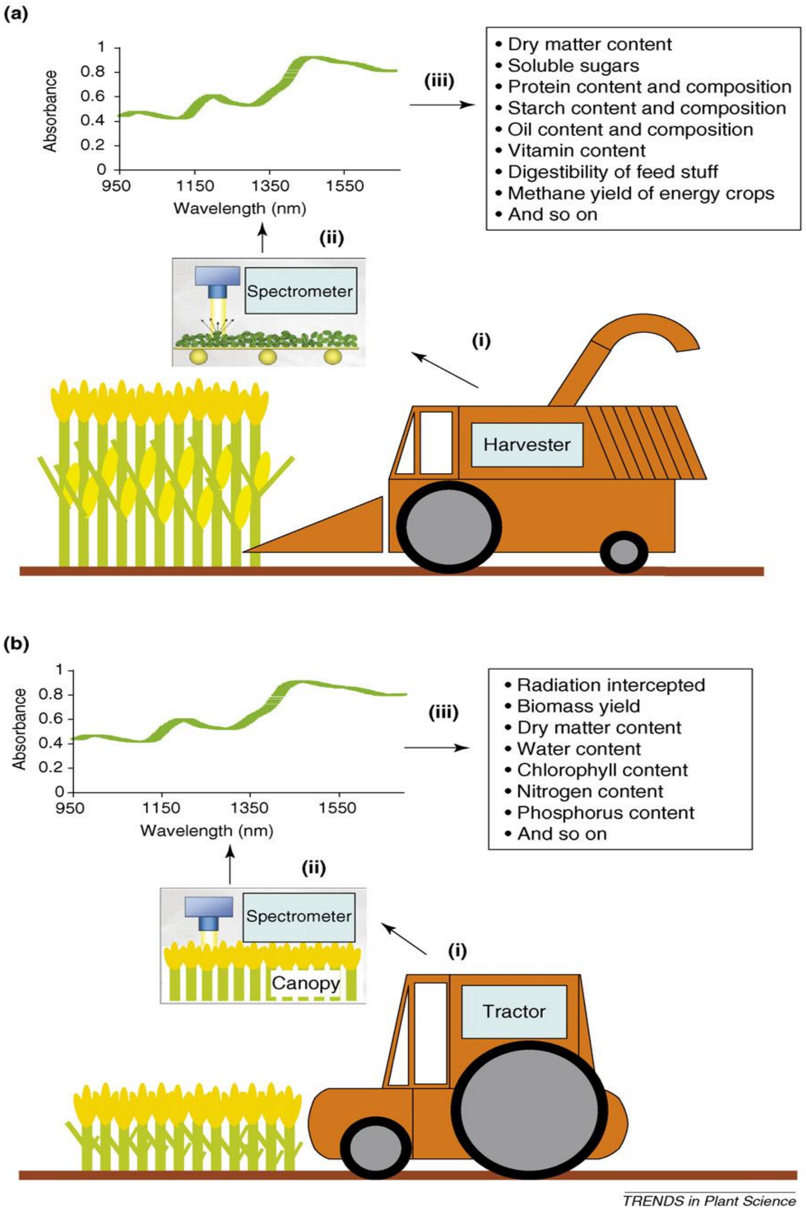
The mean percentage of genotypes selected among the top 12.5% and 25% highest yielding genotypes based on NWI-2 under two moisture conditions

Babar et al., 2006c, Euphytica, 150: 155–172

	NDVI	NWI-2	Yield	Selection efficiency (NW-2)
H (2-Irrig)	0.86	0.88	0.60	
CR (2-Irrig)	0.31	0.49	0.53(*R*)	92.4%
H (1-Irrig)	0.72	0.66	0.58	
CR (1-Irrig)	0.22	0.45	0.52(*R*)	86.5%
H(Across moisture conditions)	0.38	0.66	0.60	

