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Genotypic variability enhances the reproducibility of an ecological study

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Many scientific disciplines are currently experiencing a 'reproducibility crisis' because numerous scientific findings cannot be repeated consistently. A novel but controversial hypothesis postulates that stringent levels of environmental and biotic standardization in experimental studies reduce reproducibility by amplifying the impacts of laboratory-specific environmental factors not accounted for in study designs. A corollary to this hypothesis is that a deliberate introduction of controlled systematic variability (CSV) in experimental designs may lead to increased reproducibility. To test this hypothesis, we had 14 European laboratories run a simple microcosm experiment using grass (*Brachypodium distachyon* L.) monocultures and grass and legume (*Medicago truncatula* Gaertn.) mixtures. Each laboratory introduced environmental and genotypic CSV within and among replicated microcosms established in either growth chambers (with stringent control of environmental conditions) or glasshouses (with more variable environmental conditions). The introduction of genotypic CSV led to 18% lower among-laboratory variability in growth chambers, indicating increased reproducibility, but had no significant effect in glasshouses where reproducibility was generally lower. Environmental CSV had little effect on reproducibility. Although there are multiple causes for the 'reproducibility crisis', deliberately including genetic variability may be a simple solution for increasing the reproducibility of ecological studies performed under stringently controlled environmental conditions.

Reproducibility—the ability to duplicate a study and its findings—is a defining feature of scientific research. In ecology, it is often argued that it is virtually impossible to accurately duplicate any single ecological experiment or observational study. The rationale is that the complex ecological interactions between the ever-changing environment and the extraordinary diversity of biological systems exhibiting a wide range of plastic responses at different levels of biological organization make exact duplication unfeasible[1,2]. Although this may be true for observational and field studies, numerous ecological (and agronomic) studies are carried out with artificially assembled simplified ecosystems and controlled environmental conditions in experimental microcosms or mesocosms (henceforth, 'microcosms')[3–5]. Since biotic and environmental parameters can be tightly controlled in microcosms, the results

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from such studies should be easier to reproduce. Even though microcosms have frequently been used to address fundamental ecological questions[4,6,7], there has been no quantitative assessment of the reproducibility of any microcosm experiment.

Experimental standardization—the implementation of strictly defined and controlled properties of organisms and their environment—is widely thought to increase both the reproducibility and sensitivity of statistical tests[8,9] because it reduces within-treatment variability. This paradigm has recently been challenged by several studies on animal behaviour, suggesting that stringent standardization may, counterintuitively, be responsible for generating non-reproducible results[9–11] and contribute to the actual reproducibility crisis[12–15]; the results may be valid under given conditions (that is, they are local 'truths'), but are not generalizable[8,16]. Despite rigorous adherence to experimental protocols, laboratories inherently vary in many conditions that are not measured and are thus unaccounted for, such as experimenter, micro-scale environmental heterogeneity, physico-chemical properties of reagents and laboratory-ware, pre-experimental conditioning of organisms, and their genetic and epigenetic background. It has even been suggested that attempts to stringently control all sources of biological and environmental variability might inadvertently lead to amplification of the effects of these unmeasured variations among laboratories, thus reducing reproducibility[9–11].

Some studies have gone even further, hypothesizing that the introduction of controlled systematic variability (CSV) among the replicates of a treatment (for example, using different genotypes or varying the organisms' pre-experimental conditions among the experimental replicates) should lead to less variable mean response values between the laboratories that duplicate the experiments[9,11]. In short, it has been argued that reproducibility may be improved by shifting the variance from among experiments to within them[9]. If true, introducing CSV will increase researchers' ability to draw generalizable conclusions about the directions and effect sizes of experimental treatments and reduce the probability of false positives. The trade-off inherent to this approach is that increasing within-experiment variability will reduce the sensitivity (that is, the probability of detecting true positives) of statistical tests. However, it currently remains unclear whether introducing CSV increases the reproducibility of ecological microcosm experiments and, if so, at what cost for the sensitivity of statistical tests.

To test the hypothesis that introducing CSV enhances reproducibility in an ecological context, we had 14 European laboratories simultaneously run a simple microcosm experiment using grass (*Brachypodium distachyon* L.) monocultures and grass and legume (*Medicago truncatula* Gaertn.) mixtures. As part of the reproducibility experiment, the 14 laboratories independently tested the hypothesis that the presence of the legume species *M. truncatula* in mixtures would lead to higher total plant productivity in the microcosms and enhanced growth of the non-legume *B. distachyon* via rhizobia-mediated nitrogen fertilization and/or nitrogen-sparing effects[17–19].

All laboratories were provided with the same experimental protocol, seed stock from the same batch and identical containers in which to establish microcosms with grass only and grass–legume mixtures. Alongside a control with no CSV and containing a homogenized soil substrate (a mixture of soil and sand) and a single genotype of each plant species, we explored the effects of five different types of within- and among-microcosm CSV on experimental reproducibility of the legume effect (Fig. 1): (1) within-microcosm environmental CSV (ENV_W) achieved by spatially varying soil resource distribution through the introduction of six sand patches into the soil; (2) among-microcosm environmental CSV (ENV_A), which varied the number of sand patches (none, three or six) among replicate microcosms; (3) within-microcosm genotypic CSV (GEN_W), which used three distinct genotypes per species planted in homogenized soil in each microcosm; (4) among-microcosm genotypic CSV (GEN_A), which varied the number of genotypes (one, two or three) planted in homogenized soil among replicate microcosms; and (5) both genotypic and environmental CSV ($GEN_W + ENV_W$) within microcosms, which used six sand patches and three plant genotypes per species in each microcosm. In addition, we tested whether CSV effects are modified by the level of standardization within laboratories by using two common experimental approaches ('setups' hereafter): growth chambers with tightly controlled environmental conditions and identical soil (eight laboratories) or glasshouses with more loosely controlled environmental conditions and different soils (six laboratories; see Supplementary Table 1 for the physico-chemical properties of the soils).

We measured 12 parameters representing a typical ensemble of response variables reported for plant-soil microcosm experiments. Six of these were measured at the microcosm level (shoot biomass, root biomass, total biomass, shoot-to-root ratio, evapotranspiration and decomposition of a common substrate using a simplified version of the 'tea bag litter decomposition method'[20]). The other six were measured on *B. distachyon* alone (seed biomass, height and four shoot-tissue chemical variables: N%, C%, $\delta^{15}N$ and $\delta^{13}C$). All 12 variables were used to calculate the effect of the presence of a nitrogen-fixing legume on ecosystem functions in grass–legume mixtures ('net legume effect' hereafter) (Supplementary Table 2), calculated as the difference between the values measured in the microcosms with and without legumes—an approach often used in grass–legume binary cropping systems[19,21] and biodiversity–ecosystem function experiments[17,22].

Statistically significant differences among the 14 laboratories were considered an indication of irreproducibility. In the first instance, we assessed how our experimental treatments (CSV and setup) affected the number of laboratories that produced results that could be considered to have reproduced the same finding. We then determined how experimental treatments affected the s.d. of the legume effect for each of the 12 variables both within and among laboratories (lower among-laboratory s.d. implies that the results were more similar, suggesting increased reproducibility). Finally, we explored the relationship between within- and among-laboratory s.d. and how the experimental treatments affected the statistical power of detecting the net legume effect.

Results

Although each laboratory followed the same experimental protocol, we found a remarkably high level of among-laboratory variation for most response variables (Supplementary Fig. 1) and the net legume effect on those variables (Fig. 2). For example, the net legume effect on mean total plant biomass varied among laboratories from 1.31 to 6.72 g dry weight per microcosm in growth chambers, suggesting that unmeasured laboratory-specific conditions outweighed the effects of experimental standardization. Among glasshouses, the differences were even larger: the net legume effect on mean plant biomass varied by two orders of magnitude from 0.14 to 14.57 g dry weight per microcosm (Fig. 2). Furthermore, for half of the variables (root biomass, litter decomposition, grass height, foliar C%, $\delta^{15}C$ and $\delta^{15}N$), the direction of the net legume effect varied with the laboratory.

Mixed-effects models were used to test the effect of legume species presence, laboratory, CSV and their interactions (with experimental block—within-laboratory growth chamber or glasshouse bench—as a random factor) on the 12 response variables. The impact of the presence of legumes varied significantly with laboratory and CSV for half of the variables, as indicated by the legume × laboratory × CSV three-way interaction (Table 1 and Supplementary Figs. 2 and 3). For the other half, significant two-way interactions between legume × laboratory and CSV × laboratory were found. The same significant interactions were found when analysing the first (PC1) and second (PC2)

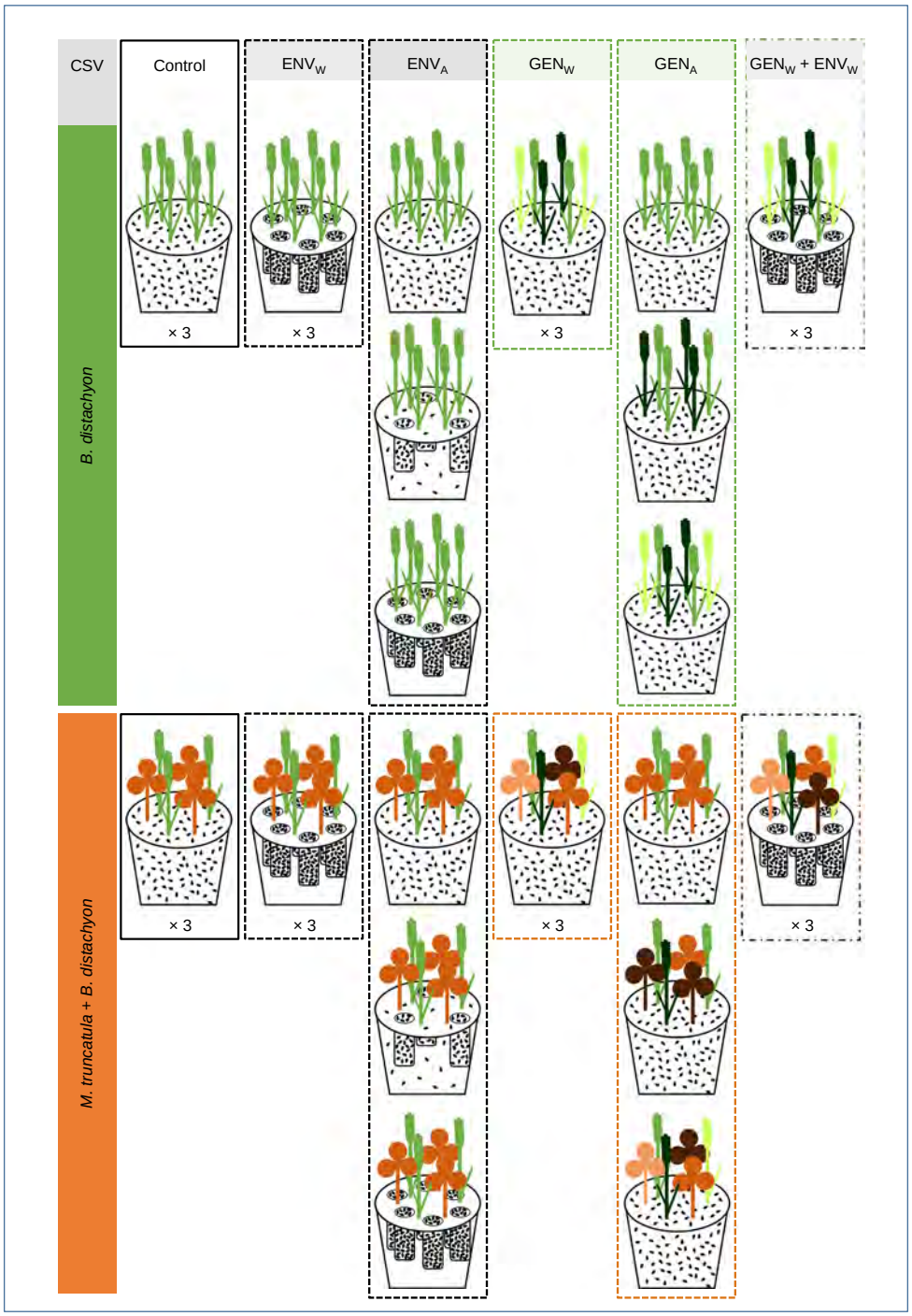

Fig. 1 | Experimental design of one block. Grass monocultures of *Brachypodium distachyon* (genotypes Bd21, Bd21-3 and Bd3-1 represented by green shades) and grass–legume mixtures with the legume *M. truncatula* (genotypes L000738, L000530 and L000174 represented by orange-brown shades) were established in 14 laboratories. Combinations of these distinct genotypes were used to establish genotypic CSV. Plants were established in a substrate with equal proportions of sand (black spots) and soil (white), with the sand being either mixed with the soil or concentrated in sand patches to induce environmental controlled systematic variability (CSV). As indicated, for some treatments, the same genotypic and sand composition was repeated in three microcosms per block. The spatial arrangement of the microcosms in each block was re-randomized every two weeks. For the growth chamber setups, the blocks represent two distinct chambers, whereas for glasshouse setups they represent two distinct growth benches in the same glasshouse.

principal components from a principal component analysis that included all 12 response variables. PC1 and PC2 together explained 45% of the variation (Table 1 and Supplementary Fig. 4a,b). Taken together, these results suggest that the effect size or direction of the net legume effect was significantly different (that is, not reproducible) in some laboratories and that the introduced CSV treatment affected reproducibility. In a complementary analysis including the setup in the model (and accounting for the laboratory effect as a random factor), we found that the impact of the CSV treatment varied significantly with the setup (CSV × setup or legume × CSV × setup interactions; Supplementary Table 3), suggesting that the reproducibility of the results differed between glasshouses and growth chambers.

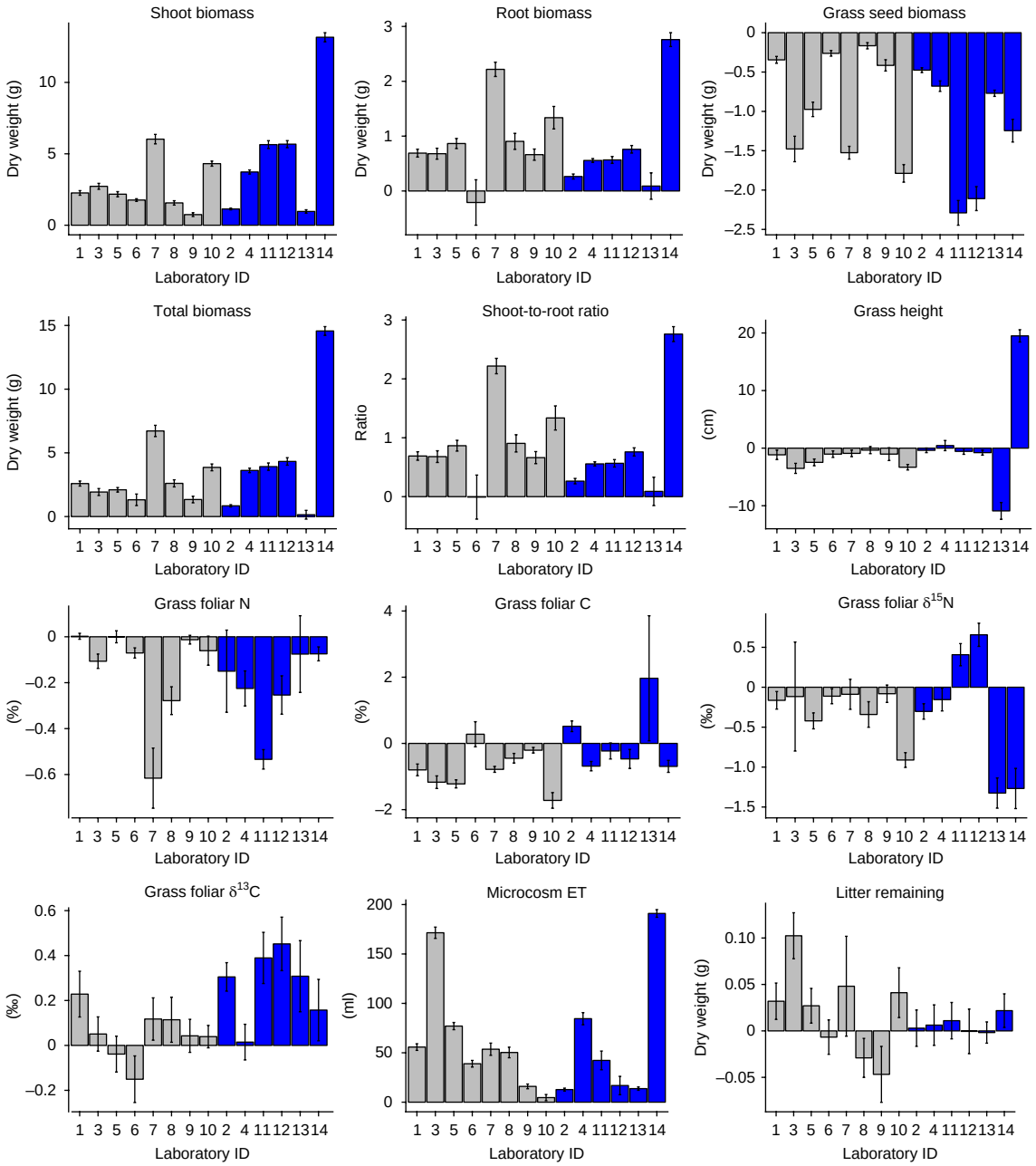

Fig. 2 | Net legume effect for the 12 response variables in 14 laboratories as affected by laboratory and setup (growth chamber versus glasshouse) treatments. The grey and blue bars represent laboratories that used growth chamber and glasshouse setups, respectively. ET, evapotranspiration. Bars show means by laboratory obtained by averaging over all CSV treatments, with error bars indicating ±1 s.e.m. ($n = 72$ microcosms per laboratory).

To answer the question of how many laboratories produced results that were statistically indistinguishable from one another (that is, reproduced the same finding), we used Tukey's post-hoc honest significant difference test for the laboratory effect on PC1 and PC2 describing the net legume effect, which together explained 49% of the variation (Supplementary Fig. 4c,d). Of the 14 laboratories, 7 (PC1) and 11 (PC2) were statistically indistinguishable in controls. This value increased in the treatments with environmental or genotypic CSV for PC1 but not PC2 (Table 2). When we analysed the responses in growth chambers alone, five of eight laboratories were statistically indistinguishable in controls, but this increased to six laboratories when we considered treatments with only environmental CSV and seven in treatments with genotypic CSV (GEN_W, GEN_A and $GEN_W + ENV_W$). In glasshouses, introducing CSV did not affect the number of statistically indistinguishable laboratories with respect to PC1, but decreased the number of statistically indistinguishable laboratories with respect to PC2 (Table 2).

We also assessed the impact of the experimental treatments on the among- and within-laboratory s.d. Analysis of the among-laboratory s.d. of the net legume effect revealed a significant CSV × setup interaction ($F_{5,121} = 7.38$, $P < 0.001$; Fig. 3a,b). This interaction included significantly lower fitted coefficients (that is, lower among-laboratory s.d.) in growth chambers for GEN_W ($t_{5,121} = -3.37$, $P = 0.001$), GEN_A ($t_{5,121} = -2.95$, $P = 0.004$) and $ENV_W + GEN_W$ treatments ($t_{1,121} = -3.73$, $P < 0.001$) relative to the control (see full model output for among-laboratory s.d. in the Supplementary Note). For these three treatments, the among-laboratory s.d. of the net legume effect was 18% lower with genotypic CSV than without it, indicating increased reproducibility (Fig. 3a). The same analysis performed on within-laboratory s.d. of the net legume effect only

Table 1 | Impact of experimental treatments on response variables

	DF	Shoot biomass (n=1,005)	Root biomass (n=989)	Seed biomass[a] (n=997)	Total biomass (n=976)	Shoot/root (n=987)	Grass height[a] (n=1,008)	Shoot N%[a] (n=1,008)
Legume	1	4602.95****	1131.65****	2186.64****	690.73****	1137.01****	3.33*	449.87****
CSV	5	15.57****	23.93****	58.01****	1.78 (NS)	23.98****	23.36****	0.78 (NS)
Laboratory	13	1088.67****	182.53****	364.57****	1251.96****	183.42****	317.33****	335.18****
Legume × CSV	5	23.64****	4.48****	33.62****	3.49***	4.51****	2.62**	1.34 (NS)
Legume × laboratory	13	235.99****	40.58****	78.17****	116.63****	40.38****	49.89****	14.12****
CSV × laboratory	65	6.55****	3.15****	6.93****	7.33****	3.17****	10.16****	1.98****
Legume × laboratory × CSV	65	2.22****	1.12 (NS)	2.70****	1.18 (NS)	1.12 (NS)	1.45**	1.71****

	DF	Shoot C%[a] (n=1,008)	Shoot $\delta^{15}N$[a] (n=963)	Shoot $\delta^{13}C$[a] (n=973)	Evapotranspiration (n=1,002)	Litter (n=974)	PC1 (n=1,008)	PC2 (n=1,008)
Legume	1	110.67****	14.43****	26.62****	1269.93****	1.81 (NS)	1242.53****	988.88****
CSV	5	0.16 (NS)	8.85****	75.73****	9.37****	1.05 (NS)	12.87****	22.56****
Laboratory	13	174.50****	258.30****	888.42****	748.66****	117.34****	920.65****	513.83****
Legume × CSV	5	2.55**	6.48****	5.15****	1.24 (NS)	1.77 (NS)	7.08****	11.79****
Legume × laboratory	13	11.90****	16.78****	2.52***	172.74****	2.05**	118.12****	28.22****
CSV × laboratory	65	1.67***	4.39****	4.97****	21.69****	2.97****	7.22****	2.76****
Legume × laboratory × CSV	65	1.33**	1.84****	1.23 (NS)	1.53***	1.17 (NS)	0.93 (NS)	1.65***

Mixed-effects model outputs summarizing the F and P values (as asterisks) for the impacts of the presence of legumes, CSV and laboratory on the 12 response variables. We also present the impact of experimental treatments on PC1 and PC2 of all 12 response variables.[a]Response variables measured for the grass *B. distachyon* only. The rest of the variables were measured at the microcosm level; that is, including the contribution of both the legume and the grass species.****P <0.001; ***P <0.01; **P< 0.05; *P <0.1; DF, degrees of freedom; NS, not significant (P > 0.1).

Table 2 | Impact of experimental treatments on the number of laboratories that reproduced the same finding

Source	All laboratories (n=14)		Glasshouses (n=6)		Growth chambers (n=8)	
	PC1	PC2	PC1	PC2	PC1	PC2
Control	7	11	3	5	5	5
ENV_W	10	9	3	3	6	6
ENV_A	8	8	3	4	6	6
GEN_W	8	10	3	3	6	7
GEN_A	11	10	3	3	7	8
$ENV_W + GEN_W$	11	10	4	3	7	7

Numbers represent the total number of statistically indistinguishable laboratories based on a Tukey's post-hoc honest significant difference test of PC1 and PC2 of the net legume effect of the 12 response variables (see Supplementary Fig. 4c,d for the principal component analysis results). For a detailed description of experimental treatments and abbreviations, see Fig. 1.

found a slight but significant increase of within-laboratory s.d. in the GEN_A treatment ($t_{5,121}$=3.52, P<0.001) (see model output for within-laboratory s.d. in the Supplementary Note). We then tested whether there was a relationship between within- and among-laboratory s.d. with a statistical model for among-laboratory s.d. as a function of within-laboratory s.d., setup, CSV and their interactions. We found a significant within-laboratory s.d. × setup × CSV three-way interaction ($F_{5,109}$=2.4, P<0.040) affecting among-laboratory s.d. (Supplementary Note). This interaction was the result of a more negative relationship between within- and among-laboratory s.d. in glasshouses relative to growth chambers, but with different slopes for the different CSV treatments (Fig. 4).

Introducing CSV can increase within-laboratory variation, as indicated by the positive coefficients fitted in some of the CSV treatments (see model output for within-laboratory s.d. in the Supplementary Note). Thus, for the three CSV treatments that produced the most consistent results (GEN_W, GEN_A and $ENV_W + GEN_W$), we analysed the statistical power of detecting the net legume effect within individual laboratories. In growth chambers, adding genotypic CSV led to a slight reduction in statistical power relative to the control (57% in the control versus 46% in the three treatments containing genotypic variability) that could have been compensated for by using 11 instead of 6 replicated microcosms per treatment. In glasshouses, owing to a higher effect size of legume presence on the response variables, the statistical power for detecting the legume effect in the control was slightly higher (68%) than in growth chambers, but was reduced to 51% on average for the three treatments containing genotypic CSV—a decrease that could have been compensated for by using 16 replicated microcosms instead of 6.

Discussion

Overall, our study shows that results produced by microcosm experiments can be strongly biased by laboratory-specific factors. Based on the PC explaining most of the variation in the 12 response variables (PC1), only 7 of the 14 laboratories produced results that can be considered reproducible (Table 2) with the current standardization procedures. This result is in line with ref. [12], which reports that out of ten laboratories, only four generated similar leaf growth phenotypes of *Arabidopsis thaliana* (L.). In addition to highlighting that approximately one in two ecological studies performed in microcosms under controlled environments produce statistically different results, our study provides supporting evidence for the hypothesis that introducing genotypic CSV can increase the reproducibility of ecological studies[9–11]. However, the effectiveness of genotypic CSV for enhancing reproducibility varied with the setup; that is, it led to lower (−18%) among-laboratory s.d. in growth chambers only, with no benefit observed in glasshouses. Lower among-laboratory s.d. in growth chambers implies that the microcosms containing genotypic CSV were less strongly affected by unaccounted-for laboratory-specific environmental or biotic variables. Analyses performed at the level of individual variables (Table 1) showed that introduc-

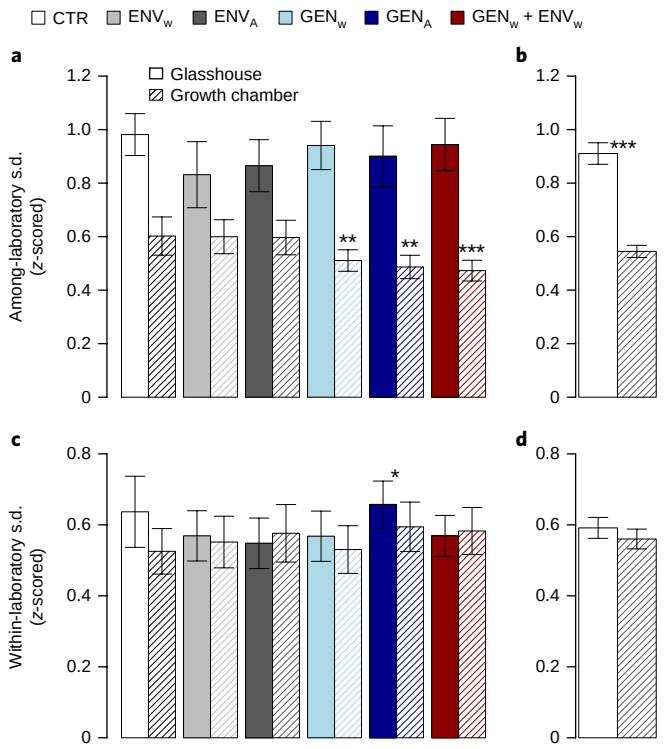

Fig. 3 | Among- and within-laboratory s.d. of the net legume effect as affected by experimental treatments. a,**b**, Among-laboratory s.d. as affected by CSV and setup (**a**) and setup only (**b**). **c**,**d**, Within-laboratory s.d. as affected by CSV and setup (**c**) and setup only (**d**). Lower among-laboratory s.d. indicates enhanced reproducibility. Solid and striped bars represent glasshouse ($n=6$) and growth chamber setups ($n=8$), respectively. *P* values (***$P<0.001$, **$P<0.01$ and *$P<0.05$) indicate significantly different fitted coefficients according to the mixed-effects models (see Supplementary Note for full model outputs). The asterisk in **c** indicates the significant difference between GEN$_A$ and the control, irrespective of the type of setup.

ing genotypic CSV affected the among-laboratory s.d. in most, but not all variables. This suggests that the relationship between genotypic CSV and reproducibility is probabilistic and results from the decreased likelihood that microcosms containing CSV will respond to unaccounted-for laboratory-specific environmental factors in the same direction and with the same magnitude. The mechanism is likely to be analogous to the stabilizing effect of biodiversity on ecosystem functions under changing environmental conditions[23–26], but additional empirical evidence is needed to confirm this conjecture.

Introducing genotypic CSV increased reproducibility in growth chambers (with stringent control of environmental conditions), but not in glasshouses (with more variable environmental conditions). Higher among-laboratory s.d. in glasshouses may indicate the existence therein of stronger laboratory-specific factors and our deliberate use of different soils in the glasshouses presumably contributed to this effect. However, the among-laboratory s.d. in glasshouses decreased with increasing within-laboratory s.d., irrespective of CSV—an effect that was less clear in growth chambers (Fig. 4). This observation appears to be in line with the hypothesis put forward in ref. [9], where it was proposed that increasing the variance within experiments can reduce the among-laboratory variability of the mean effect sizes observed in each laboratory. Yet, despite the negative correlation between within- and among-laboratory s.d. observed in glasshouses, the among-laboratory s.d. remained higher in glasshouses than growth chambers. Therefore, we consider that the hypothesized mechanistic link between CSV-induced higher within-laboratory s.d. and increased reproducibility is poorly supported by our dataset. Nevertheless, one possible explanation for the lack of effect on reproducibility in glasshouses is that our CSV treatments did not introduce a sufficiently high level of within-laboratory variability to buffer against laboratory-specific factors for all response variables; across the 12 response variables, the average main effect (that is, without the interaction terms) of the CSV treatment contributed to a low percentage (2.6% ± 1.6 s.e.m.) of the total sum of squares relative to the main effects of laboratory (43.4% ± 5.2 s.e.m.) and legumes (10.9% ± 3.1 s.e.m.). A similar conjecture was put forward by the other two studies that explored the role of CSV for reproducibility in animal behaviour[9,10]. At present, we are unable to conclude that the introduction of stronger sources of controlled within-laboratory variability can increase reproducibility in glasshouses with more loosely controlled environmental conditions and different soils.

Our results indicate that genotypic CSV is more effective at increasing reproducibility than environmental CSV, irrespective of whether the CSV is introduced within or among individual replicates (that is, microcosms). However, we cannot discount the possibility that we found this result because our treatments with environmental CSV were less successful in increasing within-microcosm variability. Additional experiments could test whether other types of environmental CSV, such as soil nutrients, texture or water availability, might be more effective at increasing reproducibility.

We expected higher overall productivity (that is, a net legume effect) in the grass–legume mixtures and enhanced growth of *B. distachyon* because of the presence of the nitrogen-fixing *M. truncatula*. However, these species were not selected because of their routine pairings in agronomic or ecological experiments (they are rarely used that way), but rather because they are frequently present in controlled environment experiments looking at functional genomics. In contrast with our expectation and despite the generally lower ^{15}N signature of *B. distachyon* in the presence of nitrogen-fixing *M. truncatula* (suggesting that some of the nitrogen fixed by *M. truncatula* was taken up by the grass), the biomass of *B. distachyon* was lower in the microcosms containing *M. truncatula*. The seed mass and shoot N% data of *B. distachyon* were lower in mixtures (Supplementary Fig. 1), suggesting that the two species competed for nitrogen. The lack of a significant nitrogen fertilization effect of *M. truncatula* on *B. distachyon* could have resulted from the asynchronous phenologies of the two species: the eight- to ten-week life cycle of *B. distachyon* may have been too short to benefit from the nitrogen fixation by *M. truncatula*.

