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1 The effects of local climate on the correlation between weather and seed production differ in
2 two species with contrasting masting habit

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18

19 **Abstract**

20 Many plant species present inter-annual cycles of seed production (mast seeding), with
21 synchronized high seed production across populations in some years. Weather is believed to
22 be centrally involved in triggering masting. The links between meteorological conditions and
23 seeding are well-recognized for some species, but in others consistent correlates have not
24 been found. We used a spatially extensive data set of fruit production to test the hypothesis
25 that the influence of weather on seed production is conditioned by local climate and that this
26 influence varies between species with different life history traits. We used two model species.
27 European beech (*Fagus sylvatica*) that is a flowering masting species, i.e. seed production is
28 determined by variable flower production, and sessile oak (*Quercus petraea*) that is a fruit-
29 maturation masting species, i.e. seed production is determined by variable ripening of more
30 constant flower production. We predicted that climate should strongly modulate the
31 relationship between meteorological cue and fruit production in *Q. petraea*, while the
32 relationship should be uniform in *F. sylvatica*. The influence of meteorological cue on
33 reproduction in fruiting masting species should be strongly conditioned by local climate
34 because the strength of environmental constraint that modulates the success of flower-to-fruit
35 transition is likely to vary with local climatic conditions. In accordance, the meteorological
36 cueing was consistent in *F. sylvatica*. In contrast, in *Q. petraea* the relationship between spring
37 temperature and seed production varied among sites and was stronger in populations at colder
38 sites. The clear difference in meteorological conditioning of seed production between the two
39 studied species suggests the responses of masting plants to weather can be potentially
40 systematized according to their masting habit: i.e. fruiting or flowering.

41

42 Key-words: environmental variability, mast seeding, masting, Moran effect, plant
43 reproduction, seed production

44

45 **Introduction**

46 Masting is characterized by synchronized and highly variable levels of seed production over
47 years within a population or a community (Kelly and Sork 2002). It is a ubiquitous
48 reproductive strategy of plants worldwide that has major cascading effects on ecosystem
49 functioning (Jones et al. 1998, Ascoli et al. 2015, Bogdziewicz et al. 2016, Pearse et al. 2017,
50 Vacchiano et al. 2018). Masting is spatially synchronous, often over large portions of species
51 distributions (Koenig and Knops 1998, Ascoli et al. 2017, Fernández-Martínez et al. 2017a,
52 Vacchiano et al. 2017). The Moran effect (correlated environmental disturbances driving the
53 spatial autocorrelation of ecological phenomena, cf. Koenig 1999) is a major mechanism that
54 can account for large-scale synchrony of reproduction (Koenig and Knops 1998, Kelly and
55 Sork 2002). Specifically, some weather signals (cues) may have large effects on reproduction
56 because selection has favored plants that all respond to the cue in the same way, resulting in
57 high synchrony and individual variability (Kelly et al., 2013, Pearse et al. 2016).

58 Consequently, the correlations between seed production and weather have often been
59 investigated (Crawley and Long 1995, Piovesan and Adams 2001, Kon and Noda 2007, Allen
60 et al. 2012, Koenig and Knops 2014, Fernández-Martínez et al. 2017a, Koenig et al. 2017,
61 Vacchiano et al. 2017). Despite the large effort, consistently linking and predicting the effects
62 of weather on seed production across species has proven to be surprisingly difficult (Crone
63 and Rapp 2014). In particular, consistent and unequivocal links between weather and seed
64 production have not been found in some common and widely studied genera like oaks
65 (*Quercus* spp.), and the specific meteorological correlations vary among species, and even
66 within species among different studies (Sork et al. 1993, Crawley and Long 1995, Lusk et al.
67 2007, Crone and Rapp 2014, Koenig and Knops 2014, Pérez-Ramos et al. 2015, Koenig et al.
68 2016). Conversely, the link is much more consistent across space and time in some other
69 species, such as New Zealand tussock grasses (*Chionochloa* sp.) or European beech (*Fagus*
70 *sylvatica*) (Piovesan and Adams 2001, Rees et al. 2002, Schauber et al. 2002, Kelly et al.
71 2008, 2013, Tanentzap et al. 2012, Vacchiano et al. 2017). Why the correlations between seed
72 production and weather are consistent in some masting species, and how the irregularity in the
73 responses of other species can be systematized, remains unclear.

74 The lively debate that focused on the mechanistic drivers of masting has begun to
75 formulate a theoretical background that may allow us to resolve the puzzling relationship
76 between weather and masting (Kelly et al. 2013, Crone and Rapp 2014, Koenig et al. 2016,
77 Pearse et al. 2016, Pesendorfer et al. 2016, Bogdziewicz et al. 2017b, a). Specifically, masting
78 species can be broadly divided into two groups: flowering masting species and fruit-

79 maturation masting species (Pearse et al. 2016). Even though the division is continuous rather
80 than dichotomous, it may be a useful concept helping us to better understand the impact of
81 weather on plant reproduction. The annual variation in seed production in flowering masting
82 species is largely driven by variable flowering effort (Rapp et al. 2013, Monks et al. 2016,
83 Pearse et al. 2016, Bogdziewicz et al. 2017b). In contrast, the annual variation in flowering
84 effort is less relevant in fruit-maturation masting species, where variation in fruit production
85 is driven by the variable ripening of a more constant flower crop (Espelta et al. 2008, Pérez-
86 Ramos et al. 2010, Pearse et al. 2016, Bogdziewicz et al. 2017b). The theory predicts that the
87 level of synchrony will then depend on the nature of the weather cue and the biological
88 sensitivity of the plant to that signal (Pearse et al. 2016). Here, we further propose that the
89 timing of the cue (i.e. whether it happens before or after flower production) is also relevant.