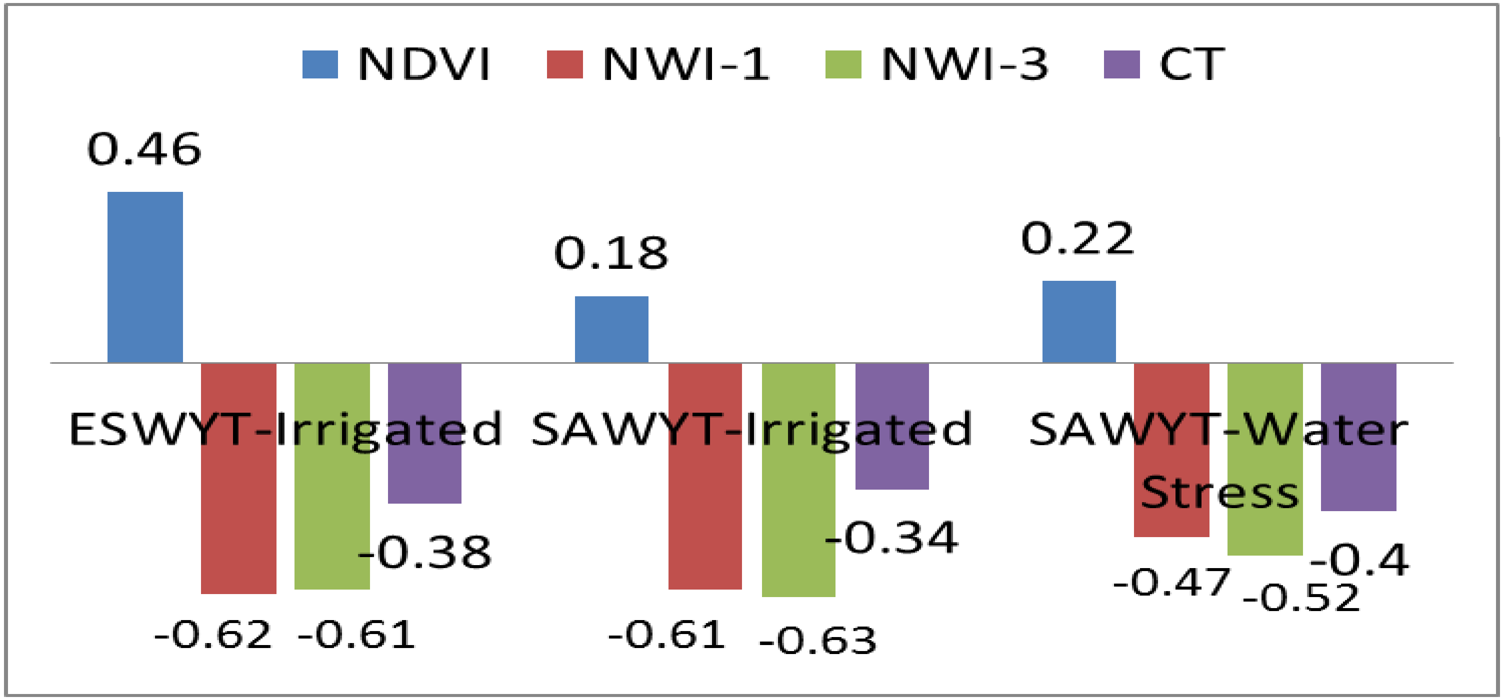
Average H and *CR* in individual environment and across environments in different experiments

