Quantifying genotype and environment interactions to benefit selection and evaluation of cereals for competitiveness against weeds

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EUCARPIA Symposium

Plant breeding for organic and sustainable low-input agriculture: dealing with genotype-environment interactions

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Outline

1. Crop-weed relations – current knowledge
2. Genotype and seasonal influences as observed in crop-weed experiments
3. Variation in weed suppression between and within genotypes
4. Working towards selection and evaluation:
   - Identifying more robust varieties
   - Improved stability of genotype performance
   - Better adaptation

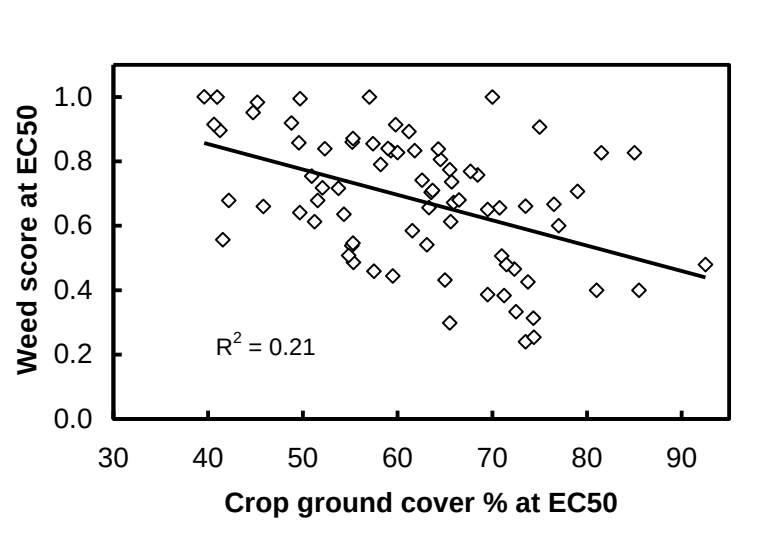
Background

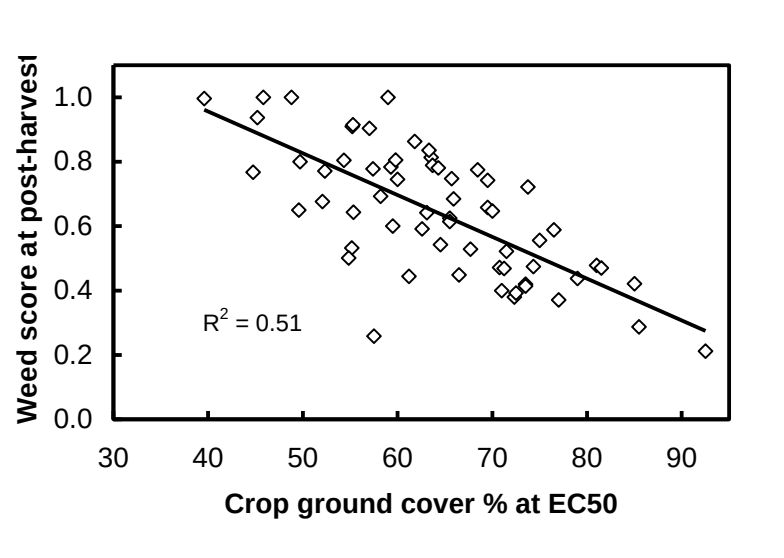
- EU funded research on Strategies of weed control in organic farming (WEOCF)
- Understanding genotype differences in their competitiveness against weeds
- Fifteen genotypes contrasting in their agronomic characteristics (13 winter wheat, 1 spring wheat, 1 winter oat)
- Contrasting growing seasons:
  - Crop establishment and yield variation
  - Different levels of weed growth

1. Crop-weed relations – current knowledge

Refer to: EUCARPIA Symposium *in* van Bueren 'Developments in breeding for organic farming systems in Europe'

Selection target: increasing crop ground cover



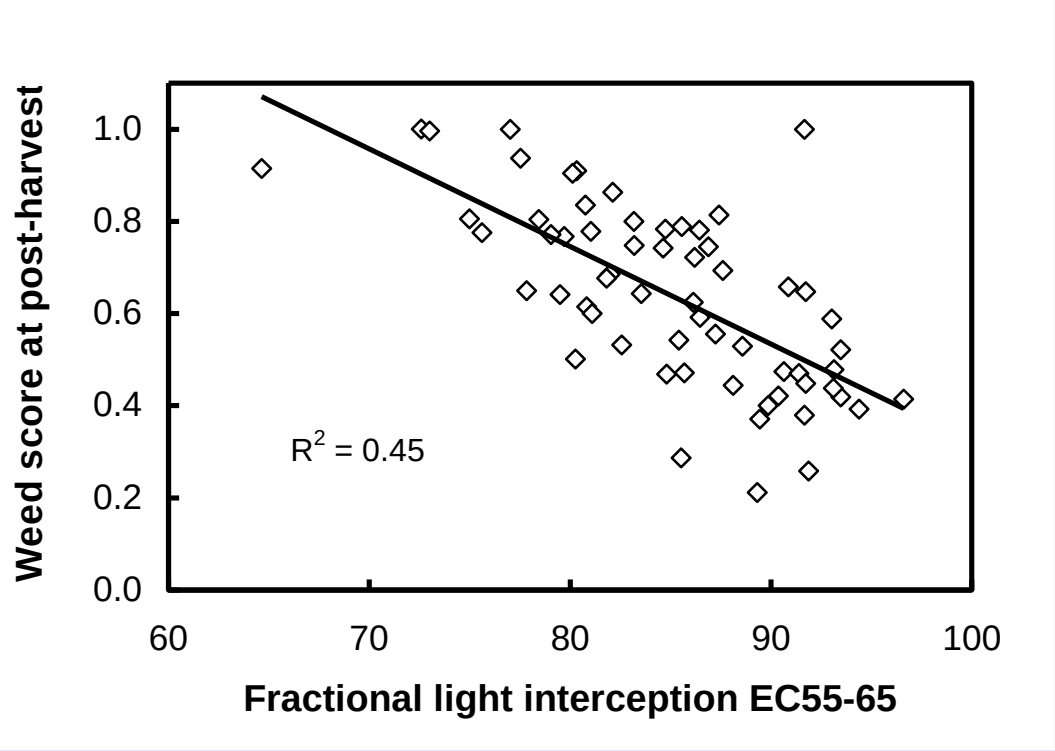


The effect of crop ground cover (%) at ear emergence on weed growth at ear emergence (upper figure) and harvest (lower figure).