90 In flowering masting species, selection favored sensitivity to weather signals that
91 trigger flower initiation (Richardson et al. 2005, Smaill et al. 2011, Tanentzap et al. 2012,
92 Kelly et al. 2013). Therefore, in these species, plants are hypersensitive to weather before
93 flowering, and once flowers are initiated, weather is less likely to affect their reproduction
94 (relatively to fruiting masting species). In contrast, fruit-maturation masting species are
95 hypersensitive to weather after flowering, i.e. weather events have strongest influence on fruit
96 production by modulating the success of fruit maturation (Espelta et al. 2008, Koenig et al.
97 2015, Pearse et al. 2016, Bogdziewicz et al. 2017a). Consequently, a large range of weather
98 events can modulate the flower-to-fruit transition, making the responsiveness of the plant to
99 particular weather event more variable. Thus, we hypothesize that in flowering masting
100 species, the effect of weather signal on seeding should be more consistent than in fruit-
101 maturation masting species. In the latter, the link between fruiting and weather should be
102 strongly modulated by local conditions, because these will define the most severe factor
103 limiting the maturation of flowers to fruits (Bogdziewicz et al. 2017a, 2018). For example,
104 drought is the most limiting factor for *Quercus spp.* individuals in dry and dense
105 Mediterranean forests (i.e. coppices), and seed production is strongly correlated with rainfall
106 (Espelta et al. 2008, Pérez-Ramos et al. 2010, Fernández-Martínez et al. 2012, Bogdziewicz et
107 al. 2017a). In contrast, water is less limiting for *Q. petraea* in temperate forests, and seed
108 production is thus correlated with spring temperature that determines flowering synchrony
109 and associated pollination efficiency (the phenology synchrony hypothesis; Koenig et al.
110 2015). Nonetheless, both constraints likely operate in both species, just with different strength
111 (Bogdziewicz et al. 2017a). Thus, similar differences may occur within species and among
112 sites. For example, the strength of the positive correlation between spring temperature and

113 seed production in case of temperate oaks, could be stronger at colder sites, because these
114 sites may have a generally lower average synchrony of flowering (due to frequent cold
115 springs) (Pessi and Pulkkinen 1994, Zhang et al. 2014). Therefore, the positive effect of
116 increased flowering synchrony and associated pollination efficiency should be more important
117 for seed production. If local climate strongly determines the weather influence on
118 reproduction in fruit-maturation masting species, it would explain the apparent inconsistency
119 of results of past studies.

120 To test how the local climate modulated the meteorological cuing of seed production
121 in two species that belong to the two contrasting masting groups described above, we
122 analyzed data for seed production by the sessile oak (*Quercus petraea*) and European beech
123 (*Fagus sylvatica*) at 17 and 19 sites, respectively. *Fagus sylvatica* is a flowering masting
124 species, and *Q. petraea* is a fruit-maturation masting species (Nilsson and Wastljung 1987,
125 Bogdziewicz et al. 2017b, Lebourgeois et al. 2018). In *F. sylvatica*, hot summers a year
126 before seed production increase flower initiation, and seeding consequently correlates
127 positively with the temperatures in the preceding year (Piovesan and Adams 2001, Hackett-
128 Pain et al. 2015, Bogdziewicz et al. 2017b). This relationship is spatially conserved
129 throughout Europe (Vacchiano et al. 2017). In contrast, acorn production in *Q. petraea* often
130 correlates with current spring temperatures (Kasprzyk et al. 2014, Bogdziewicz et al. 2017b,
131 Caignard et al. 2017, Lebourgeois et al. 2018). The mechanism driving masting is likely
132 through phenology synchrony of flowering (Koenig et al. 2015). In warm springs, flowering
133 in trees within a population is synchronized, which produces high pollination efficiency and
134 success of flower-to-fruit maturation (Bogdziewicz et al. 2017b). Conversely, cold springs
135 lead to desynchronized flowering and pollination failure (Koenig et al. 2012, Pesendorfer et
136 al. 2016, Bogdziewicz et al. 2017b). However, while the link between spring temperature and
137 seeding has been often reported, other studies did not confirm this relationship (Crawley and
138 Long 1995, Wesolowski et al. 2015, Fernández-Martínez et al. 2017a). We hypothesize that
139 such inconsistency is caused by variation in local climate. By considering the contrasting
140 masting strategies of these species, we predict that the response of *F. sylvatica* to weather will
141 be similar across climatic gradients. Specifically, warmer summers in the year preceding seed
142 dispersal in *F. sylvatica* will be consistently positively correlated with seed production
143 everywhere. In contrast, the strength of the correlation between spring temperature and seed
144 production in *Q. petraea* will vary with local climate among the sampling sites. The strength
145 of the positive correlation should be particularly stronger at colder sites.

146

147 **Materials and Methods**

148 We obtained data for seed production for *Q. petraea* and *F. sylvatica* from the ICP
149 Forests database (International Co-operative Programme on Assessment and Monitoring of
150 Air Pollution Effects on Forest, operated under the United Nations Economic Commission for
151 Europe (UNECE) Convention on Long-range Transboundary Air Pollution, <http://icp-forests.net/>). We used data for the carbon content of fruit provided by the same database to
152 calculate fruit production per plot and year expressed as fruit net primary production (units of
153 $\text{g C m}^{-2} \text{y}^{-1}$, i.e. average per unit of surface) (Fernández-Martínez et al. 2017a). These data
154 included fruit production at 17 sites for *F. sylvatica* and 19 sites for *Q. petraea*. Seed
155 production was monitored from 2002 to 2008, but the length of the time series differed
156 slightly between the sites (see Figs. S1 and S2 for details). The following analyses were thus
157 based on 95 site-year observations for *F. sylvatica* and 121 site-year observations for *Q.*
158 *petraea*.