Babar et al., 2006c, Euphytica, 150: 155–172



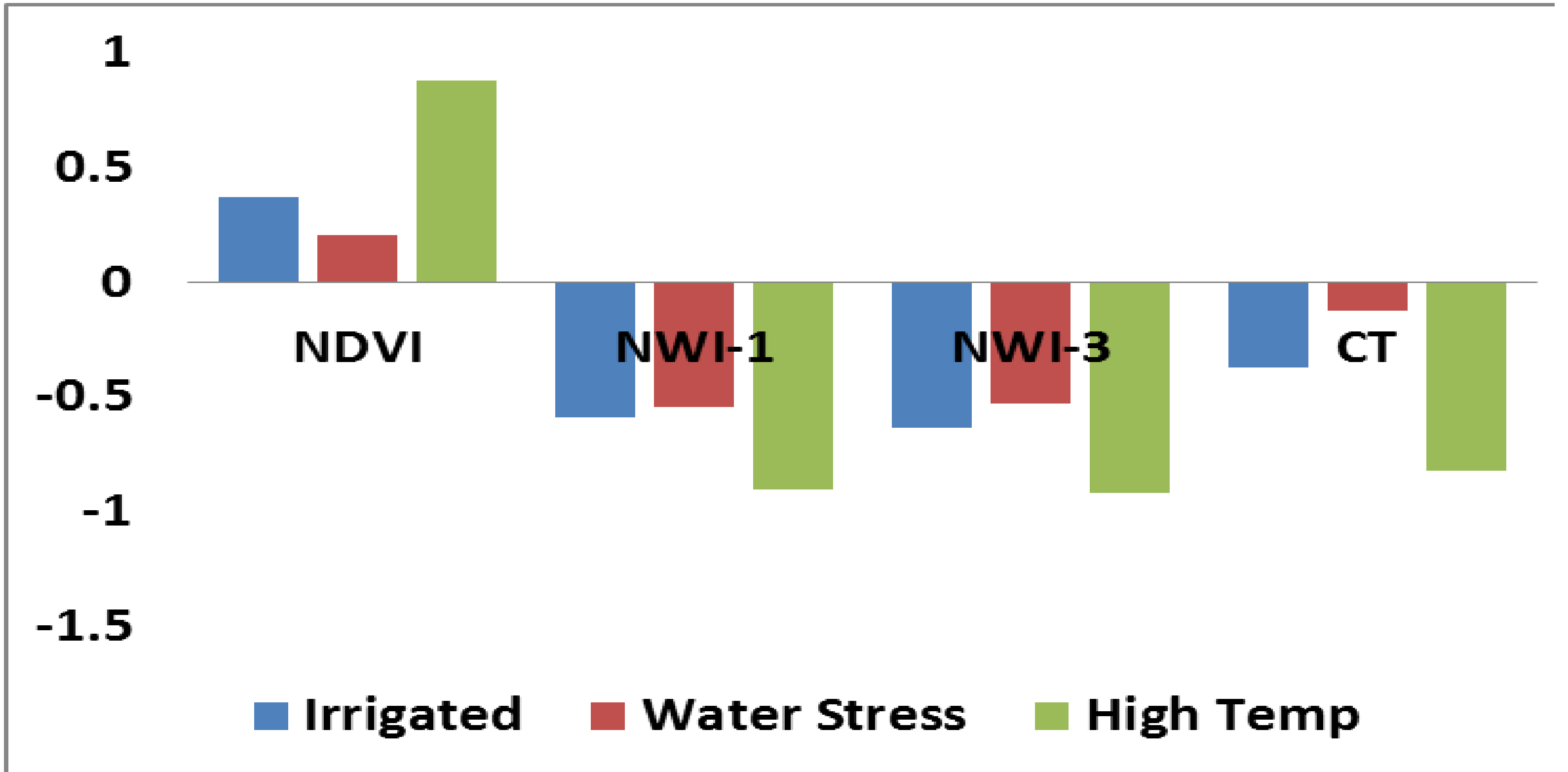
Near-infrared spectroscopy on agricultural harvesters [2,3] and spectral reflectance of plant canopy [4–6] present new opportunities to develop novel phenotyping platforms that enable large-scale screenings of genotypes for several traits in multilocation field trials.

Montes, Melchinger and Reif , 2007, TRENDS in Plant Science, Vol.12 No.10, Novel throughput phenotyping platforms in plant genetic studies



PC between indices and grain yield for Elite Spring Wheat Yield Trial (ESWYT), and Semi-Arid Wheat Yield Trial (SAWYT) grown under well-irrigated and water-stressed conditions during three years and across years.

Gutierrez et al., 2010, Crop Science, 50:197-214



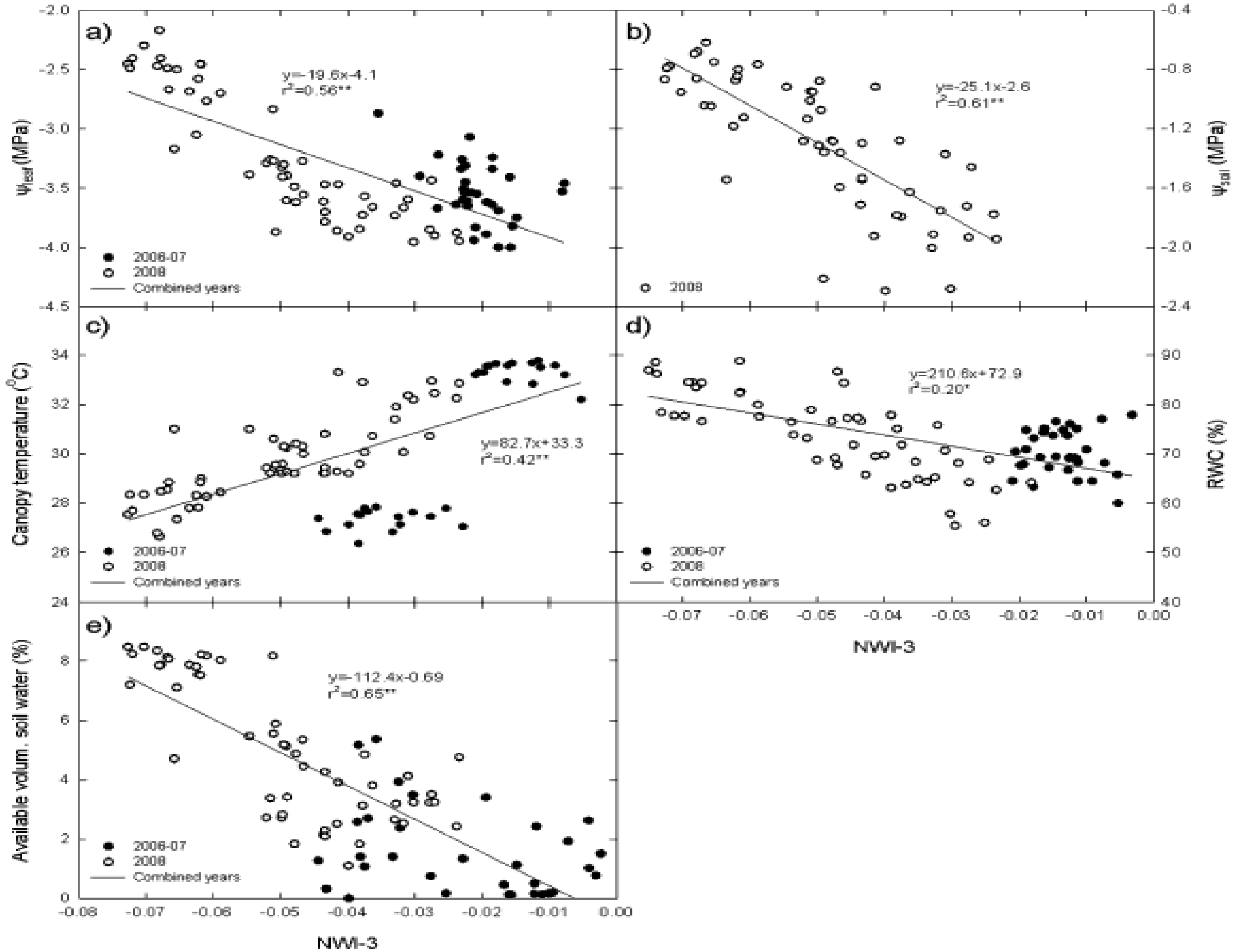
PC between indices and grain yield for High Temperature Wheat Yield Trial (HTWYT) grown under well-irrigated, water-stressed, and high-temperature conditions during three years and across years.

