Reducing initial aphid infestation by use of coloured mulch foils and newly developed biodegradable spray-films

Supplementary dataset

Results

1st Evaluation (alate aphids only)

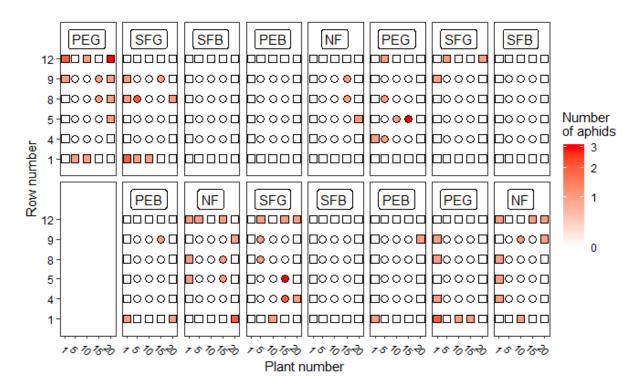


Fig.S1 Heatmap for the number of alate aphids (May 16, 2018) with overview over all evaluated lettuce plants (n=450). Five treatments with three replications each on 15 randomized plots (n=30 per plot). Number of alate aphids found in the 1st evaluation is represented by increasing colour hue. Evaluated plants are indicated by plant number (x-axis) and row number (y-axis). Outer plants at the edge to bare soil are shown as square dots, plants surrounded by other plants, as round dots. Orientation is north to south (from left to right).

Figure S1 shows the intensity of initial infestation by alate aphids (*N. ribisnigri* and *M. euphorbiae* in relation 57% to 43%) for every evaluated plant by increasing colour hue. In all treatments, more alate aphids on outer plants than on plants in the centre of the plots were counted, (except for SFB, because there were no alate aphids at all), but the ANOVA (**Tab.S2**) did not show statistical significance (p-value=0.55) for a location effect neither on average, nor within the plots (p-value=0.79). The mean ratios of counted aphids between inner and outer plants for each treatment are given in **Tab.S6**. As for the total number of aphids, only the treatment effect was significant (p-value=0.002, **Tab.S2**).

The total number of infested plants by alate aphids was 21 (23%, NF), 23 (26%, PEG), 20 (22%, SFG), 5 (6%, PEB), 0 (0%, SFB).

Niemann, Menssen, Poehling (2022) Reducing initial aphid infestation by use of coloured mulch foils and newly developed biodegradable spray-films: supplementary dataset.

For the total number of aphids (*N. ribisnigri* and *M. euphorbiae*, alate and apterous) the ANOVA (**Tab.S8**) revealed significant differences (α =0.05) between the treatments (p-value <0.001) but no significance for the location (inner or centre) nor the interaction between treatment and location. Therefore, only the differences between the treatments were statistically analysed in detail.

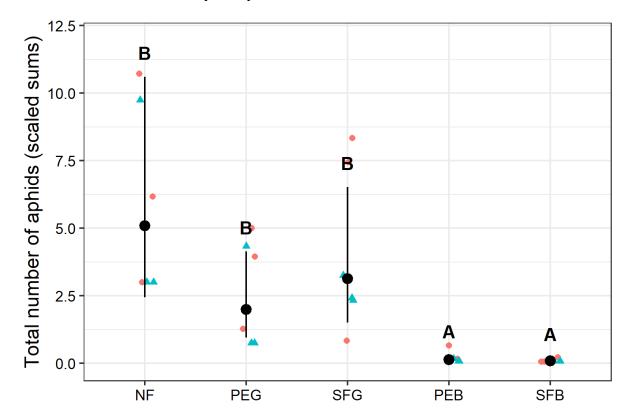


Fig.S2 Scaled sums of the total number of aphids per location in each plot (May 16, 2018). The sums were scaled to be (y+1)/n. Dots indicate sums from the border plants, triangles indicate sums from the centre of a plot. The black dots are model based least square means of the scaled sums together with their 95% confidence intervals (black bars). Treatment means that have at least one letter in common do not differ significantly (α =0.05) from each other.