Data are means for each of 15 wheat varieties across three seasons.

Hoad, Neuhoff & Davies, 2005

Increased shading ability reduces weed growth

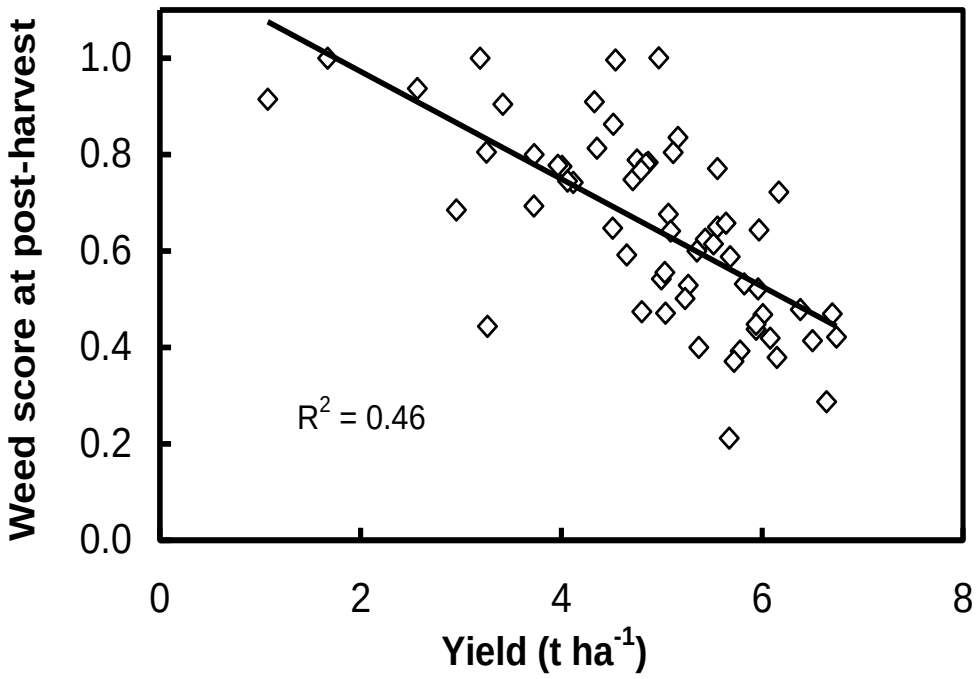


Weed growth at harvest as influenced by crop fractional light interception (shading ability) at ear emergence / flowering.

Data are means for each of 15 wheat varieties across three seasons.

Hoad, Davies & Topp, 2006

Weed growth and grain yield



Relationship between weed growth and grain yield.

Data are means for each of 15 wheat varieties across three seasons.

Hoad, Davies & Topp, 2006

2. Genotype and seasonal influences as observed in crop-weed experiments

Genotype and seasonal variation in yield

ANOVA of 15 varieties across three years.

	% SS_{Total}	v.r.	F pr.
Variety	17.9	5.98	<0.001
Season	31.8	74.22	<0.001
Variety x season	12.1	2.02	<0.004

Genotype and seasonal variation in (a) plant height and (b) shoot population

(a) Height: ANOVA of 15 varieties across three years at (i) GS31 and (ii) GS85

(i)	v.r.	F pr.
Variety	40.31	<0.001
Season	267.15	<0.001
Variety x season	5.17	<0.001

(ii)	v.r.	F pr.
Variety	42.77	<0.001
Season	7.52	<0.001
Variety x season	1.16	0.29

(b) Shoot population: ANOVA of 15 varieties across three years at (i) GS31 and (ii) GS55

(i)	v.r.	F pr.
Variety	44.9	<0.001
Season	1029.86	<0.001
Variety x season	17.12	<0.001

(ii)	v.r.	F pr.
Variety	60.95	<0.001
Season	818.26	<0.001
Variety x season	30.17	<0.001

Genotype and seasonal variation in crop ground cover (CGC) %

ANOVA of 15 varieties across three years at (a) GS31 and (b) GS55

(a)	% SS_{Total}	v.r.	F pr.
Variety	17.4	41.4	<0.001
Season	19.8	32.91	<0.001
Variety x season	21.1	2.51	<0.001

(b)	% SS_{Total}	v.r.	F pr.
Variety	17.2	3.48	<0.001
Season	23.7	33.50	<0.001
Variety x season	7.4	0.76	<0.80

Genotype and seasonal variation in weed ground cover (WGC_{var}) %

ANOVA of 15 varieties across three years at (a) GS31 and (b) GS92 (harvest)

(a)	% SS_{Total}	v.r.	F pr.
Variety	0.4	0.88	0.58
Season	94.5	1559.38	<0.001
Variety x season	0.7	0.84	0.70

(b)	% SS_{Total}	v.r.	F pr.
Variety	12.1	3.37	<0.001
Season	40.1	78.47	<0.001
Variety x season	8.3	1.16	0.287

Genotype and seasonal variation in variety weed suppression (S_{var})

ANOVA of varieties across three years at (a) GS31 and (b) GS92

(a)	% SS_{Total}	v.r.	F pr.
Variety	5.6	1.05	0.41
Season	27.0	35.2	<0.01
Variety x season	15.2	1.41	0.10