Gutierrez et al., 2010, Crop Science, 50:197-214

	Yield	NDVI	NWI-1	NWI-3
SAWYT-Well irrigated	0.81	0.89	0.8	0.79
SAWYT-Well irrigated	0.77	0.86	0.83	0.83
SAWYT-Water stress	0.62	0.49	0.37	0.41
HTWYT-Well irrigated	0.72	0.95	0.75	0.71
HTWYT-Water stress	0.74	0.96	0.87	0.87
HTWYT-High Temperature	0.78	0.90	0.83	0.84

Heritability for indices and grain yield for ESWYT, SAWYT, and HTWYT grown under different growing conditions. Average of combined growth stages (heading and grain-filling) during three years and across years.

Gutierrez et al., 2010, Crop Science, 50:197-214



Relationships of the normalized water index 3 (NWI-3) with leaf water potential (wleaf), soil water potential (wsoil), leaf relative water content (RWC), canopy temperature (CT), and available volumetric soil water (AVSW) by combining determinations across environments for a subset of sister lines (SBS-I and SBS-II), advanced lines (ALN), and synthetic lines (SYNDER).

Gutierrez et al., 2010, J Exp Bot. 61(12):3291-3303.

	Canopy reflectance					
	Uncorrected		Scattered		Smoothed	
	RNDVI	NWI-3	RNDVI	NWI-3	RNDVI	NWI-3
All combined lines (n = 20)	0.66**	−0.85**	0.59	−0.85**	0.58	−0.84**
			Wax on leaves			
Intermediate waxy leaves (n = 8)	0.37	−0.90**	0.36	−0.95**	0.37	−0.85**
Waxy leaves (n = 12)	0.82**	−0.74**	0.81**	−0.85**	0.53	−0.75*
			Wax on spikes			
Intermediate waxy spikes (n = 6)	0.27	−0.70	0.50	−0.82*	0.28	−0.58
Waxy spikes (n = 14)	0.77**	−0.83**	0.74**	−0.86**	0.60	−0.86**
			Leaf orientation			
Curved leaves (n = 9)	0.91**	−0.92**	0.90**	−0.82**	0.89**	−0.59**
Erect leaves (n = 11)	0.30	−0.74**	0.17	−0.74**	0.08	−0.71*
			Spike orientation			
Curved spikes (n = 5)	0.56	−0.65	0.23	−0.27	0.17	−0.78
Erect spikes (n = 15)	0.42	−0.64*	0.67*	−0.87**	0.46	−0.54
			Awns on spikes			
Awnless spikes (n = 6)	0.83*	−0.96**	0.83*	−0.93**	0.66	−0.94**
Awned spikes (n = 14)	0.57*	−0.81**	0.39	−0.77**	0.29	−0.72**

Correlation coefficients between grain yield and spectral reflectance indices calculated with uncorrected, scattered, and smoothed canopy reflectance of 20 advanced wheat lines.

