

Plasticity of barley in response to plant neighbors in cultivar mixtures

Plant and Soil

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Mean values of plant functional traits

Table 1. Mean values ($\pm$ SEM) of plant functional traits of cultivars Salome (S), Anakin (A), Fairytale (F), Luhkas (L) and Rosalina (R) grown in pure stands (single letter) or together with another cultivar (x with y; the first letter indicating the focal cultivar and the second letter indicating the neighbor cultivar) in field experiments in Central-Eastern Sweden in 2015 and 2016

	2015				2016			
	S	S with A	A	A with S	S	S with A	A	A with S
Growth stage ^S	48 $\pm$ 0.5	27 $\pm$ 5.2	44 $\pm$ 2.7	35 $\pm$ 4.6	41 $\pm$ 1.7	40 $\pm$ 1.8	43 $\pm$ 1.3	42 $\pm$ 1.6
Shoots [‡] plant ⁻¹	1.4 $\pm$ 0.06	1.2 $\pm$ 0.07	1.3 $\pm$ 0.08	1.2 $\pm$ 0.05	2.6 $\pm$ 0.1	2.7 $\pm$ 0.2	2.3 $\pm$ 0.1	2.5 $\pm$ 0.2
SLA [#] (cm ² g ⁻¹)	233 $\pm$ 4.8	243 $\pm$ 4.6	236 $\pm$ 7.2	234 $\pm$ 6.6	-	-	-	-
SPAD flag leaf [#]	34 $\pm$ 1.0	32 $\pm$ 1.3	28 $\pm$ 1.3	29 $\pm$ 1.2	40 $\pm$ 1.1	37 $\pm$ 1.2	39 $\pm$ 1.1	36 $\pm$ 1.4
SPAD 2 nd leaf [#]	36 $\pm$ 0.9	37 $\pm$ 1.0	33 $\pm$ 0.9	33 $\pm$ 0.8	47 $\pm$ 0.8	46 $\pm$ 0.8	44 $\pm$ 0.8	45 $\pm$ 0.8
Biomass [†] (g plant ⁻¹)	0.06 $\pm$ 0.007	0.05 $\pm$ 0.003	0.06 $\pm$ 0.003	0.05 $\pm$ 0.005	0.08 $\pm$ 0.010	0.09 $\pm$ 0.009	0.09 $\pm$ 0.01	0.09 $\pm$ 0.008
Biomass [#] (g plant ⁻¹)	0.03 $\pm$ 0.001	0.03 $\pm$ 0.002	0.03 $\pm$ 0.001	0.03 $\pm$ 0.002	1.5 $\pm$ 0.02	1.5 $\pm$ 0.02	1.5 $\pm$ 0.03	1.5 $\pm$ 0.06
Biomass [€] (g plant ⁻¹)	0.7 $\pm$ 0.03	0.7 $\pm$ 0.04	0.8 $\pm$ 0.04	0.9 $\pm$ 0.04	0.9 $\pm$ 0.06	1.0 $\pm$ 0.09	0.9 $\pm$ 0.03	1.1 $\pm$ 0.09
Height (cm)	8.8 $\pm$ 0.4	7.3 $\pm$ 0.3	9.0 $\pm$ 0.41	7.4 $\pm$ 0.3	-	-	-	-
Height ^S (cm)	34.8 $\pm$ 1.1	32.7 $\pm$ 1.3	42.5 $\pm$ 1.5	31.9 $\pm$ 1.6	29.6 $\pm$ 1.1	27.2 $\pm$ 0.9	32.6 $\pm$ 0.9	28.5 $\pm$ 1.0