(b)	% SS_{Total}	v.r.	F pr.
Variety	19.9	3.61	<0.001
Season	7.8	9.87	<0.001
Variety x season	12.9	1.16	0.278

3. Variation in weed suppression between and within genotypes

Taking a closer look at genotypic variation

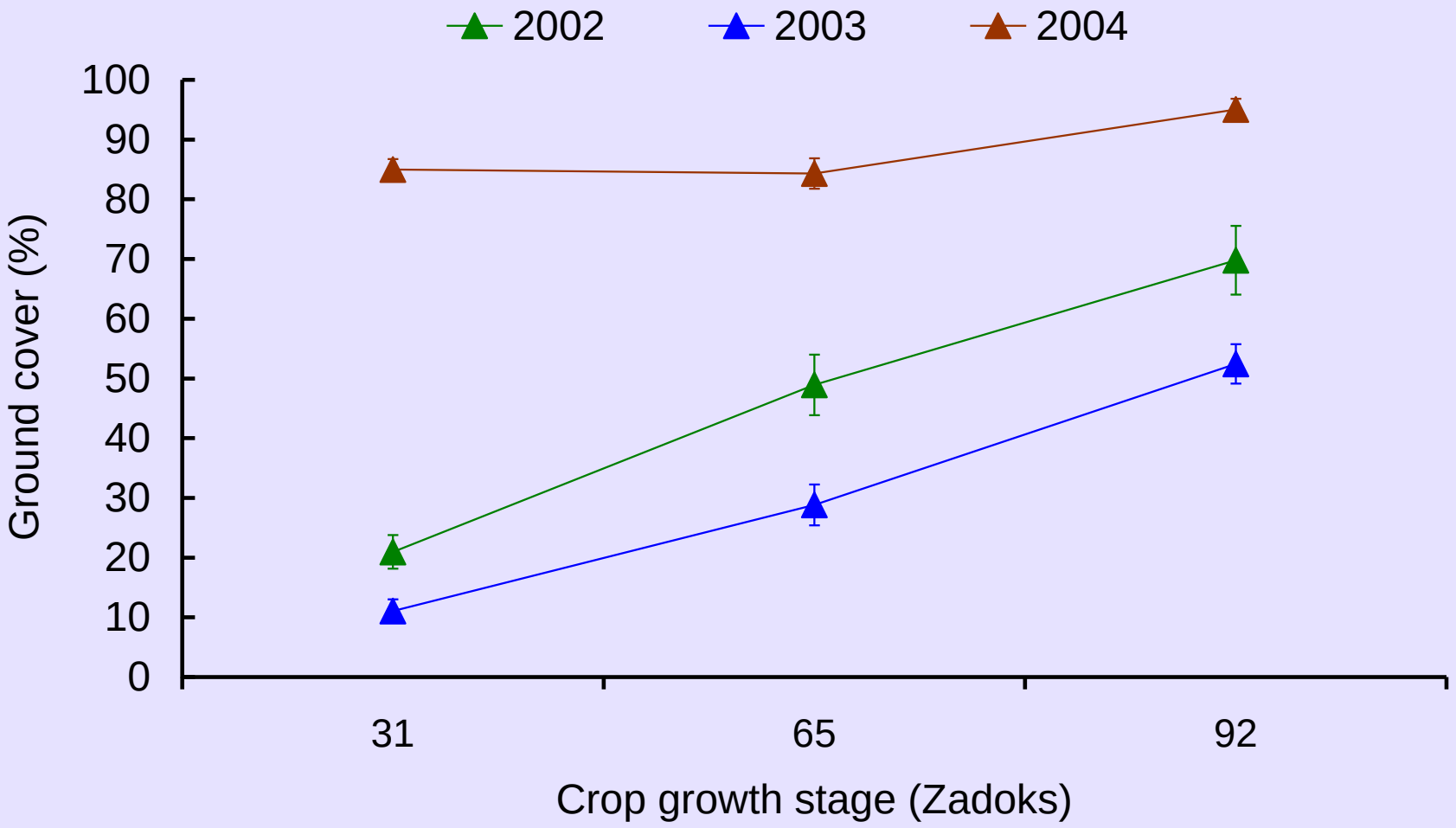
- Use of maximum weed growth (% ground cover), WGC_{max} for each block or season
- Variety effect on weed growth (% ground cover), WGC_{var}
- Variety weed suppression, S_{var}

$$S_{var} = (WGC_{max} - WGC_{var}) / WGC_{max}$$

- Sensitivity of S_{var} was estimated as the regression coefficient of S_{var} against WGC_{max}