Gutierrez et al., 2015, IJRS, 36(3):701-718.

Elisabeth Becker and Urs Schmidhalter, Frontier in Plant Science, 8, March, 2017.

water and normalized water indices (WI and NWI—1 to 4), which are only provided by the passive sensor, showed the strongest relationships with the drought stress related parameters (r = −0.49 to −0.86) and grain yield (r = −0.88) at anthesis. <u>This paper indicates that precision phenotyping allows the integration of water indices in breeding programs to rapidly and cost-effectively identify drought-tolerant genotypes</u>. <u>This is supported by the fact that grain yield and the water indices showed the same heritability under drought conditions.</u>

Gisaw et al. 2016. Use of spectral reflectance for indirect selection of yield potential and stability in Pacific Northwest winter wheat. 196: 199-206

Normalized water band index (NWI) showed consistent response to selection across environments, higher genetic correlation with yield (0.51–0.80, $p < 0.001$), and highest <u>indirect selection efficiency (up to 143%)</u>. A yield predictive model with one or more SRIs explained 41–82% of total variation in grain yield. The repeatability of genotypic performance between years increased when selection was conducted based on both SRIs and grain yield compared to selection based on yield or SRI alone<u>. The generally high heritability of SRIs and their significant genotypic correlation with grain yield highlight the possibility to improve yield and yield stability in winter wheat through remotely sensed phenotyping approaches.</u>

What we are working on ?
NDVI and early biomass

What we are working on ?
NDVI and canopy temperature

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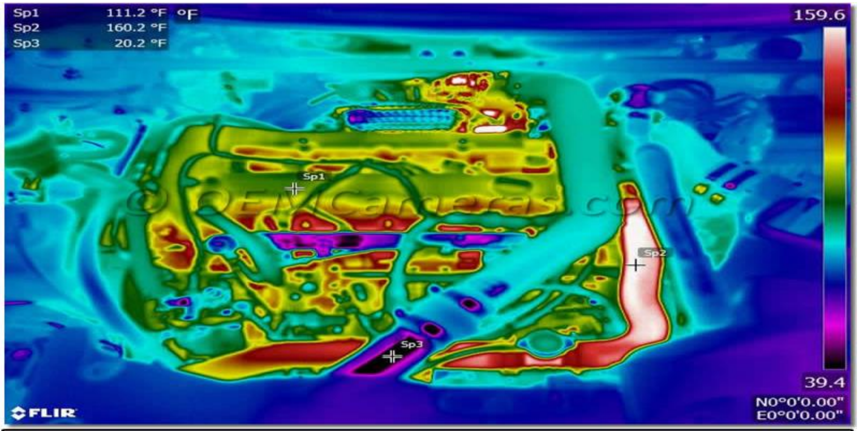
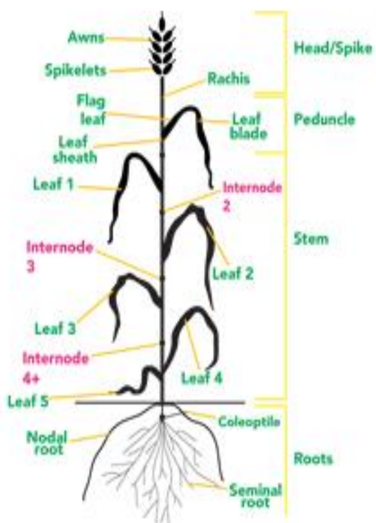
FLIR VUE PRO R
Radiometric Thermal Imaging Camera