Height [#] (cm)	47.9 $\pm$ 0.8	47.5 $\pm$ 1.1	52.9 $\pm$ 0.9	50.0 $\pm$ 0.8	47.2 $\pm$ 0.9	48.8 $\pm$ 1.1	50.3 $\pm$ 1.0	49.2 $\pm$ 1.3
Internode [#] 4 th (cm)	12.1 $\pm$ 0.3	12.2 $\pm$ 0.3	11.2 $\pm$ 0.4	11.8 $\pm$ 0.3	10.7 $\pm$ 0.5	9.8 $\pm$ 0.4	9.1 $\pm$ 0.5	9.8 $\pm$ 0.6
N leaves [†] (mg plant ⁻¹)	2.0 $\pm$ 0.3	1.3 $\pm$ 0.1	1.9 $\pm$ 0.2	1.7 $\pm$ 0.2	3.6 $\pm$ 0.7	4.0 $\pm$ 0.6	3.6 $\pm$ 0.7	3.8 $\pm$ 0.6
N leaves [#] (mg plant ⁻¹)	17 $\pm$ 2.0	17 $\pm$ 2.0	14 $\pm$ 2.0	17 $\pm$ 2.0	44 $\pm$ 2.0	44 $\pm$ 2.0	46 $\pm$ 3.0	47 $\pm$ 4.0
N grains [€] (mg plant ⁻¹)	30 $\pm$ 0.7	20 $\pm$ 0.8	20 $\pm$ 1.0	20 $\pm$ 0.5	50 $\pm$ 7.0	40 $\pm$ 10	20 $\pm$ 3.0	50 $\pm$ 8.0
N acc eff (NAE) [€]	23.4 $\pm$ 0.8	17.5 $\pm$ 2.4	17.3 $\pm$ 2.0	18.4 $\pm$ 1.0	18.0 $\pm$ 2.9	18.8 $\pm$ 4.7	12.7 $\pm$ 1.5	16.3 $\pm$ 2.9
N uptake eff (U _N) [€]	11.7 $\pm$ 1.1	11.3 $\pm$ 1.1	7.7 $\pm$ 1.0	8.9 $\pm$ 1.0	31.0 $\pm$ 1.1	30.5 $\pm$ 1.5	26.7 $\pm$ 1.3	25.1 $\pm$ 2.3
Yield N eff (EN _y) [€]	87.8 $\pm$ 13	70.2 $\pm$ 5	103.2 $\pm$ 13	93.3 $\pm$ 8	12.0 $\pm$ 1.0	15.1 $\pm$ 2.3	21.6 $\pm$ 2.2	14.5 $\pm$ 1.8
Grain mass [€] (g plant ⁻¹)	1.2 $\pm$ 0.05	1.0 $\pm$ 0.08	1.2 $\pm$ 0.08	1.2 $\pm$ 0.07	1.8 $\pm$ 0.13	1.9 $\pm$ 0.15	1.6 $\pm$ 0.05	1.9 $\pm$ 0.14
	2015				2016			
	S	S with F	F	F with S	S	S with F	F	F with S
Growth stage ^S	48 $\pm$ 0.5	28 $\pm$ 5.4	45 $\pm$ 0.8	36 $\pm$ 4.0	41 $\pm$ 1.7	39 $\pm$ 0.7	40 $\pm$ 1.0	40 $\pm$ 0.8
Shoots [‡] plant ⁻¹	1.4 $\pm$ 0.06	1.4 $\pm$ 0.1	1.7 $\pm$ 0.1	1.4 $\pm$ 0.2	2.6 $\pm$ 0.1	2.6 $\pm$ 0.1	2.4 $\pm$ 0.1	2.6 $\pm$ 0.1
SLA [#] (cm ² g ⁻¹)	233 $\pm$ 4.8	242 $\pm$ 4.0	251 $\pm$ 7.8	229 $\pm$ 4.6	-	-	-	-
SPAD flag leaf [#]	34 $\pm$ 1.0	32 $\pm$ 1.1	33 $\pm$ 1.2	32 $\pm$ 1.1	40 $\pm$ 1.1	40 $\pm$ 1.1	40 $\pm$ 1.3	39 $\pm$ 1.6