Because well-established meta-analytical approaches can account for variation caused by local factors and still detect the general trends across different types of experimental setup, environment and population, we should ask whether the additional effort required for introducing CSV in experiments is worthwhile. Considering the current reproducibility crisis in many fields of science[27], we suggest that it is, for at least three reasons. First, some studies become seminal without any attempts to reproduce them. Second, even if a seminal study that is flawed due to laboratory-specific biases is later proven wrong, it usually takes significant time and resources before its impact on the field abates. Third, the current rate of reproducibility is estimated to be as low as one-third[12–14], implying that most data entering any meta-analysis are biased by unknown laboratory-specific factors. The addition of genotypic CSV may enhance the reproducibility of individual experiments and eliminate potential biases in the data used in meta-analyses. Additionally, if each individual study was less affected by laboratory-specific unknown environmental and biotic factors, we would also need fewer studies to draw solid conclusions about the generality of phenomena. Therefore, we argue that investing more in making individual studies more reproducible and generalizable will be beneficial in both

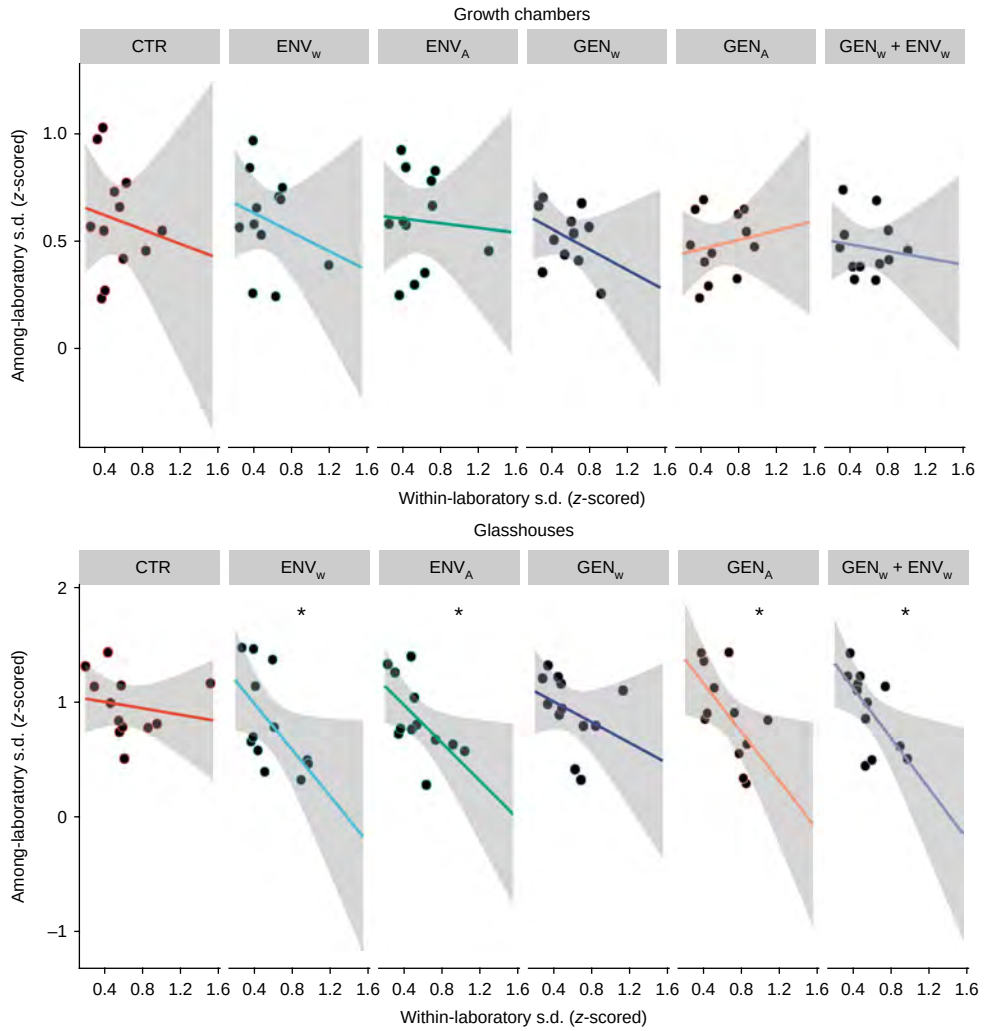

Fig. 4 | Relationship between within-laboratory s.d. and among-laboratory s.d. of the net legume effect as affected by experimental treatments. Significant within-laboratory s.d. × setup × CSV three-way interaction ($F_{5,109} = 2.4$, $P < 0.040$) affecting among-laboratory s.d. (Supplementary Note). This interaction is the result of a more negative relationship between within- and among-laboratory s.d. in glasshouses relative to growth chambers, but with different slopes for the different CSV treatments. Points represent the 12 response variables. Asterisks represent P values < 0.05 for the individual linear regressions. Note the different scale for the y axis between growth chambers and glasshouses.

the short and long term. At the same time, adding CSV can reduce the statistical power to detect experimental effects, so some additional experimental replicates would be needed when using it.

Arguably, our use of statistical significance tests of effect sizes to determine reproducibility might be viewed as overly restrictive and better suited to assessing the reproducibility of parameter estimates rather than the generality of the hypothesis under test[27]. We used this approach because no generally accepted alternative framework is available to assess how close the multivariate results from multiple laboratories need to be to conclude that they reproduced the same finding. It is worth noting that although the direction of the legume effect was the same in the majority of laboratories, the differences among laboratories were very large (for example, up to two orders of magnitude for shoot biomass) and in 10% of the 168 laboratory × variable combinations (14 laboratories × 12 response variables) the direction of the legume effect differed from the among-laboratory consensus (Fig. 2).

Conclusion

Our study shows that the current standardization procedures used in ecological microcosm experiments are inadequate in accounting for laboratory-specific environmental factors and suggests that introducing controlled variability in experiments may buffer some of the effects of laboratory-specific factors. Although there are multiple causes for the reproducibility crisis[15,28,29], deliberately including genetic variability in the studied organisms may turn out to be a simple solution for increasing the reproducibility of ecological studies performed in controlled environments. However, as the introduced genotypic variability only increased reproducibility in experimental setups with tightly controlled environmental conditions (that is, in growth chambers using identical soil), our study indicates that the reproducibility of ecological experiments may be enhanced by a combination of rigorous standardization of environmental variables at the laboratory level as well as controlled genotypic variability.

Methods

All laboratories tried, to the best of their abilities, to carry out identical experimental protocols. While not all laboratories managed to precisely recreate all of the details of the experimental protocol, we considered this to be a realistic scenario under which ecological experiments using microcosms are performed in glasshouses and growth chambers.

Germination. The seeds from three genotypes of *B. distachyon* (Bd21, Bd21-3 and Bd3-1) and *M. truncatula* (L000738, L000530 and L000174) were first sterilized by soaking 100 seeds in 100 ml of a sodium hypochlorite solution with 2.6% active chlorine, which was stirred for 15 min using a magnet. Thereafter, the seeds were rinsed three times in 250 ml of sterile water for 10–20 s under shaking. Sterilized seeds were germinated in trays (10 cm deep) filled with vermiculite. The trays were kept at 4 °C in the dark for 3 days before being moved to light conditions (300 µmol m^{-2} s^{-1} photosynthetically active radiation) and 20°C and 60% relative air humidity during the day and 16 °C and 70% relative air humidity at night. When the seedlings of both species reached 1 cm in height above the vermiculite, they were transplanted into the microcosms.

Preparation of microcosms. All laboratories used identical containers (2 l volume, 14.8 cm diameter and 17.4 cm height). Sand patches were created using custom-made identical 'patch makers' consisting of six rigid polyvinyl chloride tubes (2.5 cm in diameter and 25 cm long) arranged in a circular pattern with an outer diameter of 10 cm. A textile mesh was placed at the bottom of the containers to prevent the spilling of soil through drainage holes. The filling of microcosms containing sand patches started with the insertion of the empty tubes into the containers. Thereafter, in growth chambers, 2,000 g dry weight of soil, subtracting the weight of the sand patches, was added to the containers and around the 'patch maker' tubes. Because different soils were used in the glasshouses, the dry weight of the soil differed depending on the soil density and was first estimated individually in each laboratory as the amount of soil needed to fill the pots up to 2 cm from the top. After the soil was added to the containers, the tubes were filled with a mixture of 10% soil and 90% sand. When the microcosms did not contain sand patches, the amount of sand otherwise contained in the six patches was homogenized with the soil. During the filling of the microcosms, a common substrate for measuring litter decomposition was inserted at the centre of the microcosm at 8 cm depth. For simplicity, as well as for its fast decomposition rate, we used a single batch of commercially available tetrahedron-shaped synthetic tea bags (mesh size of 0.25 mm) containing 2 g of green tea (Lipton; Unilever), as proposed by the 'tea bag index' method[20]. Once filled, the microcosms were watered until water could be seen pouring out of the pot. The seedlings were then manually transplanted to pre-determined positions (Fig. 1), depending on the genotype and treatment. Each laboratory established two blocks of 36 microcosms, resulting in a total of 72 microcosms per laboratory, with blocks representing two distinct chambers in the growth chamber setups or two distinct growth benches in the same glasshouse.

Soils. All laboratories using growth chamber setups used the same soil, whereas the laboratories using glasshouses used different soils (see Supplementary Table 1 for the physico-chemical properties of the soils). The soil used in growth chambers was classified as a nutrient-poor cambisol and was collected from the top layer (0–20 cm) of a natural meadow at the Centre de Recherche en Ecologie Expérimentale et Prédictive (Saint-Pierre-lès-Nemours, France). Soils used in glasshouses originated from different locations. The soil used by laboratory 2 was a fluvisol collected from the top layer (0–40 cm) of a quarry site near Avignon in the Rhône valley, Southern France. The soil used by laboratory 4 was collected from near the La Cage field experimental system (Versailles, France) and was classified as a luvisol. The soil used by laboratories 11 and 12 was collected from the top layer (0–20 cm) within the haugh of the river Dreisam in the East of Freiburg, Germany. This soil was classified as an umbric gleysol with high organic carbon content. The soil used by laboratory 14 was classified as a eutric fluvisol and was collected on the field site of the Jena Experiment, Germany. Before the establishment of microcosms, all soils were air-dried at room temperature for several weeks and sieved using a 2 mm mesh sieve. A common inoculum was provided to all laboratories to ensure that rhizobia specific to *M. truncatula* were present in all soils.

Abiotic environmental conditions. The set points for environmental conditions were 16 h light (at 300 µmol m^{-2} s^{-1} photosynthetically active radiation) and 8 h dark, at 20 °C and in 60% relative air humidity during the day and 16 °C and 70% relative air humidity at night. Different soils (for glasshouses) and treatments with sand patches likely affected water drainage and evapotranspiration. The watering protocol was thus based on dry weight relative to weight at full water-holding capacity (WHC). The WHC was estimated based on the weight difference between the dry weight of the containers and the wet weight of the containers 24 h after abundant watering (until water was flowing out of the drainage holes in the bottom of each container). Soil moisture was maintained between 60 and 80% of WHC (that is, the containers were watered when the soil water dropped below 60% of WHC and water was added to reach 80% of WHC) during the first 3 weeks after seedling transplantation and between 50 and 70% of WHC for the rest of the experiment. Microcosms were watered twice a week with estimated WHC values from two microcosms per treatment. To ensure that the patch/heterogeneity treatments did not become a water availability treatment, all containers were weighed and brought to 70 or 80% of WHC every 2 weeks. This operation was synchronized with within-block randomization. All 14 experiments were performed between October 2014 and March 2015.

Sampling and analytical procedures. After 80 days, all plants were harvested. Plant shoots were cut at the soil surface, separated by species and dried at 60 °C for 3 days. Roots and any remaining litter in the tea bags were washed out of the soil using a 1 mm mesh sieve and dried at 60 °C for 3 days. The microcosm evapotranspiration rate was measured before the harvesting as the difference in weight changes from 70% of WHC after 48 h. Shoot C%, N%, $\delta^{13}C$ and $\delta^{15}N$ were measured on pooled shoot biomass (including seeds) of *B. distachyon* and analysed at the Göttingen Centre for Isotope Research and Analysis using a coupled system consisting of an Elemental Analyzer (NA 1500; Carlo-Erba) and a gas isotope mass spectrometer (Finnigan MAT 251; Thermo Electron Corporation).

Data analysis and statistics. All analyses were done using R version 3.2.4 (ref. [30]). Before data analyses, each laboratory was screened individually for outliers. Values that were lower or higher than 1.5 × interquartile range[31] within each laboratory, and representing less than 1.7% of the whole dataset, were considered to be outliers due to measurement errors or typos. These values were removed and subsequently treated as missing values. We then assessed whether the impact of the presence of legume varied with laboratory and the treatment of CSV. This was tested individually for each response variable (Table 1) with a mixed-effects model using the 'nlme' package[32]. Following the guidelines suggested by ref. [33], we first identified the most appropriate random structure using a restricted maximum likelihood approach and then selected the random structure with the lowest Akaike information criterion. For this model, CSV and laboratory were included as fixed factors, as well as experimental block as a random factor and a 'varIdent' weighting function to correct for heteroscedasticity resulting from more heteroscedastic data at the laboratory and legume level (R syntax: 'model = lme (response variable ~ legume*CSV*laboratory, random = ~1|block, weights = varIdent (form = ~1|laboratory*legume)') (Table 2). As the laboratory and setup experimental factors were not fully crossed (that is, laboratories performed the experiment only in one type of setup), the two experimental variables could not be included simultaneously as fixed effects. Therefore, to test for the setup effect, we used an additional complementary model including CSV and setup as fixed effects and laboratory as a random factor (R syntax: 'model = lme (response variable ~ legume*CSV*setup, random = ~1|laboratory/block, weights = varIdent (form = ~1|laboratory*legume)') (Supplementary Table 3). To test whether the results were affected by the collinearity among the response variables, the two models were also run on PC1 and PC2 of the 12 response variables (Fig. 4a,b). PCs were estimated using the 'FactoMineR' package[34], with missing values replaced using a regularized iterative multiple correspondence analysis[35] in the 'missMDA' package[36]. The same methodology was used to compute a second principal component analysis derived from the net legume effect on the 12 response variables (Supplementary Fig. 3c,d). To assess how many laboratories produced results that were statistically indistinguishable from one another, we applied Tukey's post-hoc honest significant difference test in the 'multcomp' package to laboratory-specific estimates of PC1 and PC2 (Table 2).

To assess how the CSV treatments affected the among- and within-laboratory variability, we used the s.d. instead of the coefficient of variation, because the net legume effect contained both positive and negative values. To calculate among- and within-laboratory s.d., we centred and scaled the raw values using the *z*-score normalization (*z*-scored variable = (raw value − mean)/s.d.) individually for each of the 12 response variables. Among-laboratory s.d. was computed from the mean of the laboratory *z*-scores for each response variable, CSV and setup treatment ($n = 144$; 6 CSV levels × 2 setup levels × 12 response variables). Within-laboratory s.d. was computed from the values measured in the six replicated microcosms for each CSV and setup treatment combination, individually for each response variable, resulting in a dataset with the same structure as that for among-laboratory s.d. ($n = 144$; 6 CSV levels × 2 setup levels × 12 response variables). Some of the 12 response variables were intrinsically correlated, but most had correlation coefficients < 0.5 (Supplementary Fig. 5) and were therefore treated as independent variables. To analyse and visualize the relationships between the s.d. calculated from variables with different units, before the calculation of the among- and within-laboratory s.d., the raw values of the 12 response variables were centred and scaled.

The impact of experimental treatments on among- and within-laboratory s.d. was analysed using mixed-effects models following the same procedure described for the individual response variables. The model with the lowest Akaike information criterion included a random slope for the setup within each response variable, as well as a 'varIdent' weighting function to correct for heteroscedasticity at the variable level (R syntax: 'model = lme (s.d. ~ CSV*setup, random = ~setup|variable, weights = varIdent (form = ~1|variable)') (see also Supplementary Note). The relationship between within- and among-laboratory s.d. was also tested with a model with similar random structure but with among-laboratory s.d. as a dependent variable and within-laboratory s.d., CSV and setup as predictors.

Because the treatments containing genotypic CSV increased reproducibility in growth chambers but slightly increased within-laboratory s.d., we also examined the effect of adding CSV on the statistical power for detecting the net legume effect in each individual laboratory. This analysis was done with the 'power.anova.test' function in the 'base' package. We computed the statistical power of detecting a

significant net legume effect (if one had used a one-way analysis of variance for the legume treatment) for the control, GEN_W, GEN_A and $ENV_W + GEN_W$ treatments for each laboratory and response variable. This allowed us to calculate the average statistical power for the aforementioned treatments and how many additional replicates would have been needed to achieve the same statistical power as we had in the control.

Life sciences reporting summary. Further information on experimental design is available in the Life Sciences Reporting Summary.

Data availability. The data that support the findings of this study are publicly available at https://doi.pangaea.de/10.1594/PANGAEA.880980.

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Author contributions

A.M. and J.R. designed the study with input from M. Blouin, S.B., M. Bonkowski and J.-C.L. Substantial methodological contributions were provided by S.S., T.G., L.R. and M.S.-L. Conceptual feedback on an early version was provided by G.T.F., N.E., J.R. and A.M.E. Data were analysed by A.M. with input from A.M.E. A.M. wrote the manuscript with input from all authors. All authors were involved in carrying out the experiments and/or analyses.

Competing interests

The authors declare no competing financial interests.

Additional information

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☐ Initial submission ☒ Revised version ☐ Final submission

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Experimental design

1. Sample size

Describe how sample size was determined.

As the aim of our study was to test how reproducible are typical microcosm experiments, we used a typical sample size for this type of experiment, i.e. six replicated microcosms per treatment. We also report the statistical power for the different treatments.

2. Data exclusions

Describe any data exclusions.

Data from each laboratory was first screen individually for outliers. We found that there was an inaccuracy in the earlier description of the outlier removal procedure. We used the Tukey fences method and considered that values that are higher or lower than 1.5 x interquartile range are outliers. This is now corrected in text and we added the relevant citation [Tukey, John W (1977). Exploratory Data Analysis]. These values are considered to be measurement errors and typos, etc. We applied the outlier removal after visually inspecting the data, but without knowing the impact on the results.

3. Replication

Describe whether the experimental findings were reliably reproduced.

The conclusions are based on the results from repeating the same expeirment in eight growth chambers and six glasshouses.

4. Randomization

Describe how samples/organisms/participants were allocated into experimental groups.

We used a randomized block design in each laboratory, with the blocks representing two distinct chambers in growth chamber setups, whereas in glasshouse setups the blocks represent two distinct growth benches in the same glasshouse. The spatial arrangement of the microcosms in each block was re-randomized every two weeks.

5. Blinding

Describe whether the investigators were blinded to group allocation during data collection and/or analysis.

The investigators were not blinded to group allocation during data collection and/or analysis.

Note: all studies involving animals and/or human research participants must disclose whether blinding and randomization were used.

6. Statistical parameters

For all figures and tables that use statistical methods, confirm that the following items are present in relevant figure legends (or in the Methods section if additional space is needed).

n/a	Confirmed
☐	☒ The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement (animals, litters, cultures, etc.)
☐	☒ A description of how samples were collected, noting whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒ A statement indicating how many times each experiment was replicated
☐	☒ The statistical test(s) used and whether they are one- or two-sided (note: only common tests should be described solely by name; more complex techniques should be described in the Methods section)
☐	☒ A description of any assumptions or corrections, such as an adjustment for multiple comparisons
☐	☒ The test results (e.g. *P* values) given as exact values whenever possible and with confidence intervals noted
☐	☒ A clear description of statistics including central tendency (e.g. median, mean) and variation (e.g. standard deviation, interquartile range)
☐	☒ Clearly defined error bars

See the web collection on statistics for biologists for further resources and guidance.

Software

Policy information about availability of computer code

7. Software

Describe the software used to analyze the data in this study.	All analyses were performed using R version 3.2.4.

For manuscripts utilizing custom algorithms or software that are central to the paper but not yet described in the published literature, software must be made available to editors and reviewers upon request. We strongly encourage code deposition in a community repository (e.g. GitHub). *Nature Methods* guidance for providing algorithms and software for publication provides further information on this topic.

Materials and reagents

Policy information about availability of materials

8. Materials availability

Indicate whether there are restrictions on availability of unique materials or if these materials are only available for distribution by a for-profit company.	Not applicable.

9. Antibodies

Describe the antibodies used and how they were validated for use in the system under study (i.e. assay and species).	Not applicable.

10. Eukaryotic cell lines

a. State the source of each eukaryotic cell line used.	Not applicable.
b. Describe the method of cell line authentication used.	Not applicable.
c. Report whether the cell lines were tested for mycoplasma contamination.	Not applicable.
d. If any of the cell lines used are listed in the database of commonly misidentified cell lines maintained by ICLAC, provide a scientific rationale for their use.	Not applicable.

Animals and human research participants

Policy information about studies involving animals; when reporting animal research, follow the ARRIVE guidelines

11. Description of research animals

Provide details on animals and/or animal-derived materials used in the study.	Not applicable.

Policy information about studies involving human research participants

12. Description of human research participants

Describe the covariate-relevant population characteristics of the human research participants.	Not applicable.

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SUPPLEMENTARY INFORMATION

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In the format provided by the authors and unedited.

Genotypic variability enhances the reproducibility of an ecological study

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Supplementary Table 1 | Physico-chemical properties of the soils used in growth chamber and glasshouse setups.

SETUP	Lab ID	C (g/kg)	N (g/kg)	C/N	Organic matter (g/kg)	P (g/kg)	Cation exchange (cmol+/kg)	Clay (g/100g)	Silt (g/100g)	Sand (g/100g)	pH
Growth chamber	L1, L3, L5, L6, L7, L8, L9, L10	7.26	0.57	12.67	12.57	0.09	3.46	10.53	19.23	70.23	5.88
Glasshouse	L2	7.41	0.45	15.23	12.83	<0.005	3.06	8.43	23.87	67.70	8.68
Glasshouse	L4	19.73	1.63	12.13	34.17	0.12	10.80	18.57	36.63	44.80	6.66
Glasshouse	L11, L12	50.03	4.58	10.90	86.53	0.05	16.73	22.83	25.00	52.17	5.35
Glasshouse	L13	16.83	1.94	8.67	29.10	0.19	8.02	18.00	10.00	72.00	5.78
Glasshouse	L14	20.13	1.83	11.00	34.77	0.06	10.70	22.60	45.97	31.23	8.23

Supplementary Table 2 | The net legume effect on measured response variables as affected by SETUP (glasshouse *vs.* growth chamber). Selected variables are typical for plant-soil microcosm experiments measuring plant productivity, biomass allocation, shoot tissue chemistry, evapotranspiration and litter decomposability (BM = biomass). † symbol indicates response variables measured for the grass *B. distachyon* only, while the rest of the variables have been measured at the microcosm level, i.e. including the contribution of both the legume and the grass species.

Variable abbreviation	Description	Unit	Mean net legume effect (±SE)	
			Glasshouse	Growth chamber
Shoot BM	shoot biomass	g DW	5.05 ± 0.29	2.72 ± 0.11
Root BM	root biomass	g DW	0.80 ± 0.08	0.96 ± 0.08
Seed BM†	*B. distachyon* total seed biomass	g DW	-1.28 ± 0.07	0.88 ± 0.05
Total BM	total biomass (shoot + root + seeds)	g DW	4.57 ± 0.34	2.80 ± 0.15
Shoot.Root	shoot (+seed) to root biomass ratio	dimensionless	-2.51 ± 0.28	-0.88 ± 0.13
Grass height†	*B. distachyon* average size	cm	1.17 ± 0.72	-1.87 ± 0.28
Shoot N%†	*B. distachyon* shoot (+seed) nitrogen %	%	-0.26 ± 0.04	-0.16 ± 0.02
Shoot C%†	*B. distachyon* shoot (+seed) carbon %	%	0.32 ± 0.0	0.73 ± 0.07
Shoot $\delta^{15}N$†	*B. distachyon* shoot (+seed) $\delta^{15}N$ signature	‰	-0.27 ± 0.09	-0.29 ± 0.1
Shoot $\delta^{13}C$†	*B. distachyon* shoot (+seed) $\delta^{13}C$ signature	‰	0.26 ± 0.04	0.05 ±0.03
ET	evapotranspiration prior to experimental harvest	ml $^{-24h}$	67.27 ± 5.41	59.8 ± 3.29
Litter	litter substrate remaining at the end of experiment	g DW	0.01 ± 0.009	0.04 ± 0.01

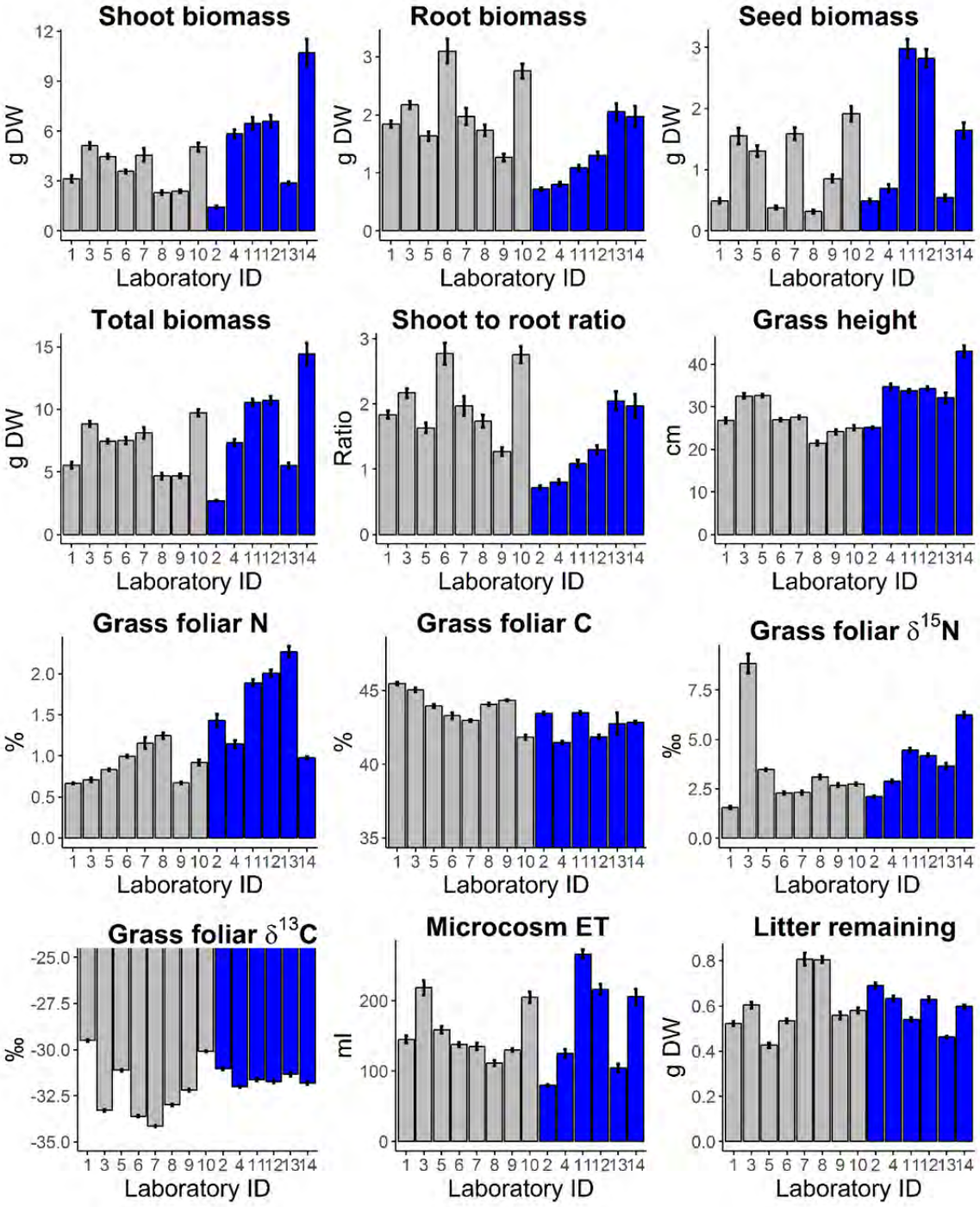
Supplementary Table 3 | Complementary analysis for the results from Table 1 (article text) presenting the impact of experimental treatments on response variables using laboratory ID as a random factor. Mixed-effects output summarizing the F- and P-values (as asterisks) for impact of the presence of legumes (LEG), controlled systematic variability (CSV) and laboratory setup (SETUP) on the 12 response variables. In addition to the results for the 12 response variables, we also present the effect of experimental treatments on the first second principal components (PC1 and PC2) summarizing all 12 response variables. The response variables shown represent a typical ensemble of variables measured in plant-soil microcosm experiments (BM = biomass). † symbol indicates response variables measured for the grass *B. distachyon* only, while the rest of the variables have been measured at the microcosm level, i.e. including the contribution of both the legume and the grass species. Asterisks indicate the significance levels (*** for $P < 0.001$; ** for $P < 0.01$; * for $P < 0.05$; + for $P < 0.1$; ns for $P > 0.1$). DF = numerator degrees of freedom.