160 We extracted climatic data for our study sites from the WorldClim database. This
161 database provides climatic data with a high spatial resolution and contains robust mean
162 monthly climatic data derived from lengthy time series (1950–2000). We used the long-term
163 annual temperature and precipitation means for the study sites as indicators of local climate.
164 We extracted meteorological time series for our forests from the interpolated meteorological
165 data of the MARS unit AGRI4CAST/JRC (<http://agri4cast.jrc.ec.europa.eu/>), with a
166 resolution of $0.25 \times 0.25^\circ$ (latitude \times longitude). This database provided monthly mean
167 temperatures and total precipitation. We used the mean summer temperature (July-September)
168 and mean spring temperature (April-June) for the analysis.

169 170 Statistical analysis

171 We calculated population-level masting metrics, including the coefficient of variation
172 (CV), synchrony between sites (Pearson's correlation coefficients) and lag-1 temporal
173 autocorrelation of seed production. The CV, synchrony, and their corresponding 95%
174 confidence intervals (CIs) were calculated by bootstrap resampling with 1000 replications. To
175 further explore the spatial synchrony, we also computed a Mantel correlograms of
176 reproduction in both species.

177 We tested our predictions in two steps, each repeated for both *F. sylvatica* and *Q.*
178 *petraea*. First, we tested whether the populations of the two species responded to the
179 meteorological cues suggested by previous studies, i.e. fruit production for *F. sylvatica* would
180 be strongly correlated with summer temperature in the year preceding seed fall. In contrast,

181 fruit production in *Q. petraea* should be correlated (at the global, complete data-set level)
182 with spring temperature. We built a linear mixed model, with log-transformed fruit production
183 as a response, study site as a random intercept and meteorological variables (i.e. summer
184 temperature for *F. sylvatica* and spring temperature for *Q. petraea*) as predictors. Second, we
185 explored whether the links between weather and seeding were conditioned by local climate.
186 We calculated Pearson correlations coefficients between (log-transformed) seed production
187 and meteorological variables separately for each study site. We then used the correlation
188 coefficients as response variables in two linear regression models, each with climatic
189 variables, i.e. either mean annual temperature at the site or mean annual precipitation,
190 included as an explanatory variable. We built separate models because these climatic
191 variables were colinear ($r = 0.56$). In case of *F. sylvatica*, we also run analogous analysis but
192 with summer temperature in year T-1 replaced by summer temperature in year T-2, as this is
193 also frequently reported cue for that species (Piovesan and Adams 2001, Vacchiano et al.
194 2017, Hackett-Pain et al. 2018). Results of that analysis are given in the Online Appendix.

195 We used the R lme4 package for the mixed models (Bates et al. 2014). All models
196 were fitted with Gaussian distributions and identity link functions. Model validation by
197 graphical inspection of the residual patterns indicated normality and homoscedasticity. We
198 calculated the R^2 for the linear models and calculated marginal R^2 (i.e. the proportion of
199 variance explained by fixed effects) and conditional R^2 (i.e. the proportion of variance
200 explained by fixed and random effects) for the GLMMs (Nakagawa and Schielzeth 2013,
201 Bartoń 2014).

202

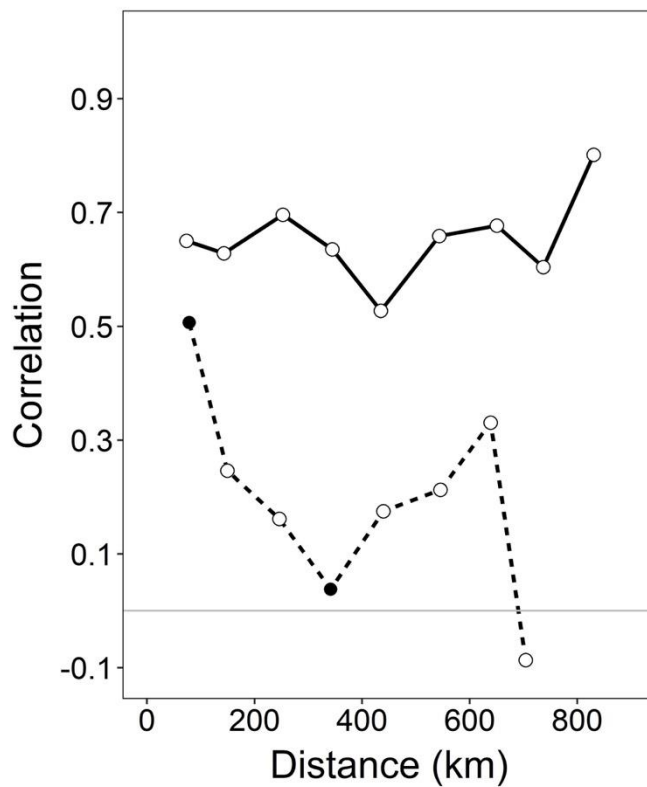
203 **Results**

204 Both species and all populations had typical masting behavior. Annual seed
205 production was more variable in *F. sylvatica*, with site-level CV ranging from 1.36 to 2.38
206 (mean = 1.75). *Q. petraea* was less variable (0.80 – 2.37, mean = 1.36). The negative
207 autocorrelation of seed production ranged from -0.77 to -0.22 (mean = -0.40) for *F. sylvatica*
208 and from -0.49 to 0.34 (mean = -0.17) for *Q. petraea*. The among-site synchrony was 0.81
209 (95% CI: 0.68–0.96) for *F. sylvatica* and 0.18 (95% CI: 0.02–0.37) for *Q. petraea*.

210 Furthermore, Mantel correlograms suggested that *F. sylvatica* seed production was
211 consistently highly synchronized among sites at all studied distances (up to 800 km), which
212 was not the case in *Q. petraea* (Fig. 1). Note, however, that most of the correlations were not
213 significant (Fig. 1).