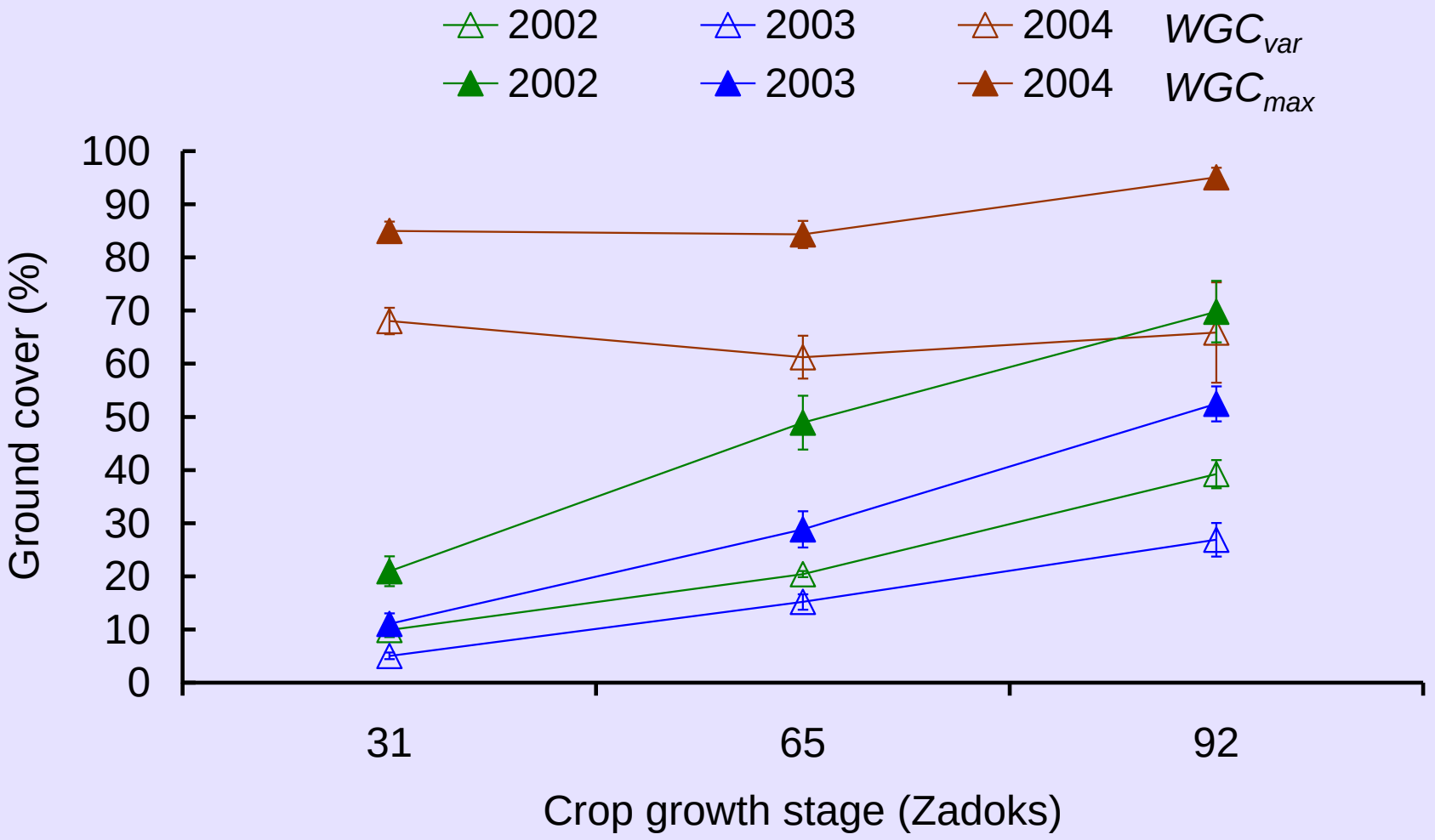
Maximum weed growth (WGC_{max})

Across all genotypes: for key growth stages in each year



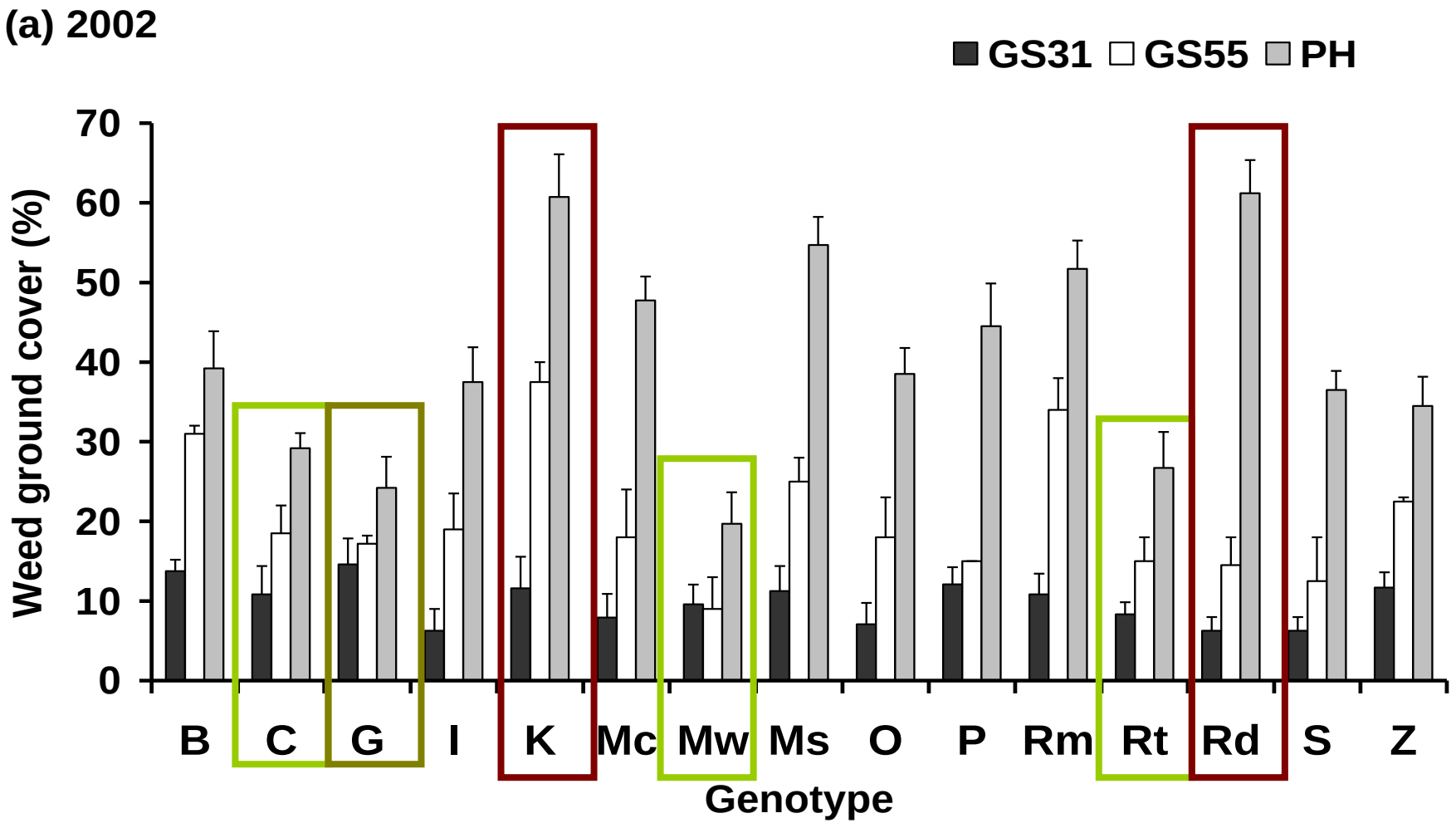
Maximum weed growth (WGC_{max}) and overall effect of genotype on weed growth (WGC_{var})