Figure S2 shows the total number of aphids (alate and apterous, scaled sums) found on the lettuce plants in the first evaluation (non-destructive) for each treatment, separated into outer (dots) and inner plants (triangles) and corresponding least square means (black dots) together with their 95% confidence interval (black line), over all repetitions. Due to the scaling (y+1)/n, a sum that equals zero leads to a scaled sum of 0.083 (n=12), respective 0.056 (n=18).

The control plots (NF) showed the highest number of aphids (least square mean 5.091) followed by the treatments SFG (3.134) and PEG (1.986), which were statistically different from the other two treatments PEB (0.139) and SFB (0.086. Least square means are shown in **Tab.S9**. The mean comparisons (contrasts) were run as

differences on the log-scale. Therefore, back transformation results in the ratio between the means of the scaled sums. These ratios, their standard error and the corresponding p-values are given in **Tab.S10**.



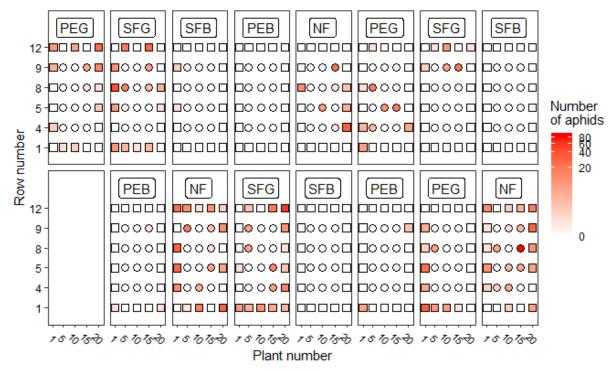


Fig.S3 Heatmap for the total number of aphids (alate and apterous) (May 16, 2018) with overview over all evaluated lettuce plants (n=450). Five treatments with three replications each on 15 randomized plots (n=30 per plot). Total number of aphids (alate and apterous) found in the 1st evaluation is represented by increasing colour hue. Evaluated plants are indicated by plant number (x-axis) and row number (y-axis). Outer plants at the edge to bare soil are shown as square dots, plants surrounded by other plants, as round dots. Orientation is north to south (from left to right).

Figure S3 shows the total number of aphids (alate and apterous) for every evaluation plant in the first evaluation by increasing colour hue. In all treatments, more alate aphids on outer plants than on plants in the centre of the plots were counted, but the ANOVA (**Tab.S9**) did not show statistical significance (p-value=0.19) for a location effect neither on average, nor within the plots (p-value=0.95). As for the total number of aphids, only the treatment effect was significant (p-value=<0.001). The mean ratios of counted aphids between inner and outer plants for each treatment are given in **Tab.S13**. Number of infested plants was 47 (52%, NF), 30 (33%, PEG), 37 (41%, SFG), 5 (6%, PEB), 2 (2%, SFB).

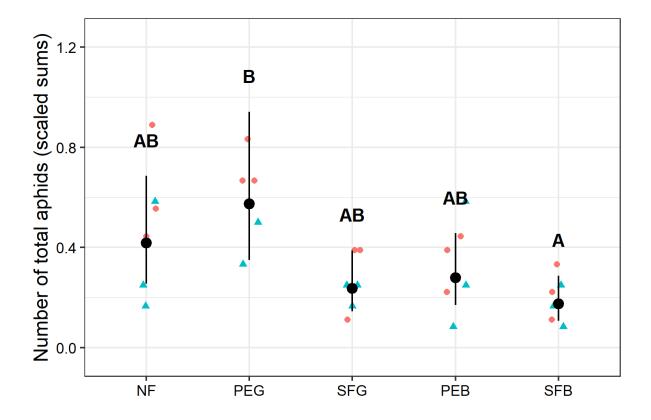


Fig.S4 Scaled sums of the total number of aphids per location in each plot (June 22, 2018). The sums were scaled to be (y+1)/n. Dots indicate sums from the border plants, triangles indicate sums from the centre of a plot. The black dots are model based least square means of the scaled sums together with their 95% confidence intervals (black bars). Treatment means that have at least one letter in common do not differ significantly (α =0.05) from each other.