214

215 **Figure 1.**



216

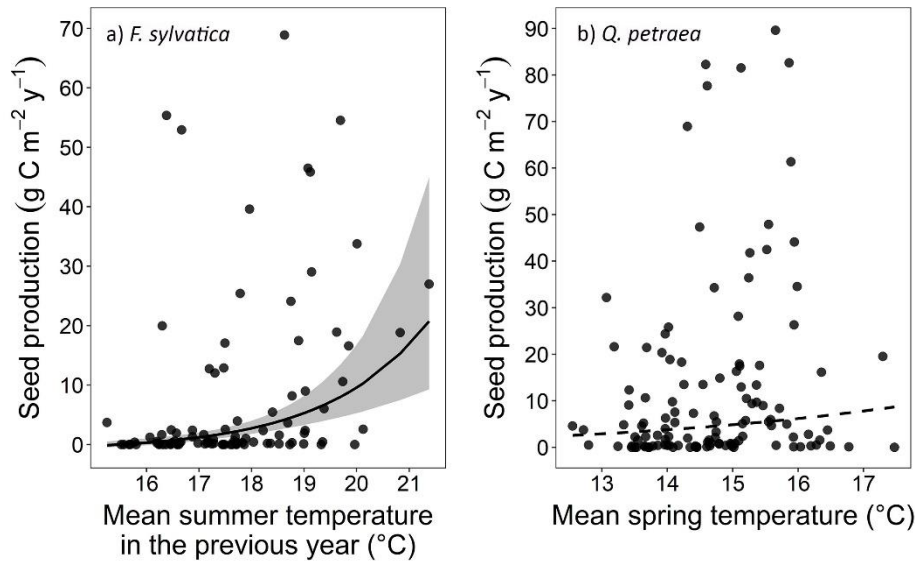
217 **Figure 1.** Mantel correlogram of seed production in *F. sylvatica* (solid line) and *Q. petraea*
218 (dashed line). The horizontal grey line indicates 0 correlation, while filled circles indicate
219 significant correlations.

220

221 *F. sylvatica* seed production was strongly correlated with summer temperatures in the
222 year preceding seed fall ($\beta = 0.52$, 95% CI range: 0.29 – 0.72, $t = 5.48$, $p < 0.001$; Fig. 2A), in
223 accordance with our predictions. The marginal R^2 of the model was 0.24, and the conditional
224 R^2 was 0.31. In contrast, seed production by *Q. petraea* was positively but not significantly
225 correlated with spring temperature ($\beta = 0.20$, 95% CI range: -0.04 – 0.45, $t = 1.63$, $p = 0.10$;
226 Fig. 2B). The marginal R^2 of the model was 0.02, and the conditional R^2 was 0.02.

227

228 **Figure 2.**



229

230

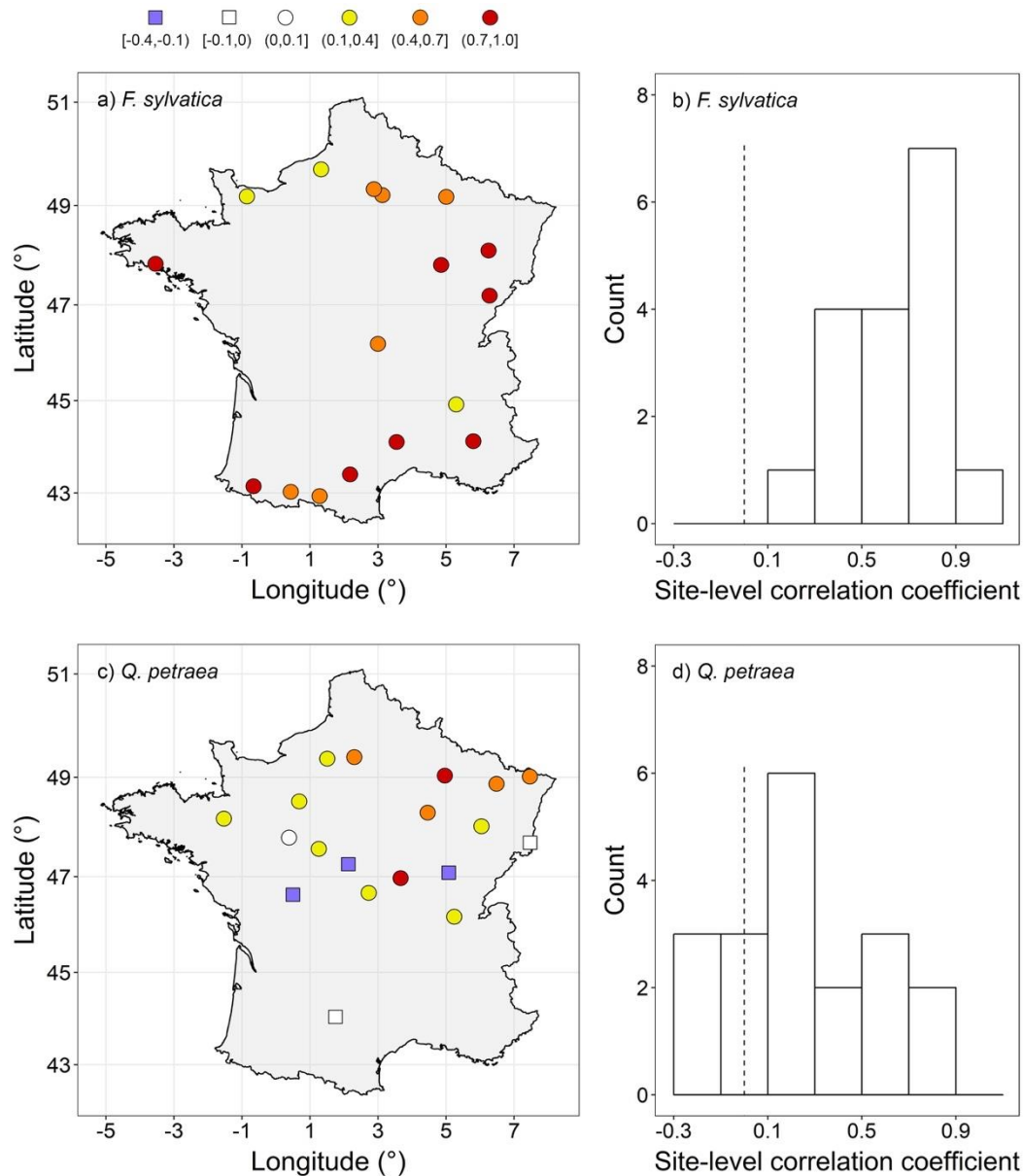
231 **Figure 2.** Relationships between a) seed production and previous summer temperature for *F.*
 232 *sylvatica* and b) seed production and current-year spring temperature for *Q. petraea*. The lines
 233 represent GLMM predictions, and the shaded regions represent 95% confidence intervals. The
 234 dashed line represents a nonsignificant relationship.