Across all genotypes: for key growth stages in each year



Variation in crop competitiveness against weeds measured as WGC_{var}

Example from harvest 2002 (WECOF)



Variation in weed suppression (S_{var}) for selected wheat varieties

Weed suppression at three growth stages. Data are means across three years, 2002 to 2004.

Variety	GS31	GS65	GS92
M. Widgeon	0.47	0.63	0.56
Rialto	0.53	0.56	0.60
Gerald	0.30	0.52	0.64
Chablis	0.44	0.53	0.48
Zyta	0.36	0.43	0.49
Pegassos	0.33	0.45	0.40
Batis	0.44	0.46	0.42
Isengrain	0.41	0.39	0.27
Marius	0.43	0.35	0.28
Ramiro	0.36	0.18	0.20

How sensitive is a genotype's ability to suppress weed (S_{var}) to changes in weed growth?

- Sensitivity was measured as a regression coefficient i.e. change in suppression of each variety (S_{var}) with mean weed growth (WGC_{max})
- Generally S_{var} decreased as WGC_{max} increased i.e. sensitivity in weed suppression was a negative value
- Sensitivity was estimated for key growth across three years

How sensitive is a genotype's ability to suppress weed (S_{var}) to changes in weed growth?

Sensitivity of weed suppression (S_{var}) at three growth stages. Data are means across three years, 2002 to 2004.

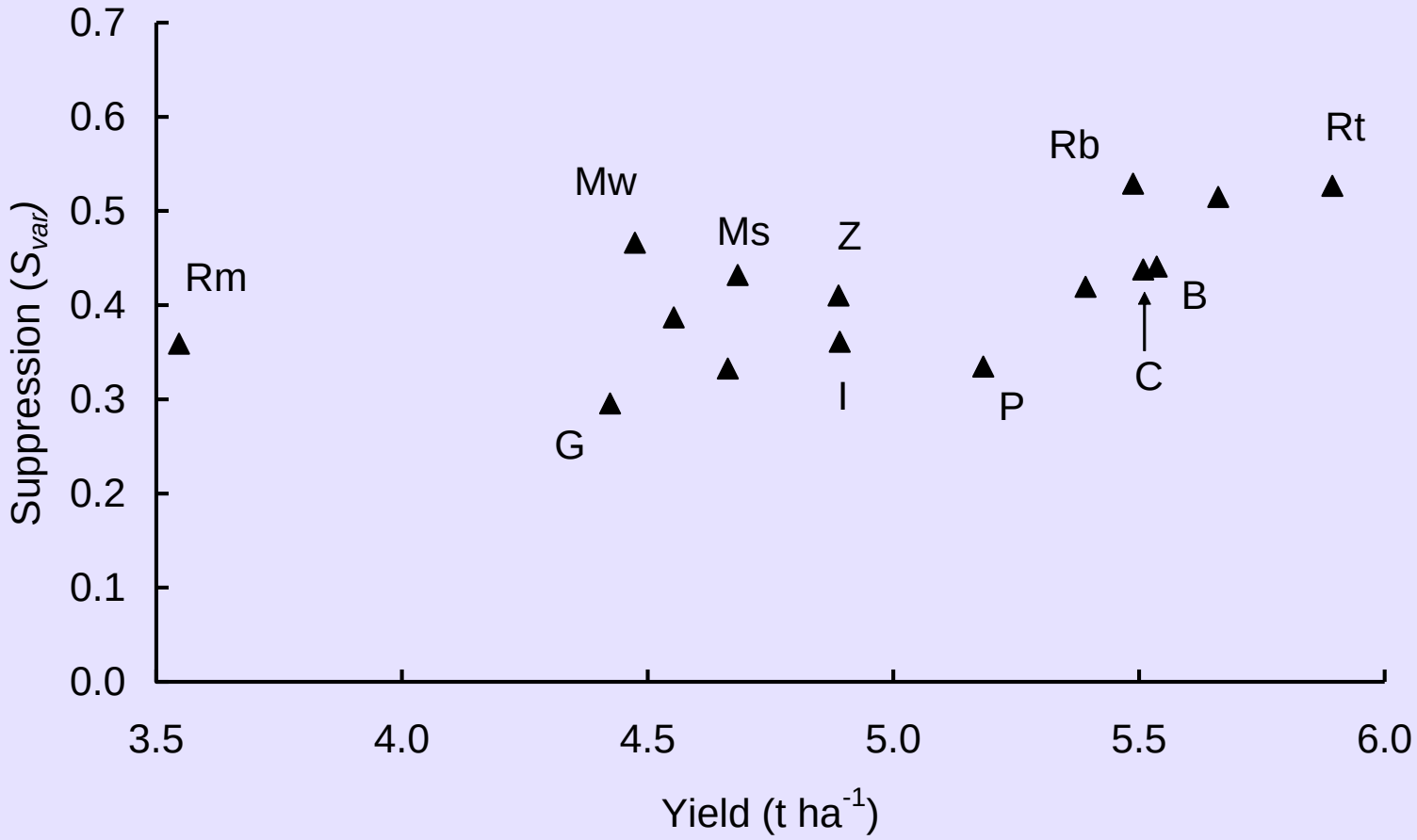
Variety	GS31	GS65	GS92
M. Widgeon	-0.48	-0.57	-0.58
Rialto	-0.59	-0.25	-0.18
Gerald	-0.34	-0.25	-0.11
Chablis	-0.34	-0.22	0.18
Zyta	-0.29	-0.28	-0.59
Pegassos	-0.35	-0.11	0.10
Batis	-0.53	-0.34	-0.47
Isengrain	-0.35	-0.26	-0.19
Marius	-0.48	-0.42	-0.38
Ramiro	-0.30	0.25	-0.21