The ANOVA (**Tab.S13**) revealed only significant differences between the treatments but no significance for the location (inner or centre) nor the interaction between treatment and location. Therefore, only the differences between the treatments were analysed in detail. **Figure S4** shows the total number of aphids (*N. ribisnigri* only) found on the lettuce heads in the second evaluation (destructive at harvest time) for each treatment, and location together with their corresponding least square means. Treatment PEG showed the highest least square mean (0.575), only statistically different to the treatment SFB (0.175) which showed the smallest mean value. Treatment NF (0.418), PEB (0.279) and SFG (0.237) were not statistically different from each other and the other two treatments (PEG, SFB). The mean comparisons (contrast tests) were run as differences on the log-scale. Therefore, back transformation results in the ratio between the means of the scaled sums. These ratios, their standard error and the corresponding p-values are given in **Tab.S15**.

Fig.S5 Overview over "sample-plots" in the field experiments. Plots are shown in different stages of lettuce growth: before planting (line1), short after planting (line2), two weeks after planting (line 3), and shortly before harvest (line4). Overview of one replicate plot per treatment, consisting of 3 dams with 4 rows of plants and 20 plants per row in each dam, thus totalling 240 plans per replicate.

Treatments (from left to right): SFB (Spray-Film Black-grey) – PEB (PE Black) – NF (No Foil/Film) – SFG (Spray-Film Green) – PEG (PE Green)

Field Trial Evaluation 1 (alate aphids)

100 Statistical analysis

101 Data

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The statistical analysis was run on the following data set called datsum with the variables:

- *var:* Different treatments
- plot: Plots on the field
- *inpl:* Location of the lettuce plants in the plots (0: border, 1: centre)
- *aphids_sum:* sum of flying aphids per location in each plot
- *n:* Number of lettuce plants for each sum
- scaled_sum: scaled sums calculated as (aphids_sum+1)/n

110 **Tab.S1** Summed total number of alate aphids in first evaluation

var	plot	inpl	aphids_sum	n	scaled_sum
NF	5	0	8	18	0.500
NF	5	1	2	12	0.250
NF	8	0	1	18	0.111
NF	8	1	2	12	0.250
NF	12	0	8	18	0.500
NF	12	1	1	12	0.167
PEB	3	0	2	18	0.167
PEB	3	1	1	12	0.167
PEB	7	0	0	18	0.056
PEB	7	1	0	12	0.083
PEB	13	0	2	18	0.167
PEB	13	1	0	12	0.083
PEG	1	0	12	18	0.722
PEG	1	1	2	12	0.250
PEG	9	0	2	18	0.167
PEG	9	1	6	12	0.583
PEG	11	0	7	18	0.444
PEG	11	1	0	12	0.083
SFB	4	0	0	18	0.056
SFB	4	1	0	12	0.083
SFB	6	0	0	18	0.056
SFB	6	1	0	12	0.083
SFB	14	0	0	18	0.056
SFB	14	1	0	12	0.083
SFG	2	0	7	18	0.444
SFG	2	1	3	12	0.333
SFG	10	0	3	18	0.222
SFG	10	1	0	12	0.083
SFG	15	0	5	18	0.333
SFG	15	1	7	12	0.667

Statistical analysis

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112 A linear mixed model was fit to the data as described in the text

```
library(lme4)
lmm_fit <- lmer(log(scaled_sum) ~ var * inpl + (1|plot), data=datsum)

ANOVA
library(lmerTest)
anova(lmm_fit)</pre>
```

Tab.S2 ANOVA table of alate aphids in first evaluation

Effect	SSQ	MSQ	NumDF	DenDF	F_value	p_Value
var	10.707	2.677	4	20	6.491	0.002
inpl	0.148	0.148	1	20	0.360	0.555
var:inpl	0.694	0.173	4	20	0.421	0.792

- The ANOVA (**Tab.S2**) revealed the significance ($\alpha = 0.05$) of the treatment (Var) since the
- p-value is 0.002, but no location effect (inpl) nor a treatment-location interaction (Var:inpl).