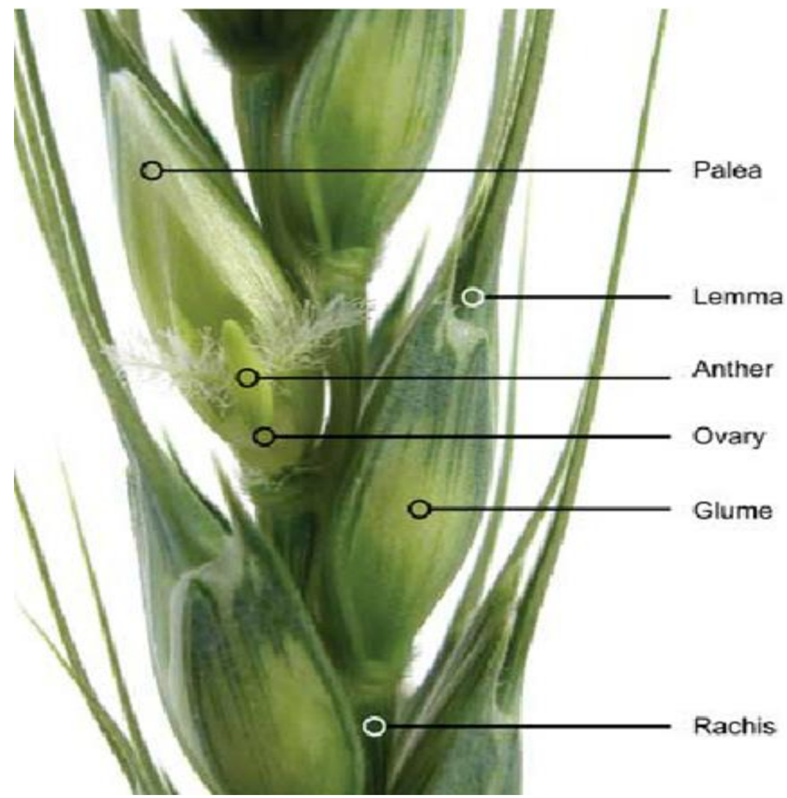


FLIR VUE PRO R 640 13mm
Measurement Example using FLIR Tools
Palette: Rainbow HC

What we are working on ?
Improve harvest index

Grain yield = AGDM x HI

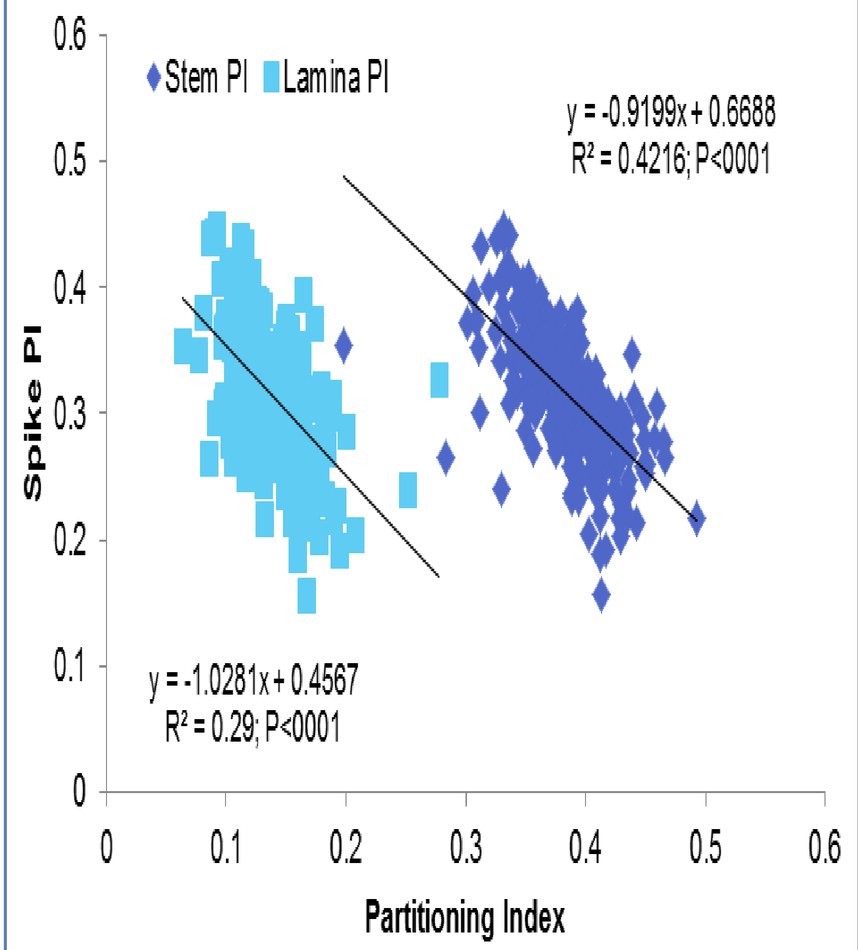




What we are working on ?