4. Working towards selection and evaluation

(Considering weed suppression and yield)

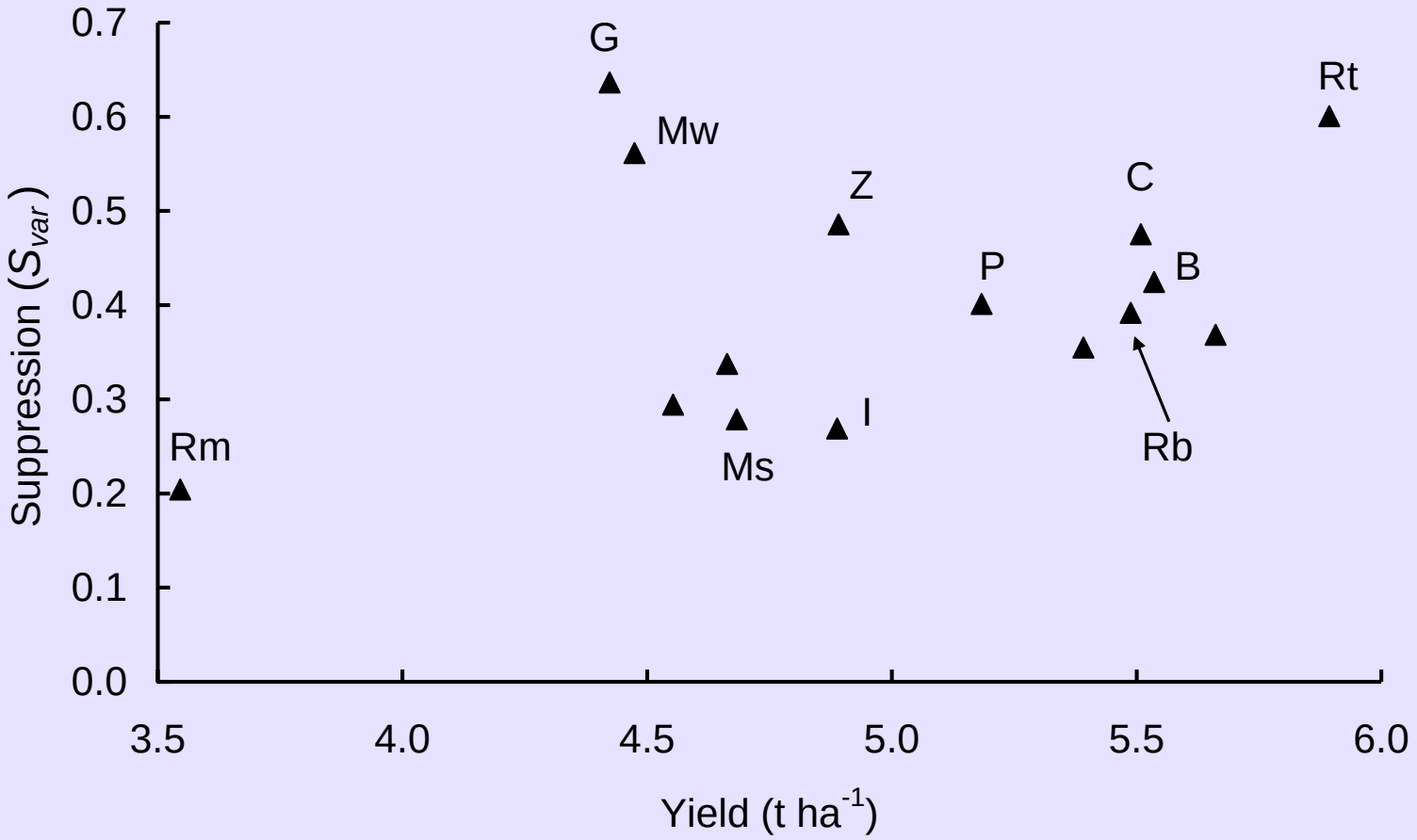
Relationship between weed suppression (S_{var}) at GS31 and grain yield

Weed suppression ability in 15 genotypes measured at the start of stem extension. Data are the mean of three seasons.