235

236 The response of the *F. sylvatica* but not the *Q. petraea* populations to weather was
 237 clearly consistent after the correlations between seeding and meteorological cues had been
 238 decomposed to the site level. All correlations for *F. sylvatica* were positive (range: 0.23–0.92,
 239 mean = 0.64; Fig. 3A, B), while the site-level correlation coefficients for *Q. petraea* ranged
 240 from -0.24 to 0.84 (mean = 0.24, Fig. 3C, D).

241

242 **Figure 3.**



243

244 **Figure 3.** Spatial variation in the response of *F. sylvatica* and *Q. petraea* to meteorological
 245 cues. A) and B) site-level Pearson correlation coefficients between log-transformed fruit
 246 production and previous summer temperature for *F. sylvatica*. C) and D) site-level Pearson
 247 correlation coefficients between log-transformed fruit production and current-year spring
 248 temperature for *Q. petraea*. The vertical dashed lines in b) and d) indicate 0 correlation.

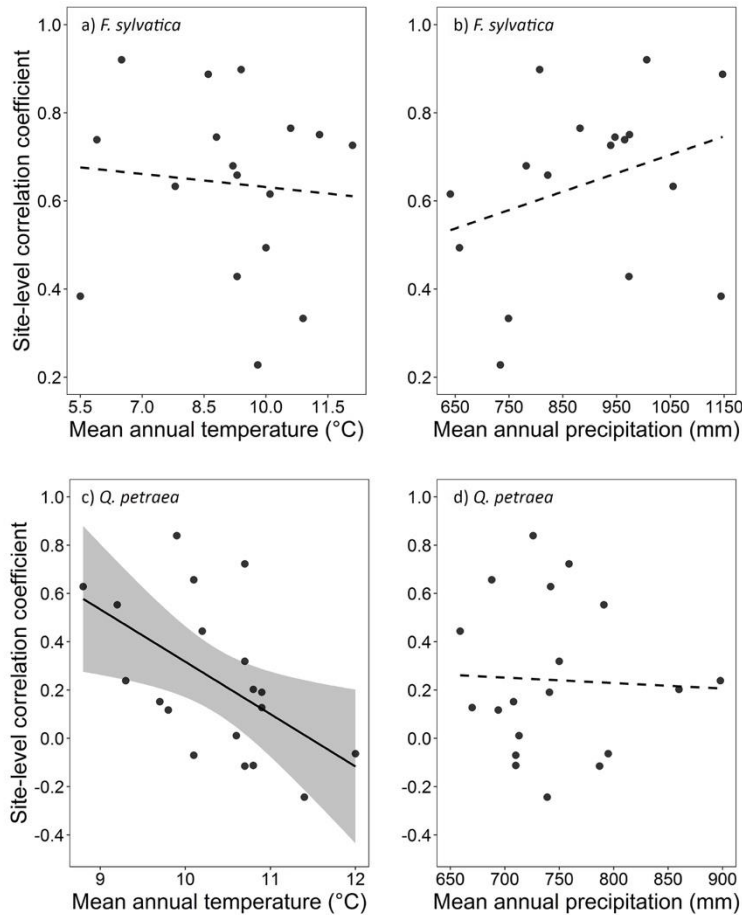
249

250 The strength of the correlation between summer temperature of the previous year and
 251 seed production for *F. sylvatica* did not differ with either the mean annual temperature of the
 252 site ($\beta = -0.01$, 95% CI range: $-0.07 - 0.05$, $t = -0.35$, $p = 0.73$; Fig. 4A) or the mean annual
 253 precipitation ($\beta = 0.0004$, 95% CI range: $-0.0002 - 0.001$, $t = 1.29$, $p = 0.22$; Fig. 4B). In
 254 contrast, the correlation between spring temperature and seed production for *Q. petraea* was

255 weaker at sites with higher mean annual temperatures ($\beta = -0.21$, 95% CI range: $-0.40 - -0.04$,
 256 $t = -2.62$, $p = 0.018$; $R^2 = 0.29$; Fig. 4C) with no effects of mean annual precipitation ($\beta = -$
 257 0.0002 , 95% CI range: $-0.002 - 0.002$, $t = -0.18$, $p = 0.86$; Fig. 4D).

258

259 **Figure 4.**



260

261 **Figure 4.** Relationships between the site-level Pearson correlation coefficients and mean
 262 annual temperature (A and C) and mean annual precipitation (B and C). The lines represent
 263 linear model predictions, and the shaded regions represent 95% confidence intervals. The
 264 dashed lines represent nonsignificant relationships.