123 Mean comparisons between the treatments

- The mean comparisons were run on the logarithm of the scaled sums (as the model does),
- but are already back transformed to the original scale for easier interpretation. The least
- square means of the scaled sums for each treatment, their standard error and their 95%
- confidence intervals are given in table 3.

```
# Model based Least square means and ther comparisons
library(emmeans)
lmm_comp <- emmeans(lmm_fit, specs="var", contr="pairwise", type="response")
# LS-means for the treatments
lmm_comp$emmeans</pre>
```

Tab.S3 Least square means and their confidence intervals of alate aphids in first evaluation

var	mean	se	df	lower	upper
NF	0.257	0.067	10	0.143	0.461
PEB	0.110	0.029	10	0.061	0.198
PEG	0.294	0.077	10	0.164	0.528
SFB	0.068	0.018	10	0.038	0.122
SFG	0.291	0.076	10	0.162	0.522

The mean comparisons (contrasts) were run as differences on the log-scale. Therefore back 134 135

transformation results in the ratio between the means of the scaled sums These ratios, their

standard error and the corresponding p-values are given in **Tab.S4**. 136

```
137
      # Contrast tests
138
      lmm comp$contrasts
```

Tab.S4 Contrasts and p-values of alate aphids in first evaluation

contrast	ratio	se	df	t_ratio	p_value
NF / PEB	2.335	0.866	10	2.287	0.226
NF / PEG	0.874	0.324	10	-0.364	0.996
NF / SFB	3.780	1.401	10	3.586	0.032
NF / SFG	0.883	0.327	10	-0.335	0.997
PEB / PEG	0.374	0.139	10	-2.651	0.133
PEB / SFB	1.619	0.600	10	1.299	0.698
PEB / SFG	0.378	0.140	10	-2.622	0.139
PEG / SFB	4.326	1.604	10	3.950	0.018
PEG / SFG	1.011	0.375	10	0.029	1.000
SFB / SFG	0.234	0.087	10	-3.921	0.019

Location effect 140

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- The model based average scaled sums for each location were compared on log-scale. Back-141
- transformations results in a ratio between both sums (0: border plant, 1: inner plant). 142
- Please note that the ratio is not significantly different from zero. 143

```
144
      # Model based least square means and ther comparisons for the location effect
145
      lmm_comp_inpl <- emmeans(lmm_fit, specs="inpl",</pre>
                                contr="pairwise", type="response")
146
147
      # Ratio between the mean scaled sums for each location
148
      lmm comp inpl$contrasts
```

Tab.S5 Ratios of scaled sums between the locations of alate aphids in first evaluation 149

```
contrast
          ratio
                   se
                       df t_ratio p_value
0 / 1
         1.151 0.27 10
                              0.6
                                     0.562
```

Location effect in each treatment

- Ratios between the scaled sums of the border plants (0) and the inner plants (1) split by the 151
- treatments are given in **Tab. S6**. Please note, that none of these ratios is significantly 152
- different from zero. 153

- 154 # Model based least square means and ther comparisons for the location effect
- 155 # in each treatment

Tab.S6 Ratios of scaled sums between the locations and p-values of alate aphids in first evaluation

contrast	var	ratio	se	df	t_ratio	p_value
0 / 1	NF	1.387	0.727	10	0.624	0.547
0 / 1	PEB	1.101	0.577	10	0.183	0.859
0/1	PEG	1.639	0.859	10	0.942	0.368
0/1	SFB	0.667	0.350	10	-0.773	0.457
0/1	SFG	1.211	0.635	10	0.366	0.722

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References are given in the main reference list.

Field Trial Evaluation 1 (alate and apterous aphids)

Data

The statistical analysis was run on the following data set called datsum with the variables:

- *var:* Different treatments
- *plot:* Plots on the field
- *inpl:* Location of the lettuce plants in the plots (0: border, 1: centre)
- *aphids_sum:* sum of aphids per location in each plot
- *n:* Number of lettuce plants for each sum
- scaled_sum: scaled sums calculated as (aphids_sum+1)/n