Improve harvest index

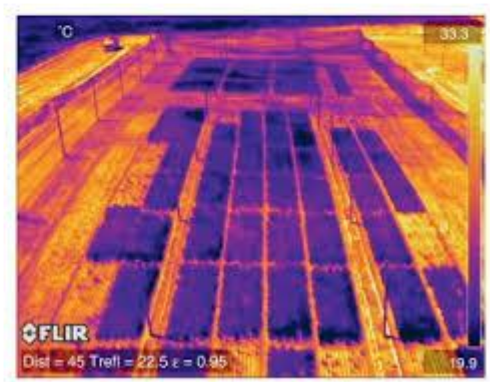
		Range 16-17 (Min-Max)	Sig.	GY	HI	Grains m^{-2}
Yield components	Yield $g\ m^{-2}$	358.7-612.9	***	*	0.64***	0.89***
	HI	31.9-52.6	***	0.64***	*	0.51***
	Grains m^{-2}	9723.7-18737	***	0.89***	0.53***	*
	FE grns g^{-1}	36.8-80.6	**	0.407***	0.402***	0.49***
	AGDM $g\ m^{-2}$	1224.6-3013.1	***	0.35***	-0.21**	0.39***
DM $shoot^{-1}$	Stem	0.36-1.75	***	0.15*	0.12	-0.10
	Spike	0.37-1.63	**	0.31***	0.36***	0.21***
	Lamina	0.11-0.86	*	0.17**	0.10	0.07
Part. Index GS65+7d	Stem	0.2-0.49	*	-0.16*	-0.17**	-0.20**
	Spike	0.16-0.45	***	0.23***	0.30***	0.25***
	Lamina	0.06-0.28	***	-0.04	-0.13*	-0.03



What we are working on ?