SPAD 2 nd leaf [#]	36 ± 0.9	37 ± 0.9	37 ± 0.8	37 ± 0.9	47 ± 0.8	47 ± 0.8	46 ± 0.8	47 ± 0.8
Biomass [†] (g plant ⁻¹)	0.06 ± 0.007	0.05 ± 0.004	0.05 ± 0.007	0.04 ± 0.004	0.08 ± 0.01	0.09 ± 0.01	0.07 ± 0.007	0.08 ± 0.008
Biomass [#] (g plant ⁻¹)	0.03 ± 0.001	0.04 ± 0.002	0.03 ± 0.002	0.03 ± 0.002	1.5 ± 0.02	1.6 ± 0.04	1.4 ± 0.02	1.5 ± 0.06
Biomass ^ε (g plant ⁻¹)	0.7 ± 0.03	0.8 ± 0.06	0.9 ± 0.05	0.8 ± 0.08	0.9 ± 0.06	1.0 ± 0.03	0.8 ± 0.04	1.0 ± 0.05
Height [‡] (cm)	8.8 ± 0.4	7.3 ± 0.4	9.9 ± 0.5	7.9 ± 0.4	-	-	-	-
Height [§] (cm)	34.8 ± 1.1	28.8 ± 1.6	44.7 ± 1.4	30.3 ± 1.7	29.6 ± 1.1	28.4 ± 1.1	32.2 ± 1.1	30.9 ± 1.0
Height [#] (cm)	47.9 ± 0.8	49.5 ± 1.1	52.4 ± 1.1	49.1 ± 1.5	47.2 ± 0.9	48.2 ± 1.5	49.8 ± 1.2	49.9 ± 1.3
Internode [#] 4 th (cm)	12.1 ± 0.3	12.0 ± 0.4	12.5 ± 0.4	11.4 ± 0.5	10.7 ± 0.5	11.2 ± 0.6	11.3 ± 0.5	11.8 ± 0.4
N leaves [†] (mg plant ⁻¹)	2.0 ± 0.3	1.7 ± 0.2	1.9 ± 0.3	1.5 ± 0.2	3.6 ± 0.7	3.8 ± 0.5	3.4 ± 0.5	3.3 ± 0.6
N leaves [#] (mg plant ⁻¹)	17 ± 2.0	20 ± 3.0	18 ± 2.0	18 ± 2.0	44 ± 2.0	47 ± 2.0	46 ± 3.0	46 ± 2.0
N grains ^ε (mg plant ⁻¹)	30 ± 0.7	20 ± 0.7	20 ± 1.0	20 ± 1.0	50 ± 7.0	40 ± 4.0	40 ± 3.0	40 ± 3.0
N acc eff (NAE) ^ε	23.4 ± 0.8	20.5 ± 3.2	23.9 ± 2.3	23.3 ± 4.4	18.0 ± 2.9	18.6 ± 1.6	14.2 ± 1.3	16.1 ± 2.1
N uptake eff (U _N) ^ε	11.7 ± 1.1	13.7 ± 2.1	13.2 ± 1.5	12.8 ± 1.8	31.0 ± 1.1	33.0 ± 1.1	33.4 ± 2.7	34.5 ± 1.3
Yield N eff (EN _Y) ^ε	87.8 ± 13	70.7 ± 11	90.0 ± 9	83.6 ± 12	12.0 ± 1.0	14.1 ± 2.1	10.7 ± 1.3	11.7 ± 1.2
Grain mass ^ε (g plant ⁻¹)	1.2 ± 0.05	1.2 ± 0.10	1.3 ± 0.08	1.1 ± 0.13	1.8 ± 0.13	1.8 ± 0.07	1.4 ± 0.08	1.7 ± 0.10