	DF	Shoot BM	Root BM	Seed BM†	Total BM	Shoot/Root	Grass height†	Shoot N%†
LEG	1	1843.37 (***)	705.35 (***)	729.57 (***)	637.80 (***)	706.29 (***)	30.90 (***)	54.14 (***)
CSV	5	9.10 (***)	20.91 (***)	39.52 (***)	3.87 (**)	21.00 (***)	20.16 (***)	0.75 (ns.)
SETUP	1	2.99 (ns.)	7.35 (*)	1.34 (ns.)	0.75 (ns.)	7.52 (*)	5.28 (*)	15.13 (**)
LEG×CSV	5	12.41 (***)	3.30 (**)	21.51 (***)	0.55 (n.s)	3.32 (**)	1.70 (ns.)	1.28 (ns.)
LEG×SETUP	1	209.81 (***)	30.33 (**)	87.11 (***)	132.91 (***)	30.37 (***)	10.92 (**)	35.93 (***)
CSV×SETUP	5	23.31 (***)	5.59 (***)	22.70 (***)	18.34 (***)	5.57 (***)	3.37 (**)	0.91(ns.)
LEG×CSV×SETUP	5	7.34 (***)	1.03 (ns.)	0.82 (ns)	1.13 (ns.)	1.00 (ns.)	2.58 (*)	3.77 (**)
		n = 1005	n = 989	n = 997	n = 976	n = 987	n = 1008	n = 1008

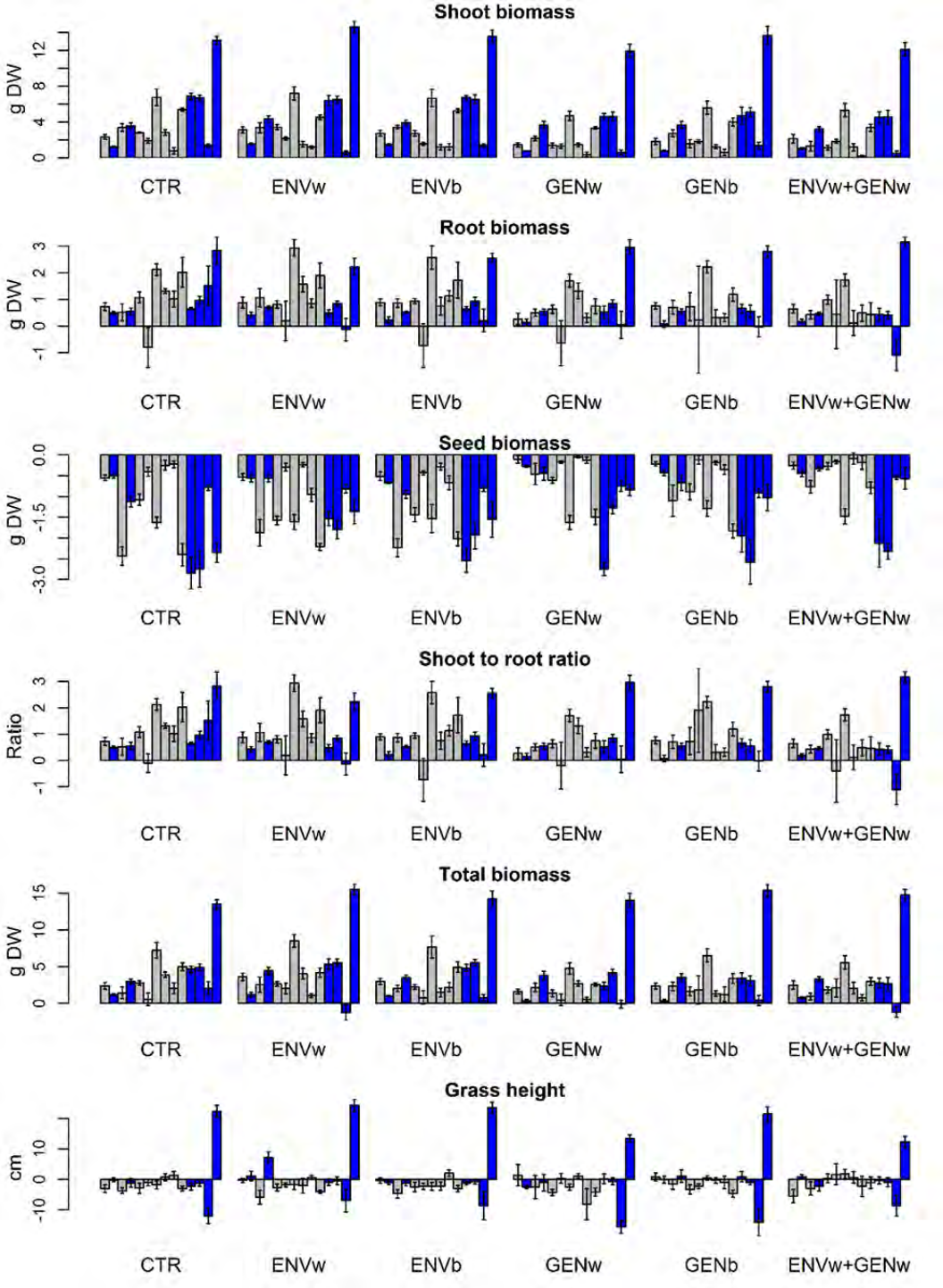
	DF	Shoot C%†	Shoot $\delta^{15}N$†	Shoot $\delta^{13}C$†	ET	Litter	PC1	PC2
LEG	1	197.32 (***)	56.15 (***)	22.20 (***)	650.80 (***)	3.63 (+)	1002.71 (***)	588.49 (***)
CSV	5	0.02 (ns.)	8.07 (***)	77.50 (***)	1.20 (***)	0.79 (ns.)	9.43 (***)	28.11 (***)

SETUP	1	4.98 (*)	0.32 (ns.)	0.55 (ns.)	0.08 (ns.)	0.03 (ns.)	0.00 (ns.)	12.27 (**)
LEG×CSV	5	2.31 (*)	6.38 (***)	6.55 (***)	0.50 (ns.)	2.08 (+)	2.84 (*)	10.12 (***)
LEG×SETUP	1	11.56 (***)	4.61(*)	16.98 (***)	281.92 (***)	1.03 (ns.)	2.31 (ns.)	6.59 (*)
CSV×SETUP	5	2.05 (+)	6.76 (***)	9.89 (***)	12.44 (***)	1.38 (ns.)	15.65 (***)	1.42 (ns.)
LEG×CSV×SETUP	5	0.65 (ns.)	1.56 (ns.)	0.98 (ns.)	4.31 (***)	1.24 (ns.)	10.03 (***)	1.42 (ns.)
		n = 1008	n = 963	n = 973	n = 1002	n = 974	n = 1008	n = 1008

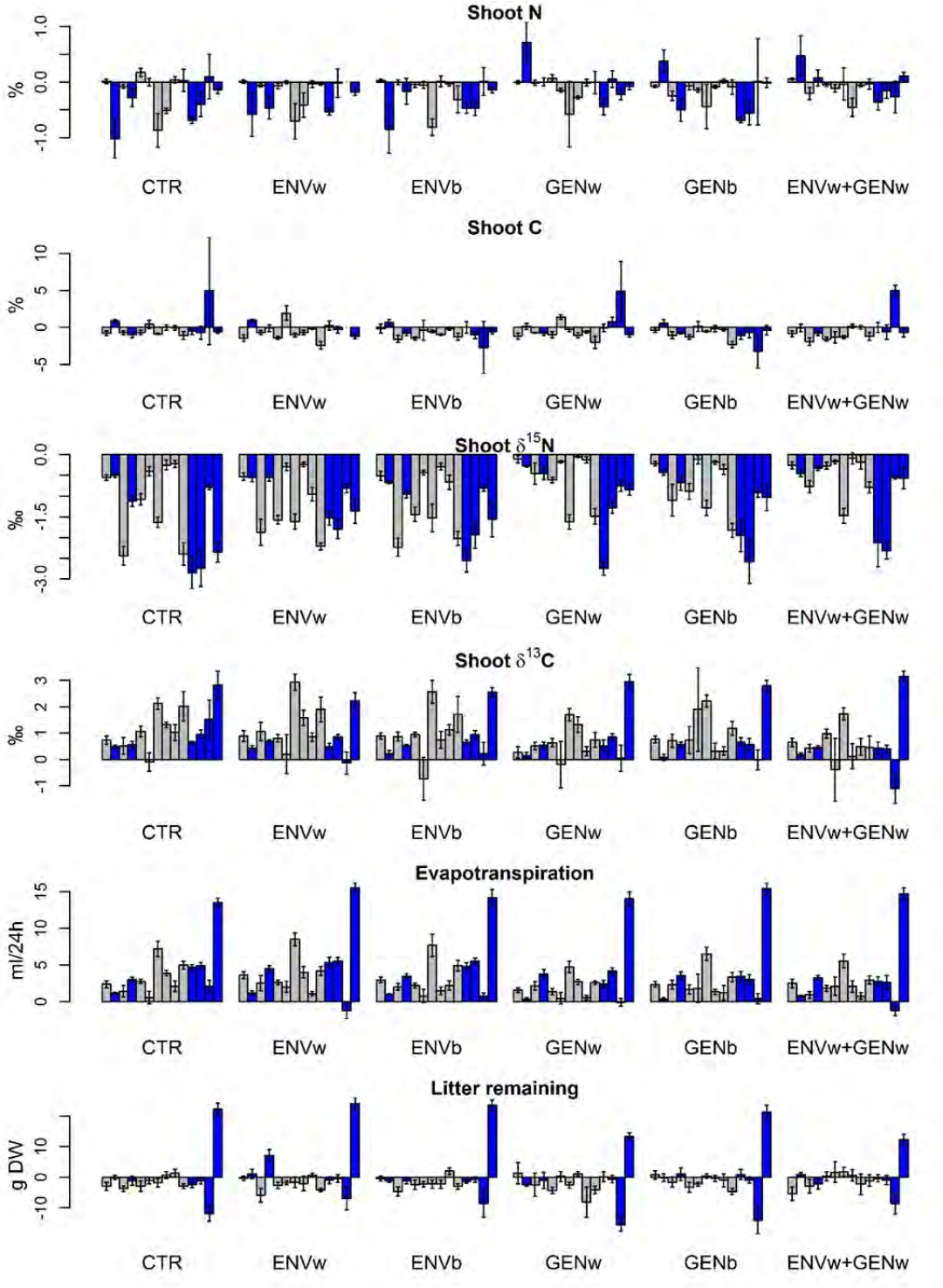
Supplementary Fig. 1 | Response variables as affected by laboratory and SETUP (growth chamber *vs.* glasshouse treatment). Grey and blue bars represent laboratories that used growth chamber and glasshouse setups, respectively. Bars show means by laboratory obtained by averaging over all CSV treatments, with error bars representing ± 1 s.e.m. (n = 72 microcosms per laboratory).



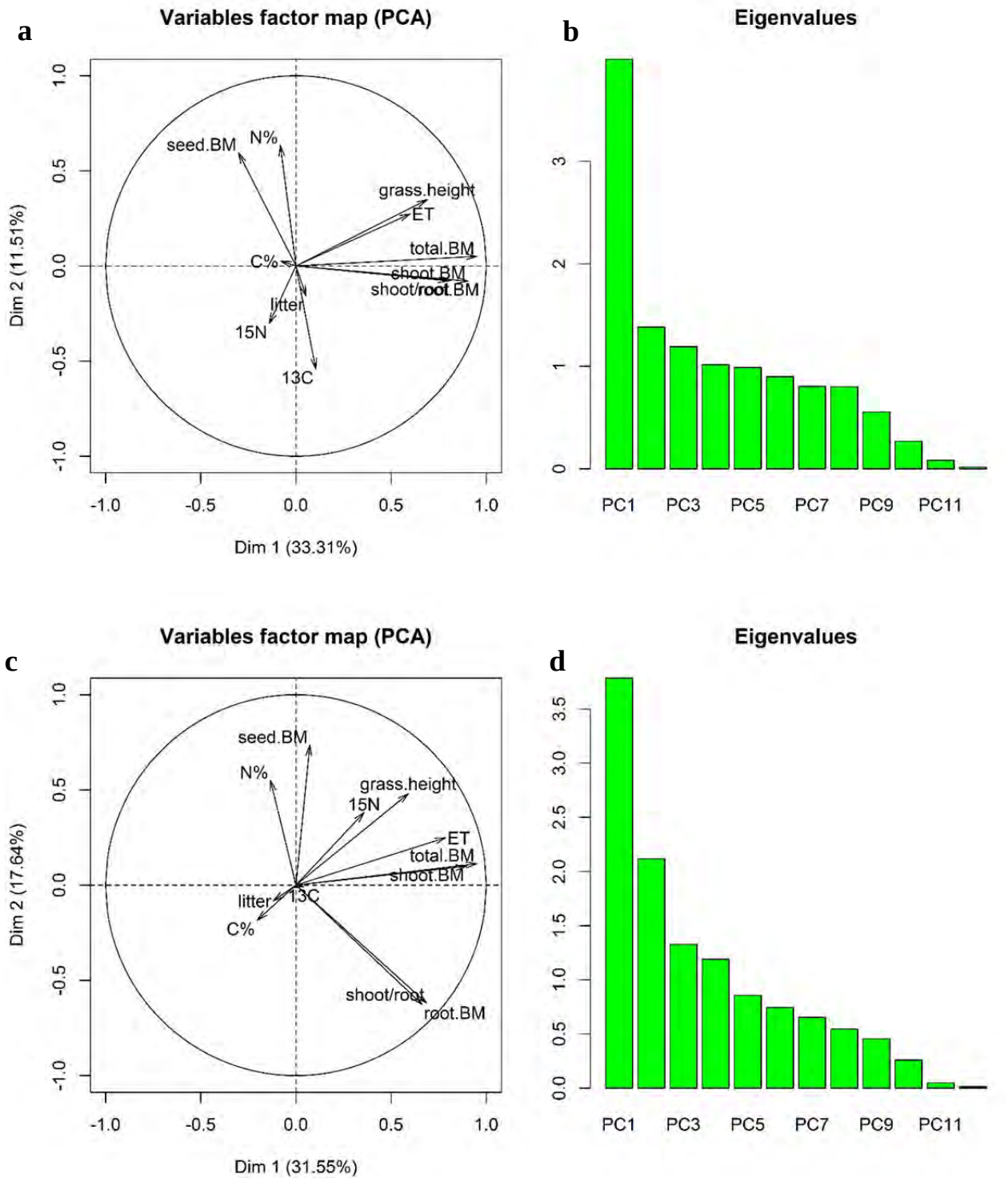
Supplementary Fig. 2 | Response variables (first six) as affected by CSV, laboratory, and SETUP. Grey and blue bars indicate laboratories that used growth chamber and glasshouse setups, respectively. Bars with error bars represent means ± 1 s.e.m. (n = 6 microcosms).



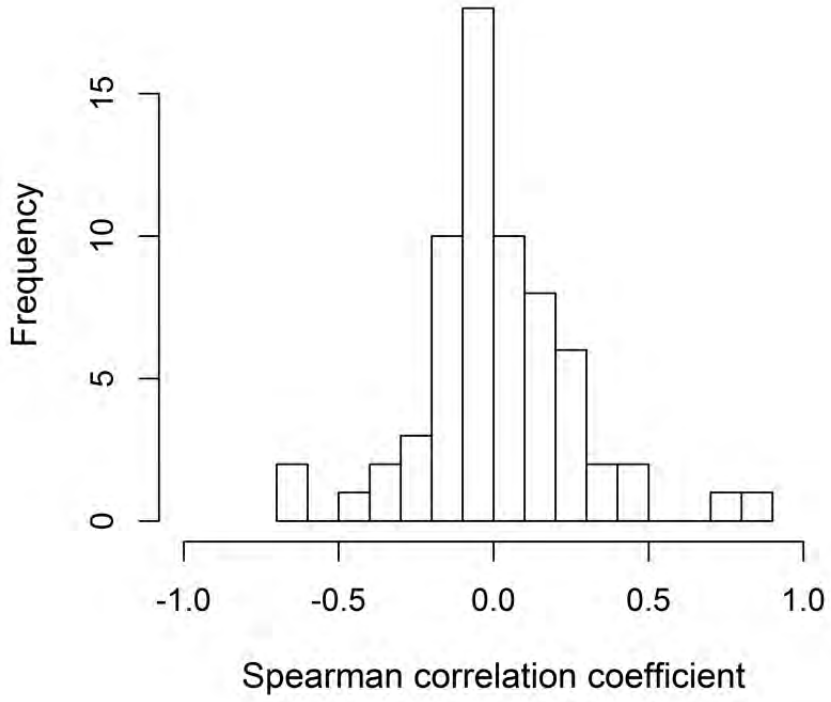
Supplementary Fig. 3 | Response variables (last six) as affected by CSV, laboratory, and SETUP. Grey and blue bars indicate laboratories that used growth chamber and glasshouse setups, respectively. Bars with error bars represent means ± 1 s.e.m. (n = 6 microcosms).



Supplementary Fig. 4 | Results from the principal components analyses for the 12 response variables (top) and for the net legume effect estimated from the 12 variables (bottom).



Supplementary Fig. 5 | Frequency distribution of Spearman's correlation coefficients between each pair of the 12 response variables (n = 36 pairs).



Supplementary Note | Model outputs for the models used to test the effect of experimental treatments on among and within laboratory SD as well as for the model of among-laboratory SD as a function of within-laboratory SD.

Model output for among-laboratory SD

```
model <-lme(amongSD~csv*setup,random=~setup|variable, weights=varIdent(form=~1|variable)
,na.action=na.omit,data=bothSD)

anova(model)
            numDF denDF   F-value p-value
(Intercept)     1   121 238.06748  <.0001
csv             5   121   1.21431  0.3065
setup           1   121  13.41761  0.0004
csv:setup       5   121   7.38356  <.0001

Summary (model)
Linear mixed-effects model fit by REML

  AIC      BIC      logLik
  1.845438 79.68109 26.07728

Random effects:
 Formula: ~setup | variable
 Structure: General positive-definite, Log-Cholesky parametrization
                   StdDev    Corr
(Intercept)        0.3015452 (Intr)
setupgrowth_chamber 0.3261794 -0.904
Residual           0.1468238

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | variable
 Parameter estimates:
    seedbm    shootbm     rootbm    totalbm    shoot.root heightB    N%
1.0000000     0.7064977  0.7891088  0.6346943  0.8230489  1.5292827  0.7959960

C%         deltaN     deltaC      finalET    litter
1.7423080  1.4579229  1.4602126  0.5335987  0.8567412
Fixed effects: betweenSD ~ csv * setup
                                      Value  Std.Error  DF   t-value p-value
(Intercept)                          0.8965986 0.09489334 121  9.448489  0.0000
csvENVw                             -0.0222416 0.05078427 121 -0.437962  0.6622
csvENVa                             -0.0462239 0.05078427 121 -0.910201  0.3645
csvGENw                              0.0497013 0.05078427 121  0.978674  0.3297
csvGENa                              0.0409573 0.05078427 121  0.806496  0.4215
csvENVw+GENw                         0.0734211 0.05078427 121  1.445745  0.1508
setupgrowth_chamber                 -0.2413145 0.10814547 121 -2.231388  0.0275
csvENVw:setupgrowth_chamber         -0.0063497 0.07181981 121 -0.088411  0.9297
csvENVa:setupgrowth_chamber          0.0299276 0.07181981 121  0.416704  0.6776
csvGENw:setupgrowth_chamber         -0.2424468 0.07181981 121 -3.375765  0.0010
csvGENa:setupgrowth_chamber         -0.2124676 0.07181981 121 -2.958343  0.0037
csvENVw+GENw:setupgrowth_chamber -0.2681373 0.07181981 121 -3.733473  0.0003

Standardized Within-Group Residuals:
        Min          Q1         Med          Q3         Max
-1.97736204 -0.72183774  0.03459952  0.53585186  2.32685019
```

```
Number of Observations: 144
Number of Groups: 12
```

Model output for within-laboratory SD

```
model <-lme(withinSD~csv*setup,random=~setup|variable,
weights=varIdent(form=~1|variable),na.action=na.omit,data=bothSD)

anova(m4)
                numDF denDF   F-value p-value
(Intercept)     1   121 117.65394  <.0001
csv             5   121   7.42343  <.0001
setup           1   121   0.09202  0.7621
csv:setup       5   121   1.39108  0.2324

summary(model)
Linear mixed-effects model fit by REML

        AIC       BIC   logLik
  -103.5979 -25.76229 78.79897

Random effects:
 Formula: ~setup | variable
 Structure: General positive-definite, Log-Cholesky parametrization
                    StdDev     Corr
(Intercept)         0.21316427 (Intr)
setupgrowth_chamber 0.24341650 -0.536
Residual            0.08340683

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | variable
 Parameter estimates:
seedbm   shootbm    rootbm    totalbm    shoot.root     heightB     N%
1.000000 0.4270974  0.9985380  0.4467339  0.9999987   1.5639029  1.1077805
C%         deltaN     deltaC      finalET   litter
3.2391887  1.0088300  1.2621380  0.6040685  1.8026937
Fixed effects: withinSD ~ csv * setup
                                     Value  Std.Error  DF   t-value p-value
(Intercept)                       0.5614479 0.06526348 121  8.602788  0.0000
csvENVw                           0.0196394 0.02672984 121  0.734738  0.4639
csvENVa                          -0.0191756 0.02672984 121 -0.717387  0.4745
csvGENw                           0.0020098 0.02672984 121  0.075190  0.9402
csvGENa                           0.0942525 0.02672984 121  3.526117  0.0006
csvENVw+GENw                      0.0338044 0.02672984 121  1.264671  0.2084
csvENVw:setupgrowth_chamber      -0.0005847 0.03780170 121 -0.015467  0.9877
csvENVa:setupgrowth_chamber       0.0525727 0.03780170 121  1.390750  0.1669
csvGENw:setupgrowth_chamber      -0.0431985 0.03780170 121 -1.142766  0.2554
csvGENa:setupgrowth_chamber      -0.0180580 0.03780170 121 -0.477703  0.6337
csvENVw+GENw:setupgrowth_chamber  0.0041737 0.03780170 121  0.110409  0.9123
 Correlation:
Standardized Within-Group Residuals:
        Min          Q1         Med          Q3         Max
-2.04926063 -0.63398623 -0.08673377  0.52628261  2.48691942
```

```
 anova(model)
                   numDF denDF   F-value p-value
(Intercept)          1   109 183.31526  <.0001
withinSD             1   109   4.83259  0.0300
csv                  5   109   2.68312  0.0251
setup                1   109  13.21629  0.0004
withinSD:csv         5   109   4.84786  0.0005
withinSD:setup       1   109   0.00623  0.9372
csv:setup            5   109  15.17262  <.0001
withinSD:csv:setup   5   109   2.40589  0.0412


Number of Observations: 144
Number of Groups: 12
```

Model output for among-laboratory SD as a function of within-laboratory SD and CSV

```
model<-lme(amongSD~withinSD*csv*setup,random=~setup|variable,weights= varIdent(for
      m = ~1|variable),data=bothSD,na.action=na.omit)
summary(model)

Linear mixed-effects model fit by REML
       AIC      BIC   logLik
  23.15262 131.8648 27.42369

Random effects:
 Formula: ~setup | variable
 Structure: General positive-definite, Log-Cholesky parametrization
                   StdDev    Corr
(Intercept)        0.3153546 (Intr)
setupgrowth_chamber 0.3256810 -0.885
Residual           0.1637205

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | variable
 Parameter estimates:
 seedbm    shootbm     rootbm    totalbm    shoot.root    heightB   N%
 1.0000000  0.7008668  0.8660312  0.2948917  0.8505491  1.3691757  0.5568015

 C%         deltaN     deltaC    finalET     litter
 1.4064467  1.4398760  1.1425713  0.2992432  0.7962738

Fixed effects: betweenSD ~ withinSD * csv * setup


                                        Value  Std.Error  DF   t-value p-value
(Intercept)                         0.5902798 0.13732089 109  4.298543  0.0000
withinSD                            0.4932791 0.17311674 109  2.849401  0.0052
csvENVw                             0.4983170 0.09666122 109  5.155294  0.0000
csvENVa                             0.2320159 0.09541446 109  2.431664  0.0167
csvGENw                             0.1903663 0.10854290 109  1.753835  0.0823
csvGENa                             0.3592284 0.09943186 109  3.612809  0.0005
csvENVw+GENw                        0.4283155 0.10789508 109  3.969740  0.0001
```

```
setupgrowth_chamber                          0.0406032 0.17893949 109  0.226910  0.8209
withinSD:csvENVw                            -0.8568180 0.18224967 109 -4.701342  0.0000
withinSD:csvENVa                            -0.4684887 0.18382314 109 -2.548584  0.0122
withinSD:csvGENw                             0.1362548 0.22132193 109 -0.615641  0.5394
withinSD:csvGENa                            -0.5051454 0.17502257 109 -2.886173  0.0047
withinSD:csvENVw+GENw                       -0.6511553 0.21015129 109 -3.098507  0.0025
withinSD:setupgrowth_chamber                -0.4601885 0.28295454 109 -1.626369  0.1068
csvENVw:setupgrowth_chamber                 -0.4438781 0.14408373 109 -3.080695  0.0026
csvENVa:setupgrowth_chamber                 -0.2414006 0.14073984 109 -1.715226  0.0891
csvGENw:setupgrowth_chamber                 -0.4818768 0.14784056 109 -3.259436  0.0015
csvGENa:setupgrowth_chamber                 -0.7383319 0.14982900 109 -4.927831  0.0000
csvENVw+GENw:setupgrowth_chamber            -0.6725627 0.15165089 109 -4.434940  0.0000
withinSD:csvENVw:setupgrowth_chamber         0.7007849 0.28840824 109  2.429837  0.0167
withinSD:csvENVa:setupgrowth_chamber         0.4426157 0.28311655 109  1.563369  0.1209
withinSD:csvGENw:setupgrowth_chamber         0.3387115 0.31505570 109  1.075084  0.2847
withinSD:csvGENa:setupgrowth_chamber         0.8779478 0.28879867 109  3.039999  0.0030
withinSD:csvENVw+GENw:setupgrowth_chamber    0.7451687 0.30808448 109  2.418716  0.0172
```

Detailed model outputs from Table 1

Model for shoot biomass (shootbm)

```
anova(m1)
                  numDF denDF  F-value p-value
(Intercept)           1   836 13032.56  <.0001
legumes               1   836  4602.95  <.0001
csv                   5   836    15.57  <.0001
lab                  13   836  1088.67  <.0001
legumes:csv           5   836    23.64  <.0001
legumes:lab          13   836   236.00  <.0001
csv:lab              65   836     6.54  <.0001
legumes:csv:lab      65   836     2.22  <.0001
```

```
summary(m1)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  2220 3152   -913

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:      0.0255    0.998

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  1.553  0.156  0.160  0.969  0.961  0.649  0.699  0.477  0.474  0.301
L6*BM   L7*B  L7*BM L8*B  L8*BM   L9*B  L9*BM  L10*B L10*BM  L11*B L11*BM
0.337  0.339  1.757 0.426  0.523  0.215  0.664  0.385  0.580  0.944  0.843
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.087  0.874  0.510  0.573  1.322  1.512
Fixed effects: shootbm ~ legumes * csv * lab
```

	Value	Std.Error	DF	t-value	p-value
(Intercept)	2.00	0.408	836	4.90	0.0000
legumesBM	2.32	0.752	836	3.08	0.0021
csvENVw	0.06	0.576	836	0.11	0.9134
csvENVb	-0.02	0.576	836	-0.04	0.9679
csvGENw	-0.08	0.576	836	-0.15	0.8845
csvGENb	-0.03	0.576	836	-0.05	0.9562
csvENVw+GENw	0.12	0.576	836	0.21	0.8303
labL2	-1.36	0.412	836	-3.29	0.0010
labL3	1.74	0.567	836	3.07	0.0022
labL4	2.76	0.485	836	5.68	0.0000
labL5	0.65	0.451	836	1.44	0.1507
labL6	0.78	0.425	836	1.82	0.0688
labL7	-0.61	0.430	836	-1.41	0.1581
labL8	-0.76	0.443	836	-1.71	0.0876
labL9	0.02	0.417	836	0.05	0.9627
labL10	0.39	0.436	836	0.88	0.3765
labL11	0.59	0.560	836	1.05	0.2933
labL12	0.80	0.602	836	1.34	0.1821
labL13	0.39	0.457	836	0.85	0.3956
labL14	1.40	0.675	836	2.07	0.0388
legumesBM:csvENVw	0.79	1.064	836	0.74	0.4579
legumesBM:csvENVb	0.42	1.064	836	0.39	0.6947
legumesBM:csvGENw	-0.88	1.064	836	-0.82	0.4106
legumesBM:csvGENb	-0.49	1.064	836	-0.46	0.6468
legumesBM:csvENVw+GENw	-0.20	1.064	836	-0.19	0.8529
legumesBM:labL2	-1.11	0.758	836	-1.46	0.1443
legumesBM:labL3	1.06	0.935	836	1.14	0.2552
legumesBM:labL4	1.28	0.846	836	1.51	0.1321
legumesBM:labL5	0.48	0.800	836	0.60	0.5486
legumesBM:labL6	-0.42	0.774	836	-0.54	0.5862
legumesBM:labL7	4.42	1.047	836	4.22	0.0000
legumesBM:labL8	0.51	0.801	836	0.64	0.5244
legumesBM:labL9	-1.54	0.804	836	-1.92	0.0558
legumesBM:labL10	3.06	0.804	836	3.81	0.0001
legumesBM:labL11	4.56	0.912	836	5.01	0.0000
legumesBM:labL12	4.39	0.943	836	4.66	0.0000
legumesBM:labL13	-0.95	0.814	836	-1.17	0.2429
legumesBM:labL14	10.79	1.111	836	9.71	0.0000
csvENVw:labL2	-0.14	0.583	836	-0.24	0.8094
csvENVb:labL2	-0.01	0.583	836	-0.01	0.9900
csvGENw:labL2	0.57	0.583	836	0.98	0.3257
csvGENb:labL2	0.44	0.583	836	0.76	0.4480
csvENVw+GENw:labL2	0.50	0.583	836	0.86	0.3905
csvENVw:labL3	-0.74	0.802	836	-0.92	0.3557
csvENVb:labL3	-0.43	0.802	836	-0.53	0.5932
csvGENw:labL3	0.69	0.802	836	0.87	0.3872
csvGENb:labL3	0.42	0.802	836	0.52	0.6035
csvENVw+GENw:labL3	0.15	0.802	836	0.19	0.8469
csvENVw:labL4	-2.28	0.686	836	-3.32	0.0009
csvENVb:labL4	-0.67	0.686	836	-0.98	0.3291
csvGENw:labL4	-0.18	0.686	836	-0.27	0.7887
csvGENb:labL4	-0.14	0.686	836	-0.21	0.8341
csvENVw+GENw:labL4	-1.46	0.686	836	-2.12	0.0340
csvENVw:labL5	0.07	0.638	836	0.11	0.9110
csvENVb:labL5	0.22	0.638	836	0.35	0.7251
csvGENw:labL5	1.53	0.638	836	2.40	0.0166
csvGENb:labL5	1.04	0.638	836	1.64	0.1023
csvENVw+GENw:labL5	1.58	0.638	836	2.48	0.0134
csvENVw:labL6	-0.14	0.601	836	-0.23	0.8205
csvENVb:labL6	0.14	0.601	836	0.23	0.8182
csvGENw:labL6	-0.15	0.601	836	-0.25	0.8033
csvGENb:labL6	-0.15	0.601	836	-0.24	0.8068

```
299   csvENVw+GENw:labL6             -0.18     0.601 836   -0.30  0.7644
300   csvENVw:labL7                   0.03     0.608 836    0.05  0.9578
301   csvENVb:labL7                  -0.05     0.608 836   -0.08  0.9362
302   csvGENw:labL7                   0.43     0.608 836    0.71  0.4803
303   csvGENb:labL7                   0.17     0.608 836    0.29  0.7755
304   csvENVw+GENw:labL7              0.34     0.608 836    0.57  0.5720
305   csvENVw:labL8                   0.56     0.626 836    0.89  0.3712
306   csvENVb:labL8                   0.61     0.626 836    0.98  0.3284
307   csvGENw:labL8                   0.05     0.626 836    0.09  0.9309
308   csvGENb:labL8                  -0.07     0.626 836   -0.12  0.9051
309   csvENVw+GENw:labL8              0.56     0.626 836    0.90  0.3690
310   csvENVw:labL9                  -0.01     0.589 836   -0.01  0.9894
311   csvENVb:labL9                  -0.07     0.589 836   -0.12  0.9061
312   csvGENw:labL9                  -0.07     0.589 836   -0.13  0.8992
313   csvGENb:labL9                   0.02     0.589 836    0.03  0.9765
314   csvENVw+GENw:labL9              0.06     0.589 836    0.10  0.9189
315   csvENVw:labL10                  0.24     0.617 836    0.39  0.6991
316   csvENVb:labL10                 -0.16     0.617 836   -0.25  0.7997
317   csvGENw:labL10                  1.36     0.617 836    2.20  0.0278
318   csvGENb:labL10                  1.04     0.617 836    1.68  0.0928
319   csvENVw+GENw:labL10             0.54     0.617 836    0.88  0.3807
320   csvENVw:labL11                 -0.11     0.792 836   -0.14  0.8884
321   csvENVb:labL11                  0.06     0.792 836    0.07  0.9423
322   csvGENw:labL11                  2.19     0.792 836    2.77  0.0058
323   csvGENb:labL11                  2.08     0.792 836    2.63  0.0087
324   csvENVw+GENw:labL11             2.16     0.792 836    2.73  0.0065
325   csvENVw:labL12                 -0.66     0.851 836   -0.77  0.4389
326   csvENVb:labL12                 -0.19     0.851 836   -0.22  0.8250
327   csvGENw:labL12                  2.75     0.851 836    3.24  0.0013
328   csvGENb:labL12                  1.67     0.851 836    1.97  0.0495
329   csvENVw+GENw:labL12             2.11     0.851 836    2.48  0.0133
330   csvENVw:labL13                 -0.28     0.647 836   -0.44  0.6599
331   csvENVb:labL13                 -0.27     0.647 836   -0.42  0.6738
332   csvGENw:labL13                  0.51     0.647 836    0.79  0.4284
333   csvGENb:labL13                  0.07     0.647 836    0.11  0.9116
334   csvENVw+GENw:labL13             0.03     0.647 836    0.04  0.9675
335   csvENVw:labL14                 -1.19     0.955 836   -1.25  0.2133
336   csvENVb:labL14                 -0.47     0.955 836   -0.49  0.6257
337   csvGENw:labL14                  3.03     0.955 836    3.17  0.0016
338   csvGENb:labL14                  1.39     0.955 836    1.45  0.1466
339   csvENVw+GENw:labL14             1.71     0.955 836    1.79  0.0736
340   legumesBM:csvENVw:labL2        -0.47     1.071 836   -0.44  0.6587
341   legumesBM:csvENVb:labL2        -0.15     1.071 836   -0.14  0.8883
342   legumesBM:csvGENw:labL2         0.43     1.071 836    0.40  0.6860
343   legumesBM:csvGENb:labL2         0.04     1.071 836    0.04  0.9671
344   legumesBM:csvENVw+GENw:labL2    0.04     1.071 836    0.04  0.9673
345   legumesBM:csvENVw:labL3        -0.82     1.322 836   -0.62  0.5343
346   legumesBM:csvENVb:labL3        -0.37     1.322 836   -0.28  0.7787
347   legumesBM:csvGENw:labL3        -0.36     1.322 836   -0.28  0.7830
348   legumesBM:csvGENb:labL3        -0.16     1.322 836   -0.12  0.9042
349   legumesBM:csvENVw+GENw:labL3   -1.89     1.322 836   -1.43  0.1535
350   legumesBM:csvENVw:labL4        -0.03     1.197 836   -0.02  0.9810
351   legumesBM:csvENVb:labL4        -0.08     1.197 836   -0.07  0.9461
352   legumesBM:csvGENw:labL4         0.91     1.197 836    0.76  0.4480
353   legumesBM:csvGENb:labL4         0.56     1.197 836    0.47  0.6403
354   legumesBM:csvENVw+GENw:labL4   -0.21     1.197 836   -0.18  0.8582
355   legumesBM:csvENVw:labL5        -0.17     1.132 836   -0.15  0.8798
356   legumesBM:csvENVb:labL5        -0.48     1.132 836   -0.42  0.6714
357   legumesBM:csvGENw:labL5        -0.56     1.132 836   -0.49  0.6209
358   legumesBM:csvGENb:labL5        -0.74     1.132 836   -0.66  0.5126
359   legumesBM:csvENVw+GENw:labL5   -1.45     1.132 836   -1.28  0.1992
360   legumesBM:csvENVw:labL6        -0.54     1.095 836   -0.49  0.6233
361   legumesBM:csvENVb:labL6        -0.74     1.095 836   -0.68  0.4980
```

```
legumesBM:csvGENw:labL6          0.28     1.095 836    0.25  0.8018
legumesBM:csvGENb:labL6          0.42     1.095 836    0.38  0.7031
legumesBM:csvENVw+GENw:labL6     0.14     1.095 836    0.12  0.9018
legumesBM:csvENVw:labL7         -0.34     1.481 836   -0.23  0.8196
legumesBM:csvENVb:labL7         -0.51     1.481 836   -0.34  0.7309
legumesBM:csvGENw:labL7         -1.18     1.481 836   -0.80  0.4241
legumesBM:csvGENb:labL7         -0.66     1.481 836   -0.45  0.6539
legumesBM:csvENVw+GENw:labL7    -1.23     1.481 836   -0.83  0.4068
legumesBM:csvENVw:labL8         -1.94     1.142 836   -1.69  0.0906
legumesBM:csvENVb:labL8         -2.08     1.132 836   -1.84  0.0666
legumesBM:csvGENw:labL8         -0.51     1.132 836   -0.45  0.6525
legumesBM:csvGENb:labL8         -1.10     1.132 836   -0.97  0.3319
legumesBM:csvENVw+GENw:labL8    -1.46     1.132 836   -1.29  0.1963
legumesBM:csvENVw:labL9         -0.38     1.137 836   -0.33  0.7413
legumesBM:csvENVb:labL9          0.04     1.137 836    0.03  0.9745
legumesBM:csvGENw:labL9          0.45     1.137 836    0.40  0.6900
legumesBM:csvGENb:labL9          0.31     1.137 836    0.27  0.7850
legumesBM:csvENVw+GENw:labL9    -0.37     1.143 836   -0.33  0.7450
legumesBM:csvENVw:labL10        -1.65     1.137 836   -1.45  0.1472
legumesBM:csvENVb:labL10        -0.55     1.137 836   -0.49  0.6256
legumesBM:csvGENw:labL10        -1.17     1.137 836   -1.03  0.3046
legumesBM:csvGENb:labL10        -0.86     1.137 836   -0.76  0.4472
legumesBM:csvENVw+GENw:labL10 -1.84     1.137 836   -1.62  0.1054
legumesBM:csvENVw:labL11        -1.28     1.289 836   -0.99  0.3200
legumesBM:csvENVb:labL11        -0.57     1.289 836   -0.45  0.6560
legumesBM:csvGENw:labL11        -1.37     1.289 836   -1.06  0.2882
legumesBM:csvGENb:labL11        -1.66     1.289 836   -1.29  0.1970
legumesBM:csvENVw+GENw:labL11 -2.19     1.289 836   -1.70  0.0901
legumesBM:csvENVw:labL12        -0.97     1.333 836   -0.73  0.4649
legumesBM:csvENVb:labL12        -0.59     1.333 836   -0.44  0.6602
legumesBM:csvGENw:labL12        -1.22     1.333 836   -0.92  0.3588
legumesBM:csvGENb:labL12        -1.12     1.333 836   -0.84  0.3993
legumesBM:csvENVw+GENw:labL12 -1.95     1.333 836   -1.46  0.1438
legumesBM:csvENVw:labL13        -1.59     1.152 836   -1.38  0.1665
legumesBM:csvENVb:labL13        -0.42     1.152 836   -0.36  0.7184
legumesBM:csvGENw:labL13         0.12     1.152 836    0.11  0.9153
legumesBM:csvGENb:labL13         0.51     1.152 836    0.44  0.6579
legumesBM:csvENVw+GENw:labL13 -0.69     1.152 836   -0.60  0.5513
legumesBM:csvENVw:labL14         0.74     1.571 836    0.47  0.6380
legumesBM:csvENVb:labL14         0.03     1.571 836    0.02  0.9859
legumesBM:csvGENw:labL14        -0.30     1.571 836   -0.19  0.8510
legumesBM:csvGENb:labL14         1.02     1.571 836    0.65  0.5171
legumesBM:csvENVw+GENw:labL14 -0.78     1.571 836   -0.50  0.6179


Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-2.8575 -0.6141 -0.0245  0.6276  3.2740

Number of Observations: 1005
Number of Groups: 2
```