265

266 **Discussion**

267 The relationship between weather and fruit production for *F. sylvatica* was
 268 consistently positive at all 19 sites studied (Figure 3A). In contrast, the relationship between
 269 spring temperature and seed production for *Q. petraea* was not significant at the whole
 270 database level. Yet, decomposition of this relationship to the site-level, hinted that it was
 271 because the relationship largely varied among sites (Figure 3C) and was stronger in
 272 populations at colder locations. While certainly further studies are warranted, our results are

273 consistent with the prediction that the climatic modulation of the responses of flowering
274 masting and fruit-maturation masting species to weather should be different. The flowering
275 masting *F. sylvatica* is hypersensitive to weather cue that triggers flowering (Bogdziewicz et
276 al. 2017b), possibly through increased expression of genes involved in floral transition
277 (Miyazaki et al. 2014, Pearse et al. 2016). Thus, the general positive effect of temperature on
278 flower initiation should be less susceptible to varying local climate, and therefore more
279 uniform across sites. In contrast, the key meteorological variable in fruit-maturation masting
280 species favors (or prevents) the transition from flower to fruit. The environmental constraint
281 that modulates this success is likely to vary with local conditions, as we observed in *Q.*
282 *petraea*.

283 The response of *Q. petraea* to spring temperature was stronger at colder sites. Low
284 temperatures during flowering are associated in oaks with desynchronized flowering, because
285 meteorological variability in microhabitats is high in cold springs, which leads to a variable
286 onset of flowering (Koenig et al. 2015, Pesendorfer et al. 2016, Bogdziewicz et al. 2017b).
287 The phenological mismatch among individuals within a population leads to relatively lower
288 pollen availability for each tree and therefore lower pollination success and seed production
289 (Koenig et al. 2012, Bogdziewicz et al. 2017b). Warm springs enhance the synchronization of
290 flowering, allowing high pollination success and lead to high fruit production. We thus
291 believe that this variable background synchronization of flowering (Koenig et al. 2015,
292 Pesendorfer et al. 2016, Bogdziewicz et al. 2017b) is the mechanism responsible for the
293 systematic among-site variation of oaks response to spring weather. The average flowering
294 synchrony is likely lower at cold sites (Pessi and Pulkkinen 1994, Zhang et al. 2014), so
295 pollination success would be a strong constraint on seed production. Consequently, the effect
296 of increased spring temperature on fruits production was clear at these sites. In contrast,
297 pollination success probably affects seed production less at warmer sites, because the
298 synchrony of flowering is generally higher, so the correlations would be weaker. As an
299 indirect support, pollen seasons in *Pinus sylvestris* are longer at northern sites (Pessi and
300 Pulkkinen 1994), and were also found to be shorter at warmer sites in *Betula sp.* (Zhang et al.
301 2014). Nonetheless, the opposite can also be true (e.g. Qiu et al. 2018). Thus, direct tests of
302 that hypothesis are necessary, and can include evaluating the effects of spring temperatures
303 and phenological synchrony on oak seeding across elevations.

304 Spring temperature may also condition acorn production in oaks by different
305 mechanisms, e.g. by modulating the acorn development process (Sork et al. 1993, Koenig and
306 Knops 2014). Spring temperature had a negative influence on seed production in 4 of the 19

307 populations. Trees may respond to meteorological variables in a symmetric, Gaussian-like
308 fashion, with an optimal response (Fernández-Martínez et al. 2017b). The direction of the
309 response (positive/negative) could then depend on the range of the meteorological variable at
310 different sites. If the meteorological cue has a mode below the optimum in one region, then
311 the correlation between the meteorological variable and the response at that site will be
312 positive (Lusk et al. 2007, Fernández-Martínez et al. 2017b). Likewise, if the mode of the
313 meteorological cue is above the optimum at a site, then the correlation between the
314 meteorological variable and the response in that region will be negative. Our sites at which we
315 observed the negative correlations may operate above the environmental optimum for *Q.*
316 *petraea*, e.g. excessively hot springs will lead to flower abortion. *F. sylvatica* probably has a
317 similar optimum, but it may not be as strongly modulated by local climate as for *Q. petraea*
318 due to differences in the life-history traits discussed here. Experimental investigations of the
319 influence of weather on flower and seed development in masting plants are rare (Kon and
320 Noda 2007, Kelly et al. 2008, Pérez-Ramos et al. 2010), but will provide necessary insight
321 into the mechanistic links between weather and seeding variation.

322 The spatial consistency in the response of *F. sylvatica* to weather explains why *F.*
323 *sylvatica* populations were on average 4-times better synchronized than *Q. petraea* (0.81 vs
324 0.18, respectively; for similar result see Nussbaumer et al. 2016). The response of *F. sylvatica*
325 to meteorological cues was spatially uniform, so all populations within a region fluctuated
326 similarly in response to correlated meteorological conditions (see also Fig. 1). The synchrony
327 of reproduction may then be easily scaled up to a continental scale, as shown in Vacchiano et
328 al. (2017). Conversely, each population of *Q. petraea* probably responded more in accordance
329 with its local optimum, which consequently lowered the large-scale spatial synchronization.
330 Spatial synchrony of masting has been intensively studied (e.g. Koenig and Knops 1998,
331 Kelly and Sork 2002, Fernández-Martínez et al. 2017, Vacchiano et al et al. 2017) but why
332 species differ in how well they are synchronized is unclear. We propose that synchrony will
333 differ between flowering and fruit-maturation masting species, with the former having a
334 higher average large-scale synchrony due to spatially conserved meteorological cuing, i.e. a
335 regional pattern more consistent with the Moran effect.