	2015				2016			
	S	S with L	L	L with S	S	S with L	L	L with S
Growth stage [§]	48 ± 0.5	31 ± 5.3	49 ± 0.6	46 ± 0.8	41 ± 1.7	40 ± 1.5	43 ± 1.6	41 ± 1.4
Shoots [‡] plant ⁻¹	1.4 ± 0.06	1.4 ± 0.07	1.3 ± 0.06	1.1 ± 0.09	2.6 ± 0.1	2.4 ± 0.2	2.3 ± 0.1	2.2 ± 0.2
SLA [#] (cm ² g ⁻¹)	233 ± 4.8	244 ± 5.0	220 ± 4.4	213 ± 4.9	-	-	-	-
SPAD flag leaf [#]	34 ± 1.0	36 ± 0.9	34 ± 1.0	33 ± 1.4	40 ± 1.1	40 ± 0.9	38 ± 1.3	40 ± 1.4
SPAD 2 nd leaf [#]	36 ± 0.9	38 ± 1.0	38 ± 0.9	37 ± 1.2	47 ± 0.8	47 ± 1.0	48 ± 0.7	49 ± 0.7
Biomass [†] (g plant ⁻¹)	0.06 ± 0.007	0.06 ± 0.005	0.06 ± 0.005	0.05 ± 0.004	0.08 ± 0.01	0.10 ± 0.006	0.08 ± 0.008	0.09 ± 0.01
Biomass [#] (g plant ⁻¹)	0.03 ± 0.001	0.04 ± 0.002	0.04 ± 0.002	0.04 ± 0.002	1.5 ± 0.02	1.5 ± 0.06	1.5 ± 0.06	1.5 ± 0.05
Biomass ^ε (g plant ⁻¹)	0.7 ± 0.03	0.7 ± 0.04	0.7 ± 0.03	0.6 ± 0.05	0.9 ± 0.06	0.9 ± 0.10	0.8 ± 0.07	0.8 ± 0.08
Height [‡] (cm)	8.8 ± 0.4	7.5 ± 0.3	12.6 ± 0.7	9.7 ± 0.4	-	-	-	-
Height [§] (cm)	34.8 ± 1.1	37.0 ± 1.4	45.4 ± 1.4	36.7 ± 1.3	29.6 ± 1.1	28.6 ± 1.1	34.4 ± 1.0	33.5 ± 1.1
Height [#] (cm)	47.9 ± 0.8	50.2 ± 1.1	50.2 ± 1.1	49.3 ± 1.1	47.2 ± 0.9	48.8 ± 1.5	50.3 ± 1.0	50.1 ± 1.3
Internode [#] 4 th (cm)	12.1 ± 0.3	12.7 ± 0.5	11.8 ± 0.4	11.7 ± 0.4	10.7 ± 0.5	11.1 ± 0.4	11.0 ± 0.3	10.9 ± 0.3
N leaves [†] (mg plant ⁻¹)	2.0 ± 0.3	1.7 ± 0.3	2.1 ± 0.3	1.7 ± 0.2	3.6 ± 0.7	3.4 ± 0.5	3.4 ± 0.5	3.9 ± 0.7
N leaves [#] (mg plant ⁻¹)	17 ± 2.0	19 ± 3.0	21 ± 2.0	19 ± 3.0	44 ± 2.0	44 ± 2.0	48 ± 2.0	46 ± 3.0
N grains ^ε (mg plant ⁻¹)	30 ± 0.7	20 ± 0.5	30 ± 1.0	20 ± 1.0	50 ± 7.0	40 ± 4.0	50 ± 8.0	40 ± 4.0
N acc eff (NAE) ^ε	23.4 ± 0.8	19.7 ± 1.2	25.5 ± 2.6	19.2 ± 2.4	18.0 ± 2.9	15.3 ± 2.9	20.9 ± 4.1	12.8 ± 3.1
N uptake eff (U _N) ^ε	11.7 ± 1.1	13.0 ± 2.4	15.3 ± 1.6	13.7 ± 2.5	31.0 ± 1.1	31.9 ± 1.8	35.3 ± 1.3	35.3 ± 3.1
Yield N eff (EN _Y) ^ε	87.8 ± 13	75.4 ± 12	67.0 ± 7.8	61.5 ± 6.8	12.0 ± 1.0	12.8 ± 1.7	11.4 ± 0.9	11.1 ± 3.4
Grain mass ^ε (g plant ⁻¹)	1.2 ± 0.05	1.2 ± 0.08	1.1 ± 0.07	1.0 ± 0.08	1.8 ± 0.13	1.7 ± 0.17	1.6 ± 0.14	1.6 ± 0.16