Model for root biomass (rootbm)

```
anova(m2)
```

```
                numDF denDF F-value p-value
(Intercept)         1   820  922.07  <.0001
legumes             1   820 1131.65  <.0001
csv                 5   820   23.93  <.0001
```

```
lab                13   820  182.53  <.0001
legumes:csv         5   820    4.48  0.0005
legumes:lab        13   820   40.58  <.0001
csv:lab            65   820    3.15  <.0001
legumes:csv:lab    65   820    1.12  0.2462
```

```
summary(m2)
```

Linear mixed-effects model fit by REML

```
 Data: repro
   AIC  BIC logLik
  1635 2563   -620

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:      0.0468    0.285

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes

 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  1.381  0.705  0.561  1.597  1.553  0.406  0.623  1.548  1.194  7.691
L6*BM   L7*B  L7*BM L8*B  L8*BM   L9*B  L9*BM  L10*B L10*BM  L11*B L11*BM
4.156  1.152  2.112 1.775  2.131  0.994  1.611  3.242  2.304  0.995  0.925
L1  2*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.150  1.211  3.864  3.922  0.917  2.876

Fixed effects: rootbm ~ legumes * csv * lab
                                Value Std.Error  DF t-value p-value
(Intercept)                     1.410     0.121 820   11.64  0.0000
legumesBM                       0.729     0.199 820    3.67  0.0003
csvENVw                         0.029     0.165 820    0.18  0.8595
csvENVb                        -0.041     0.165 820   -0.25  0.8042
csvGENw                         0.339     0.165 820    2.06  0.0398
csvGENb                         0.006     0.165 820    0.03  0.9734
csvENVw+GENw                    0.205     0.165 820    1.25  0.2128
labL2                          -0.927     0.142 820   -6.51  0.0000
labL3                           0.225     0.219 820    1.03  0.3043
labL4                          -0.837     0.126 820   -6.66  0.0000
labL5                          -0.592     0.215 820   -2.76  0.0060
labL6                           1.724     0.988 820    1.75  0.0813
labL7                          -0.630     0.178 820   -3.55  0.0004
labL8                          -0.658     0.237 820   -2.77  0.0057
labL9                          -0.661     0.164 820   -4.02  0.0001
labL10                          0.207     0.395 820    0.52  0.6013
labL11                         -0.860     0.164 820   -5.24  0.0000
labL12                         -0.839     0.177 820   -4.73  0.0000
labL13                         -0.017     0.465 820   -0.04  0.9714
labL14                         -0.850     0.158 820   -5.38  0.0000
legumesBM:csvENVw               0.126     0.290 820    0.43  0.6639
legumesBM:csvENVb               0.159     0.281 820    0.57  0.5702
legumesBM:csvGENw              -0.463     0.281 820   -1.65  0.0995
legumesBM:csvGENb               0.035     0.281 820    0.12  0.9013
legumesBM:csvENVw+GENw         -0.083     0.281 820   -0.29  0.7686
legumesBM:labL2                -0.235     0.225 820   -1.05  0.2954
legumesBM:labL3                -0.214     0.327 820   -0.66  0.5125
legumesBM:labL4                -0.168     0.217 820   -0.77  0.4388
legumesBM:labL5                 0.341     0.302 820    1.13  0.2596
```

legumesBM:labL6	-1.531	1.133	820	-1.35	0.1767
legumesBM:labL7	1.397	0.343	820	4.07	0.0001
legumesBM:labL8	0.588	0.379	820	1.55	0.1214
legumesBM:labL9	0.204	0.325	820	0.63	0.5304
legumesBM:labL10	1.293	0.504	820	2.57	0.0105
legumesBM:labL11	-0.085	0.254	820	-0.33	0.7384
legumesBM:labL12	0.234	0.278	820	0.84	0.4005
legumesBM:labL13	0.788	0.671	820	1.17	0.2409
legumesBM:labL14	2.103	0.404	820	5.21	0.0000
csvENVw:labL2	-0.036	0.201	820	-0.18	0.8582
csvENVb:labL2	0.070	0.201	820	0.35	0.7265
csvGENw:labL2	-0.039	0.210	820	-0.19	0.8512
csvGENb:labL2	0.204	0.201	820	1.02	0.3104
csvENVw+GENw:labL2	-0.062	0.201	820	-0.31	0.7584
csvENVw:labL3	-0.096	0.310	820	-0.31	0.7583
csvENVb:labL3	-0.035	0.310	820	-0.11	0.9111
csvGENw:labL3	0.298	0.310	820	0.96	0.3379
csvGENb:labL3	0.238	0.310	820	0.77	0.4429
csvENVw+GENw:labL3	0.228	0.310	820	0.74	0.4619
csvENVw:labL4	-0.319	0.178	820	-1.80	0.0729
csvENVb:labL4	-0.048	0.178	820	-0.27	0.7879
csvGENw:labL4	-0.205	0.178	820	-1.15	0.2495
csvGENb:labL4	0.007	0.178	820	0.04	0.9678
csvENVw+GENw:labL4	-0.212	0.178	820	-1.19	0.2344
csvENVw:labL5	0.153	0.304	820	0.51	0.6136
csvENVb:labL5	0.039	0.304	820	0.13	0.8982
csvGENw:labL5	0.315	0.304	820	1.04	0.3000
csvGENb:labL5	0.903	0.304	820	2.97	0.0030
csvENVw+GENw:labL5	0.436	0.304	820	1.44	0.1511
csvENVw:labL6	-0.728	1.339	820	-0.54	0.5866
csvENVb:labL6	0.642	1.339	820	0.48	0.6315
csvGENw:labL6	0.675	1.339	820	0.50	0.6140
csvGENb:labL6	-0.127	1.397	820	-0.09	0.9279
csvENVw+GENw:labL6	-0.314	1.339	820	-0.23	0.8148
csvENVw:labL7	0.109	0.251	820	0.44	0.6631
csvENVb:labL7	0.023	0.251	820	0.09	0.9276
csvGENw:labL7	-0.133	0.251	820	-0.53	0.5963
csvGENb:labL7	-0.105	0.251	820	-0.42	0.6752
csvENVw+GENw:labL7	0.073	0.251	820	0.29	0.7710
csvENVw:labL8	0.863	0.335	820	2.57	0.0103
csvENVb:labL8	0.762	0.335	820	2.27	0.0234
csvGENw:labL8	-0.259	0.335	820	-0.77	0.4403
csvGENb:labL8	0.502	0.335	820	1.50	0.1347
csvENVw+GENw:labL8	1.142	0.335	820	3.41	0.0007
csvENVw:labL9	0.178	0.232	820	0.76	0.4448
csvENVb:labL9	0.078	0.232	820	0.34	0.7375
csvGENw:labL9	-0.155	0.232	820	-0.67	0.5045
csvGENb:labL9	0.281	0.232	820	1.21	0.2270
csvENVw+GENw:labL9	0.280	0.232	820	1.21	0.2276
csvENVw:labL10	0.404	0.559	820	0.72	0.4698
csvENVb:labL10	0.217	0.559	820	0.39	0.6972
csvGENw:labL10	0.635	0.559	820	1.14	0.2557
csvGENb:labL10	0.671	0.559	820	1.20	0.2303
csvENVw+GENw:labL10	0.369	0.559	820	0.66	0.5092
csvENVw:labL11	0.080	0.232	820	0.34	0.7307
csvENVb:labL11	0.041	0.232	820	0.18	0.8594
csvGENw:labL11	0.145	0.232	820	0.62	0.5327
csvGENb:labL11	0.239	0.232	820	1.03	0.3046
csvENVw+GENw:labL11	0.475	0.232	820	2.05	0.0411
csvENVw:labL12	-0.015	0.251	820	-0.06	0.9534
csvENVb:labL12	0.121	0.251	820	0.48	0.6304
csvGENw:labL12	0.199	0.251	820	0.79	0.4270
csvGENb:labL12	0.588	0.251	820	2.34	0.0195

```
csvENVw+GENw:labL12            0.662     0.251 820    2.64  0.0085
csvENVw:labL13                 0.138     0.687 820    0.20  0.8407
csvENVb:labL13                -0.146     0.657 820   -0.22  0.8243
csvGENw:labL13                 0.933     0.657 820    1.42  0.1562
csvGENb:labL13                 1.143     0.657 820    1.74  0.0823
csvENVw+GENw:labL13            1.143     0.657 820    1.74  0.0823
csvENVw:labL14                -0.279     0.223 820   -1.25  0.2120
csvENVb:labL14                -0.059     0.223 820   -0.26  0.7919
csvGENw:labL14                -0.059     0.223 820   -0.26  0.7919
csvGENb:labL14                 0.093     0.223 820    0.42  0.6758
csvENVw+GENw:labL14           -0.042     0.223 820   -0.19  0.8504
legumesBM:csvENVw:labL2       -0.198     0.326 820   -0.61  0.5427
legumesBM:csvENVb:labL2       -0.429     0.318 820   -1.35  0.1767
legumesBM:csvGENw:labL2        0.098     0.323 820    0.30  0.7627
legumesBM:csvGENb:labL2       -0.454     0.318 820   -1.43  0.1536
legumesBM:csvENVw+GENw:labL2  -0.229     0.318 820   -0.72  0.4715
legumesBM:csvENVw:labL3        0.424     0.468 820    0.91  0.3642
legumesBM:csvENVb:labL3        0.189     0.462 820    0.41  0.6825
legumesBM:csvGENw:labL3        0.454     0.462 820    0.98  0.3256
legumesBM:csvGENb:labL3        0.155     0.462 820    0.33  0.7381
legumesBM:csvENVw+GENw:labL3  -0.006     0.462 820   -0.01  0.9891
legumesBM:csvENVw:labL4        0.009     0.315 820    0.03  0.9781
legumesBM:csvENVb:labL4       -0.198     0.306 820   -0.65  0.5187
legumesBM:csvGENw:labL4        0.446     0.308 820    1.45  0.1481
legumesBM:csvGENb:labL4       -0.038     0.306 820   -0.12  0.9013
legumesBM:csvENVw+GENw:labL4  -0.018     0.306 820   -0.06  0.9527
legumesBM:csvENVw:labL5       -0.388     0.433 820   -0.90  0.3710
legumesBM:csvENVb:labL5       -0.286     0.427 820   -0.67  0.5037
legumesBM:csvGENw:labL5        0.027     0.427 820    0.06  0.9493
legumesBM:csvGENb:labL5       -0.370     0.432 820   -0.86  0.3918
legumesBM:csvENVw+GENw:labL5  -0.003     0.427 820   -0.01  0.9938
legumesBM:csvENVw:labL6        0.868     1.537 820    0.56  0.5723
legumesBM:csvENVb:labL6       -0.879     1.551 820   -0.57  0.5712
legumesBM:csvGENw:labL6        0.629     1.536 820    0.41  0.6824
legumesBM:csvGENb:labL6        0.961     1.602 820    0.60  0.5486
legumesBM:csvENVw+GENw:labL6   1.334     1.536 820    0.87  0.3854
legumesBM:csvENVw:labL7        0.686     0.491 820    1.40  0.1625
legumesBM:csvENVb:labL7        0.293     0.486 820    0.60  0.5461
legumesBM:csvGENw:labL7        0.044     0.486 820    0.09  0.9278
legumesBM:csvGENb:labL7        0.064     0.486 820    0.13  0.8949
legumesBM:csvENVw+GENw:labL7  -0.308     0.486 820   -0.63  0.5262
legumesBM:csvENVw:labL8       -0.071     0.569 820   -0.13  0.9002
legumesBM:csvENVb:labL8       -0.733     0.536 820   -1.37  0.1721
legumesBM:csvGENw:labL8        0.469     0.536 820    0.87  0.3822
legumesBM:csvGENb:labL8       -1.037     0.536 820   -1.93  0.0533
legumesBM:csvENVw+GENw:labL8  -0.916     0.564 820   -1.62  0.1048
legumesBM:csvENVw:labL9       -0.203     0.446 820   -0.45  0.6493
legumesBM:csvENVb:labL9        0.047     0.448 820    0.10  0.9165
legumesBM:csvGENw:labL9       -0.162     0.440 820   -0.37  0.7123
legumesBM:csvGENb:labL9       -0.575     0.448 820   -1.28  0.1998
legumesBM:csvENVw+GENw:labL9  -0.365     0.440 820   -0.83  0.4077
legumesBM:csvENVw:labL10      -0.244     0.716 820   -0.34  0.7331
legumesBM:csvENVb:labL10      -0.462     0.713 820   -0.65  0.5171
legumesBM:csvGENw:labL10      -0.815     0.713 820   -1.14  0.2529
legumesBM:csvGENb:labL10      -0.869     0.713 820   -1.22  0.2230
legumesBM:csvENVw+GENw:labL10 -1.496     0.713 820   -2.10  0.0361
legumesBM:csvENVw:labL11      -0.279     0.366 820   -0.76  0.4466
legumesBM:csvENVb:labL11      -0.155     0.359 820   -0.43  0.6651
legumesBM:csvGENw:labL11       0.341     0.359 820    0.95  0.3423
legumesBM:csvGENb:labL11      -0.012     0.359 820   -0.03  0.9730
legumesBM:csvENVw+GENw:labL11 -0.134     0.359 820   -0.37  0.7094
legumesBM:csvENVw:labL12      -0.237     0.400 820   -0.59  0.5536
legumesBM:csvENVb:labL12      -0.188     0.393 820   -0.48  0.6326
```

```
legumesBM:csvGENw:labL12       0.349     0.393 820    0.89  0.3745
legumesBM:csvGENb:labL12      -0.442     0.393 820   -1.12  0.2610
legumesBM:csvENVw+GENw:labL12 -0.472     0.393 820   -1.20  0.2304
legumesBM:csvENVw:labL13      -1.969     0.973 820   -2.02  0.0433
legumesBM:csvENVb:labL13      -1.468     0.949 820   -1.55  0.1224
legumesBM:csvGENw:labL13      -1.010     0.949 820   -1.06  0.2874
legumesBM:csvGENb:labL13      -1.576     0.949 820   -1.66  0.0972
legumesBM:csvENVw+GENw:labL13 -2.539     0.949 820   -2.68  0.0076
legumesBM:csvENVw:labL14      -0.719     0.576 820   -1.25  0.2119
legumesBM:csvENVb:labL14      -0.432     0.571 820   -0.76  0.4495
legumesBM:csvGENw:labL14       0.597     0.571 820    1.05  0.2958
legumesBM:csvGENb:labL14      -0.068     0.571 820   -0.12  0.9045
legumesBM:csvENVw+GENw:labL14  0.420     0.571 820    0.73  0.4627

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-3.2331 -0.5866 -0.0851  0.4929  3.7528

Number of Observations: 989
Number of Groups: 2
```

Model for seed biomass (seedbm)

```
anova(m3)
                numDF denDF F-value p-value
(Intercept)         1   828 1019.92  <.0001
legumes             1   828 2186.64  <.0001
csv                 5   828   58.01  <.0001
lab                13   828  364.57  <.0001
legumes:csv         5   828   33.62  <.0001
legumes:lab        13   828   78.17  <.0001
csv:lab            65   828    6.93  <.0001
legumes:csv:lab    65   828    2.70  <.0001

summary(m3)
Linear mixed-effects model fit by REML
 Data: repro
  AIC  BIC logLik
  813 1743   -209

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:      0.0183    0.272

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes

Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B  L6*BM
1.000  0.496  0.463  0.161  2.475  1.352  1.214  0.581  1.348  0.699  0.630  0.446
L7*B  L7*BM  L8*B  L8*BM  L9*B  L9*BM  L10*B L10*BM  L11*B L11*BM  L12*B L12*BM
1.596 0.765 0.666  0.741  1.074 0.866  1.406  0.866  2.885  1.811  2.546 1.352
L13*B  L13*BM  L14*B L14*BM
0.799  0.343  2.491  1.377

Fixed effects: seedbm ~ legumes * csv * lab
                             Value Std.Error  DF t-value p-value
(Intercept)                   0.98     0.122 828    7.98  0.0000
legumesBM                    -0.54     0.134 828   -4.02  0.0001
csvENVw                       0.06     0.165 828    0.35  0.7259
```

csvENVb	-0.01	0.183	828	-0.06	0.9488
csvGENw	-0.69	0.165	828	-4.20	0.0000
csvGENb	-0.50	0.165	828	-3.03	0.0025
csvENVw+GENw	-0.60	0.165	828	-3.61	0.0003
labL2	-0.19	0.132	828	-1.46	0.1440
labL3	2.61	0.301	828	8.67	0.0000
labL4	0.68	0.182	828	3.76	0.0002
labL5	1.17	0.193	828	6.06	0.0000
labL6	-0.27	0.140	828	-1.92	0.0552
labL7	1.43	0.215	828	6.65	0.0000
labL8	-0.43	0.143	828	-3.02	0.0026
labL9	0.15	0.171	828	0.87	0.3841
labL10	2.52	0.198	828	12.71	0.0000
labL11	3.25	0.343	828	9.46	0.0000
labL12	3.15	0.308	828	10.21	0.0000
labL13	-0.03	0.151	828	-0.19	0.8517
labL14	3.01	0.327	828	9.22	0.0000
legumesBM:csvENVw	0.01	0.182	828	0.06	0.9519
legumesBM:csvENVb	0.11	0.199	828	0.56	0.5768
legumesBM:csvGENw	0.43	0.182	828	2.37	0.0180
legumesBM:csvGENb	0.33	0.182	828	1.78	0.0748
legumesBM:csvENVw+GENw	0.28	0.182	828	1.56	0.1187
legumesBM:labL2	0.04	0.144	828	0.26	0.7915
legumesBM:labL3	-1.90	0.341	828	-5.58	0.0000
legumesBM:labL4	-0.59	0.201	828	-2.93	0.0035
legumesBM:labL5	-0.53	0.215	828	-2.48	0.0132
legumesBM:labL6	0.14	0.159	828	0.86	0.3903
legumesBM:labL7	-1.09	0.238	828	-4.58	0.0000
legumesBM:labL8	0.29	0.174	828	1.67	0.0944
legumesBM:labL9	0.32	0.203	828	1.56	0.1201
legumesBM:labL10	-1.86	0.227	828	-8.19	0.0000
legumesBM:labL11	-2.31	0.402	828	-5.75	0.0000
legumesBM:labL12	-2.21	0.347	828	-6.35	0.0000
legumesBM:labL13	-0.25	0.165	828	-1.49	0.1354
legumesBM:labL14	-1.76	0.365	828	-4.82	0.0000
csvENVw:labL2	-0.01	0.182	828	-0.07	0.9453
csvENVb:labL2	0.15	0.197	828	0.76	0.4471
csvGENw:labL2	0.37	0.180	828	2.06	0.0396
csvGENb:labL2	0.45	0.180	828	2.50	0.0126
csvENVw+GENw:labL2	0.49	0.180	828	2.72	0.0067
csvENVw:labL3	-1.06	0.422	828	-2.50	0.0126
csvENVb:labL3	-0.46	0.430	828	-1.06	0.2885
csvGENw:labL3	-1.74	0.422	828	-4.12	0.0000
csvGENb:labL3	-1.06	0.422	828	-2.51	0.0122
csvENVw+GENw:labL3	-1.71	0.422	828	-4.04	0.0001
csvENVw:labL4	-0.70	0.252	828	-2.79	0.0054
csvENVb:labL4	-0.27	0.264	828	-1.02	0.3104
csvGENw:labL4	-0.27	0.252	828	-1.08	0.2823
csvGENb:labL4	-0.15	0.252	828	-0.58	0.5628
csvENVw+GENw:labL4	-0.61	0.252	828	-2.42	0.0156
csvENVw:labL5	0.46	0.268	828	1.70	0.0889
csvENVb:labL5	0.34	0.280	828	1.23	0.2179
csvGENw:labL5	-0.40	0.268	828	-1.50	0.1329
csvGENb:labL5	-0.09	0.268	828	-0.35	0.7277
csvENVw+GENw:labL5	-0.67	0.268	828	-2.48	0.0134
csvENVw:labL6	-0.09	0.192	828	-0.46	0.6424
csvENVb:labL6	0.00	0.208	828	0.00	0.9978
csvGENw:labL6	0.28	0.192	828	1.48	0.1405
csvGENb:labL6	0.21	0.192	828	1.10	0.2706
csvENVw+GENw:labL6	0.15	0.192	828	0.78	0.4335
csvENVw:labL7	0.05	0.300	828	0.17	0.8681
csvENVb:labL7	-0.11	0.310	828	-0.34	0.7341
csvGENw:labL7	0.68	0.300	828	2.25	0.0247

```
csvGENb:labL7                   0.34     0.300 828    1.13  0.2592
csvENVw+GENw:labL7              0.47     0.300 828    1.56  0.1201
csvENVw:labL8                  -0.09     0.209 828   -0.42  0.6723
csvENVb:labL8                  -0.07     0.217 828   -0.32  0.7497
csvGENw:labL8                   0.28     0.195 828    1.41  0.1587
csvGENb:labL8                   0.22     0.195 828    1.15  0.2521
csvENVw+GENw:labL8              0.39     0.195 828    2.00  0.0458
csvENVw:labL9                   0.67     0.236 828    2.83  0.0048
csvENVb:labL9                   0.41     0.249 828    1.64  0.1005
csvGENw:labL9                  -0.06     0.236 828   -0.24  0.8103
csvGENb:labL9                   0.22     0.236 828    0.94  0.3477
csvENVw+GENw:labL9              0.12     0.236 828    0.49  0.6216
csvENVw:labL10                 -0.29     0.276 828   -1.07  0.2867
csvENVb:labL10                 -0.24     0.287 828   -0.83  0.4079
csvGENw:labL10                 -0.38     0.276 828   -1.39  0.1649
csvGENb:labL10                 -0.25     0.276 828   -0.91  0.3646
csvENVw+GENw:labL10            -1.19     0.276 828   -4.31  0.0000
csvENVw:labL11                 -0.68     0.483 828   -1.42  0.1562
csvENVb:labL11                  0.13     0.489 828    0.26  0.7945
csvGENw:labL11                  1.19     0.483 828    2.47  0.0138
csvGENb:labL11                 -0.04     0.483 828   -0.09  0.9318
csvENVw+GENw:labL11             0.54     0.483 828    1.11  0.2658
csvENVw:labL12                 -0.59     0.433 828   -1.37  0.1708
csvENVb:labL12                 -0.31     0.440 828   -0.72  0.4744
csvGENw:labL12                 -0.15     0.433 828   -0.36  0.7212
csvGENb:labL12                  0.55     0.433 828    1.28  0.2010
csvENVw+GENw:labL12             0.75     0.433 828    1.74  0.0821
csvENVw:labL13                 -0.02     0.207 828   -0.08  0.9398
csvENVb:labL13                 -0.01     0.222 828   -0.06  0.9505
csvGENw:labL13                  0.64     0.207 828    3.11  0.0019
csvGENb:labL13                  0.56     0.207 828    2.70  0.0070
csvENVw+GENw:labL13             0.43     0.207 828    2.08  0.0381
csvENVw:labL14                 -1.35     0.443 828   -3.05  0.0024
csvENVb:labL14                 -1.02     0.466 828   -2.19  0.0289
csvGENw:labL14                 -2.02     0.443 828   -4.56  0.0000
csvGENb:labL14                 -1.63     0.443 828   -3.68  0.0002
csvENVw+GENw:labL14            -2.20     0.443 828   -4.96  0.0000
legumesBM:csvENVw:labL2        -0.07     0.199 828   -0.36  0.7179
legumesBM:csvENVb:labL2        -0.28     0.213 828   -1.31  0.1906
legumesBM:csvGENw:labL2        -0.21     0.198 828   -1.04  0.3008
legumesBM:csvGENb:labL2        -0.25     0.198 828   -1.28  0.1993
legumesBM:csvENVw+GENw:labL2   -0.23     0.198 828   -1.18  0.2396
legumesBM:csvENVw:labL3         0.55     0.479 828    1.16  0.2483
legumesBM:csvENVb:labL3         0.09     0.486 828    0.19  0.8456
legumesBM:csvGENw:labL3         1.55     0.479 828    3.23  0.0013
legumesBM:csvGENb:labL3         1.01     0.479 828    2.11  0.0348
legumesBM:csvENVw+GENw:labL3    1.39     0.479 828    2.89  0.0039
legumesBM:csvENVw:labL4         0.56     0.279 828    2.01  0.0446
legumesBM:csvENVb:labL4         0.06     0.290 828    0.21  0.8351
legumesBM:csvGENw:labL4         0.24     0.279 828    0.87  0.3846
legumesBM:csvGENb:labL4         0.13     0.279 828    0.46  0.6469
legumesBM:csvENVw+GENw:labL4    0.51     0.279 828    1.84  0.0664
legumesBM:csvENVw:labL5        -0.51     0.300 828   -1.70  0.0890
legumesBM:csvENVb:labL5        -0.48     0.310 828   -1.55  0.1218
legumesBM:csvGENw:labL5         0.03     0.300 828    0.11  0.9157
legumesBM:csvGENb:labL5        -0.14     0.300 828   -0.45  0.6504
legumesBM:csvENVw+GENw:labL5    0.52     0.300 828    1.73  0.0832
legumesBM:csvENVw:labL6         0.10     0.219 828    0.46  0.6460
legumesBM:csvENVb:labL6        -0.14     0.233 828   -0.61  0.5450
legumesBM:csvGENw:labL6        -0.20     0.219 828   -0.92  0.3570
legumesBM:csvGENb:labL6        -0.04     0.219 828   -0.18  0.8569
legumesBM:csvENVw+GENw:labL6   -0.05     0.219 828   -0.23  0.8206
legumesBM:csvENVw:labL7         0.00     0.333 828    0.01  0.9924
```

```
legumesBM:csvENVb:labL7       -0.01     0.342 828   -0.03  0.9730
legumesBM:csvGENw:labL7       -0.43     0.333 828   -1.29  0.1985
legumesBM:csvGENb:labL7        0.02     0.333 828    0.06  0.9517
legumesBM:csvENVw+GENw:labL7  -0.13     0.333 828   -0.40  0.6908
legumesBM:csvENVw:labL8        0.30     0.252 828    1.19  0.2326
legumesBM:csvENVb:labL8        0.03     0.258 828    0.13  0.8946
legumesBM:csvGENw:labL8       -0.23     0.240 828   -0.95  0.3411
legumesBM:csvGENb:labL8       -0.26     0.240 828   -1.09  0.2776
legumesBM:csvENVw+GENw:labL8  -0.12     0.240 828   -0.48  0.6286
legumesBM:csvENVw:labL9       -0.74     0.283 828   -2.62  0.0090
legumesBM:csvENVb:labL9       -0.56     0.294 828   -1.89  0.0593
legumesBM:csvGENw:labL9       -0.33     0.283 828   -1.17  0.2416
legumesBM:csvGENb:labL9       -0.46     0.283 828   -1.61  0.1087
legumesBM:csvENVw+GENw:labL9  -0.25     0.283 828   -0.87  0.3871
legumesBM:csvENVw:labL10       0.18     0.317 828    0.56  0.5760
legumesBM:csvENVb:labL10       0.27     0.327 828    0.81  0.4155
legumesBM:csvGENw:labL10       0.48     0.317 828    1.50  0.1341
legumesBM:csvGENb:labL10       0.25     0.317 828    0.78  0.4328
legumesBM:csvENVw+GENw:labL10  1.32     0.317 828    4.17  0.0000
legumesBM:csvENVw:labL11       1.31     0.566 828    2.32  0.0208
legumesBM:csvENVb:labL11       0.19     0.571 828    0.34  0.7371
legumesBM:csvGENw:labL11      -0.33     0.566 828   -0.58  0.5600
legumesBM:csvGENb:labL11       0.57     0.566 828    1.01  0.3117
legumesBM:csvENVw+GENw:labL11  0.44     0.566 828    0.78  0.4341
legumesBM:csvENVw:labL12       0.94     0.488 828    1.91  0.0559
legumesBM:csvENVb:labL12       0.70     0.495 828    1.42  0.1548
legumesBM:csvGENw:labL12       1.03     0.488 828    2.11  0.0349
legumesBM:csvGENb:labL12      -0.16     0.488 828   -0.33  0.7386
legumesBM:csvENVw+GENw:labL12  0.14     0.488 828    0.28  0.7779
legumesBM:csvENVw:labL13      -0.04     0.228 828   -0.18  0.8607
legumesBM:csvENVb:labL13      -0.13     0.241 828   -0.55  0.5825
legumesBM:csvGENw:labL13      -0.40     0.228 828   -1.75  0.0802
legumesBM:csvGENb:labL13      -0.46     0.228 828   -2.02  0.0435
legumesBM:csvENVw+GENw:labL13 -0.05     0.228 828   -0.21  0.8372
legumesBM:csvENVw:labL14       0.93     0.499 828    1.86  0.0639
legumesBM:csvENVb:labL14       0.66     0.520 828    1.26  0.2071
legumesBM:csvGENw:labL14       1.02     0.499 828    2.04  0.0412
legumesBM:csvGENb:labL14       0.94     0.499 828    1.89  0.0585
legumesBM:csvENVw+GENw:labL14  1.45     0.499 828    2.90  0.0038
```