336

337 **Conclusions**

338 The clear difference in meteorological conditioning of seed production between the
339 two species suggests that the responses of masting plants to weather can be systematized and
340 predicted. Meteorological cues in species where annual flowering intensity is the main

341 determinant of seed production should include variables associated with resource acquisition
342 and flower initiation, and be generally similar across species ranges (Richardson et al. 2005,
343 Monks et al. 2016, Vacchiano et al. 2017). Meteorological cues in fruit-maturation masting
344 species, though, could be predicted by considering the likely key environmental constraint (so
345 called ‘veto’ cf. Pearse et al. 2016, Bogdziewicz et al. 2018) to fruit maturation for the
346 particular species and region studies. We note, however, that the differentiation between
347 flowering and fruit-maturation masting species is not distinct but a continuum of species with
348 more or fewer mixed strategies (Montesinos et al. 2012, Abe et al. 2016, Pearse et al. 2016).
349 Accurate predictions will therefore need detailed information of species biology. Our research
350 nonetheless provides new insights into the resolution of apparently inconsistent responses of
351 plant reproduction to meteorological variation. Finally, climate appears to condition the
352 species responses to weather stronger in fruit-maturation masting species. It indicates that
353 these species may be more sensitive to global climate change than flowering masting species.

354

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361 2013-610028 IMBALANCE-P.

362

363 **Competing interest statement**

364 Authors declare no competing interests.

365

366 **Literature**

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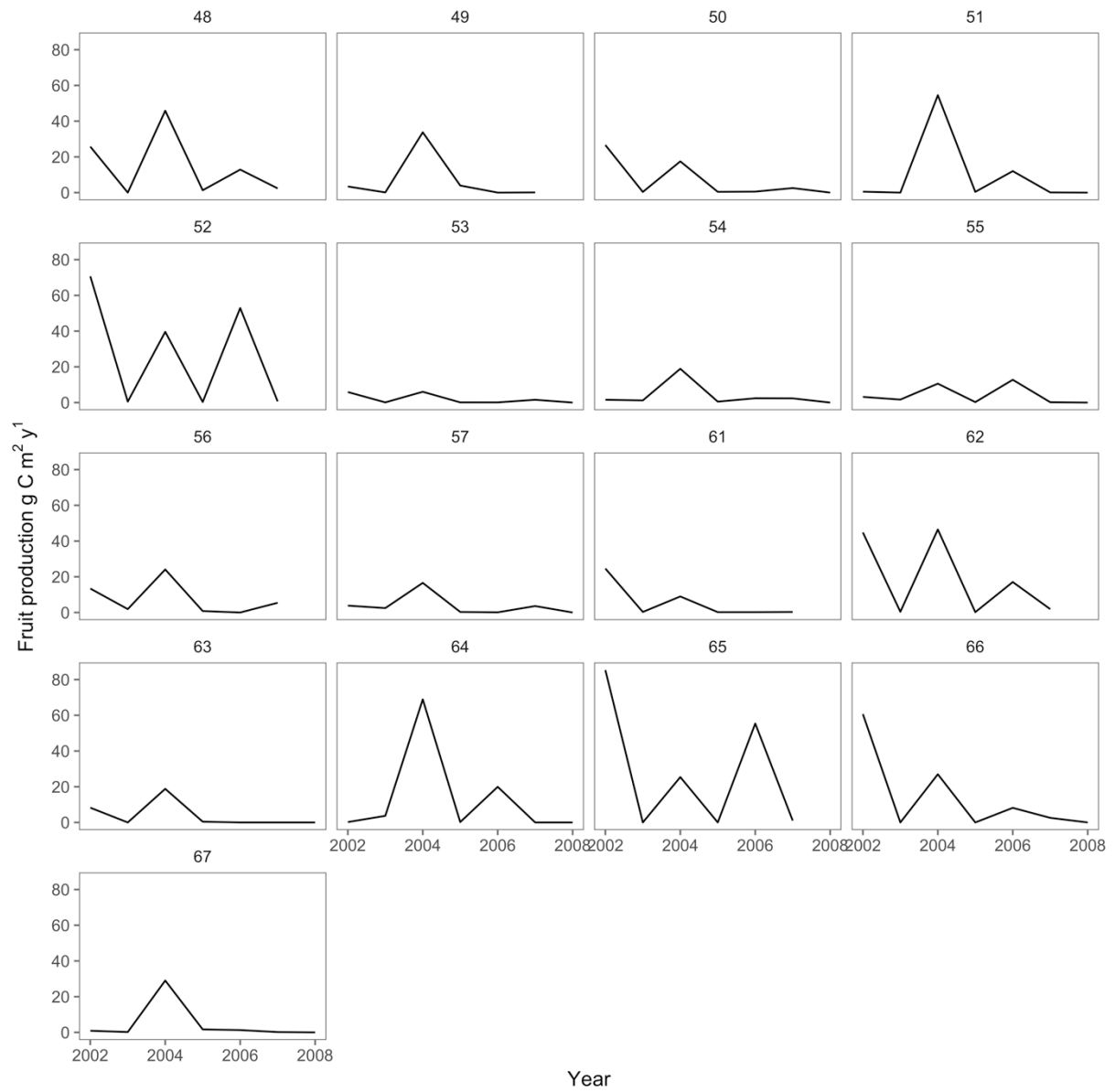
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502 Online Appendix. Bogdziewicz et al. The effects of local climate on the correlation between
503 weather and seed production differ in two species with contrasting masting habit.

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506 Figure 1S. Fruit production time series for *F. sylvatica*. Each plot represents a site.