	2015				2016			
	S	S with R	R	R with S	S	S with R	R	R with S
Growth stage [§]	48 ± 0.5	34 ± 4.5	42 ± 4.0	34 ± 4.5	41 ± 1.7	38 ± 1.4	40 ± 1.4	39 ± 1.3
Shoots [‡] plant ⁻¹	1.4 ± 0.06	1.6 ± 0.1	1.3 ± 0.1	1.6 ± 0.1	2.6 ± 0.1	2.6 ± 0.2	2.5 ± 0.1	2.8 ± 0.2
SLA [#] (cm ² g ⁻¹)	233 ± 4.8	226 ± 3.5	214 ± 4.7	216 ± 4.5	-	-	-	-
SPAD flag leaf [#]	34 ± 1.0	35 ± 1.1	34 ± 1.3	31 ± 1.5	40 ± 1.1	42 ± 0.9	39 ± 1.4	40 ± 0.9
SPAD 2 nd leaf [#]	36 ± 0.9	39 ± 0.9	39 ± 1.1	39 ± 1.5	47 ± 0.8	49 ± 0.8	47 ± 1.1	49 ± 0.6

Biomass [†] (g plant ⁻¹)	0.06 ± 0.007	0.05 ± 0.004	0.05 ± 0.004	0.05 ± 0.004	0.08 ± 0.010	0.09 ± 0.008	0.09 ± 0.005	0.08 ± 0.006
Biomass [#] (g plant ⁻¹)	0.03 ± 0.001	0.03 ± 0.001	0.03 ± 0.002	0.03 ± 0.002	1.5 ± 0.02	1.6 ± 0.04	1.5 ± 0.02	1.6 ± 0.06
Biomass [€] (g plant ⁻¹)	0.7 ± 0.03	1.0 ± 0.08	0.7 ± 0.04	1.0 ± 0.06	0.9 ± 0.06	1.1 ± 0.07	0.8 ± 0.04	1.0 ± 0.08
Height ^{!!} (cm)	8.8 ± 0.4	7.0 ± 0.3	8.4 ± 0.3	6.9 ± 0.3	-	-	-	-
Height [§] (cm)	34.8 ± 1.1	31.5 ± 1.3	33.7 ± 1.9	25.9 ± 1.5	29.6 ± 1.1	27.1 ± 0.9	31.2 ± 1.0	28.4 ± 1.2
Height [#] (cm)	47.9 ± 0.8	48.3 ± 0.8	49.4 ± 1.6	48.3 ± 1.0	47.2 ± 0.9	48.8 ± 1.1	47.8 ± 1.1	47.6 ± 1.1
Internode [#] 4 th (cm)	12.1 ± 0.3	12.3 ± 0.3	11.4 ± 0.3	11.4 ± 0.3	10.7 ± 0.5	10.4 ± 0.5	10.2 ± 0.4	9.7 ± 0.4
N leaves [†] (mg plant ⁻¹)	2.0 ± 0.3	1.7 ± 0.3	1.6 ± 0.2	1.7 ± 0.3	3.6 ± 0.7	4.0 ± 0.6	3.8 ± 0.5	4.0 ± 0.6
N leaves [#] (mg plant ⁻¹)	17 ± 2.0	22 ± 4.0	16 ± 4.0	19 ± 2.0	44 ± 2.0	51 ± 3.0	45 ± 1.0	51 ± 5.0
N grains [€] (mg plant ⁻¹)	30 ± 0.7	20 ± 0.7	30 ± 1.0	30 ± 0.9	50 ± 7.0	50 ± 7.0	60 ± 7.0	50 ± 3.0
N acc eff (NAE) [€]	23.4 ± 0.8	30.6 ± 4.7	25.3 ± 3.7	33.5 ± 4.2	18.0 ± 2.9	21.4 ± 3.5	22.2 ± 3.0	23.5 ± 4.1
N uptake eff (U _N) [€]	11.7 ± 1.1	14.8 ± 2.5	13.3 ± 3.5	15.5 ± 1.8	31.0 ± 1.1	34.8 ± 2.6	37.2 ± 1.3	43.6 ± 3.5
Yield N eff (EN _Y) [€]	87.8 ± 13	96.9 ± 15	82.9 ± 12	88.8 ± 8.9	12.0 ± 1.0	11.4 ± 0.7	10.9 ± 0.9	11.8 ± 1.6
Grain mass [€] (g plant ⁻¹)	1.2 ± 0.05	1.5 ± 0.12	1.2 ± 0.08	1.6 ± 0.11	1.8 ± 0.13	2.0 ± 0.12	1.7 ± 0.09	1.9 ± 0.16

Abbreviations: SLA – Specific leaf area; SPAD – reading from a ‘Soil-plant analyses development’ meter; NAE – Nitrogen accumulation efficiency; U_N – Nitrogen uptake efficiency; EN_Y – Grain-specific nitrogen efficiency (see Materials and Methods for details)

[†] 24 days after sowing (das); [‡] 38 das; ^{!!} 40 das; [§] 52 das; [#] 68 das; [€] 110 das