Model for total biomass (totalbm)

```
anova (m4)
  numDF denDF F-value p-value
(Intercept)         1   839  3534.7  <.0001
legumes             1   839   690.7  <.0001
csv                 5   839     1.8  0.1145
lab                13   839  1252.0  <.0001
legumes:csv         5   839     3.5  0.0040
legumes:lab        13   839   116.6  <.0001
csv:lab            65   839     7.3  <.0001
legumes:csv:lab    65   839     1.2  0.1677

summary(m4)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  3241 4174  -1424

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:       0.114     1.43
```

```
Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B  L6*BM
1.000  1.367  0.261  0.156  1.256  0.906  0.646  0.509  0.551  0.417  2.014  1.603
L7*B  L7*BM   L8*B L8*BM   L9*B  L9*BM  L10*B L10*BM  L11*B L11*BM  L12*B L12*BM
0.605  1.438  0.616 0.816  0.263  1.073  0.685  0.679  0.764  0.674  1.058  0.639
1.175  1.012  1.227  1.403
L13*B L13*BM  L14*B L14*BM


Fixed effects: totalbm ~ legumes * csv * lab
                            Value Std.Error  DF t-value p-value
(Intercept)                  4.48     0.590 839    7.60  0.0000
legumesBM                    2.41     0.989 839    2.44  0.0150
csvENVw                      0.05     0.826 839    0.06  0.9495
csvENVb                      0.03     0.826 839    0.03  0.9726
csvGENw                     -0.53     0.826 839   -0.65  0.5180
csvGENb                     -0.62     0.826 839   -0.76  0.4503
csvENVw+GENw                -0.36     0.826 839   -0.44  0.6590
labL2                       -2.57     0.604 839   -4.26  0.0000
labL3                        4.48     0.938 839    4.78  0.0000
labL4                        2.51     0.695 839    3.60  0.0003
labL5                        1.13     0.667 839    1.69  0.0908
labL6                        3.57     1.313 839    2.72  0.0066
labL7                        0.10     0.683 839    0.14  0.8892
labL8                       -1.94     0.686 839   -2.83  0.0047
labL9                       -0.59     0.604 839   -0.98  0.3288
labL10                       3.01     0.708 839    4.26  0.0000
labL11                       2.88     0.735 839    3.91  0.0001
labL12                       3.01     0.850 839    3.54  0.0004
labL13                       0.25     0.901 839    0.27  0.7848
labL14                       3.60     0.925 839    3.89  0.0001
legumesBM:csvENVw            1.22     1.399 839    0.87  0.3839
legumesBM:csvENVb            0.58     1.399 839    0.42  0.6765
legumesBM:csvGENw           -0.81     1.399 839   -0.58  0.5634
legumesBM:csvGENb           -0.03     1.399 839   -0.02  0.9830
legumesBM:csvENVw+GENw       0.10     1.399 839    0.07  0.9415
legumesBM:labL2             -1.21     1.005 839   -1.20  0.2304
legumesBM:labL3             -0.95     1.341 839   -0.71  0.4779
legumesBM:labL4              0.62     1.100 839    0.56  0.5738
legumesBM:labL5              0.38     1.069 839    0.36  0.7194
legumesBM:labL6             -1.83     1.800 839   -1.02  0.3094
legumesBM:labL7              4.83     1.345 839    3.59  0.0004
legumesBM:labL8              1.49     1.156 839    1.29  0.1988
legumesBM:labL9             -0.31     1.181 839   -0.26  0.7923
legumesBM:labL10             2.60     1.139 839    2.28  0.0229
legumesBM:labL11             2.27     1.155 839    1.96  0.0501
legumesBM:labL12             2.52     1.225 839    2.06  0.0402
legumesBM:labL13            -0.31     1.341 839   -0.23  0.8157
legumesBM:labL14            11.09     1.471 839    7.54  0.0000
csvENVw:labL2                0.08     0.854 839    0.09  0.9257
csvENVb:labL2                0.11     0.854 839    0.13  0.8991
csvGENw:labL2                1.24     0.854 839    1.45  0.1463
csvGENb:labL2                1.19     0.854 839    1.40  0.1620
csvENVw+GENw:labL2           1.03     0.854 839    1.20  0.2296
csvENVw:labL3               -1.80     1.326 839   -1.35  0.1761
csvENVb:labL3               -1.02     1.326 839   -0.77  0.4405
csvGENw:labL3               -0.65     1.326 839   -0.49  0.6240
csvGENb:labL3               -0.31     1.326 839   -0.23  0.8159
csvENVw+GENw:labL3          -1.23     1.326 839   -0.93  0.3550
```

```
csvENVw:labL4                  -3.21     0.983 839   -3.26  0.0012
csvENVb:labL4                  -1.09     0.983 839   -1.11  0.2679
csvGENw:labL4                  -0.56     0.983 839   -0.57  0.5675
csvGENb:labL4                  -0.18     0.983 839   -0.19  0.8508
csvENVw+GENw:labL4             -2.18     0.983 839   -2.22  0.0267
csvENVw:labL5                   0.78     0.943 839    0.83  0.4090
csvENVb:labL5                   0.50     0.943 839    0.53  0.5932
csvGENw:labL5                   1.54     0.943 839    1.63  0.1028
csvGENb:labL5                   1.95     0.943 839    2.07  0.0389
csvENVw+GENw:labL5              1.45     0.943 839    1.54  0.1246
csvENVw:labL6                  -2.30     1.857 839   -1.24  0.2163
csvENVb:labL6                  -0.76     1.857 839   -0.41  0.6808
csvGENw:labL6                  -0.53     1.857 839   -0.29  0.7736
csvGENb:labL6                  -0.49     1.857 839   -0.26  0.7913
csvENVw+GENw:labL6             -1.69     1.857 839   -0.91  0.3639
csvENVw:labL7                   0.29     0.965 839    0.30  0.7649
csvENVb:labL7                  -0.24     0.965 839   -0.24  0.8075
csvGENw:labL7                   1.07     0.965 839    1.11  0.2683
csvGENb:labL7                   0.50     0.965 839    0.52  0.6015
csvENVw+GENw:labL7              0.98     0.965 839    1.02  0.3095
csvENVw:labL8                   1.82     0.970 839    1.87  0.0616
csvENVb:labL8                   1.50     0.970 839    1.55  0.1214
csvGENw:labL8                   0.17     0.970 839    0.17  0.8621
csvGENb:labL8                   0.75     0.970 839    0.77  0.4404
csvENVw+GENw:labL8              2.19     0.970 839    2.26  0.0240
csvENVw:labL9                   0.93     0.854 839    1.09  0.2747
csvENVb:labL9                   0.31     0.854 839    0.37  0.7140
csvGENw:labL9                  -0.19     0.854 839   -0.22  0.8252
csvGENb:labL9                   0.62     0.854 839    0.72  0.4703
csvENVw+GENw:labL9              0.55     0.854 839    0.65  0.5164
csvENVw:labL10                  0.45     1.001 839    0.45  0.6561
csvENVb:labL10                 -0.28     1.001 839   -0.28  0.7793
csvGENw:labL10                  1.71     1.001 839    1.71  0.0880
csvGENb:labL10                  1.56     1.001 839    1.55  0.1204
csvENVw+GENw:labL10            -0.18     1.001 839   -0.18  0.8567
csvENVw:labL11                 -0.62     1.039 839   -0.60  0.5518
csvENVb:labL11                  0.12     1.039 839    0.12  0.9067
csvGENw:labL11                  3.63     1.039 839    3.49  0.0005
csvGENb:labL11                  2.38     1.039 839    2.29  0.0224
csvENVw+GENw:labL11             3.27     1.039 839    3.15  0.0017
csvENVw:labL12                 -1.17     1.202 839   -0.97  0.3311
csvENVb:labL12                 -0.49     1.202 839   -0.40  0.6863
csvGENw:labL12                  2.90     1.202 839    2.41  0.0162
csvGENb:labL12                  2.91     1.202 839    2.42  0.0156
csvENVw+GENw:labL12             3.62     1.202 839    3.01  0.0027
csvENVw:labL13                  0.56     1.274 839    0.44  0.6626
csvENVb:labL13                 -0.54     1.274 839   -0.42  0.6742
csvGENw:labL13                  2.19     1.274 839    1.72  0.0865
csvGENb:labL13                  1.87     1.274 839    1.47  0.1422
csvENVw+GENw:labL13             1.70     1.274 839    1.33  0.1831
csvENVw:labL14                 -2.86     1.308 839   -2.18  0.0292
csvENVb:labL14                 -1.43     1.308 839   -1.09  0.2741
csvGENw:labL14                  0.91     1.308 839    0.70  0.4858
csvGENb:labL14                 -0.19     1.308 839   -0.15  0.8837
csvENVw+GENw:labL14            -0.57     1.308 839   -0.43  0.6640
legumesBM:csvENVw:labL2        -1.21     1.422 839   -0.85  0.3959
legumesBM:csvENVb:labL2        -0.75     1.422 839   -0.53  0.5956
legumesBM:csvGENw:labL2        -0.01     1.422 839   -0.01  0.9943
legumesBM:csvGENb:labL2        -0.76     1.422 839   -0.54  0.5927
legumesBM:csvENVw+GENw:labL2   -0.52     1.422 839   -0.36  0.7169
legumesBM:csvENVw:labL3        -0.14     1.896 839   -0.07  0.9428
legumesBM:csvENVb:labL3         0.02     1.896 839    0.01  0.9933
legumesBM:csvGENw:labL3         1.54     1.896 839    0.81  0.4167
```

```
legumesBM:csvGENb:labL3        0.91     1.896 839    0.48  0.6310
legumesBM:csvENVw+GENw:labL3  -0.61     1.896 839   -0.32  0.7489
legumesBM:csvENVw:labL4        0.25     1.556 839    0.16  0.8725
legumesBM:csvENVb:labL4       -0.11     1.556 839   -0.07  0.9413
legumesBM:csvGENw:labL4        1.60     1.556 839    1.03  0.3047
legumesBM:csvGENb:labL4        0.55     1.556 839    0.35  0.7229
legumesBM:csvENVw+GENw:labL4   0.18     1.556 839    0.12  0.9061
legumesBM:csvENVw:labL5       -1.36     1.511 839   -0.90  0.3674
legumesBM:csvENVb:labL5       -1.14     1.511 839   -0.76  0.4500
legumesBM:csvGENw:labL5       -0.60     1.511 839   -0.40  0.6922
legumesBM:csvGENb:labL5       -1.10     1.511 839   -0.73  0.4652
legumesBM:csvENVw+GENw:labL5  -1.03     1.511 839   -0.68  0.4938
legumesBM:csvENVw:labL6        0.25     2.545 839    0.10  0.9217
legumesBM:csvENVb:labL6       -0.36     2.545 839   -0.14  0.8887
legumesBM:csvGENw:labL6        0.72     2.545 839    0.28  0.7787
legumesBM:csvGENb:labL6        1.29     2.545 839    0.51  0.6132
legumesBM:csvENVw+GENw:labL6   1.43     2.545 839    0.56  0.5736
legumesBM:csvENVw:labL7        0.06     1.902 839    0.03  0.9750
legumesBM:csvENVb:labL7       -0.12     1.902 839   -0.07  0.9482
legumesBM:csvGENw:labL7       -1.67     1.902 839   -0.88  0.3815
legumesBM:csvGENb:labL7       -0.68     1.902 839   -0.36  0.7219
legumesBM:csvENVw+GENw:labL7  -1.77     1.902 839   -0.93  0.3531
legumesBM:csvENVw:labL8       -1.07     1.634 839   -0.65  0.5137
legumesBM:csvENVb:labL8       -2.98     1.634 839   -1.82  0.0688
legumesBM:csvGENw:labL8       -0.37     1.634 839   -0.23  0.8220
legumesBM:csvGENb:labL8       -2.50     1.634 839   -1.53  0.1271
legumesBM:csvENVw+GENw:labL8  -1.91     1.634 839   -1.17  0.2432
legumesBM:csvENVw:labL9       -2.22     1.671 839   -1.33  0.1836
legumesBM:csvENVb:labL9       -0.47     1.671 839   -0.28  0.7799
legumesBM:csvGENw:labL9       -0.75     1.671 839   -0.45  0.6541
legumesBM:csvGENb:labL9       -0.82     1.671 839   -0.49  0.6234
legumesBM:csvENVw+GENw:labL9  -1.39     1.671 839   -0.83  0.4045
legumesBM:csvENVw:labL10      -2.01     1.610 839   -1.25  0.2127
legumesBM:csvENVb:labL10      -0.65     1.610 839   -0.40  0.6882
legumesBM:csvGENw:labL10      -1.60     1.610 839   -1.00  0.3193
legumesBM:csvGENb:labL10      -1.58     1.610 839   -0.98  0.3261
legumesBM:csvENVw+GENw:labL10 -2.11     1.610 839   -1.31  0.1894
legumesBM:csvENVw:labL11      -0.54     1.633 839   -0.33  0.7391
legumesBM:csvENVb:labL11      -0.43     1.633 839   -0.27  0.7903
legumesBM:csvGENw:labL11      -1.46     1.633 839   -0.89  0.3726
legumesBM:csvGENb:labL11      -1.20     1.633 839   -0.74  0.4619
legumesBM:csvENVw+GENw:labL11 -1.98     1.633 839   -1.21  0.2263
legumesBM:csvENVw:labL12      -0.57     1.732 839   -0.33  0.7429
legumesBM:csvENVb:labL12       0.03     1.732 839    0.02  0.9843
legumesBM:csvGENw:labL12       0.06     1.732 839    0.03  0.9723
legumesBM:csvGENb:labL12      -1.83     1.732 839   -1.06  0.2917
legumesBM:csvENVw+GENw:labL12 -2.38     1.732 839   -1.38  0.1693
legumesBM:csvENVw:labL13      -4.52     1.897 839   -2.38  0.0175
legumesBM:csvENVb:labL13      -1.91     1.897 839   -1.01  0.3137
legumesBM:csvGENw:labL13      -1.38     1.897 839   -0.73  0.4658
legumesBM:csvGENb:labL13      -1.62     1.897 839   -0.86  0.3924
legumesBM:csvENVw+GENw:labL13 -3.37     1.897 839   -1.78  0.0760
legumesBM:csvENVw:labL14       0.79     2.080 839    0.38  0.7033
legumesBM:csvENVb:labL14       0.14     2.080 839    0.07  0.9470
legumesBM:csvGENw:labL14       1.36     2.080 839    0.66  0.5125
legumesBM:csvGENb:labL14       1.94     2.080 839    0.93  0.3524
legumesBM:csvENVw+GENw:labL14  1.12     2.080 839    0.54  0.5898

Standardized Within-Group Residuals:
     Min       Q1      Med       Q3      Max
-3.36073 -0.66483 -0.00439  0.58740  3.00416

Number of Observations: 1008
```

```
Number of Groups: 2
```

Model for shoot to root biomass ratio (shoot.root)

```
anova(m5)
                numDF denDF F-value p-value
(Intercept)         1   815     932  <.0001
legumes             1   815    1137  <.0001
csv                 5   815      24  <.0001
lab                13   815     183  <.0001
legumes:csv         5   815       5  0.0005
legumes:lab        13   815      40  <.0001
csv:lab            65   815       3  <.0001
legumes:csv:lab    65   815       1  0.2502

summary(m5)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  1590 2517   -598

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:      0.0466    0.284

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  1.385  0.706  0.563  1.602  1.557  0.408  0.625  1.553  1.197  5.762
L6*BM   L7*B  L7*BM L8*B  L8*BM   L9*B  L9*BM  L10*B L10*BM  L11*B L11*BM
3.503  1.156  2.119 1.780  2.139  0.997  1.616  3.251  2.310  0.998  0.928
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.154  1.215  3.875  3.935  0.920  2.885

Fixed effects: shoot.root ~ legumes * csv * lab
                               Value Std.Error  DF t-value p-value
(Intercept)                    1.410     0.121 815   11.68  0.0000
legumesBM                      0.728     0.198 815    3.67  0.0003
csvENVw                        0.029     0.164 815    0.18  0.8591
csvENVb                       -0.041     0.164 815   -0.25  0.8037
csvGENw                        0.339     0.164 815    2.07  0.0392
csvGENb                        0.005     0.164 815    0.03  0.9733
csvENVw+GENw                   0.205     0.164 815    1.25  0.2115
labL2                         -0.927     0.142 815   -6.52  0.0000
labL3                          0.225     0.219 815    1.03  0.3041
labL4                         -0.837     0.125 815   -6.67  0.0000
labL5                         -0.592     0.214 815   -2.76  0.0059
labL6                          0.685     0.828 815    0.83  0.4084
labL7                         -0.630     0.177 815   -3.55  0.0004
labL8                         -0.658     0.237 815   -2.78  0.0056
labL9                         -0.661     0.164 815   -4.03  0.0001
labL10                         0.206     0.395 815    0.52  0.6012
labL11                        -0.860     0.164 815   -5.24  0.0000
labL12                        -0.840     0.177 815   -4.73  0.0000
labL13                        -0.017     0.465 815   -0.04  0.9714
labL14                        -0.850     0.158 815   -5.39  0.0000
legumesBM:csvENVw              0.126     0.290 815    0.44  0.6634
legumesBM:csvENVb              0.160     0.280 815    0.57  0.5697
```

```
686   legumesBM:csvGENw             -0.463     0.280 815   -1.65  0.0990
687   legumesBM:csvGENb              0.035     0.280 815    0.12  0.9012
688   legumesBM:csvENVw+GENw        -0.083     0.280 815   -0.29  0.7683
689   legumesBM:labL2               -0.235     0.224 815   -1.05  0.2948
690   legumesBM:labL3               -0.214     0.327 815   -0.66  0.5124
691   legumesBM:labL4               -0.168     0.216 815   -0.78  0.4383
692   legumesBM:labL5                0.341     0.302 815    1.13  0.2593
693   legumesBM:labL6               -0.492     0.954 815   -0.52  0.6062
694   legumesBM:labL7                1.397     0.343 815    4.07  0.0001
695   legumesBM:labL8                0.588     0.379 815    1.55  0.1214
696   legumesBM:labL9                0.204     0.325 815    0.63  0.5302
697   legumesBM:labL10               1.293     0.504 815    2.57  0.0104
698   legumesBM:labL11              -0.085     0.254 815   -0.33  0.7382
699   legumesBM:labL12               0.234     0.278 815    0.84  0.4002
700   legumesBM:labL13               0.788     0.671 815    1.17  0.2409
701   legumesBM:labL14               2.103     0.404 815    5.21  0.0000
702   csvENVw:labL2                 -0.036     0.201 815   -0.18  0.8579
703   csvENVb:labL2                  0.071     0.201 815    0.35  0.7259
704   csvGENw:labL2                 -0.039     0.209 815   -0.19  0.8513
705   csvGENb:labL2                  0.205     0.201 815    1.02  0.3093
706   csvENVw+GENw:labL2            -0.062     0.201 815   -0.31  0.7578
707   csvENVw:labL3                 -0.095     0.310 815   -0.31  0.7582
708   csvENVb:labL3                 -0.035     0.310 815   -0.11  0.9110
709   csvGENw:labL3                  0.297     0.310 815    0.96  0.3377
710   csvGENb:labL3                  0.238     0.310 815    0.77  0.4427
711   csvENVw+GENw:labL3             0.228     0.310 815    0.74  0.4618
712   csvENVw:labL4                 -0.319     0.177 815   -1.80  0.0722
713   csvENVb:labL4                 -0.048     0.177 815   -0.27  0.7874
714   csvGENw:labL4                 -0.205     0.177 815   -1.16  0.2484
715   csvGENb:labL4                  0.007     0.177 815    0.04  0.9678
716   csvENVw+GENw:labL4            -0.211     0.177 815   -1.19  0.2333
717   csvENVw:labL5                  0.153     0.303 815    0.51  0.6133
718   csvENVb:labL5                  0.039     0.303 815    0.13  0.8981
719   csvGENw:labL5                  0.315     0.303 815    1.04  0.2995
720   csvGENb:labL5                  0.903     0.303 815    2.98  0.0030
721   csvENVw+GENw:labL5             0.436     0.303 815    1.44  0.1508
722   csvENVw:labL6                  0.312     1.071 815    0.29  0.7711
723   csvENVb:labL6                  0.892     1.112 815    0.80  0.4226
724   csvGENw:labL6                  1.207     1.112 815    1.09  0.2778
725   csvGENb:labL6                 -0.142     1.170 815   -0.12  0.9031
726   csvENVw+GENw:labL6             0.726     1.071 815    0.68  0.4978
727   csvENVw:labL7                  0.110     0.251 815    0.44  0.6627
728   csvENVb:labL7                  0.023     0.251 815    0.09  0.9275
729   csvGENw:labL7                 -0.133     0.251 815   -0.53  0.5958
730   csvGENb:labL7                 -0.105     0.251 815   -0.42  0.6748
731   csvENVw+GENw:labL7             0.073     0.251 815    0.29  0.7707
732   csvENVw:labL8                  0.863     0.335 815    2.57  0.0103
733   csvENVb:labL8                  0.762     0.335 815    2.27  0.0233
734   csvGENw:labL8                 -0.259     0.335 815   -0.77  0.4401
735   csvGENb:labL8                  0.502     0.335 815    1.50  0.1345
736   csvENVw+GENw:labL8             1.142     0.335 815    3.41  0.0007
737   csvENVw:labL9                  0.178     0.232 815    0.77  0.4441
738   csvENVb:labL9                  0.078     0.232 815    0.34  0.7372
739   csvGENw:labL9                 -0.155     0.232 815   -0.67  0.5040
740   csvGENb:labL9                  0.281     0.232 815    1.21  0.2264
741   csvENVw+GENw:labL9             0.280     0.232 815    1.21  0.2269
742   csvENVw:labL10                 0.404     0.559 815    0.72  0.4697
743   csvENVb:labL10                 0.218     0.559 815    0.39  0.6971
744   csvGENw:labL10                 0.636     0.559 815    1.14  0.2556
745   csvGENb:labL10                 0.671     0.559 815    1.20  0.2302
746   csvENVw+GENw:labL10            0.369     0.559 815    0.66  0.5090
747   csvENVw:labL11                 0.080     0.232 815    0.34  0.7303
748   csvENVb:labL11                 0.041     0.232 815    0.18  0.8592
```

```
749  csvGENw:labL11                  0.145     0.232 815    0.63  0.5321
750  csvGENb:labL11                  0.239     0.232 815    1.03  0.3039
751  csvENVw+GENw:labL11             0.475     0.232 815    2.05  0.0409
752  csvENVw:labL12                 -0.015     0.251 815   -0.06  0.9534
753  csvENVb:labL12                  0.121     0.251 815    0.48  0.6300
754  csvGENw:labL12                  0.200     0.251 815    0.80  0.4265
755  csvGENb:labL12                  0.588     0.251 815    2.34  0.0193
756  csvENVw+GENw:labL12             0.663     0.251 815    2.64  0.0084
757  csvENVw:labL13                  0.138     0.687 815    0.20  0.8406
758  csvENVb:labL13                 -0.146     0.657 815   -0.22  0.8242
759  csvGENw:labL13                  0.933     0.657 815    1.42  0.1561
760  csvGENb:labL13                  1.144     0.657 815    1.74  0.0822
761  csvENVw+GENw:labL13             1.143     0.657 815    1.74  0.0822
762  csvENVw:labL14                 -0.279     0.223 815   -1.25  0.2113
763  csvENVb:labL14                 -0.059     0.223 815   -0.26  0.7915
764  csvGENw:labL14                 -0.059     0.223 815   -0.26  0.7915
765  csvGENb:labL14                  0.094     0.223 815    0.42  0.6753
766  csvENVw+GENw:labL14            -0.042     0.223 815   -0.19  0.8502
767  legumesBM:csvENVw:labL2        -0.198     0.325 815   -0.61  0.5421
768  legumesBM:csvENVb:labL2        -0.430     0.317 815   -1.35  0.1762
769  legumesBM:csvGENw:labL2         0.097     0.323 815    0.30  0.7628
770  legumesBM:csvGENb:labL2        -0.454     0.317 815   -1.43  0.1531
771  legumesBM:csvENVw+GENw:labL2   -0.229     0.317 815   -0.72  0.4709
772  legumesBM:csvENVw:labL3         0.424     0.467 815    0.91  0.3641
773  legumesBM:csvENVb:labL3         0.189     0.462 815    0.41  0.6824
774  legumesBM:csvGENw:labL3         0.454     0.462 815    0.98  0.3255
775  legumesBM:csvGENb:labL3         0.154     0.462 815    0.33  0.7380
776  legumesBM:csvENVw+GENw:labL3   -0.006     0.462 815   -0.01  0.9891
777  legumesBM:csvENVw:labL4         0.009     0.314 815    0.03  0.9782
778  legumesBM:csvENVb:labL4        -0.198     0.306 815   -0.65  0.5182
779  legumesBM:csvGENw:labL4         0.446     0.308 815    1.45  0.1476
780  legumesBM:csvGENb:labL4        -0.038     0.306 815   -0.12  0.9012
781  legumesBM:csvENVw+GENw:labL4   -0.018     0.306 815   -0.06  0.9527
782  legumesBM:csvENVw:labL5        -0.388     0.433 815   -0.90  0.3706
783  legumesBM:csvENVb:labL5        -0.286     0.427 815   -0.67  0.5034
784  legumesBM:csvGENw:labL5         0.027     0.427 815    0.06  0.9493
785  legumesBM:csvGENb:labL5        -0.370     0.431 815   -0.86  0.3916
786  legumesBM:csvENVw+GENw:labL5   -0.003     0.427 815   -0.01  0.9938
787  legumesBM:csvENVw:labL6        -0.171     1.252 815   -0.14  0.8912
788  legumesBM:csvENVb:labL6        -1.128     1.298 815   -0.87  0.3850
789  legumesBM:csvGENw:labL6         0.097     1.285 815    0.08  0.9397
790  legumesBM:csvGENb:labL6         0.977     1.348 815    0.72  0.4688
791  legumesBM:csvENVw+GENw:labL6   -0.342     1.263 815   -0.27  0.7869
792  legumesBM:csvENVw:labL7         0.686     0.491 815    1.40  0.1623
793  legumesBM:csvENVb:labL7         0.293     0.486 815    0.60  0.5459
794  legumesBM:csvGENw:labL7         0.044     0.486 815    0.09  0.9278
795  legumesBM:csvGENb:labL7         0.064     0.486 815    0.13  0.8949
796  legumesBM:csvENVw+GENw:labL7   -0.308     0.486 815   -0.63  0.5260
797  legumesBM:csvENVw:labL8        -0.071     0.569 815   -0.13  0.9001
798  legumesBM:csvENVb:labL8        -0.733     0.536 815   -1.37  0.1720
799  legumesBM:csvGENw:labL8         0.469     0.536 815    0.87  0.3821
800  legumesBM:csvGENb:labL8        -1.038     0.536 815   -1.94  0.0533
801  legumesBM:csvENVw+GENw:labL8   -0.916     0.564 815   -1.62  0.1047
802  legumesBM:csvENVw:labL9        -0.203     0.446 815   -0.46  0.6490
803  legumesBM:csvENVb:labL9         0.047     0.448 815    0.10  0.9164
804  legumesBM:csvGENw:labL9        -0.162     0.440 815   -0.37  0.7122
805  legumesBM:csvGENb:labL9        -0.575     0.448 815   -1.28  0.1997
806  legumesBM:csvENVw+GENw:labL9   -0.365     0.440 815   -0.83  0.4075
807  legumesBM:csvENVw:labL10       -0.244     0.716 815   -0.34  0.7330
808  legumesBM:csvENVb:labL10       -0.462     0.712 815   -0.65  0.5170
809  legumesBM:csvGENw:labL10       -0.815     0.712 815   -1.14  0.2528
810  legumesBM:csvGENb:labL10       -0.869     0.712 815   -1.22  0.2228
811  legumesBM:csvENVw+GENw:labL10 -1.496     0.712 815   -2.10  0.0360
```

```
legumesBM:csvENVw:labL11      -0.279     0.366 815   -0.76  0.4462
legumesBM:csvENVb:labL11      -0.156     0.359 815   -0.43  0.6648
legumesBM:csvGENw:labL11       0.341     0.359 815    0.95  0.3420
legumesBM:csvGENb:labL11      -0.012     0.359 815   -0.03  0.9730
legumesBM:csvENVw+GENw:labL11 -0.134     0.359 815   -0.37  0.7092
legumesBM:csvENVw:labL12      -0.237     0.399 815   -0.59  0.5533
legumesBM:csvENVb:labL12      -0.188     0.393 815   -0.48  0.6324
legumesBM:csvGENw:labL12       0.349     0.393 815    0.89  0.3742
legumesBM:csvGENb:labL12      -0.442     0.393 815   -1.13  0.2607
legumesBM:csvENVw+GENw:labL12 -0.472     0.393 815   -1.20  0.2301
legumesBM:csvENVw:labL13      -1.969     0.973 815   -2.02  0.0433
legumesBM:csvENVb:labL13      -1.468     0.949 815   -1.55  0.1224
legumesBM:csvGENw:labL13      -1.010     0.949 815   -1.06  0.2874
legumesBM:csvGENb:labL13      -1.576     0.949 815   -1.66  0.0972
legumesBM:csvENVw+GENw:labL13 -2.539     0.949 815   -2.68  0.0076
legumesBM:csvENVw:labL14      -0.719     0.575 815   -1.25  0.2118
legumesBM:csvENVb:labL14      -0.432     0.571 815   -0.76  0.4494
legumesBM:csvGENw:labL14       0.597     0.571 815    1.05  0.2957
legumesBM:csvGENb:labL14      -0.069     0.571 815   -0.12  0.9045
legumesBM:csvENVw+GENw:labL14  0.419     0.571 815    0.73  0.4627

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-3.2346 -0.5889 -0.0817  0.4892  3.7536

Number of Observations: 984
Number of Groups: 2
```