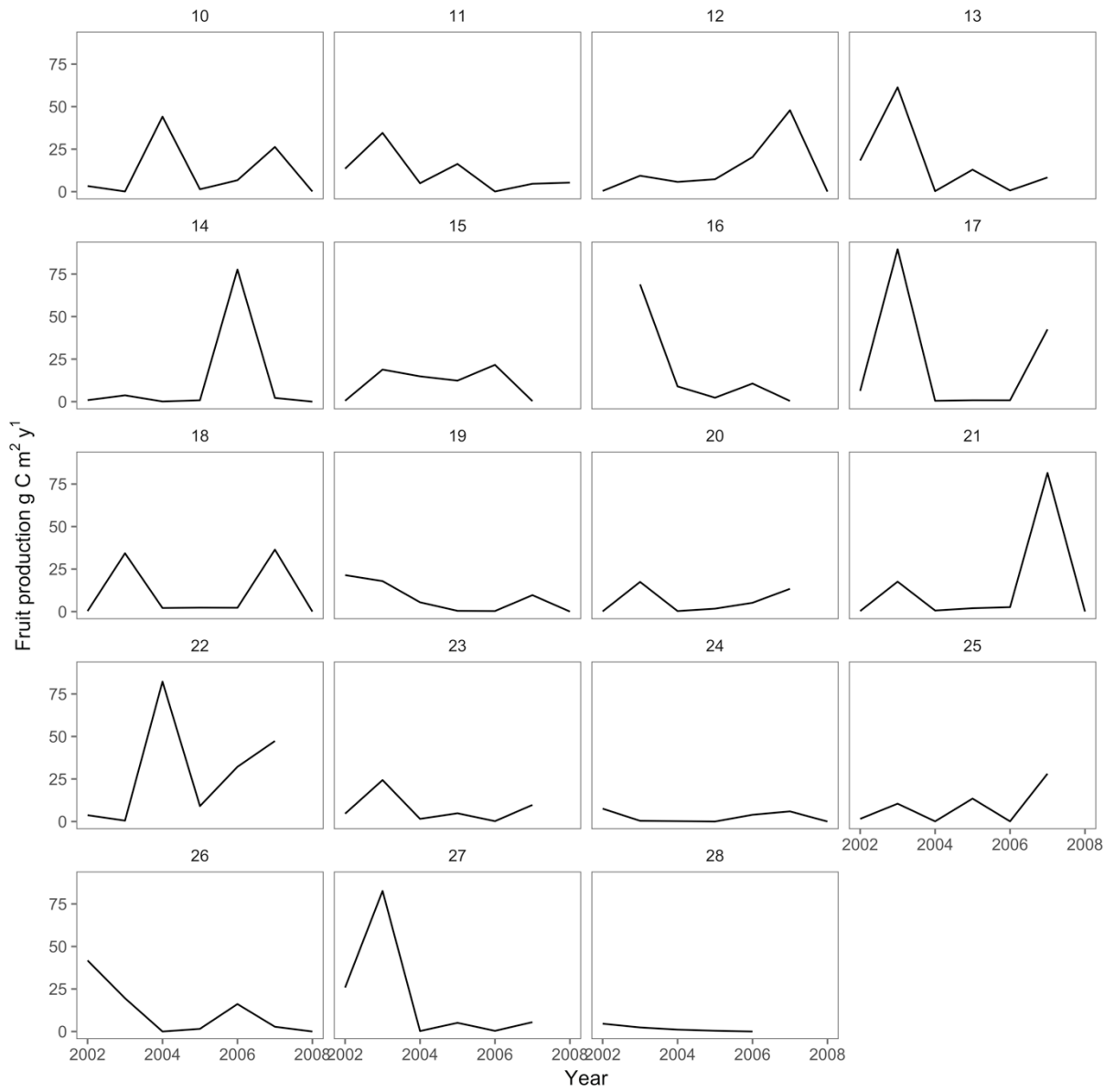


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509 Figure 2S. Fruit production time series for *Q. petraea*. Each plot represents a site.

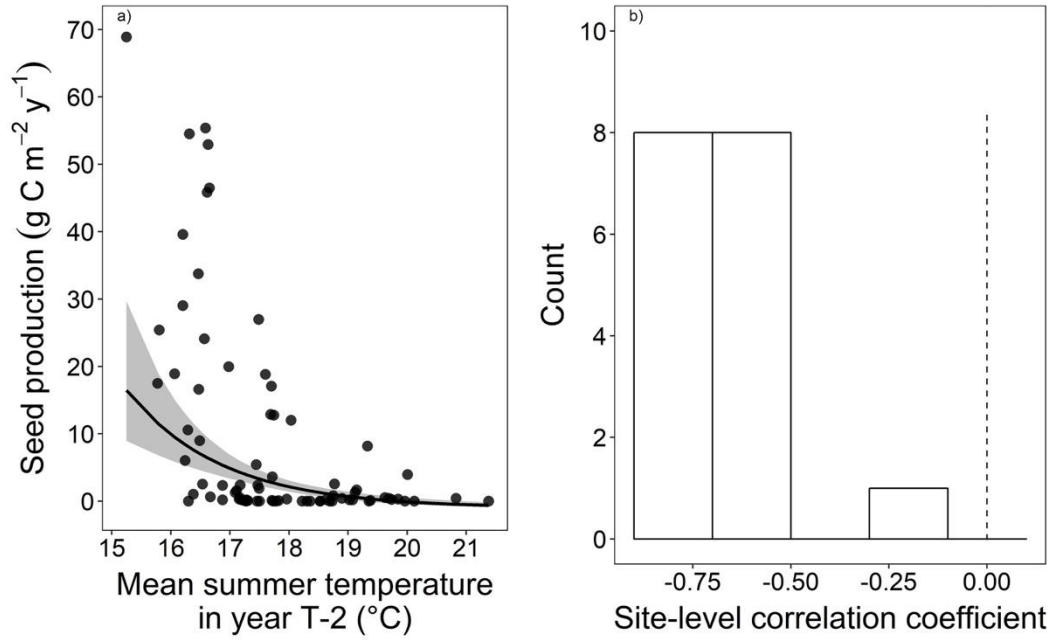
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513 Figure S3. A) The relationship between seed production and mean summer temperature two
514 years before seed dispersal ($\beta = -0.62$, 95% CI range: $-0.82 - -0.42$, $t = -6.13$, $p < 0.001$). B)
515 Site-level Pearson correlation coefficients between log-transformed fruit production and
516 summer temperature two years before seed dispersal. Both figures for *F. sylvatica*.
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