Genomic selection

NURS	ENT	DESIG	Rht-B1	Rht-D1	Fhb1	3BL	Fhb_2DL-Wuhan/W14	Fhb_5A	Lr34/Yr18	Yr17	Lr9	Lr19	Sr24	Sr2	Sr36	1RS	H13	H9	Bdv2/3	Sbm1	Ppd-A1	Ppd-B1	Ppd-D1	vrn-A1	Predicted A1	vrn-B1	Vrn-A1	Vrn-B1	Vrn-D1	Tsn1	Glu-B1	Glu-A1	Glu-D1
SUNW16	1	LA06146E-P4	B1a	D1b	no	no	no	no	no	Yr17	Lr9	no	no	no	no	no	no	no	no	Sbm1	**	**	nser	A1	A1	_sh	n-A	n-B	n-D	no	no	Ax2*	5+10
SUNW16	2	SS8641	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	no	no	no	no	Sbm1	**	**	nser	A1	A1	B1	n-A	n-B	n-D	Tsn1	no	Ax2*	2+12
SUNW16	3	Hilliard	B1a	D1b	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	Sbm1	ens_	**	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	4	Savoy	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	no	H13	no	no	Sbm1	**	**	nser	A1	A1	_sh	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	5	NC13-20076	B1a	D1b	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	Sbm1	**	**	nser	_sh	_2cc	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	6	NC13-22836	B1a	D1b	Fhb1	no	no	no	no	no	Lr9	no	Sr24	no	no	no	no	no	no	Sbm1	nser	**	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	7	NC13-23443	B1b	)1b_he	no	no	no	no	no	no	Lr9	no	no	no	36_h	no	no	no	no	Sbm1	**	**	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	8	NC10014-9B	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	Sr36	no	no	no	ND	Sbm1	**	null	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	5+10
SUNW16	9	NC13-21987	B1a	D1b	no	no	no	no	no	no	Lr9	no	no	no	Sr36	no	no	no	no	Sbm1	**	null	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	5+10
SUNW16	10	NC13-20227	B1a	D1b	no	no	no	no	no	no	Lr9	no	no	no	Sr36	no	no	no	no	Sbm1	**	null	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	het
SUNW16	11	NC10034-50	B1b	D1a	no	3BL	no	no	no	no	no	no	no	no	Sr36	no	no	no	no	Sbm1	**	5_ins	nser	A1	A1	B1	n-A	n-B	n-D	no	no	_or_	2+12
SUNW16	12	NC10034-47	B1b	D1a	no	3BL	no	no	no	no	no	no	no	no	Sr36	no	no	no	no	Sbm1	nser	5_ins	nser	A1	A1	B1	n-A	n-B	n-D	no	no	_or_	2+12
SUNW16	13	NC10034-86	B1b	D1a	no	BL_he	no	no	no	no	no	no	no	no	Sr36	BL_he	no	no	no	Sbm1	nser	5_ins	nser	A1	A1	B1	n-A	n-B	n-D	no	no	_or_	het
SUNW16	14	NC10034-43	B1b	D1a	no	3BL	no	no	no	no	no	no	no	no	Sr36	no	no	no	no	Sbm1	**	**	nser	A1	A1	B1	n-A	n-B	n-D	no	no	_or_	5+10
SUNW16	15	NC10034-26	B1b	)1b_he	no	BL_he	no	no	no	17_h	Lr9	no	no	no	36_h	no	no	no	no	m1_h	ens_	nser	ens_	A1	A1	hort	n-A	n-B	n-D	no	no	Ax2*	het
SUNW16	16	NC13-21213	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	no	H13	no	no	Sbm1	**	**	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	17	NC13-21217	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	no	H13	no	no	Sbm1	**	**	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	18	NC13-20278	B1a	D1b	no	3BL	no	no	no	17_h	Lr9	Lr19	no	no	Sr36	1BL	no	no	no	Sbm1	**	null	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	19	NC13-21445	B1a	D1b	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	Sbm1	nser	**	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	20	LA08090C-26-:	B1a	D1b	no	no	no	no	no	17_h	Lr9	no	Sr24	no	no	no	no	no	no	no	ens_	4_ins	**	A1	A1	hort	n-A	n-B	n-D	no	no	_or_	5+10
SUNW16	21	LA9050C-P4	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no?	BL_he	no	no	no	no	nser	4_ins	nser	hort	copy	hort	n-A	n-B	n-D	no	3x7OE	Ax2*	2+12
SUNW16	22	LA08234D-18	B1a	D1b	no	3BL?	no	no	no	17_h	Lr9	no	no	Sr2?	no	no	H13	no	no	m1_h	**	5_ins	nser	A1	A1	B1	n-A	n-B	n-D	Tsn1	no	Ax2*	2+12
SUNW16	23	LA08090C-9-1	B1a	D1b	no	no	no	no	no	17_h	Lr9	no	no	no	36_h	no	no	no	no	no	ens_	S64_	ens_	A1	A1	hort	n-A	n-B	n-D	no	no	Ax2*	0_or_
SUNW16	24	LA09179C-5	B1a	D1b	no	no	no	no	no	no	no	no	no	no	Sr36	no	no	no	no	Sbm1	**	5_ins	nser	A1	A1	B1	n-A	n-B	n-D	no	3x7OE	_or_	5+10
SUNW16	25	LA09202C-34	B1a	D1a	no	no	no	no	no	Yr17	no	no	Sr24	no	Sr36	no	no	no	no	m1_h	**	null	nser	A1	A1	_sh	n-A	n-B	n-D	no	no	_or_	2+12
SUNW16	26	GA08391-EL19	ND	ND	no	ND	ND	no	no call	ND	no	no	no	no	ND	no call	ND	no	no	ND	ND	_or_	ND	o ca	o ca	o ca	ND	n-B	n-D	no	ND	ND	no cal
SUNW16	27	GA081446-EL4	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	1BL	no	no	no	Sbm1	nser	4_ins	ens_	A1	A1	hort	n-A	n-B	n-D	no	no	Ax2*	het
SUNW16	28	GA06474-EL56	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	no	no	no	no	Sbm1	**	**	nser	A1	A1	_sh	n-A	n-B	n-D	no	no	_or_	2+12
SUNW16	29	GA08510-EL9	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no?	no	no	no	no	Sbm1	nser	4_ins	**	A1	A1	_sh	n-A	n-B	n-D	no	no	Ax2*	5+10
SUNW16	30	GA081113-EL8	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	no	H13	no	no	Sbm1	**	4_ins	nser	A1	A1	B1	n-A	n-B	n-D	no	no	_or_	2+12
SUNW16	31	GA081104-EL2	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	no	no	no	no	no	**	**	nser	_sh	_1cc	B1	n-A	n-B	n-D	no	no	_or_	2+12
SUNW16	32	GA05450-EL52	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	no	no	no	no	Sbm1	**	**	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	33	GA071171-EL6	B1a	D1b	no	no	no	no	no	no	no	no	no	no	no?	no	no	no	no	Sbm1	nser	4_ins	ens_	_sh	_2cc	B1	n-A	n-B	n-D	no	no	Ax2*	5+10
SUNW16	34	GA08261-EL7	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no	no	no	no	no	Sbm1	**	4_ins	nser	_sh	_2cc	B1	n-A	n-B	n-D	no	3x7OE	Ax2*	5+10
SUNW16	35	GA07144-LE16	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no?	no	no	no	ND	Sbm1	**	**	nser	A1	A1	B1	n-A	n-B	n-D	no	no	Ax2*	2+12
SUNW16	36	GA06283-LE25	B1a	D1b	no	no	no	no	no	Yr17	no	no	Sr24	no	36_h	no	no	no	no	m1_h	**	null	ens_	hort	copy	hort	n-A	n-B	n-D	no	no	Ax2*	5+10
SUNW16	37	GA08535-LE29	B1a	D1b	no	no	no	no	no	Yr17	no	no	no	no	no?	1BL	no	no	no	Sbm1	nser	4_ins	**	_sh	_2cc	_sh	n-A	n-B	n-D	no	3x7OE	Ax2*	5+10



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