Model for Brachipodyum distachyon height (heightB)

```
anova(m6)
                numDF denDF  F-value p-value
(Intercept)         1   825 94752.31  <.0001
legumes             1   825     3.33  0.0683
csv                 5   825    23.36  <.0001
lab                13   825   317.33  <.0001
legumes:csv         5   825     2.62  0.0231
legumes:lab        13   825    49.89  <.0001
csv:lab            65   825    10.16  <.0001
legumes:csv:lab    65   825     1.45  0.0136

summary(m6)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  4866 5795  -2236

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:      0.0718     5.27

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes
 Parameter estimates:
  L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
 1.000  0.890  0.164  0.388  0.504  0.857  0.684  0.948  0.422  0.571  0.479
 L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B L9*BM  L10*B L10*BM  L11*B L11*BM
0.394  0.453  0.540  0.629  0.582  0.754 0.740  0.483  0.374  0.389  0.552
```

```
  L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
  0.415  0.434  1.201  1.184  0.736  0.641

  Fixed effects: heightB ~ legumes * csv * lab
                                Value Std.Error  DF t-value p-value
  (Intercept)                   30.57      2.15 825   14.21  0.0000
  legumesBM                     -2.97      2.88 825   -1.03  0.3031
  csvENVw                       -1.01      3.04 825   -0.33  0.7404
  csvENVb                       -0.73      3.04 825   -0.24  0.8096
  csvGENw                       -8.13      3.04 825   -2.67  0.0077
  csvGENb                       -5.32      3.04 825   -1.75  0.0807
  csvENVw+GENw                  -4.16      3.04 825   -1.37  0.1714
  labL2                         -4.84      2.18 825   -2.22  0.0268
  labL3                          3.20      2.41 825    1.33  0.1846
  labL4                          9.62      2.61 825    3.69  0.0002
  labL5                          2.36      2.33 825    1.01  0.3126
  labL6                         -2.43      2.39 825   -1.02  0.3096
  labL7                         -4.97      2.36 825   -2.11  0.0354
  labL8                         -5.98      2.54 825   -2.35  0.0189
  labL9                         -4.27      2.69 825   -1.59  0.1129
  labL10                        -8.06      2.39 825   -3.37  0.0008
  labL11                         2.93      2.31 825    1.27  0.2050
  labL12                         2.59      2.33 825    1.11  0.2655
  labL13                         1.60      3.36 825    0.48  0.6336
  labL14                         4.22      2.67 825    1.58  0.1142
  legumesBM:csvENVw              2.65      4.07 825    0.65  0.5157
  legumesBM:csvENVb              2.59      4.07 825    0.64  0.5256
  legumesBM:csvGENw              4.36      4.07 825    1.07  0.2847
  legumesBM:csvGENb              3.74      4.07 825    0.92  0.3591
  legumesBM:csvENVw+GENw        -2.48      4.07 825   -0.61  0.5425
  legumesBM:labL2                2.90      3.04 825    0.95  0.3402
  legumesBM:labL3               -0.71      3.59 825   -0.20  0.8423
  legumesBM:labL4                1.79      3.82 825    0.47  0.6399
  legumesBM:labL5                0.08      3.26 825    0.02  0.9803
  legumesBM:labL6                1.90      3.17 825    0.60  0.5489
  legumesBM:labL7                1.20      3.25 825    0.37  0.7130
  legumesBM:labL8                3.70      3.42 825    1.08  0.2790
  legumesBM:labL9                4.30      3.67 825    1.17  0.2417
  legumesBM:labL10               0.04      3.16 825    0.01  0.9908
  legumesBM:labL11               1.03      3.27 825    0.31  0.7532
  legumesBM:labL12               1.57      3.18 825    0.49  0.6215
  legumesBM:labL13              -8.88      4.63 825   -1.92  0.0554
  legumesBM:labL14              25.27      3.56 825    7.09  0.0000
  csvENVw:labL2                 -0.45      3.08 825   -0.15  0.8840
  csvENVb:labL2                 -0.79      3.08 825   -0.26  0.7967
  csvGENw:labL2                  8.01      3.08 825    2.60  0.0095
  csvGENb:labL2                  5.76      3.08 825    1.87  0.0619
  csvENVw+GENw:labL2             4.27      3.08 825    1.39  0.1659
  csvENVw:labL3                 -0.97      3.41 825   -0.28  0.7766
  csvENVb:labL3                 -1.00      3.41 825   -0.29  0.7683
  csvGENw:labL3                  9.89      3.41 825    2.91  0.0038
  csvGENb:labL3                  7.30      3.41 825    2.14  0.0324
  csvENVw+GENw:labL3             7.31      3.41 825    2.15  0.0322
  csvENVw:labL4                 -8.78      3.69 825   -2.38  0.0174
  csvENVb:labL4                 -0.24      3.69 825   -0.06  0.9489
  csvGENw:labL4                  0.28      3.69 825    0.07  0.9405
  csvGENb:labL4                 -0.90      3.69 825   -0.24  0.8071
  csvENVw+GENw:labL4            -5.36      3.69 825   -1.45  0.1466
  csvENVw:labL5                  1.06      3.30 825    0.32  0.7486
  csvENVb:labL5                  0.47      3.30 825    0.14  0.8870
  csvGENw:labL5                 12.12      3.33 825    3.64  0.0003
  csvGENb:labL5                  6.67      3.30 825    2.02  0.0438
  csvENVw+GENw:labL5             5.39      3.30 825    1.63  0.1028
```

```
                                    2.58      3.37 825    0.77  0.4445
csvENVb:labL6                       1.28      3.37 825    0.38  0.7043
csvGENw:labL6                       5.03      3.37 825    1.49  0.1367
csvGENb:labL6                       4.54      3.37 825    1.35  0.1788
csvENVw+GENw:labL6                  1.70      3.40 825    0.50  0.6174
csvENVw:labL7                       1.99      3.34 825    0.60  0.5516
csvENVb:labL7                       2.13      3.37 825    0.63  0.5263
csvGENw:labL7                      14.56      3.34 825    4.36  0.0000
csvGENb:labL7                       6.72      3.34 825    2.01  0.0443
csvENVw+GENw:labL7                  8.97      3.34 825    2.69  0.0073
csvENVw:labL8                       2.41      3.59 825    0.67  0.5025
csvENVb:labL8                       1.00      3.59 825    0.28  0.7815
csvGENw:labL8                       0.31      3.59 825    0.09  0.9310
csvGENb:labL8                       0.54      3.59 825    0.15  0.8802
csvENVw+GENw:labL8                 -2.49      3.59 825   -0.69  0.4887
csvENVw:labL9                      -0.50      3.81 825   -0.13  0.8950
csvENVb:labL9                      -1.65      3.81 825   -0.43  0.6644
csvGENw:labL9                       8.47      3.81 825    2.22  0.0264
csvGENb:labL9                       3.71      3.88 825    0.96  0.3385
csvENVw+GENw:labL9                  0.48      3.81 825    0.13  0.9003
csvENVw:labL10                      3.30      3.38 825    0.98  0.3288
csvENVb:labL10                      1.11      3.38 825    0.33  0.7429
csvGENw:labL10                     16.32      3.38 825    4.83  0.0000
csvGENb:labL10                     10.68      3.38 825    3.16  0.0016
csvENVw+GENw:labL10                13.25      3.38 825    3.92  0.0001
csvENVw:labL11                     -1.12      3.26 825   -0.34  0.7304
csvENVb:labL11                     -1.29      3.26 825   -0.40  0.6917
csvGENw:labL11                     11.47      3.26 825    3.51  0.0005
csvGENb:labL11                      7.20      3.26 825    2.21  0.0276
csvENVw+GENw:labL11                 6.19      3.26 825    1.90  0.0582
csvENVw:labL12                     -0.80      3.29 825   -0.24  0.8075
csvENVb:labL12                      0.36      3.29 825    0.11  0.9134
csvGENw:labL12                     13.58      3.29 825    4.12  0.0000
csvGENb:labL12                      8.31      3.29 825    2.52  0.0119
csvENVw+GENw:labL12                 7.31      3.29 825    2.22  0.0267
csvENVw:labL13                      4.08      4.75 825    0.86  0.3906
csvENVb:labL13                     -1.67      4.75 825   -0.35  0.7260
csvGENw:labL13                     17.28      4.75 825    3.63  0.0003
csvGENb:labL13                     13.27      4.75 825    2.79  0.0054
csvENVw+GENw:labL13                18.64      4.75 825    3.92  0.0001
csvENVw:labL14                     -3.71      3.78 825   -0.98  0.3267
csvENVb:labL14                     -0.91      3.78 825   -0.24  0.8099
csvGENw:labL14                      7.56      3.78 825    2.00  0.0455
csvGENb:labL14                      3.31      3.78 825    0.88  0.3809
csvENVw+GENw:labL14                 4.24      3.78 825    1.12  0.2620
legumesBM:csvENVw:labL2            -1.47      4.30 825   -0.34  0.7322
legumesBM:csvENVb:labL2            -3.60      4.28 825   -0.84  0.4004
legumesBM:csvGENw:labL2            -6.72      4.28 825   -1.57  0.1169
legumesBM:csvGENb:labL2            -3.77      4.28 825   -0.88  0.3793
legumesBM:csvENVw+GENw:labL2        3.37      4.30 825    0.78  0.4336
legumesBM:csvENVw:labL3            -4.80      5.07 825   -0.95  0.3441
legumesBM:csvENVb:labL3            -3.54      5.07 825   -0.70  0.4850
legumesBM:csvGENw:labL3            -3.17      5.07 825   -0.62  0.5325
legumesBM:csvGENb:labL3            -1.60      5.07 825   -0.32  0.7524
legumesBM:csvENVw+GENw:labL3        3.26      5.07 825    0.64  0.5207
legumesBM:csvENVw:labL4             5.69      5.41 825    1.05  0.2926
legumesBM:csvENVb:labL4            -2.61      5.41 825   -0.48  0.6294
legumesBM:csvGENw:labL4            -4.20      5.41 825   -0.78  0.4378
legumesBM:csvGENb:labL4            -1.48      5.41 825   -0.27  0.7839
legumesBM:csvENVw+GENw:labL4        1.48      5.41 825    0.27  0.7847
legumesBM:csvENVw:labL5            -2.41      4.61 825   -0.52  0.6014
legumesBM:csvENVb:labL5            -2.17      4.61 825   -0.47  0.6385
legumesBM:csvGENw:labL5            -6.57      4.63 825   -1.42  0.1559
```

```
legumesBM:csvGENb:labL5         -3.70      4.64 825   -0.80  0.4253
legumesBM:csvENVw+GENw:labL5     5.68      4.61 825    1.23  0.2185
legumesBM:csvENVw:labL6         -3.35      4.49 825   -0.75  0.4559
legumesBM:csvENVb:labL6         -3.78      4.49 825   -0.84  0.3995
legumesBM:csvGENw:labL6         -2.98      4.49 825   -0.66  0.5068
legumesBM:csvGENb:labL6         -4.92      4.49 825   -1.10  0.2736
legumesBM:csvENVw+GENw:labL6     4.83      4.53 825    1.07  0.2862
legumesBM:csvENVw:labL7         -2.51      4.60 825   -0.54  0.5862
legumesBM:csvENVb:labL7         -3.00      4.62 825   -0.65  0.5168
legumesBM:csvGENw:labL7         -5.91      4.63 825   -1.28  0.2023
legumesBM:csvGENb:labL7         -1.49      4.60 825   -0.32  0.7459
legumesBM:csvENVw+GENw:labL7     5.99      4.60 825    1.30  0.1932
legumesBM:csvENVw:labL8         -5.41      4.83 825   -1.12  0.2634
legumesBM:csvENVb:labL8         -5.54      4.83 825   -1.15  0.2518
legumesBM:csvGENw:labL8         -3.99      4.83 825   -0.83  0.4095
legumesBM:csvGENb:labL8         -4.79      4.83 825   -0.99  0.3219
legumesBM:csvENVw+GENw:labL8     2.41      4.83 825    0.50  0.6181
legumesBM:csvENVw:labL9         -3.34      5.19 825   -0.64  0.5196
legumesBM:csvENVb:labL9         -1.89      5.19 825   -0.36  0.7159
legumesBM:csvGENw:labL9        -14.33      5.24 825   -2.74  0.0063
legumesBM:csvGENb:labL9         -7.25      5.24 825   -1.38  0.1668
legumesBM:csvENVw+GENw:labL9    -1.13      5.19 825   -0.22  0.8271
legumesBM:csvENVw:labL10        -3.80      4.47 825   -0.85  0.3960
legumesBM:csvENVb:labL10        -2.66      4.47 825   -0.59  0.5531
legumesBM:csvGENw:labL10        -5.58      4.47 825   -1.25  0.2127
legumesBM:csvGENb:labL10        -5.46      4.47 825   -1.22  0.2229
legumesBM:csvENVw+GENw:labL10    4.34      4.47 825    0.97  0.3322
legumesBM:csvENVw:labL11        -1.63      4.59 825   -0.36  0.7225
legumesBM:csvENVb:labL11        -2.21      4.62 825   -0.48  0.6321
legumesBM:csvGENw:labL11        -2.21      4.59 825   -0.48  0.6301
legumesBM:csvGENb:labL11        -0.87      4.59 825   -0.19  0.8489
legumesBM:csvENVw+GENw:labL11    4.06      4.59 825    0.88  0.3770
legumesBM:csvENVw:labL12        -1.66      4.48 825   -0.37  0.7105
legumesBM:csvENVb:labL12        -1.93      4.48 825   -0.43  0.6674
legumesBM:csvGENw:labL12        -3.59      4.48 825   -0.80  0.4235
legumesBM:csvGENb:labL12        -3.22      4.48 825   -0.72  0.4732
legumesBM:csvENVw+GENw:labL12    3.00      4.48 825    0.67  0.5028
legumesBM:csvENVw:labL13         2.30      6.55 825    0.35  0.7252
legumesBM:csvENVb:labL13         0.71      6.55 825    0.11  0.9132
legumesBM:csvGENw:labL13        -8.03      6.55 825   -1.23  0.2203
legumesBM:csvGENb:labL13        -5.91      6.55 825   -0.90  0.3670
legumesBM:csvENVw+GENw:labL13    5.78      6.55 825    0.88  0.3777
legumesBM:csvENVw:labL14        -0.80      5.04 825   -0.16  0.8745
legumesBM:csvENVb:labL14        -1.40      5.04 825   -0.28  0.7814
legumesBM:csvGENw:labL14       -13.24      5.04 825   -2.63  0.0088
legumesBM:csvGENb:labL14        -4.74      5.04 825   -0.94  0.3476
legumesBM:csvENVw+GENw:labL14   -7.50      5.04 825   -1.49  0.1372

Standardized Within-Group Residuals:
     Min       Q1      Med       Q3      Max
-3.10279 -0.61473  0.00168  0.55965  3.06272

Number of Observations: 994
Number of Groups: 2
```

Model for shoot N% (N.)

```
anova(m7)
                numDF denDF F-value p-value
(Intercept)         1   839 1961.43  <.0001
legumes             1   839  449.87  <.0001
csv                 5   839    0.78  0.5664
```

```
lab                13   839  335.18  <.0001
legumes:csv         5   839    1.34  0.2449
legumes:lab        13   839   14.12  <.0001
csv:lab            65   839    1.98  <.0001
legumes:csv:lab    65   839    1.71  0.0006

summary(m7)
Linear mixed-effects model fit by REML
 Data: reproz
  AIC  BIC logLik
  523 1456  -64.7

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:      0.0279     0.11

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes

 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  0.469  4.991  6.048  2.026  1.610  3.800  2.978  0.966  1.084  0.959
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B L9*BM  L10*B  L10*BM  L11*B  L11*BM
1.013  4.379  3.800  2.162  1.686  1.370 1.070  2.293  2.407  1.508  1.799
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
3.219  3.142  5.776  4.602  1.224  0.802

Fixed effects: N. ~ legumes * csv * lab
                                Value Std.Error  DF t-value p-value
(Intercept)                     0.665     0.049 839   13.51  0.0000
legumesBM                       0.012     0.050 839    0.24  0.8097
csvENVw                         0.003     0.064 839    0.04  0.9687
csvENVb                        -0.034     0.064 839   -0.53  0.5959
csvGENw                         0.009     0.064 839    0.14  0.8919
csvGENb                         0.053     0.064 839    0.83  0.4047
csvENVw+GENw                    0.064     0.064 839    1.01  0.3122
labL2                           1.440     0.230 839    6.27  0.0000
labL3                           0.167     0.102 839    1.64  0.1024
labL4                           0.454     0.177 839    2.56  0.0106
labL5                           0.025     0.063 839    0.39  0.6961
labL6                           0.383     0.062 839    6.12  0.0000
labL7                           1.198     0.203 839    5.91  0.0000
labL8                           0.664     0.107 839    6.18  0.0000
labL9                          -0.050     0.076 839   -0.65  0.5163
labL10                          0.386     0.113 839    3.42  0.0007
labL11                          1.613     0.082 839   19.76  0.0000
labL12                          1.648     0.152 839   10.84  0.0000
labL13                          1.464     0.264 839    5.54  0.0000
labL14                          0.425     0.071 839    5.97  0.0000
legumesBM:csvENVw              -0.003     0.070 839   -0.04  0.9679
legumesBM:csvENVb               0.014     0.070 839    0.20  0.8388
legumesBM:csvGENw              -0.016     0.070 839   -0.22  0.8222
legumesBM:csvGENb              -0.090     0.070 839   -1.28  0.2001
legumesBM:csvENVw+GENw         -0.064     0.070 839   -0.90  0.3665
legumesBM:labL2                -1.033     0.357 839   -2.89  0.0039
legumesBM:labL3                -0.109     0.127 839   -0.86  0.3915
legumesBM:labL4                -0.298     0.223 839   -1.33  0.1832
legumesBM:labL5                 0.160     0.082 839    1.95  0.0519
legumesBM:labL6                -0.077     0.080 839   -0.96  0.3359
legumesBM:labL7                -0.886     0.266 839   -3.33  0.0009
legumesBM:labL8                -0.475     0.133 839   -3.56  0.0004
```

legumesBM:labL9	0.030	0.093	839	0.33	0.7427
legumesBM:labL10	0.017	0.158	839	0.11	0.9143
legumesBM:labL11	-0.703	0.117	839	-6.01	0.0000
legumesBM:labL12	-0.412	0.209	839	-1.97	0.0491
legumesBM:labL13	-0.403	0.337	839	-1.20	0.2318
legumesBM:labL14	-0.162	0.083	839	-1.96	0.0505
csvENVw:labL2	-0.145	0.325	839	-0.45	0.6542
csvENVb:labL2	-0.162	0.325	839	-0.50	0.6176
csvGENw:labL2	-1.330	0.325	839	-4.10	0.0000
csvGENb:labL2	-1.011	0.325	839	-3.11	0.0019
csvENVw+GENw:labL2	-1.053	0.325	839	-3.24	0.0012
csvENVw:labL3	-0.056	0.144	839	-0.39	0.6962
csvENVb:labL3	-0.056	0.144	839	-0.39	0.6953
csvGENw:labL3	-0.074	0.144	839	-0.52	0.6055
csvGENb:labL3	-0.122	0.144	839	-0.85	0.3976
csvENVw+GENw:labL3	-0.143	0.144	839	-0.99	0.3215
csvENVw:labL4	0.210	0.251	839	0.84	0.4027
csvENVb:labL4	0.045	0.251	839	0.18	0.8581
csvGENw:labL4	0.286	0.251	839	1.14	0.2550
csvGENb:labL4	0.191	0.251	839	0.76	0.4466
csvENVw+GENw:labL4	-0.004	0.251	839	-0.02	0.9862
csvENVw:labL5	0.181	0.089	839	2.04	0.0420
csvENVb:labL5	0.223	0.089	839	2.52	0.0120
csvGENw:labL5	0.118	0.089	839	1.33	0.1831
csvGENb:labL5	0.158	0.089	839	1.78	0.0755
csvENVw+GENw:labL5	0.069	0.089	839	0.77	0.4389
csvENVw:labL6	-0.097	0.088	839	-1.10	0.2731
csvENVb:labL6	-0.003	0.088	839	-0.04	0.9698
csvGENw:labL6	0.089	0.088	839	1.01	0.3127
csvGENb:labL6	0.007	0.088	839	0.08	0.9363
csvENVw+GENw:labL6	0.030	0.088	839	0.34	0.7322
csvENVw:labL7	-0.451	0.286	839	-1.57	0.1159
csvENVb:labL7	-0.183	0.286	839	-0.64	0.5227
csvGENw:labL7	-0.395	0.286	839	-1.38	0.1680
csvGENb:labL7	-0.699	0.286	839	-2.44	0.0150
csvENVw+GENw:labL7	-0.889	0.286	839	-3.10	0.0020
csvENVw:labL8	-0.007	0.152	839	-0.04	0.9648
csvENVb:labL8	-0.131	0.152	839	-0.86	0.3893
csvGENw:labL8	0.077	0.152	839	0.51	0.6111
csvGENb:labL8	0.082	0.152	839	0.54	0.5883
csvENVw+GENw:labL8	0.120	0.152	839	0.79	0.4315
csvENVw:labL9	0.139	0.108	839	1.29	0.1979
csvENVb:labL9	0.082	0.108	839	0.76	0.4505
csvGENw:labL9	0.095	0.108	839	0.88	0.3775
csvGENb:labL9	0.096	0.108	839	0.89	0.3750
csvENVw+GENw:labL9	0.046	0.108	839	0.42	0.6741
csvENVw:labL10	-0.103	0.160	839	-0.64	0.5201
csvENVb:labL10	0.080	0.160	839	0.50	0.6181
csvGENw:labL10	-0.175	0.160	839	-1.10	0.2730
csvGENb:labL10	-0.153	0.160	839	-0.96	0.3382
csvENVw+GENw:labL10	-0.187	0.160	839	-1.17	0.2413
csvENVw:labL11	-0.061	0.115	839	-0.53	0.5983
csvENVb:labL11	-0.089	0.115	839	-0.77	0.4434
csvGENw:labL11	-0.333	0.115	839	-2.89	0.0040
csvGENb:labL11	-0.202	0.115	839	-1.75	0.0802
csvENVw+GENw:labL11	-0.188	0.115	839	-1.63	0.1031
csvENVw:labL12	-0.362	0.215	839	-1.69	0.0923
csvENVb:labL12	-0.211	0.215	839	-0.98	0.3275
csvGENw:labL12	-0.431	0.215	839	-2.00	0.0455
csvGENb:labL12	-0.164	0.215	839	-0.76	0.4448
csvENVw+GENw:labL12	-0.286	0.215	839	-1.33	0.1838
csvENVw:labL13	0.273	0.374	839	0.73	0.4660
csvENVb:labL13	0.340	0.374	839	0.91	0.3631

```
                                  0.063     0.374 839    0.17  0.8655
csvGENb:labL13                   -0.267     0.374 839   -0.71  0.4760
csvENVw+GENw:labL13              -0.248     0.374 839   -0.66  0.5077
csvENVw:labL14                    0.003     0.101 839    0.03  0.9800
csvENVb:labL14                    0.000     0.101 839    0.00  0.9971
csvGENw:labL14                   -0.051     0.101 839   -0.50  0.6145
csvGENb:labL14                   -0.161     0.101 839   -1.60  0.1099
csvENVw+GENw:labL14              -0.278     0.101 839   -2.76  0.0060
legumesBM:csvENVw:labL2           0.438     0.505 839    0.87  0.3863
legumesBM:csvENVb:labL2           0.156     0.505 839    0.31  0.7568
legumesBM:csvGENw:labL2           1.747     0.505 839    3.46  0.0006
legumesBM:csvGENb:labL2           1.487     0.505 839    2.94  0.0033
legumesBM:csvENVw+GENw:labL2      1.557     0.505 839    3.08  0.0021
legumesBM:csvENVw:labL3           0.047     0.179 839    0.26  0.7944
legumesBM:csvENVb:labL3           0.146     0.179 839    0.81  0.4160
legumesBM:csvGENw:labL3           0.100     0.179 839    0.56  0.5770
legumesBM:csvGENb:labL3          -0.062     0.179 839   -0.34  0.7303
legumesBM:csvENVw+GENw:labL3     -0.043     0.179 839   -0.24  0.8104
legumesBM:csvENVw:labL4          -0.179     0.316 839   -0.57  0.5722
legumesBM:csvENVb:labL4           0.105     0.316 839    0.33  0.7393
legumesBM:csvGENw:labL4           0.301     0.316 839    0.95  0.3404
legumesBM:csvGENb:labL4          -0.130     0.316 839   -0.41  0.6808
legumesBM:csvENVw+GENw:labL4      0.423     0.316 839    1.34  0.1811
legumesBM:csvENVw:labL5          -0.242     0.116 839   -2.08  0.0374
legumesBM:csvENVb:labL5          -0.236     0.116 839   -2.03  0.0425
legumesBM:csvGENw:labL5          -0.086     0.116 839   -0.74  0.4600
legumesBM:csvGENb:labL5          -0.151     0.116 839   -1.30  0.1952
legumesBM:csvENVw+GENw:labL5     -0.159     0.116 839   -1.37  0.1712
legumesBM:csvENVw:labL6           0.107     0.113 839    0.94  0.3483
legumesBM:csvENVb:labL6           0.017     0.113 839    0.15  0.8804
legumesBM:csvGENw:labL6          -0.068     0.113 839   -0.60  0.5466
legumesBM:csvGENb:labL6           0.075     0.113 839    0.66  0.5105
legumesBM:csvENVw+GENw:labL6      0.023     0.113 839    0.20  0.8427
legumesBM:csvENVw:labL7           0.170     0.376 839    0.45  0.6517
legumesBM:csvENVb:labL7           0.044     0.376 839    0.12  0.9066
legumesBM:csvGENw:labL7           0.332     0.376 839    0.88  0.3778
legumesBM:csvGENb:labL7           0.690     0.376 839    1.83  0.0672
legumesBM:csvENVw+GENw:labL7      0.777     0.376 839    2.06  0.0393
legumesBM:csvENVw:labL8           0.054     0.189 839    0.29  0.7744
legumesBM:csvENVb:labL8           0.459     0.189 839    2.43  0.0152
legumesBM:csvGENw:labL8           0.328     0.189 839    1.74  0.0822
legumesBM:csvGENb:labL8           0.466     0.189 839    2.47  0.0136
legumesBM:csvENVw+GENw:labL8      0.156     0.189 839    0.83  0.4094
legumesBM:csvENVw:labL9          -0.160     0.131 839   -1.22  0.2243
legumesBM:csvENVb:labL9          -0.091     0.131 839   -0.69  0.4894
legumesBM:csvGENw:labL9           0.053     0.131 839    0.40  0.6890
legumesBM:csvGENb:labL9          -0.033     0.131 839   -0.25  0.7996
legumesBM:csvENVw+GENw:labL9     -0.032     0.131 839   -0.25  0.8055
legumesBM:csvENVw:labL10         -0.056     0.223 839   -0.25  0.8022
legumesBM:csvENVb:labL10         -0.285     0.223 839   -1.28  0.2025
legumesBM:csvGENw:labL10         -0.022     0.223 839   -0.10  0.9204
legumesBM:csvGENb:labL10         -0.088     0.223 839   -0.40  0.6929
legumesBM:csvENVw+GENw:labL10    -0.060     0.223 839   -0.27  0.7897
legumesBM:csvENVw:labL11          0.159     0.165 839    0.96  0.3364
legumesBM:csvENVb:labL11          0.209     0.165 839    1.26  0.2077
legumesBM:csvGENw:labL11          0.231     0.165 839    1.40  0.1628
legumesBM:csvGENb:labL11          0.095     0.165 839    0.58  0.5647
legumesBM:csvENVw+GENw:labL11     0.394     0.165 839    2.38  0.0174
legumesBM:csvENVw:labL12          0.443     0.295 839    1.50  0.1337
legumesBM:csvENVb:labL12          0.001     0.295 839    0.00  0.9969
legumesBM:csvGENw:labL12          0.330     0.295 839    1.12  0.2638
legumesBM:csvGENb:labL12         -0.188     0.295 839   -0.64  0.5242
legumesBM:csvENVw+GENw:labL12     0.308     0.295 839    1.04  0.2980
```

```
legumesBM:csvENVw:labL13      -0.785     0.476 839   -1.65  0.0996
legumesBM:csvENVb:labL13      -0.435     0.476 839   -0.91  0.3612
legumesBM:csvGENw:labL13      -0.288     0.476 839   -0.61  0.5453
legumesBM:csvGENb:labL13       0.394     0.476 839    0.83  0.4083
legumesBM:csvENVw+GENw:labL13  0.447     0.476 839    0.94  0.3477
legumesBM:csvENVw:labL14      -0.025     0.117 839   -0.21  0.8306
legumesBM:csvENVb:labL14      -0.006     0.117 839   -0.05  0.9623
legumesBM:csvGENw:labL14       0.087     0.117 839    0.75  0.4547
legumesBM:csvGENb:labL14       0.181     0.117 839    1.55  0.1213
legumesBM:csvENVw+GENw:labL14  0.319     0.117 839    2.73  0.0065

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-2.7004 -0.6720 -0.0372  0.5961  4.5580

Number of Observations: 1008
Number of Groups: 2
```