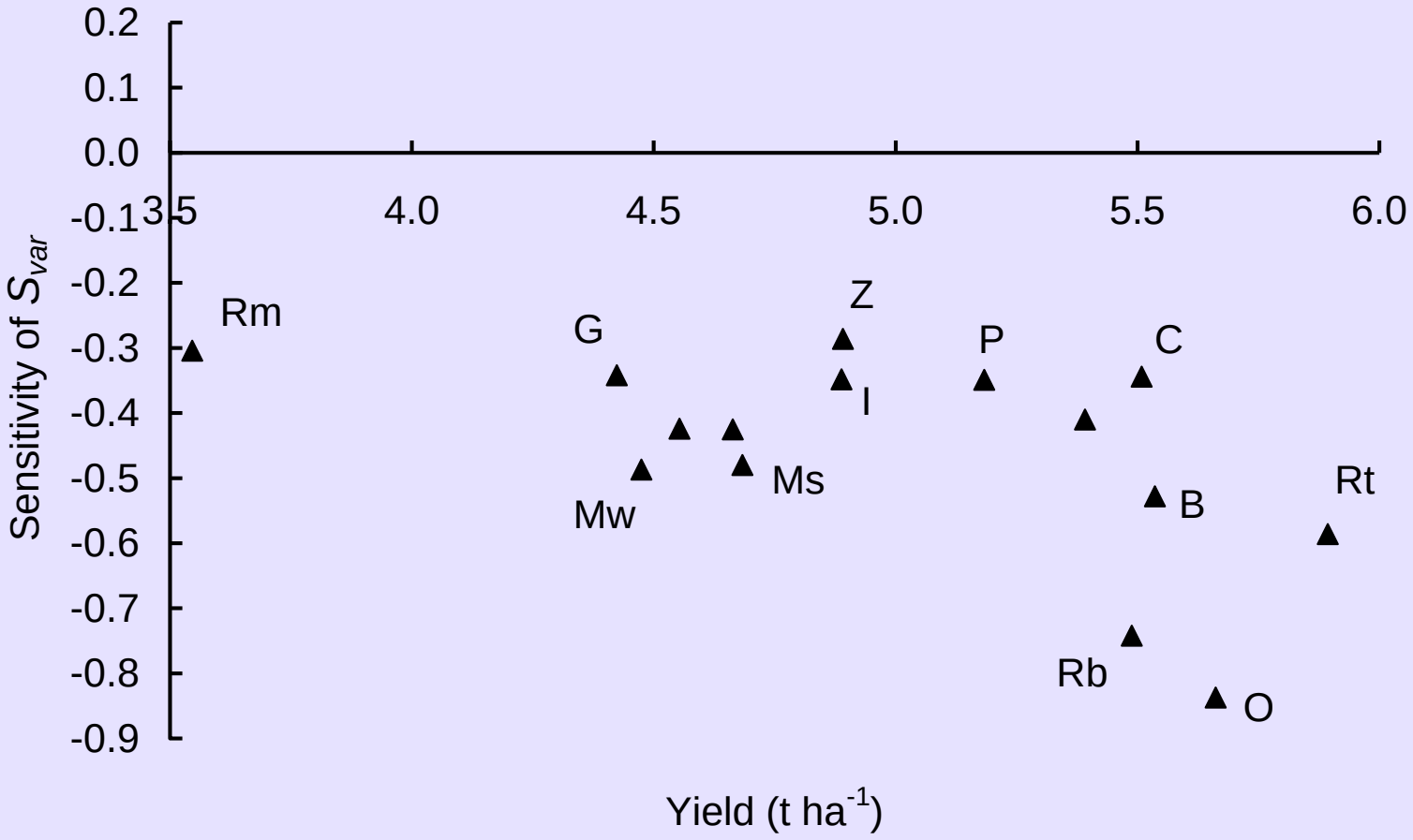
Relationship between weed suppression (S_{var}) at GS92 and grain yield

Weed suppression ability in 15 genotypes measured at harvest. Data are the mean of three seasons.



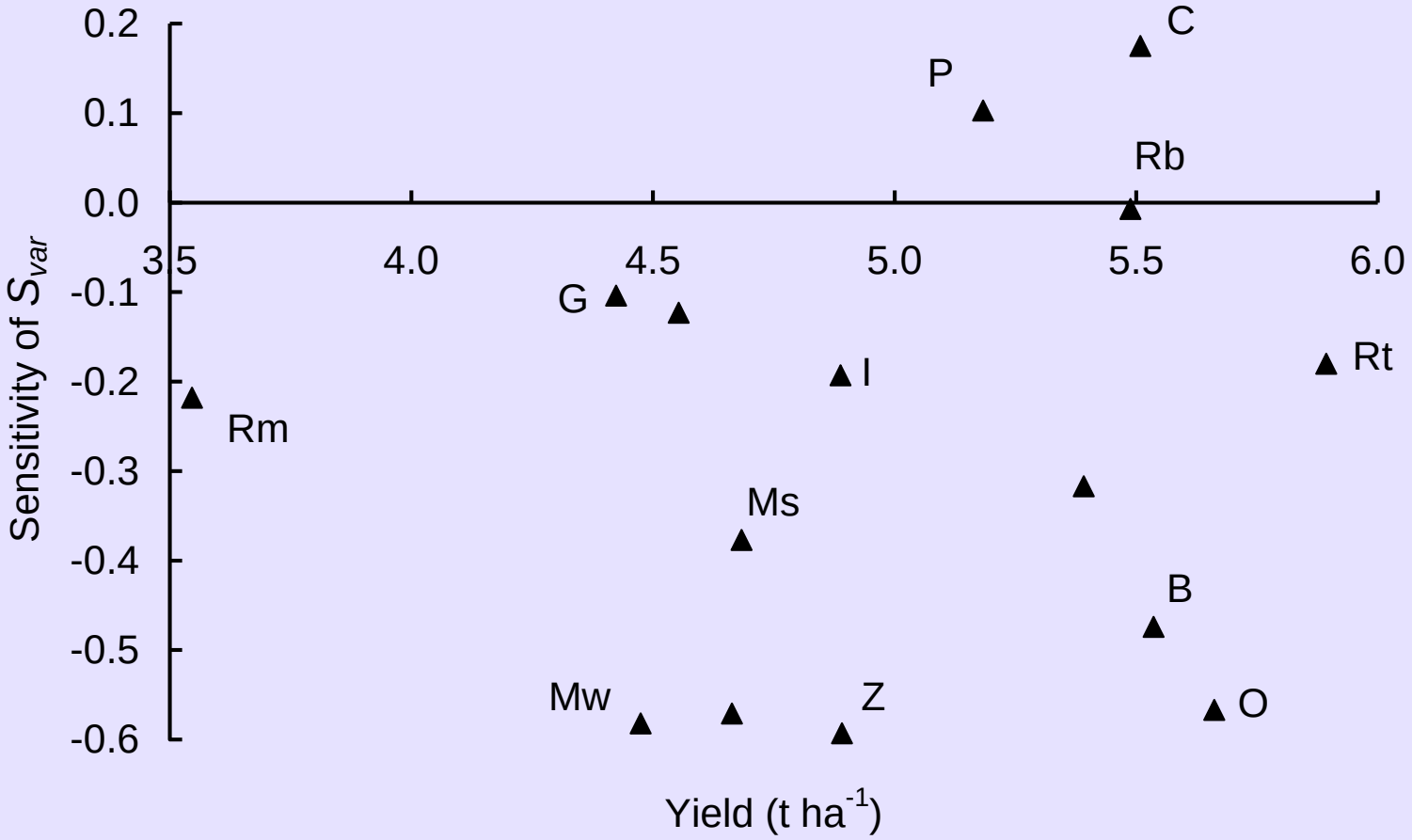
Relationship between suppression (S_{var}) sensitivity at GS31 and grain yield