174 **Tab.S7** Summed total number of alate and apterous aphids in first evaluation

var	plot	inpl	aphids_sum	n	scaled_sum
NF	5	0	192	18	10.722
NF	5	1	35	12	3.000
NF	8	0	53	18	3.000
NF	8	1	35	12	3.000
NF	12	0	110	18	6.167
NF	12	1	116	12	9.750
PEB	3	0	2	18	0.167
PEB	3	1	1	12	0.167
PEB	7	0	0	18	0.056
PEB	7	1	0	12	0.083
PEB	13	0	11	18	0.667
PEB	13	1	0	12	0.083
PEG	1	0	70	18	3.944
PEG	1	1	8	12	0.750
PEG	9	0	22	18	1.278

```
PEG 9
           1
                        51 12
                                      4<sub>1</sub>3<sub>7</sub>3<sub>5</sub>3
PEG 11
           0
                        89 18
                                      5.000
PEG
                         8 12
                                      0.750
     11
           1
SFB
     4
           0
                          3 18
                                      0.222
SFB
                          0 12
                                      0.083
           1
     4
SFB
    6
           0
                          0 18
                                      0.056
SFB
                          0 12
                                      0.083
     6
           1
SFB
     14
           0
                          0 18
                                      0.056
                                      0.083
SFB 14
           1
                         0 12
SFG
     2
           0
                       133
                            18
                                      7.444
SFG 2
           1
                        28 12
                                      2.417
SFG 10
           0
                        14 18
                                      0.833
SFG
     10
           1
                        27
                            12
                                      2.333
SFG
     15
                       149 18
                                      8.333
           0
SFG
    15
                        38 12
                                      3.250
           1
```

176 Statistical analysis

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177 A linear mixed model was fit to the data as described in the text

```
178  library(lme4)
179
180  lmm_fit <- lmer(log(scaled_sum) ~ var * inpl + (1|plot), data=datsum)

181  ANOVA
182  library(lmerTest)
183
184  anova(lmm_fit)</pre>
```

Tab.S8 ANOVA table of alate and apterous aphids in first evaluation

Effect	SSQ	MSQ	NumDF	DenDF	F_value	p_Value
var	85.014	21.254	4	20	32.711	< 0.001
inpl	1.213	1.213	1	20	1.867	0.187
var:inpl	0.458	0.115	4	20	0.176	0.948

The ANOVA (**Tab.S8**) revealed the significance ($\alpha = 0.05$) of the treatment (Var) since the p-value is far smaller than 0.05, but no location effect (inpl) nor a treatment-location interaction (Var:inpl).

Mean comparisons between the treatments

The mean comparisons were run on the logarithm of the scaled sums (as the model does), but are already back transformed to the original scale for easier interpretation. The least square means of the scaled sums for each treatment, their standard error and their 95% confidence intervals are given in table 3.

```
# Model based least square means and ther comparisons
195 library(emmeans)
196 lmm_comp <- emmeans(lmm_fit, specs="var", contr="pairwise", type="response")</pre>
```

LS-means for the treatments 197

198 lmm comp\$emmeans

199 200

206

Tab.S9 Least square means and their confidence intervals of alate and apterous aphids in first evaluation

 var	mean	se	df	lower	upper
NF	5.091	1.675	10	2.445	10.598
PEB	0.139	0.046	10	0.067	0.289
PEG	1.986	0.654	10	0.954	4.135
SFB	0.086	0.028	10	0.041	0.178
SFG	3.134	1.031	10	1.505	6.524

The mean comparisons (contrasts) were run as differences on the log-scale. Therefore back 201

transformation results in the ratio between the means of the scaled sums. These ratios, 202

their standard error and the corresponding p-values are given in **Tab.S10**. 203

```
204
      # Contrast tests
205
      lmm comp$contrasts
```

Tab.S10 Contrasts and p-values of alate and apterous aphids in first evaluation

contrast	ratio	se	df	t_ratio	p_value
NF / PEB	36.682	17.071	10	7.741	0.000
NF / PEG	2.563	1.193	10	2.022	0.322
NF / SFB	59.384	27.636	10	8.776	0.000
NF / SFG	1.624	0.756	10	1.042	0.830
PEB / PEG	0.070	0.033	10	-5.718	0.001
PEB / SFB	1.619	0.753	10	1.035	0.834
PEB / SFG	0.044	0.021	10	-6.698	0.000
PEG / SFB	23.171	10.783	10	6.753	0.000
PEG / SFG	0.634	0.295	10	-0.980	0.858
SFB / SFG	0.027	0.013	10	-7.733	0.000