Model for shoot C% (C.)

```
anova(m8)
                numDF denDF F-value p-value
(Intercept)         1   839 2288364  <.0001
legumes             1   839     111  <.0001
csv                 5   839       0  0.9782
lab                13   839     174  <.0001
legumes:csv         5   839       3  0.0267
legumes:lab        13   839      12  <.0001
csv:lab            65   839       2  0.0011
legumes:csv:lab    65   839       1  0.0449

summary(m8)
Linear mixed-effects model fit by REML
 Data: reproz
   AIC  BIC logLik
  2718 3650  -1162

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:      0.0296     0.73

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  1.022  0.711  1.010  1.238  0.969  1.068  0.838  0.970  0.590  2.252
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B L9*BM  L10*B L10*BM  L11*B L11*BM
1.929  0.440  0.592  0.989  0.802  0.550 0.445  1.652  1.362  0.977  1.424
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.417  1.691  5.870  4.150  0.906  0.971
Fixed effects: C. ~ legumes * csv * lab
                               Value Std.Error  DF t-value p-value
(Intercept)                     46.0     0.299 839   153.8  0.0000
legumesBM                       -0.8     0.426 839    -1.9  0.0635
csvENVw                          0.4     0.422 839     1.0  0.3012
csvENVb                         -0.4     0.422 839    -0.9  0.3915
csvGENw                         -0.1     0.422 839    -0.1  0.8891
csvGENb                         -0.4     0.422 839    -0.9  0.3658
csvENVw+GENw                    -0.1     0.422 839    -0.4  0.7248
labL2                           -3.0     0.366 839    -8.2  0.0000
```

labL3	-0.2	0.474	839	-0.4	0.7225
labL4	-3.5	0.436	839	-8.1	0.0000
labL5	-1.7	0.415	839	-4.0	0.0001
labL6	-2.6	0.735	839	-3.5	0.0004
labL7	-2.7	0.326	839	-8.3	0.0000
labL8	-2.1	0.419	839	-4.9	0.0000
labL9	-1.6	0.340	839	-4.8	0.0000
labL10	-3.4	0.576	839	-5.9	0.0000
labL11	-2.7	0.417	839	-6.4	0.0000
labL12	-3.8	0.517	839	-7.4	0.0000
labL13	-7.5	1.776	839	-4.2	0.0000
labL14	-2.9	0.402	839	-7.1	0.0000
legumesBM:csvENVw	-0.7	0.603	839	-1.1	0.2732
legumesBM:csvENVb	0.6	0.603	839	1.0	0.3001
legumesBM:csvGENw	-0.4	0.603	839	-0.6	0.5443
legumesBM:csvGENb	0.4	0.603	839	0.7	0.4994
legumesBM:csvENVw+GENw	-0.1	0.603	839	-0.1	0.9271
legumesBM:labL2	1.6	0.563	839	2.9	0.0039
legumesBM:labL3	-0.4	0.634	839	-0.6	0.5589
legumesBM:labL4	-0.6	0.588	839	-0.9	0.3433
legumesBM:labL5	0.1	0.544	839	0.2	0.8080
legumesBM:labL6	1.3	0.981	839	1.4	0.1712
legumesBM:labL7	0.0	0.480	839	0.1	0.9367
legumesBM:labL8	0.8	0.571	839	1.4	0.1549
legumesBM:labL9	0.9	0.475	839	1.8	0.0732
legumesBM:labL10	-0.3	0.768	839	-0.4	0.6893
legumesBM:labL11	0.2	0.668	839	0.3	0.7355
legumesBM:labL12	0.1	0.784	839	0.1	0.9157
legumesBM:labL13	5.9	2.186	839	2.7	0.0075
legumesBM:labL14	0.2	0.582	839	0.4	0.7026
csvENVw:labL2	-0.3	0.517	839	-0.6	0.5285
csvENVb:labL2	0.7	0.517	839	1.3	0.1972
csvGENw:labL2	0.4	0.517	839	0.8	0.4352
csvGENb:labL2	0.6	0.517	839	1.1	0.2543
csvENVw+GENw:labL2	0.7	0.517	839	1.4	0.1599
csvENVw:labL3	-0.9	0.671	839	-1.4	0.1580
csvENVb:labL3	0.3	0.671	839	0.5	0.6186
csvGENw:labL3	-0.4	0.671	839	-0.6	0.5816
csvGENb:labL3	-0.2	0.671	839	-0.3	0.7578
csvENVw+GENw:labL3	0.1	0.671	839	0.2	0.8322
csvENVw:labL4	-1.4	0.617	839	-2.3	0.0201
csvENVb:labL4	0.2	0.617	839	0.3	0.7989
csvGENw:labL4	-0.1	0.617	839	-0.1	0.8931
csvGENb:labL4	0.0	0.617	839	-0.1	0.9417
csvENVw+GENw:labL4	-0.8	0.617	839	-1.4	0.1772
csvENVw:labL5	0.1	0.587	839	0.1	0.9295
csvENVb:labL5	0.9	0.587	839	1.5	0.1300
csvGENw:labL5	0.1	0.587	839	0.1	0.9261
csvGENb:labL5	0.6	0.587	839	1.1	0.2821
csvENVw+GENw:labL5	0.4	0.587	839	0.6	0.5318
csvENVw:labL6	-1.1	1.039	839	-1.1	0.2844
csvENVb:labL6	0.8	1.039	839	0.7	0.4684
csvGENw:labL6	0.3	1.039	839	0.3	0.7964
csvGENb:labL6	-0.5	1.039	839	-0.5	0.6394
csvENVw+GENw:labL6	0.2	1.039	839	0.2	0.8625
csvENVw:labL7	-0.4	0.461	839	-0.8	0.4186
csvENVb:labL7	0.3	0.461	839	0.6	0.5527
csvGENw:labL7	0.3	0.461	839	0.6	0.5766
csvGENb:labL7	0.6	0.461	839	1.3	0.1959
csvENVw+GENw:labL7	0.4	0.461	839	1.0	0.3302
csvENVw:labL8	0.5	0.593	839	0.9	0.3862
csvENVb:labL8	1.2	0.593	839	2.1	0.0359
csvGENw:labL8	0.4	0.593	839	0.6	0.5197

```
1371  csvGENb:labL8                    0.2     0.593 839     0.3  0.7274
1372  csvENVw+GENw:labL8               0.4     0.593 839     0.7  0.5119
1373  csvENVw:labL9                   -0.1     0.481 839    -0.2  0.8278
1374  csvENVb:labL9                    0.3     0.481 839     0.6  0.5304
1375  csvGENw:labL9                    0.2     0.481 839     0.5  0.6288
1376  csvGENb:labL9                    0.4     0.481 839     0.9  0.3604
1377  csvENVw+GENw:labL9               0.0     0.481 839    -0.1  0.9409
1378  csvENVw:labL10                  -0.4     0.814 839    -0.6  0.5824
1379  csvENVb:labL10                   0.2     0.814 839     0.3  0.8013
1380  csvGENw:labL10                   0.3     0.814 839     0.3  0.7320
1381  csvGENb:labL10                   0.6     0.814 839     0.7  0.4714
1382  csvENVw+GENw:labL10              0.3     0.814 839     0.4  0.6805
1383  csvENVw:labL11                  -1.0     0.589 839    -1.6  0.1054
1384  csvENVb:labL11                   0.4     0.589 839     0.8  0.4516
1385  csvGENw:labL11                   0.9     0.589 839     1.6  0.1173
1386  csvGENb:labL11                   1.1     0.589 839     1.9  0.0608
1387  csvENVw+GENw:labL11              0.9     0.589 839     1.5  0.1245
1388  csvENVw:labL12                  -0.7     0.731 839    -1.0  0.3180
1389  csvENVb:labL12                   0.4     0.731 839     0.5  0.6094
1390  csvGENw:labL12                  -0.5     0.731 839    -0.7  0.4993
1391  csvGENb:labL12                   0.7     0.731 839     1.0  0.3180
1392  csvENVw+GENw:labL12              0.4     0.731 839     0.5  0.5885
1393  csvENVw:labL13                  10.6     2.511 839     4.2  0.0000
1394  csvENVb:labL13                   4.7     2.511 839     1.9  0.0635
1395  csvGENw:labL13                   1.3     2.511 839     0.5  0.6139
1396  csvGENb:labL13                   5.2     2.511 839     2.1  0.0377
1397  csvENVw+GENw:labL13              3.3     2.511 839     1.3  0.1923
1398  csvENVw:labL14                  -0.4     0.569 839    -0.6  0.5309
1399  csvENVb:labL14                   0.5     0.569 839     0.8  0.4227
1400  csvGENw:labL14                   0.6     0.569 839     1.0  0.3012
1401  csvGENb:labL14                   0.2     0.569 839     0.4  0.7184
1402  csvENVw+GENw:labL14              0.1     0.569 839     0.2  0.8610
1403  legumesBM:csvENVw:labL2          0.8     0.797 839     1.0  0.3356
1404  legumesBM:csvENVb:labL2         -0.8     0.797 839    -1.0  0.3005
1405  legumesBM:csvGENw:labL2         -0.4     0.797 839    -0.5  0.6502
1406  legumesBM:csvGENb:labL2         -1.0     0.797 839    -1.3  0.1994
1407  legumesBM:csvENVw+GENw:labL2    -0.8     0.797 839    -1.0  0.3419
1408  legumesBM:csvENVw:labL3          0.1     0.896 839     0.2  0.8700
1409  legumesBM:csvENVb:labL3         -1.8     0.896 839    -2.0  0.0506
1410  legumesBM:csvGENw:labL3         -0.3     0.896 839    -0.3  0.7554
1411  legumesBM:csvGENb:labL3          0.0     0.896 839     0.1  0.9556
1412  legumesBM:csvENVw+GENw:labL3    -0.7     0.896 839    -0.8  0.4431
1413  legumesBM:csvENVw:labL4          1.9     0.831 839     2.3  0.0214
1414  legumesBM:csvENVb:labL4          0.0     0.831 839     0.0  0.9640
1415  legumesBM:csvGENw:labL4          0.6     0.831 839     0.7  0.4839
1416  legumesBM:csvGENb:labL4          0.2     0.831 839     0.2  0.8396
1417  legumesBM:csvENVw+GENw:labL4     0.6     0.831 839     0.8  0.4451
1418  legumesBM:csvENVw:labL5         -0.1     0.770 839    -0.1  0.9066
1419  legumesBM:csvENVb:labL5         -1.4     0.770 839    -1.8  0.0648
1420  legumesBM:csvGENw:labL5          0.1     0.770 839     0.1  0.9382
1421  legumesBM:csvGENb:labL5         -1.0     0.770 839    -1.3  0.1802
1422  legumesBM:csvENVw+GENw:labL5    -0.8     0.770 839    -1.1  0.2725
1423  legumesBM:csvENVw:labL6          1.2     1.388 839     0.8  0.4003
1424  legumesBM:csvENVb:labL6         -1.5     1.388 839    -1.1  0.2935
1425  legumesBM:csvGENw:labL6          0.4     1.388 839     0.3  0.7674
1426  legumesBM:csvGENb:labL6         -0.7     1.388 839    -0.5  0.6133
1427  legumesBM:csvENVw+GENw:labL6    -1.8     1.388 839    -1.3  0.1869
1428  legumesBM:csvENVw:labL7          0.5     0.678 839     0.8  0.4349
1429  legumesBM:csvENVb:labL7         -0.4     0.678 839    -0.6  0.5225
1430  legumesBM:csvGENw:labL7          0.5     0.678 839     0.7  0.4641
1431  legumesBM:csvGENb:labL7         -0.2     0.678 839    -0.3  0.7840
1432  legumesBM:csvENVw+GENw:labL7    -0.4     0.678 839    -0.5  0.5971
1433  legumesBM:csvENVw:labL8         -0.1     0.807 839    -0.1  0.9475
```

```
legumesBM:csvENVb:labL8        -1.6     0.807 839    -2.0  0.0494
legumesBM:csvGENw:labL8        -0.7     0.807 839    -0.9  0.3836
legumesBM:csvGENb:labL8        -0.6     0.807 839    -0.7  0.4733
legumesBM:csvENVw+GENw:labL8    0.2     0.807 839     0.3  0.7864
legumesBM:csvENVw:labL9         0.4     0.672 839     0.6  0.5468
legumesBM:csvENVb:labL9        -0.7     0.672 839    -1.0  0.3121
legumesBM:csvGENw:labL9        -0.3     0.672 839    -0.4  0.6709
legumesBM:csvGENb:labL9        -0.7     0.672 839    -1.1  0.2762
legumesBM:csvENVw+GENw:labL9    0.0     0.672 839     0.0  0.9606
legumesBM:csvENVw:labL10       -0.6     1.086 839    -0.6  0.5614
legumesBM:csvENVb:labL10       -0.5     1.086 839    -0.5  0.6476
legumesBM:csvGENw:labL10       -0.6     1.086 839    -0.5  0.6121
legumesBM:csvGENb:labL10       -1.6     1.086 839    -1.5  0.1409
legumesBM:csvENVw+GENw:labL10   0.0     1.086 839     0.0  0.9696
legumesBM:csvENVw:labL11        1.5     0.945 839     1.6  0.1158
legumesBM:csvENVb:labL11       -0.1     0.945 839    -0.1  0.9468
legumesBM:csvGENw:labL11        0.5     0.945 839     0.5  0.5932
legumesBM:csvGENb:labL11       -0.9     0.945 839    -1.0  0.3354
legumesBM:csvENVw+GENw:labL11   0.6     0.945 839     0.7  0.5127
legumesBM:csvENVw:labL12        1.1     1.109 839     1.0  0.3297
legumesBM:csvENVb:labL12       -0.9     1.109 839    -0.8  0.4022
legumesBM:csvGENw:labL12        2.0     1.109 839     1.8  0.0705
legumesBM:csvGENb:labL12       -0.4     1.109 839    -0.4  0.7100
legumesBM:csvENVw+GENw:labL12   0.2     1.109 839     0.1  0.8913
legumesBM:csvENVw:labL13      -10.4     3.091 839    -3.4  0.0008
legumesBM:csvENVb:labL13       -6.6     3.091 839    -2.1  0.0335
legumesBM:csvGENw:labL13       -0.1     3.091 839     0.0  0.9696
legumesBM:csvGENb:labL13       -5.6     3.091 839    -1.8  0.0682
legumesBM:csvENVw+GENw:labL13  -3.2     3.091 839    -1.0  0.3050
legumesBM:csvENVw:labL14        0.1     0.823 839     0.1  0.8843
legumesBM:csvENVb:labL14       -0.6     0.823 839    -0.7  0.4604
legumesBM:csvGENw:labL14       -0.1     0.823 839    -0.1  0.9312
legumesBM:csvGENb:labL14       -0.2     0.823 839    -0.2  0.8056
legumesBM:csvENVw+GENw:labL14   0.0     0.823 839     0.0  0.9886

Standardized Within-Group Residuals:
   Min     Q1    Med     Q3    Max
-3.213 -0.550  0.014  0.614  3.326

Number of Observations: 1008
Number of Groups: 2
```

Model for foliar delta ^{15}N (deltaN)

```
anova(m9)
                numDF denDF F-value p-value
(Intercept)         1   794 10217.6  <.0001
legumes             1   794    14.4   2e-04
csv                 5   794     8.9  <.0001
lab                13   794   258.3  <.0001
legumes:csv         5   794     6.5  <.0001
legumes:lab        13   794    16.8  <.0001
csv:lab            65   794     4.4  <.0001
legumes:csv:lab    65   794     1.8   1e-04

summary(m9)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  2222 3144   -914

Random effects:
```

```
 Formula: ~1 | block
        (Intercept) Residual
StdDev:      0.0365    0.687

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes

 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  0.949  0.548  0.516  6.240  5.814  0.817  0.911  0.569  0.612  0.740
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B L9*BM  L10*B L10*BM  L11*B L11*BM
0.706  0.915  1.429  1.012  1.356  0.725  0.891  0.312  0.424  0.885  0.732
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.031  0.491  0.949  0.978  1.655  1.275

Fixed effects: deltaN ~ legumes * csv * lab
                               Value Std.Error  DF t-value p-value
(Intercept)                     1.49      0.28 794    5.31  0.0000
legumesBM                      -0.38      0.39 794   -0.97  0.3316
csvENVw                         0.35      0.40 794    0.88  0.3795
csvENVb                         0.24      0.40 794    0.60  0.5503
csvGENw                         0.07      0.40 794    0.18  0.8572
csvGENb                        -0.20      0.40 794   -0.51  0.6134
csvENVw+GENw                    0.49      0.42 794    1.17  0.2427
labL2                           0.50      0.33 794    1.54  0.1233
labL3                           5.40      1.94 794    2.79  0.0054
labL4                           1.36      0.36 794    3.75  0.0002
labL5                           1.86      0.32 794    5.78  0.0000
labL6                           0.20      0.35 794    0.57  0.5664
labL7                           0.66      0.40 794    1.67  0.0952
labL8                           1.41      0.40 794    3.54  0.0004
labL9                           0.54      0.35 794    1.56  0.1181
labL10                          1.58      0.29 794    5.37  0.0000
labL11                          2.62      0.37 794    7.01  0.0000
labL12                          2.26      0.40 794    5.61  0.0000
labL13                          3.46      0.39 794    8.96  0.0000
labL14                          5.52      0.54 794   10.19  0.0000
legumesBM:csvENVw               0.02      0.56 794    0.04  0.9720
legumesBM:csvENVb               0.42      0.55 794    0.76  0.4451
legumesBM:csvGENw               0.31      0.55 794    0.57  0.5692
legumesBM:csvGENb               0.48      0.55 794    0.88  0.3796
legumesBM:csvENVw+GENw          0.01      0.56 794    0.02  0.9865
legumesBM:labL2                -0.09      0.45 794   -0.20  0.8439
legumesBM:labL3                 0.69      2.54 794    0.27  0.7876
legumesBM:labL4                 0.18      0.52 794    0.35  0.7235
legumesBM:labL5                 0.10      0.45 794    0.22  0.8275
legumesBM:labL6                 0.61      0.48 794    1.27  0.2042
legumesBM:labL7                 0.07      0.62 794    0.11  0.9132
legumesBM:labL8                 0.57      0.61 794    0.94  0.3488
legumesBM:labL9                 0.65      0.50 794    1.29  0.1990
legumesBM:labL10               -0.13      0.41 794   -0.31  0.7580
legumesBM:labL11                0.92      0.50 794    1.83  0.0674
legumesBM:labL12                1.31      0.50 794    2.62  0.0091
legumesBM:labL13               -0.93      0.58 794   -1.61  0.1069
legumesBM:labL14               -1.73      0.70 794   -2.46  0.0141
csvENVw:labL2                  -0.05      0.46 794   -0.11  0.9141
csvENVb:labL2                  -0.07      0.46 794   -0.15  0.8799
csvGENw:labL2                   0.26      0.46 794    0.56  0.5761
csvGENb:labL2                   0.01      0.46 794    0.03  0.9772
csvENVw+GENw:labL2              0.38      0.47 794    0.81  0.4206
csvENVw:labL3                   2.83      2.74 794    1.03  0.3022
csvENVb:labL3                   3.38      2.62 794    1.29  0.1975
```

```
csvGENw:labL3                  1.13      2.62 794    0.43  0.6663
csvGENb:labL3                  0.87      2.62 794    0.33  0.7392
csvENVw+GENw:labL3             2.51      2.63 794    0.95  0.3403
csvENVw:labL4                  0.10      0.51 794    0.19  0.8495
csvENVb:labL4                  0.07      0.51 794    0.14  0.8876
csvGENw:labL4                  0.00      0.51 794    0.00  0.9961
csvGENb:labL4                 -0.06      0.51 794   -0.11  0.9103
csvENVw+GENw:labL4            -0.45      0.53 794   -0.86  0.3910
csvENVw:labL5                  0.44      0.46 794    0.97  0.3310
csvENVb:labL5                 -0.04      0.46 794   -0.09  0.9258
csvGENw:labL5                 -0.02      0.46 794   -0.05  0.9612
csvGENb:labL5                  0.48      0.46 794    1.05  0.2926
csvENVw+GENw:labL5             0.17      0.47 794    0.35  0.7239
csvENVw:labL6                  0.77      0.49 794    1.57  0.1165
csvENVb:labL6                  0.53      0.49 794    1.08  0.2814
csvGENw:labL6                  0.32      0.49 794    0.64  0.5220
csvGENb:labL6                  0.92      0.49 794    1.86  0.0638
csvENVw+GENw:labL6             0.41      0.51 794    0.81  0.4163
csvENVw:labL7                  0.41      0.55 794    0.75  0.4558
csvENVb:labL7                 -0.07      0.55 794   -0.12  0.9039
csvGENw:labL7                 -0.43      0.61 794   -0.71  0.4807
csvGENb:labL7                  0.16      0.55 794    0.29  0.7715
csvENVw+GENw:labL7            -0.18      0.58 794   -0.32  0.7488
csvENVw:labL8                  0.57      0.56 794    1.01  0.3140
csvENVb:labL8                  0.07      0.56 794    0.13  0.8984
csvGENw:labL8                  0.31      0.58 794    0.54  0.5874
csvGENb:labL8                  0.33      0.58 794    0.56  0.5736
csvENVw+GENw:labL8            -0.52      0.61 794   -0.85  0.3928
csvENVw:labL9                  0.76      0.49 794    1.55  0.1225
csvENVb:labL9                  1.01      0.49 794    2.06  0.0394
csvGENw:labL9                  0.27      0.49 794    0.56  0.5747
csvGENb:labL9                  0.55      0.49 794    1.12  0.2620
csvENVw+GENw:labL9             0.62      0.51 794    1.23  0.2203
csvENVw:labL10                -0.49      0.42 794   -1.17  0.2428
csvENVb:labL10                -0.25      0.42 794   -0.60  0.5454
csvGENw:labL10                -0.17      0.42 794   -0.40  0.6870
csvGENb:labL10                 0.35      0.42 794    0.85  0.3935
csvENVw+GENw:labL10            0.29      0.43 794    0.66  0.5104
csvENVw:labL11                -1.23      0.53 794   -2.33  0.0202
csvENVb:labL11                -0.81      0.53 794   -1.53  0.1255
csvGENw:labL11                 1.36      0.53 794    2.57  0.0103
csvGENb:labL11                 1.27      0.53 794    2.40  0.0166
csvENVw+GENw:labL11           -0.35      0.54 794   -0.64  0.5251
csvENVw:labL12                -0.89      0.58 794   -1.53  0.1275
csvENVb:labL12                -0.51      0.57 794   -0.90  0.3705
csvGENw:labL12                 0.80      0.57 794    1.41  0.1595
csvGENb:labL12                 0.53      0.57 794    0.93  0.3517
csvENVw+GENw:labL12           -0.16      0.60 794   -0.27  0.7880
csvENVw:labL13                -1.51      0.55 794   -2.76  0.0060
csvENVb:labL13                -0.01      0.58 794   -0.03  0.9799
csvGENw:labL13                 0.01      0.61 794    0.01  0.9893
csvGENb:labL13                -1.25      0.66 794   -1.89  0.0590
csvENVw+GENw:labL13           -2.10      0.62 794   -3.39  0.0007
csvENVw:labL14                -0.22      0.77 794   -0.29  0.7706
csvENVb:labL14                -0.82      0.77 794   -1.07  0.2860
csvGENw:labL14                -0.55      0.77 794   -0.71  0.4751
csvGENb:labL14                 0.54      0.77 794    0.70  0.4824
csvENVw+GENw:labL14           -0.74      0.78 794   -0.95  0.3404
legumesBM:csvENVw:labL2        0.25      0.64 794    0.39  0.6953
legumesBM:csvENVb:labL2       -0.18      0.63 794   -0.29  0.7710
legumesBM:csvGENw:labL2       -0.11      0.63 794   -0.18  0.8572
legumesBM:csvGENb:labL2        0.06      0.63 794    0.10  0.9196
legumesBM:csvENVw+GENw:labL2  -0.17      0.64 794   -0.27  0.7894
```

```
                                  Value Std.Error  DF t-value p-value
legumesBM:csvENVw:labL3           -3.10      3.60 794   -0.86  0.3899
legumesBM:csvENVb:labL3           -0.61      3.70 794   -0.17  0.8689
legumesBM:csvGENw:labL3            0.36      3.51 794    0.10  0.9180
legumesBM:csvGENb:labL3           -0.62      3.51 794   -0.18  0.8591
legumesBM:csvENVw+GENw:labL3       1.35      3.51 794    0.38  0.7020
legumesBM:csvENVw:labL4           -0.63      0.74 794   -0.85  0.3952
legumesBM:csvENVb:labL4           -0.42      0.73 794   -0.58  0.5646
legumesBM:csvGENw:labL4           -0.50      0.73 794   -0.69  0.4935
legumesBM:csvGENb:labL4            0.13      0.73 794    0.18  0.8574
legumesBM:csvENVw+GENw:labL4       0.41      0.74 794    0.55  0.5837
legumesBM:csvENVw:labL5           -0.69      0.65 794   -1.06  0.2911
legumesBM:csvENVb:labL5           -0.62      0.64 794   -0.97  0.3328
legumesBM:csvGENw:labL5            0.10      0.64 794    0.16  0.8730
legumesBM:csvGENb:labL5           -0.47      0.64 794   -0.74  0.4579
legumesBM:csvENVw+GENw:labL5      -0.43      0.65 794   -0.65  0.5127
legumesBM:csvENVw:labL6           -0.61      0.69 794   -0.88  0.3796
legumesBM:csvENVb:labL6           -0.95      0.68 794   -1.40  0.1627
legumesBM:csvGENw:labL6           -0.45      0.68 794   -0.67  0.5046
legumesBM:csvGENb:labL6           -1.06      0.68 794   -1.56  0.1181
legumesBM:csvENVw+GENw:labL6      -0.25      0.69 794   -0.36  0.7169
legumesBM:csvENVw:labL7           -0.01      0.88 794   -0.01  0.9895
legumesBM:csvENVb:labL7            0.24      0.87 794    0.28  0.7831
legumesBM:csvGENw:labL7            0.47      0.91 794    0.51  0.6077
legumesBM:csvGENb:labL7           -0.37      0.89 794   -0.42  0.6759
legumesBM:csvENVw+GENw:labL7       0.15      0.91 794    0.17  0.8653
legumesBM:csvENVw:labL8           -1.10      0.87 794   -1.26  0.2080
legumesBM:csvENVb:labL8           -1.11      0.87 794   -1.28  0.2016
legumesBM:csvGENw:labL8           -0.57      0.87 794   -0.65  0.5171
legumesBM:csvGENb:labL8           -0.85      0.87 794   -0.97  0.3322
legumesBM:csvENVw+GENw:labL8       0.17      0.90 794    0.19  0.8455
legumesBM:csvENVw:labL9           -0.44      0.72 794   -0.61  0.5426
legumesBM:csvENVb:labL9           -0.93      0.71 794   -1.30  0.1930
legumesBM:csvGENw:labL9           -1.10      0.71 794   -1.55  0.1222
legumesBM:csvGENb:labL9           -0.82      0.71 794   -1.15  0.2498
legumesBM:csvENVw+GENw:labL9      -0.07      0.72 794   -0.09  0.9260
legumesBM:csvENVw:labL10           0.09      0.60 794    0.15  0.8845
legumesBM:csvENVb:labL10          -0.69      0.59 794   -1.18  0.2379
legumesBM:csvGENw:labL10          -0.64      0.58 794   -1.09  0.2755
legumesBM:csvGENb:labL10          -1.26      0.58 794   -2.15  0.0321
legumesBM:csvENVw+GENw:labL10     -1.27      0.60 794   -2.11  0.0353
legumesBM:csvENVw:labL11           0.25      0.72 794    0.35  0.7244
legumesBM:csvENVb:labL11           0.19      0.71 794    0.26  0.7930
legumesBM:csvGENw:labL11          -1.33      0.72 794   -1.86  0.0636
legumesBM:csvGENb:labL11          -1.09      0.72 794   -1.51  0.1307
legumesBM:csvENVw+GENw:labL11     -0.59      0.72 794   -0.81  0.4168
legumesBM:csvENVw:labL12           0.13      0.73 794    0.18  0.8555
legumesBM:csvENVb:labL12          -0.63      0.71 794   -0.89  0.3715
legumesBM:csvGENw:labL12          -0.82      0.71 794   -1.15  0.2509
legumesBM:csvGENb:labL12          -0.79      0.71 794   -1.11  0.2662
legumesBM:csvENVw+GENw:labL12     -0.90      0.73 794   -1.23  0.2189
legumesBM:csvENVw:labL13          -0.09      0.80 794   -0.11  0.9146
legumesBM:csvENVb:labL13          -0.96      0.81 794   -1.18  0.2370
legumesBM:csvGENw:labL13          -0.63      0.84 794   -0.74  0.4568
legumesBM:csvGENb:labL13           0.51      0.89 794    0.57  0.5673
legumesBM:csvENVw+GENw:labL13      0.85      0.85 794    1.00  0.3164
legumesBM:csvENVw:labL14           0.64      1.00 794    0.64  0.5219
legumesBM:csvENVb:labL14           0.89      0.99 794    0.90  0.3693
legumesBM:csvGENw:labL14           1.44      0.99 794    1.45  0.1482
legumesBM:csvGENb:labL14           0.07      0.99 794    0.07  0.9470
legumesBM:csvENVw+GENw:labL14      0.73      1.00 794    0.73  0.4638

Standardized Within-Group Residuals:
     Min       Q1      Med       Q3      Max
```

```
-2.90315 -0.63626 -0.00634  0.63610  2.82546

Number of Observations: 963
Number of Groups: 2
```