Sensitivity was estimated as the regression coefficient from S_{var} plotted against maximal weed growth (WGC_{max})



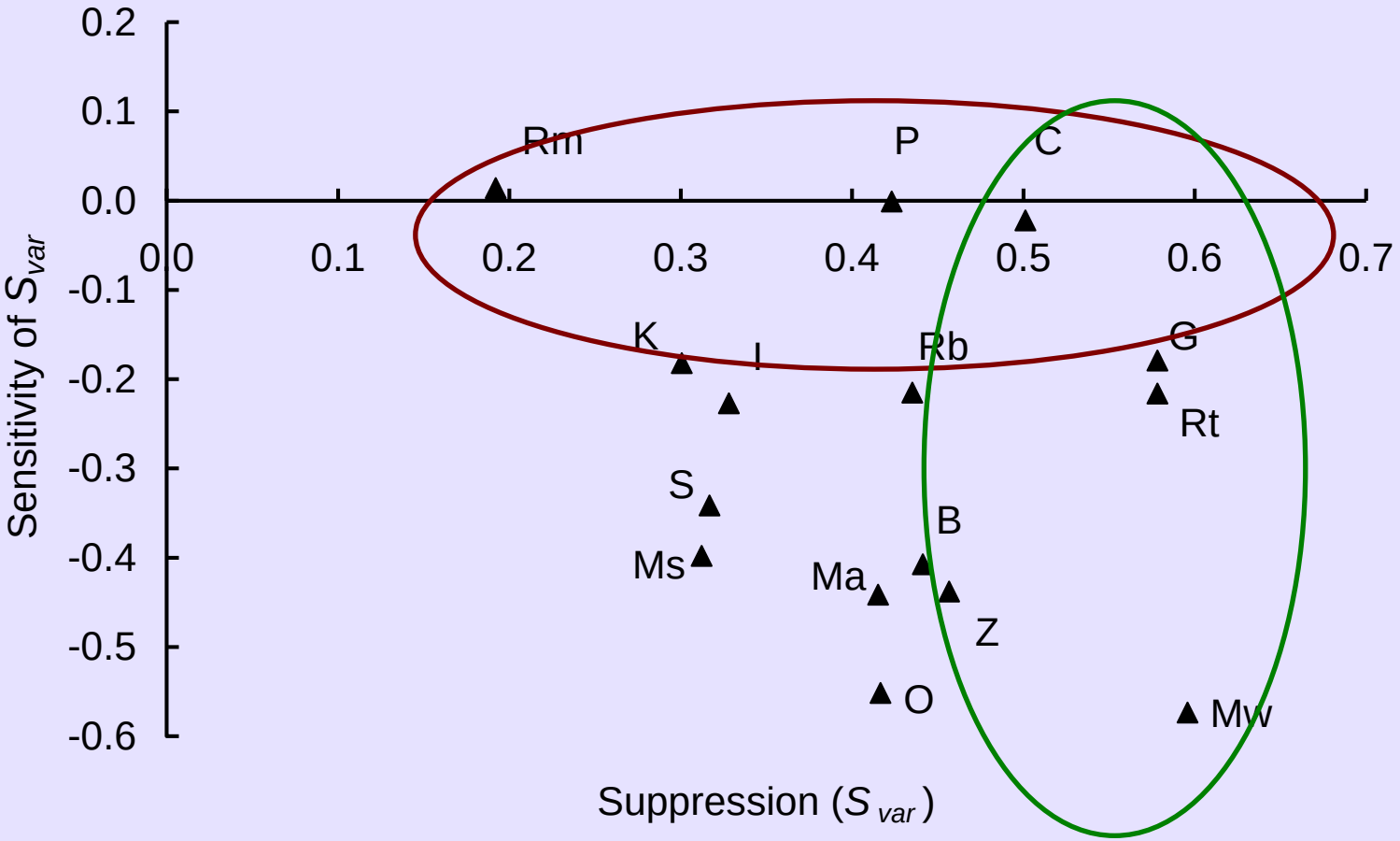
Relationship between suppression (S_{var}) sensitivity at GS92 and grain yield

Sensitivity was estimated as the regression coefficient from S_{var} plotted against maximal weed growth (WGC_{max})



Towards selection by understanding S_{var} and its sensitivity to weed growth

Data are the combined values of S_{var} for GS65 and GS92 i.e. representing late season effects of genotype on weed growth



Working towards evaluation and selection for weed suppression

- Some general relationships between crop competitive ability have been established
- However, selection and testing need to take into account large seasonal and site effects on weed and crop growth
- Genotypes could be selected using a score of WGC_{var}
- And, varietal weed suppression (S_{var}) could be used to evaluate genotypes across sites & seasons

Working towards evaluation and selection for weed suppression

- Scores made late in the season appear to be good indicators of weed suppression, though seasonal effects on WGC_{max} and S_{var} are highly significant
- Therefore, the sensitivity of a genotype's ability to suppress weeds (e.g. S_{var}) should be taken into account
- Select genotypes with low WGC_{var} or high S_{var} and / or low sensitivity in S_{var} to increasing weed growth (e.g. WGC_{max})

Acknowledgements

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