Location effect 207

- The model based average scaled sums for each location were compared on log-scale. Back-208
- transformations results in a ratio between both sums (0: border plant, 1: inner plant). 209
- 210 Please note that the ratio is not significantly different from zero.

```
211
      # Model based least square means and ther comparisons for the location effect
      lmm_comp_inpl <- emmeans(lmm_fit, specs="inpl",</pre>
212
213
                                contr="pairwise", type="response")
```

214 # Ratio between the mean scaled sums for each location 215

lmm comp inpl\$contrasts

Tab.S11 Ratios of scaled sums between the locations of alate and apterous aphids in first

217 evaluation

216

```
        contrast
        ratio
        se
        df
        t_ratio
        p_value

        0 / 1
        1.495
        0.44
        10
        1.366
        0.202
```

218 Location effect in each treatment

- 219 Ratios between the scaled sums of the border plants (0) and the inner plants (1) split by the
- treatments are given in **Tab.S12** . Please note, that none of these ratios is significantly
- 221 different from zero.

```
# Model based least square means and ther comparisons for the location effect
# in each treatment
| lmm_comp_inter <- emmeans(lmm_fit, specs="inpl", by="var",
| contr="pairwise", type="response")

# Ratios
| lmm_comp_inter$contrasts</pre>
```

Tab.S12 Ratios of scaled sums between the locations and p-values of alate and apterousaphids in first evaluation

contrast	var	ratio	se	df	t_ratio	p_value
0 / 1	NF	1.312	0.864	10	0.413	0.688
0 / 1	PEB	1.747	1.150	10	0.848	0.416
0 / 1	PEG	2.178	1.434	10	1.183	0.264
0 / 1	SFB	1.058	0.696	10	0.086	0.933
0/1	SFG	1.413	0.930	10	0.525	0.611

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Field Trial Evaluation 2

233 **Data**

- The statistical analysis was run on the following data set called datsum with the variables:
- *var:* Different treatments
- plot: Plots on the field
- *inpl:* Location of the lettuce plants in the plots (0: border, 1: centre)
- aphids sum: sum of aphids per location in each plot
- *n:* Number of lettuce plants for each sum
- scaled_sum: scaled sums calculated as (aphids_sum+1)/n

Tab.S13 Summed total number of alate and apterous aphids in second evaluation

var	plot	inpl	aphids_sum	n	scaled_sum
NF	5	0	7	18	0.444
NF	5	1	1	12	0.167
NF	8	0	9	18	0.556
NF	8	1	6	12	0.583
NF	12	0	15	18	0.889
NF	12	1	2	12	0.250
PEB	3	0	3	18	0.222
PEB	3	1	0	12	0.083
PEB	7	0	7	18	0.444
PEB	7	1	6	12	0.583
PEB	13	0	6	18	0.389
PEB	13	1	2	12	0.250
PEG	1	0	11	18	0.667
PEG	1	1	3	12	0.333
PEG	9	0	14	18	0.833
PEG	9	1	6	12	0.583
PEG	11	0	11	18	0.667
PEG	11	1	5	12	0.500
SFB	4	0	1	18	0.111
SFB	4	1	2	12	0.250
SFB	6	0	5	18	0.333
SFB	6	1	0	12	0.083
SFB	14	0	3	18	0.222
SFB	14	1	1	12	0.167
SFG	2	0	6	18	0.389
SFG	2	1	1	12	0.167
SFG	10	0	1	18	0.111
SFG	10	1	2	12	0.250
SFG	15	0	6	18	0.389
SFG	15	1	2	12	0.250

243 Statistical analysis

A linear mixed model was fit to the data as described in the text

```
245  library(lme4)
246
247  lmm_fit <- lmer(log(scaled_sum) ~ var * inpl + (1|plot), data=datsum)
248  ANOVA
249  library(lmerTest)
250
251  anova(lmm_fit)</pre>
```

Tab.S14 ANOVA table of alate and apterous aphids in second evaluation

Effect	SSQ	MSQ	NumDF	DenDF	F_value	p_Value
var	5.151	1.288	4	10	4.478	0.025
inpl	1.212	1.212	1	10	4.215	0.067
var:inpl	0.276	0.069	4	10	0.240	0.909

- The ANOVA (**Tab.S14**) revealed the significance ($\alpha = 0.05$) of the treatment (Var) since the p-value is 0.025, but no location effect (inpl) nor a treatment-location interaction (Var:inpl).
- 255 Mean comparisons between the treatments
- 256 The mean comparisons were run on the logarithm of the scaled sums (as the model does),
- but are already back transformed to the original scale for easier interpretation. The least
- 258 square means of the scaled sums for each treatment, their standard error and their 95%
- confidence intervals are given in table 3.

```
# Model based least square means and ther comparisons
library(emmeans)
lmm_comp <- emmeans(lmm_fit, specs="var", contr="pairwise", type="response")
# LS-means for the treatments
lmm_comp$emmeans</pre>
```

Tab.S15 Least square means and their confidence intervals of alate and apterous aphids infirst evaluation

var	mean	se	df	lower	upper
NF	0.418	0.093	10	0.255	0.685
PEB	0.279	0.062	10	0.170	0.457
PEG	0.575	0.128	10	0.350	0.942
SFB	0.175	0.039	10	0.107	0.287
SFG	0.237	0.053	10	0.144	0.388

- The mean comparisons (contrasts) were run as differences on the log-scale. Therefore back
- transformation results in the ratio between the means of the scaled sums. These ratios,
- their standard error and the corresponding p-values are given in **Tab.S16**.

```
270 # Contrast tests
271 lmm_comp$contrasts
```

Tab.S16 Contrasts and p-values of alate and apterous aphids in second evaluation

contrast	ratio	se	df	t_ratio	p_value
NF / PEB	1.501	0.471	10	1.293	0.701
NF / PEG	0.727	0.228	10	-1.014	0.844
NF / SFB	2.391	0.751	10	2.776	0.110

```
NF / SFG
          1.767 0.555 10
                                     0.417
                            1.814
PEB / PEG 0.485 0.152 10 -2.307
                                     0.219
PEB / SFB
          1.593 0.500
                                    0.594
                       10
                            1.483
                                    0.983
PEB / SFG
          1.178 0.370
                       10
                            0.521
PEG / SFB
          3.286
                 1.032
                            3.790
                       10
                                     0.023
PEG / SFG
         2.430 0.763
                       10
                            2.828
                                     0.102
SFB / SFG
          0.739 0.232
                       10 -0.962
                                     0.866
```

Location effect

- 274 The model based average scaled sums for each location were compared on log-scale. Back-
- transformations results in a ratio between both sums (0: border plant, 1: inner plant).
- 276 Please note that the ratio is not significantly different from zero.

Tab.S17 Ratios of scaled sums between the locations of alate and apterous aphids in secondevaluation

```
        contrast
        ratio
        se
        df
        t_ratio
        p_value

        0 / 1
        1.495
        0.293
        10
        2.053
        0.067
```

284 Location effect in each treatment

Ratios between the scaled sums of the border plants (0) and the inner plants (1) split by the treatments are given in **Tab.S18**. Please note, that none of these ratios is significantly

287 different from zero.

294

```
# Model based least square means and ther comparisons for the location effect
# in each treatment
| lmm_comp_inter <- emmeans(lmm_fit, specs="inpl", by="var",
| contr="pairwise", type="response")

# Ratios
| lmm_comp_inter$contrasts</pre>
```

Tab.S18 Ratios of scaled sums between the locations and p-values of alate and apterous aphids in second evaluation

contrast	var	ratio	se	df	t_ratio	p_value
0 / 1	NF	2.082	0.912	10	1.675	0.125
0/1	PEB	1.468	0.643	10	0.876	0.402
0 / 1	PEG	1.562	0.684	10	1.018	0.333

0 / 1 SFB 1.333 0.584 10 0.657 0.526 0 / 1 SFG 1.173 0.514 10 0.364 0.723