Model for foliar delta ^{13}C (deltaC)

```
anova(m10)
                numDF denDF F-value p-value
(Intercept)         1   804  434648  <.0001
legumes             1   804      27  <.0001
csv                 5   804      76  <.0001
lab                13   804     888  <.0001
legumes:csv         5   804       5  0.0001
legumes:lab        13   804       3  0.0021
csv:lab            65   804       5  <.0001
legumes:csv:lab    65   804       1  0.1081

summary(m10)
Linear mixed-effects model fit by REML
 Data: reproz
   AIC  BIC logLik
  1750 2682   -678

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:      0.0415    0.437

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  1.788  0.652  0.991  0.685  1.131  0.771  0.854  1.112  0.992  1.127
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B L9*BM  L10*B L10*BM  L11*B L11*BM
1.095  1.819  1.490  0.920  0.823  0.883 0.900  0.590  0.913  1.184  1.002
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.198  1.167  0.989  1.637  1.529  0.952

Fixed effects: deltaC ~ legumes * csv * lab
                                Value Std.Error  DF t-value p-value
(Intercept)                   -30.02     0.181 839  -166.1  0.0000
legumesBM                       0.57     0.365 839     1.5  0.1216
csvENVw                         0.19     0.252 839     0.7  0.4630
csvENVb                         0.20     0.252 839     0.8  0.4203
csvGENw                         0.83     0.252 839     3.3  0.0010
csvGENb                         0.48     0.252 839     1.9  0.0576
csvENVw+GENw                    0.79     0.252 839     3.1  0.0018
labL2                          -1.57     0.213 839    -7.4  0.0000
labL3                          -3.65     0.216 839   -16.9  0.0000
labL4                          -2.04     0.225 839    -9.0  0.0000
labL5                          -1.37     0.267 839    -5.1  0.0000
labL6                          -3.82     0.269 839   -14.2  0.0000
labL7                          -4.33     0.370 839   -11.7  0.0000
labL8                          -3.67     0.242 839   -15.1  0.0000
labL9                          -2.50     0.238 839   -10.5  0.0000
labL10                          0.07     0.207 839     0.3  0.7312
labL11                         -2.23     0.276 839    -8.1  0.0000
labL12                         -2.41     0.278 839    -8.7  0.0000
labL13                         -1.24     0.251 839    -4.9  0.0000
labL14                         -2.71     0.326 839    -8.3  0.0000
```

```
1745    legumesBM:csvENVw              -0.59     0.517 839    -1.1  0.2521
1746    legumesBM:csvENVb              -0.72     0.517 839    -1.4  0.1615
1747    legumesBM:csvGENw              -1.59     0.517 839    -3.1  0.0021
1748    legumesBM:csvGENb               0.07     0.517 839     0.1  0.8989
1749    legumesBM:csvENVw+GENw         -0.62     0.517 839    -1.2  0.2335
1750    legumesBM:labL2                -0.37     0.422 839    -0.9  0.3806
1751    legumesBM:labL3                -0.25     0.435 839    -0.6  0.5634
1752    legumesBM:labL4                -0.38     0.419 839    -0.9  0.3704
1753    legumesBM:labL5                -0.55     0.452 839    -1.2  0.2271
1754    legumesBM:labL6                -0.39     0.460 839    -0.9  0.3928
1755    legumesBM:labL7                -0.42     0.556 839    -0.8  0.4523
1756    legumesBM:labL8                 0.18     0.427 839     0.4  0.6754
1757    legumesBM:labL9                -0.53     0.429 839    -1.2  0.2160
1758    legumesBM:labL10               -0.51     0.414 839    -1.2  0.2169
1759    legumesBM:labL11               -0.25     0.458 839    -0.6  0.5817
1760    legumesBM:labL12                0.00     0.472 839     0.0  0.9927
1761    legumesBM:labL13               -0.07     0.500 839    -0.1  0.8960
1762    legumesBM:labL14                0.11     0.487 839     0.2  0.8140
1763    csvENVw:labL2                  -0.10     0.301 839    -0.3  0.7390
1764    csvENVb:labL2                  -0.34     0.301 839    -1.1  0.2654
1765    csvGENw:labL2                  -0.08     0.301 839    -0.3  0.7829
1766    csvGENb:labL2                  -0.01     0.301 839     0.0  0.9660
1767    csvENVw+GENw:labL2              0.47     0.301 839     1.6  0.1186
1768    csvENVw:labL3                  -0.27     0.306 839    -0.9  0.3805
1769    csvENVb:labL3                  -0.23     0.306 839    -0.8  0.4503
1770    csvGENw:labL3                  -0.08     0.306 839    -0.2  0.8058
1771    csvGENb:labL3                   0.08     0.306 839     0.3  0.7852
1772    csvENVw+GENw:labL3              0.01     0.306 839     0.0  0.9613
1773    csvENVw:labL4                  -0.55     0.318 839    -1.7  0.0832
1774    csvENVb:labL4                  -0.43     0.318 839    -1.4  0.1762
1775    csvGENw:labL4                  -0.47     0.318 839    -1.5  0.1393
1776    csvGENb:labL4                  -0.07     0.318 839    -0.2  0.8190
1777    csvENVw+GENw:labL4             -0.77     0.318 839    -2.4  0.0161
1778    csvENVw:labL5                  -0.18     0.377 839    -0.5  0.6421
1779    csvENVb:labL5                  -0.40     0.377 839    -1.1  0.2870
1780    csvGENw:labL5                  -0.20     0.377 839    -0.5  0.6026
1781    csvGENb:labL5                  -0.15     0.377 839    -0.4  0.7001
1782    csvENVw+GENw:labL5              0.01     0.377 839     0.0  0.9739
1783    csvENVw:labL6                  -0.15     0.380 839    -0.4  0.6941
1784    csvENVb:labL6                   0.24     0.380 839     0.6  0.5264
1785    csvGENw:labL6                  -0.40     0.380 839    -1.0  0.2965
1786    csvGENb:labL6                  -0.11     0.380 839    -0.3  0.7633
1787    csvENVw+GENw:labL6             -0.23     0.380 839    -0.6  0.5525
1788    csvENVw:labL7                  -0.06     0.524 839    -0.1  0.9161
1789    csvENVb:labL7                  -0.07     0.524 839    -0.1  0.9002
1790    csvGENw:labL7                   0.40     0.524 839     0.8  0.4439
1791    csvGENb:labL7                  -0.13     0.524 839    -0.2  0.8057
1792    csvENVw+GENw:labL7              0.04     0.524 839     0.1  0.9464
1793    csvENVw:labL8                   0.57     0.343 839     1.7  0.0940
1794    csvENVb:labL8                   0.63     0.343 839     1.8  0.0683
1795    csvGENw:labL8                  -0.11     0.343 839    -0.3  0.7498
1796    csvGENb:labL8                   0.06     0.343 839     0.2  0.8573
1797    csvENVw+GENw:labL8              0.23     0.343 839     0.7  0.4996
1798    csvENVw:labL9                  -0.21     0.336 839    -0.6  0.5320
1799    csvENVb:labL9                  -0.33     0.336 839    -1.0  0.3220
1800    csvGENw:labL9                  -0.08     0.336 839    -0.2  0.8105
1801    csvGENb:labL9                  -0.02     0.336 839    -0.1  0.9431
1802    csvENVw+GENw:labL9              0.02     0.336 839     0.1  0.9589
1803    csvENVw:labL10                 -0.66     0.293 839    -2.2  0.0250
1804    csvENVb:labL10                 -0.52     0.293 839    -1.8  0.0756
1805    csvGENw:labL10                 -0.77     0.293 839    -2.6  0.0091
1806    csvGENb:labL10                 -0.45     0.293 839    -1.5  0.1230
1807    csvENVw+GENw:labL10            -1.07     0.293 839    -3.6  0.0003
```

```
                                  -0.46     0.391 839    -1.2  0.2414
csvENVb:labL11                    -0.17     0.391 839    -0.4  0.6631
csvGENw:labL11                     0.17     0.391 839     0.4  0.6591
csvGENb:labL11                     0.23     0.391 839     0.6  0.5544
csvENVw+GENw:labL11                0.36     0.391 839     0.9  0.3559
csvENVw:labL12                    -0.13     0.394 839    -0.3  0.7368
csvENVb:labL12                    -0.28     0.394 839    -0.7  0.4812
csvGENw:labL12                    -0.07     0.394 839    -0.2  0.8506
csvGENb:labL12                     0.31     0.394 839     0.8  0.4240
csvENVw+GENw:labL12                0.60     0.394 839     1.5  0.1284
csvENVw:labL13                    -0.90     0.355 839    -2.5  0.0117
csvENVb:labL13                    -0.41     0.355 839    -1.1  0.2519
csvGENw:labL13                    -1.06     0.355 839    -3.0  0.0029
csvGENb:labL13                    -0.85     0.355 839    -2.4  0.0173
csvENVw+GENw:labL13               -1.48     0.355 839    -4.2  0.0000
csvENVw:labL14                     0.13     0.461 839     0.3  0.7779
csvENVb:labL14                    -0.18     0.461 839    -0.4  0.6897
csvGENw:labL14                     0.73     0.461 839     1.6  0.1144
csvGENb:labL14                     0.90     0.461 839     1.9  0.0519
csvENVw+GENw:labL14                0.94     0.461 839     2.0  0.0419
legumesBM:csvENVw:labL2            0.76     0.597 839     1.3  0.2025
legumesBM:csvENVb:labL2            1.20     0.597 839     2.0  0.0449
legumesBM:csvGENw:labL2            1.61     0.597 839     2.7  0.0070
legumesBM:csvGENb:labL2           -0.10     0.597 839    -0.2  0.8668
legumesBM:csvENVw+GENw:labL2       0.41     0.597 839     0.7  0.4908
legumesBM:csvENVw:labL3            0.58     0.615 839     0.9  0.3497
legumesBM:csvENVb:labL3            1.20     0.615 839     2.0  0.0511
legumesBM:csvGENw:labL3            1.07     0.615 839     1.7  0.0815
legumesBM:csvGENb:labL3           -0.43     0.615 839    -0.7  0.4796
legumesBM:csvENVw+GENw:labL3       0.11     0.615 839     0.2  0.8527
legumesBM:csvENVw:labL4            0.69     0.593 839     1.2  0.2431
legumesBM:csvENVb:labL4            0.43     0.593 839     0.7  0.4713
legumesBM:csvGENw:labL4            1.34     0.593 839     2.3  0.0243
legumesBM:csvGENb:labL4           -0.33     0.593 839    -0.6  0.5763
legumesBM:csvENVw+GENw:labL4       0.38     0.593 839     0.6  0.5206
legumesBM:csvENVw:labL5            0.92     0.639 839     1.4  0.1501
legumesBM:csvENVb:labL5            0.96     0.639 839     1.5  0.1337
legumesBM:csvGENw:labL5            1.38     0.639 839     2.2  0.0313
legumesBM:csvGENb:labL5           -0.27     0.639 839    -0.4  0.6672
legumesBM:csvENVw+GENw:labL5       0.33     0.639 839     0.5  0.6109
legumesBM:csvENVw:labL6            0.64     0.651 839     1.0  0.3285
legumesBM:csvENVb:labL6            0.61     0.651 839     0.9  0.3521
legumesBM:csvGENw:labL6            0.92     0.651 839     1.4  0.1573
legumesBM:csvGENb:labL6           -0.54     0.651 839    -0.8  0.4108
legumesBM:csvENVw+GENw:labL6      -0.11     0.651 839    -0.2  0.8689
legumesBM:csvENVw:labL7            0.58     0.787 839     0.7  0.4612
legumesBM:csvENVb:labL7            0.52     0.787 839     0.7  0.5093
legumesBM:csvGENw:labL7            0.97     0.787 839     1.2  0.2190
legumesBM:csvGENb:labL7           -0.04     0.787 839     0.0  0.9618
legumesBM:csvENVw+GENw:labL7       0.27     0.787 839     0.3  0.7301
legumesBM:csvENVw:labL8            0.15     0.603 839     0.2  0.8048
legumesBM:csvENVb:labL8           -0.39     0.603 839    -0.6  0.5200
legumesBM:csvGENw:labL8            0.90     0.603 839     1.5  0.1356
legumesBM:csvGENb:labL8           -0.92     0.603 839    -1.5  0.1291
legumesBM:csvENVw+GENw:labL8      -0.07     0.603 839    -0.1  0.9081
legumesBM:csvENVw:labL9            0.63     0.607 839     1.0  0.2995
legumesBM:csvENVb:labL9            0.67     0.607 839     1.1  0.2698
legumesBM:csvGENw:labL9            1.56     0.607 839     2.6  0.0103
legumesBM:csvGENb:labL9           -0.11     0.607 839    -0.2  0.8542
legumesBM:csvENVw+GENw:labL9       0.72     0.607 839     1.2  0.2351
legumesBM:csvENVw:labL10           0.54     0.585 839     0.9  0.3556
legumesBM:csvENVb:labL10           0.56     0.585 839     1.0  0.3384
legumesBM:csvGENw:labL10           1.47     0.585 839     2.5  0.0124
```

```
legumesBM:csvGENb:labL10       -0.17     0.585 839    -0.3  0.7682
legumesBM:csvENVw+GENw:labL10   0.65     0.585 839     1.1  0.2698
legumesBM:csvENVw:labL11        1.34     0.648 839     2.1  0.0386
legumesBM:csvENVb:labL11        0.69     0.648 839     1.1  0.2849
legumesBM:csvGENw:labL11        1.34     0.648 839     2.1  0.0386
legumesBM:csvGENb:labL11       -0.48     0.648 839    -0.7  0.4591
legumesBM:csvENVw+GENw:labL11   0.81     0.648 839     1.2  0.2130
legumesBM:csvENVw:labL12        0.47     0.667 839     0.7  0.4798
legumesBM:csvENVb:labL12        0.98     0.667 839     1.5  0.1402
legumesBM:csvGENw:labL12        1.48     0.667 839     2.2  0.0272
legumesBM:csvGENb:labL12       -0.55     0.667 839    -0.8  0.4084
legumesBM:csvENVw+GENw:labL12   0.23     0.667 839     0.3  0.7279
legumesBM:csvENVw:labL13        0.52     0.707 839     0.7  0.4633
legumesBM:csvENVb:labL13        0.60     0.707 839     0.8  0.3970
legumesBM:csvGENw:labL13        1.11     0.707 839     1.6  0.1171
legumesBM:csvGENb:labL13       -0.38     0.707 839    -0.5  0.5927
legumesBM:csvENVw+GENw:labL13   0.64     0.707 839     0.9  0.3665
legumesBM:csvENVw:labL14        0.42     0.688 839     0.6  0.5457
legumesBM:csvENVb:labL14        0.82     0.688 839     1.2  0.2325
legumesBM:csvGENw:labL14        0.55     0.688 839     0.8  0.4213
legumesBM:csvGENb:labL14       -1.04     0.688 839    -1.5  0.1324
legumesBM:csvENVw+GENw:labL14  -0.44     0.688 839    -0.6  0.5264

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-3.8010 -0.5813  0.0341  0.6093  2.9884

Number of Observations: 1008
Number of Groups: 2
```

Model for microcosm evapotranspiration before the final harvest (finalET)

```
                  numDF denDF F-value p-value
(Intercept)           1   833  693.67  <.0001
legumes               1   833 1269.93  <.0001
csv                   5   833    9.37  <.0001
lab                  13   833  748.66  <.0001
legumes:csv           5   833    1.24  0.2884
legumes:lab          13   833  172.74  <.0001
csv:lab              65   833   21.69  <.0001
legumes:csv:lab      65   833    1.53  0.0056

summary(m11)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  7942 8873  -3774

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:        6.49     25.9

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  1.366  0.244  0.236  0.732  0.824  0.301  1.396  0.570  0.793  0.422
L6*BM   L7*B  L7*BM   L8*B  L8*BM L9*B  L9*BM   L10*B L10*BM  L11*B L11*BM
0.771  1.085  1.104  0.680  0.962 0.375  0.589  0.558  0.670  1.728  1.472
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
```

```
1.931  2.157  0.238  0.235  0.844  1.035


Fixed effects: finalET ~ legumes * csv * lab
                                Value Std.Error  DF t-value p-value
(Intercept)                     121.7      11.5 833   10.56  0.0000
legumesBM                        43.7      17.9 833    2.44  0.0149
csvENVw                          -1.2      15.0 833   -0.08  0.9386
csvENVb                           4.7      15.0 833    0.31  0.7552
csvGENw                         -10.9      15.0 833   -0.73  0.4670
csvGENb                         -11.0      15.0 833   -0.73  0.4629
csvENVw+GENw                     -8.9      15.0 833   -0.60  0.5504
labL2                           -50.5      10.9 833   -4.64  0.0000
labL3                            -1.8      13.1 833   -0.13  0.8927
labL4                           -29.4      11.0 833   -2.66  0.0079
labL5                            -7.7      12.2 833   -0.63  0.5272
labL6                             2.0      11.5 833    0.17  0.8650
labL7                           -16.5      15.6 833   -1.06  0.2897
labL8                           -24.4      12.8 833   -1.91  0.0570
labL9                             3.5      11.3 833    0.31  0.7569
labL10                           19.1      12.1 833    1.58  0.1152
labL11                           98.6      21.1 833    4.67  0.0000
labL12                           49.8      23.0 833    2.17  0.0306
labL13                            8.7      10.9 833    0.80  0.4233
labL14                           -7.0      13.8 833   -0.50  0.6148
legumesBM:csvENVw                28.8      25.3 833    1.14  0.2551
legumesBM:csvENVb                12.6      25.3 833    0.50  0.6188
legumesBM:csvGENw                 1.2      25.3 833    0.05  0.9611
legumesBM:csvGENb                 8.0      25.3 833    0.32  0.7516
legumesBM:csvENVw+GENw           21.7      25.3 833    0.86  0.3909
legumesBM:labL2                 -40.4      18.3 833   -2.21  0.0271
legumesBM:labL3                 154.7      21.4 833    7.24  0.0000
legumesBM:labL4                  30.9      23.4 833    1.32  0.1877
legumesBM:labL5                  35.7      20.7 833    1.73  0.0845
legumesBM:labL6                  -6.0      20.2 833   -0.30  0.7654
legumesBM:labL7                  15.7      24.3 833    0.65  0.5172
legumesBM:labL8                  -4.2      21.8 833   -0.19  0.8489
legumesBM:labL9                 -25.7      19.4 833   -1.33  0.1850
legumesBM:labL10                -50.9      20.1 833   -2.53  0.0117
legumesBM:labL11                 26.4      29.9 833    0.88  0.3789
legumesBM:labL12                 11.3      35.5 833    0.32  0.7503
legumesBM:labL13                -24.2      18.2 833   -1.33  0.1845
legumesBM:labL14                141.1      22.8 833    6.19  0.0000
csvENVw:labL2                     7.9      15.4 833    0.51  0.6068
csvENVb:labL2                    -5.0      15.4 833   -0.32  0.7478
csvGENw:labL2                    11.2      15.4 833    0.73  0.4673
csvGENb:labL2                    10.1      15.4 833    0.66  0.5100
csvENVw+GENw:labL2               15.9      15.4 833    1.03  0.3020
csvENVw:labL3                     1.0      18.5 833    0.05  0.9562
csvENVb:labL3                    -7.9      18.5 833   -0.43  0.6702
csvGENw:labL3                    37.6      18.5 833    2.03  0.0429
csvGENb:labL3                    36.4      18.5 833    1.97  0.0497
csvENVw+GENw:labL3               36.8      18.5 833    1.98  0.0478
csvENVw:labL4                   -16.1      15.6 833   -1.03  0.3042
csvENVb:labL4                   -12.5      15.6 833   -0.80  0.4240
csvGENw:labL4                     3.0      15.6 833    0.19  0.8489
csvGENb:labL4                     3.6      15.6 833    0.23  0.8173
csvENVw+GENw:labL4               -8.3      15.6 833   -0.53  0.5968
csvENVw:labL5                     1.0      17.2 833    0.06  0.9559
csvENVb:labL5                     1.1      17.2 833    0.06  0.9505
csvGENw:labL5                    13.0      17.2 833    0.75  0.4521
csvGENb:labL5                    24.5      17.2 833    1.42  0.1548
csvENVw+GENw:labL5               25.8      17.2 833    1.50  0.1339
```

1995	csvENVw:labL6	6.4	16.2	833	0.39	0.6946
1996	csvENVb:labL6	-5.4	16.2	833	-0.33	0.7395
1997	csvGENw:labL6	-3.0	16.2	833	-0.18	0.8557
1998	csvGENb:labL6	4.2	16.2	833	0.26	0.7955
1999	csvENVw+GENw:labL6	-6.2	16.2	833	-0.38	0.7015
2000	csvENVw:labL7	0.3	22.1	833	0.01	0.9893
2001	csvENVb:labL7	14.2	22.1	833	0.65	0.5188
2002	csvGENw:labL7	10.2	22.1	833	0.46	0.6425
2003	csvGENb:labL7	30.5	22.7	833	1.34	0.1791
2004	csvENVw+GENw:labL7	-5.9	22.1	833	-0.27	0.7904
2005	csvENVw:labL8	3.3	18.1	833	0.18	0.8548
2006	csvENVb:labL8	-5.7	18.1	833	-0.32	0.7508
2007	csvGENw:labL8	-16.3	18.1	833	-0.90	0.3686
2008	csvGENb:labL8	-11.7	18.1	833	-0.65	0.5175
2009	csvENVw+GENw:labL8	-9.1	18.1	833	-0.50	0.6139
2010	csvENVw:labL9	5.7	16.0	833	0.36	0.7206
2011	csvENVb:labL9	0.6	16.0	833	0.04	0.9697
2012	csvGENw:labL9	-7.1	16.0	833	-0.45	0.6546
2013	csvGENb:labL9	6.4	16.0	833	0.40	0.6901
2014	csvENVw+GENw:labL9	5.1	16.0	833	0.32	0.7518
2015	csvENVw:labL10	137.3	17.1	833	8.01	0.0000
2016	csvENVb:labL10	-3.5	17.1	833	-0.20	0.8383
2017	csvGENw:labL10	131.4	17.1	833	7.67	0.0000
2018	csvGENb:labL10	4.1	17.1	833	0.24	0.8099
2019	csvENVw+GENw:labL10	130.6	17.1	833	7.62	0.0000
2020	csvENVw:labL11	-20.0	29.9	833	-0.67	0.5023
2021	csvENVb:labL11	-17.0	29.9	833	-0.57	0.5704
2022	csvGENw:labL11	83.6	29.9	833	2.80	0.0052
2023	csvGENb:labL11	72.0	29.9	833	2.41	0.0162
2024	csvENVw+GENw:labL11	51.9	29.9	833	1.74	0.0828
2025	csvENVw:labL12	-0.3	32.5	833	-0.01	0.9937
2026	csvENVb:labL12	-15.7	32.5	833	-0.48	0.6293
2027	csvGENw:labL12	98.3	32.5	833	3.02	0.0026
2028	csvGENb:labL12	87.6	32.5	833	2.69	0.0072
2029	csvENVw+GENw:labL12	74.0	32.5	833	2.28	0.0231
2030	csvENVw:labL13	-2.0	15.4	833	-0.13	0.8961
2031	csvENVb:labL13	-8.9	15.4	833	-0.58	0.5641
2032	csvGENw:labL13	17.0	15.4	833	1.10	0.2695
2033	csvGENb:labL13	11.6	15.4	833	0.75	0.4525
2034	csvENVw+GENw:labL13	11.1	15.4	833	0.72	0.4718
2035	csvENVw:labL14	-17.0	19.6	833	-0.87	0.3852
2036	csvENVb:labL14	-13.1	19.6	833	-0.67	0.5037
2037	csvGENw:labL14	14.4	19.6	833	0.74	0.4622
2038	csvGENb:labL14	8.1	19.6	833	0.41	0.6807
2039	csvENVw+GENw:labL14	6.8	19.6	833	0.35	0.7285
2040	legumesBM:csvENVw:labL2	-20.9	25.8	833	-0.81	0.4192
2041	legumesBM:csvENVb:labL2	3.8	25.8	833	0.15	0.8817
2042	legumesBM:csvGENw:labL2	6.1	25.8	833	0.24	0.8140
2043	legumesBM:csvGENb:labL2	0.2	25.8	833	0.01	0.9948
2044	legumesBM:csvENVw+GENw:labL2	-4.7	25.8	833	-0.18	0.8558
2045	legumesBM:csvENVw:labL3	-25.2	30.2	833	-0.84	0.4038
2046	legumesBM:csvENVb:labL3	-26.3	30.2	833	-0.87	0.3843
2047	legumesBM:csvGENw:labL3	-52.6	30.2	833	-1.74	0.0821
2048	legumesBM:csvGENb:labL3	-64.0	30.2	833	-2.12	0.0344
2049	legumesBM:csvENVw+GENw:labL3	-65.8	30.2	833	-2.18	0.0298
2050	legumesBM:csvENVw:labL4	-22.8	33.1	833	-0.69	0.4917
2051	legumesBM:csvENVb:labL4	12.0	33.1	833	0.36	0.7173
2052	legumesBM:csvGENw:labL4	6.9	33.1	833	0.21	0.8361
2053	legumesBM:csvGENb:labL4	8.8	33.1	833	0.26	0.7914
2054	legumesBM:csvENVw+GENw:labL4	-17.7	33.1	833	-0.53	0.5933
2055	legumesBM:csvENVw:labL5	-13.8	29.2	833	-0.47	0.6362
2056	legumesBM:csvENVb:labL5	-7.0	29.2	833	-0.24	0.8099
2057	legumesBM:csvGENw:labL5	-2.6	29.2	833	-0.09	0.9291

```
legumesBM:csvGENb:labL5       -30.5      29.2 833   -1.04  0.2973
legumesBM:csvENVw+GENw:labL5  -32.8      29.2 833   -1.12  0.2622
legumesBM:csvENVw:labL6       -29.7      28.5 833   -1.04  0.2975
legumesBM:csvENVb:labL6       -25.5      28.5 833   -0.89  0.3720
legumesBM:csvGENw:labL6         3.0      28.5 833    0.11  0.9158
legumesBM:csvGENb:labL6        -5.4      28.5 833   -0.19  0.8499
legumesBM:csvENVw+GENw:labL6   -5.5      28.8 833   -0.19  0.8470
legumesBM:csvENVw:labL7       -11.1      34.3 833   -0.32  0.7474
legumesBM:csvENVb:labL7       -52.1      34.3 833   -1.52  0.1290
legumesBM:csvGENw:labL7         2.4      34.3 833    0.07  0.9441
legumesBM:csvGENb:labL7       -35.2      35.1 833   -1.00  0.3161
legumesBM:csvENVw+GENw:labL7  -16.7      34.3 833   -0.49  0.6255
legumesBM:csvENVw:labL8       -33.8      30.8 833   -1.09  0.2740
legumesBM:csvENVb:labL8         4.3      30.8 833    0.14  0.8901
legumesBM:csvGENw:labL8        20.0      30.8 833    0.65  0.5163
legumesBM:csvGENb:labL8         3.6      30.8 833    0.12  0.9076
legumesBM:csvENVw+GENw:labL8   -2.0      30.8 833   -0.06  0.9483
legumesBM:csvENVw:labL9       -21.3      27.7 833   -0.77  0.4438
legumesBM:csvENVb:labL9       -13.9      27.4 833   -0.51  0.6124
legumesBM:csvGENw:labL9        -6.7      27.4 833   -0.24  0.8076
legumesBM:csvGENb:labL9       -12.6      27.4 833   -0.46  0.6455
legumesBM:csvENVw+GENw:labL9  -27.5      27.4 833   -1.01  0.3151
legumesBM:csvENVw:labL10      -18.7      28.5 833   -0.66  0.5112
legumesBM:csvENVb:labL10       -4.5      28.5 833   -0.16  0.8747
legumesBM:csvGENw:labL10       22.7      28.5 833    0.80  0.4248
legumesBM:csvGENb:labL10       18.0      28.5 833    0.63  0.5278
legumesBM:csvENVw+GENw:labL10 -19.1      28.5 833   -0.67  0.5031
legumesBM:csvENVw:labL11      -46.8      42.3 833   -1.11  0.2693
legumesBM:csvENVb:labL11      -14.5      42.3 833   -0.34  0.7320
legumesBM:csvGENw:labL11      -53.4      42.9 833   -1.24  0.2136
legumesBM:csvGENb:labL11      -51.1      42.3 833   -1.21  0.2283
legumesBM:csvENVw+GENw:labL11 -56.6      42.3 833   -1.34  0.1814
legumesBM:csvENVw:labL12      -58.2      50.2 833   -1.16  0.2462
legumesBM:csvENVb:labL12      -43.6      50.2 833   -0.87  0.3847
legumesBM:csvGENw:labL12      -85.1      50.2 833   -1.70  0.0900
legumesBM:csvGENb:labL12      -38.6      50.2 833   -0.77  0.4422
legumesBM:csvENVw+GENw:labL12 -75.8      50.2 833   -1.51  0.1312
legumesBM:csvENVw:labL13      -40.3      25.8 833   -1.56  0.1188
legumesBM:csvENVb:labL13      -12.6      25.8 833   -0.49  0.6263
legumesBM:csvGENw:labL13      -12.0      25.8 833   -0.46  0.6433
legumesBM:csvGENb:labL13       -7.7      25.8 833   -0.30  0.7656
legumesBM:csvENVw+GENw:labL13 -34.3      25.8 833   -1.33  0.1840
legumesBM:csvENVw:labL14      -11.9      32.2 833   -0.37  0.7129
legumesBM:csvENVb:labL14       -8.0      32.2 833   -0.25  0.8038
legumesBM:csvGENw:labL14       -1.9      32.2 833   -0.06  0.9523
legumesBM:csvGENb:labL14        4.5      32.2 833    0.14  0.8894
legumesBM:csvENVw+GENw:labL14 -18.0      32.2 833   -0.56  0.5759
```

Model for teabag litter remaining (teabag)

```
anova(m12)
                numDF denDF  F-value p-value
(Intercept)         1   805 49915.31  <.0001
legumes             1   805     1.81  0.1784
csv                 5   805     1.05  0.3881
lab                13   805   117.34  <.0001
legumes:csv         5   805     1.77  0.1156
legumes:lab        13   805     2.05  0.0149
csv:lab            65   805     2.97  <.0001
legumes:csv:lab    65   805     1.17  0.1800
```

Model for PC1 (PC1)

```
anova(mpc1)
                numDF denDF F-value p-value
(Intercept)         1   839  175.72  <.0001
legumes             1   839 1242.53  <.0001
csv                 5   839   12.87  <.0001
lab                13   839  920.65  <.0001
legumes:csv         5   839    7.08  <.0001
legumes:lab        13   839  118.12  <.0001
csv:lab            65   839    7.23  <.0001
legumes:csv:lab    65   839    0.94  0.6133

summary(m12)
Linear mixed-effects model fit by REML
 Data: repro
   AIC   BIC logLik
  -935 -10.5    664

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:    0.000226   0.0777

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes
 Parameter estimates:
  L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
 1.000  1.175  0.892  1.162  1.295  1.214  1.058  1.035  1.346  0.974  1.236
 L6*BM   L7*B  L7*BM   L8*B  L8*BM L9*B  L9*BM  L10*B L10*BM  L11*B L11*BM
 0.849  3.316  2.370  1.447  0.989 1.212  1.793  1.374  1.346  1.042  0.934
 L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
 1.200  1.430  0.540  0.515  0.854  0.882

Fixed effects: teabag ~ legumes * csv * lab
                                Value Std.Error  DF t-value p-value
(Intercept)                     0.524    0.0317 805   16.53  0.0000
legumesBM                       0.076    0.0517 805    1.47  0.1429
csvENVw                        -0.045    0.0449 805   -1.01  0.3107
csvENVb                        -0.042    0.0449 805   -0.93  0.3513
csvGENw                         0.000    0.0449 805    0.00  0.9970
csvGENb                         0.016    0.0449 805    0.35  0.7242
csvENVw+GENw                   -0.029    0.0449 805   -0.65  0.5181
labL2                           0.223    0.0425 805    5.25  0.0000
labL3                          -0.006    0.0519 805   -0.13  0.9003
labL4                           0.071    0.0486 805    1.46  0.1450
labL5                          -0.158    0.0532 805   -2.98  0.0030
labL6                          -0.018    0.0504 805   -0.35  0.7237
labL7                           0.222    0.1099 805    2.02  0.0441
labL8                           0.314    0.0558 805    5.63  0.0000
labL9                           0.231    0.0498 805    4.63  0.0000
labL10                          0.061    0.0573 805    1.06  0.2904
labL11                          0.008    0.0458 805    0.18  0.8557
labL12                          0.147    0.0495 805    2.97  0.0031
labL13                         -0.081    0.0361 805   -2.25  0.0249
labL14                          0.068    0.0417 805    1.63  0.1043
legumesBM:csvENVw              -0.048    0.0712 805   -0.67  0.5049
legumesBM:csvENVb              -0.021    0.0712 805   -0.29  0.7681
legumesBM:csvGENw              -0.051    0.0712 805   -0.71  0.4783
legumesBM:csvGENb              -0.077    0.0712 805   -1.08  0.2808
legumesBM:csvENVw+GENw         -0.061    0.0712 805   -0.86  0.3905
legumesBM:labL2                -0.076    0.0695 805   -1.10  0.2725
legumesBM:labL3                 0.053    0.0764 805    0.70  0.4855
legumesBM:labL4                 0.031    0.0751 805    0.42  0.6758
```

```
2182   legumesBM:labL5              -0.046    0.0738 805   -0.63  0.5305
2183   legumesBM:labL6              -0.086    0.0702 805   -1.22  0.2230
2184   legumesBM:labL7              -0.024    0.1432 805   -0.17  0.8686
2185   legumesBM:labL8              -0.023    0.0759 805   -0.30  0.7620
2186   legumesBM:labL9              -0.215    0.0859 805   -2.50  0.0126
2187   legumesBM:labL10              0.002    0.0877 805    0.02  0.9807
2188   legumesBM:labL11             -0.095    0.0682 805   -1.40  0.1630
2189   legumesBM:labL12             -0.200    0.0786 805   -2.54  0.0112
2190   legumesBM:labL13             -0.075    0.0569 805   -1.32  0.1876
2191   legumesBM:labL14             -0.033    0.0659 805   -0.51  0.6122
2192   csvENVw:labL2                -0.082    0.0601 805   -1.36  0.1747
2193   csvENVb:labL2                -0.086    0.0601 805   -1.43  0.1537
2194   csvGENw:labL2                 0.073    0.0601 805    1.21  0.2260
2195   csvGENb:labL2                -0.034    0.0601 805   -0.57  0.5718
2196   csvENVw+GENw:labL2           -0.117    0.0601 805   -1.95  0.0513
2197   csvENVw:labL3                 0.131    0.0756 805    1.73  0.0841
2198   csvENVb:labL3                 0.115    0.0756 805    1.52  0.1296
2199   csvGENw:labL3                 0.006    0.0734 805    0.08  0.9367
2200   csvGENb:labL3                -0.029    0.0734 805   -0.39  0.6978
2201   csvENVw+GENw:labL3            0.132    0.0734 805    1.80  0.0724
2202   csvENVw:labL4                 0.058    0.0670 805    0.87  0.3856
2203   csvENVb:labL4                 0.138    0.0670 805    2.06  0.0395
2204   csvGENw:labL4                -0.036    0.0670 805   -0.53  0.5947
2205   csvGENb:labL4                 0.026    0.0687 805    0.38  0.7054
2206   csvENVw+GENw:labL4            0.113    0.0670 805    1.68  0.0926
2207   csvENVw:labL5                 0.076    0.0752 805    1.01  0.3115
2208   csvENVb:labL5                 0.097    0.0752 805    1.29  0.1991
2209   csvGENw:labL5                 0.041    0.0752 805    0.55  0.5828
2210   csvGENb:labL5                 0.072    0.0752 805    0.95  0.3410
2211   csvENVw+GENw:labL5            0.090    0.0752 805    1.20  0.2318
2212   csvENVw:labL6                 0.107    0.0713 805    1.50  0.1338
2213   csvENVb:labL6                 0.090    0.0713 805    1.27  0.2056
2214   csvGENw:labL6                 0.018    0.0713 805    0.25  0.7990
2215   csvGENb:labL6                 0.015    0.0734 805    0.21  0.8336
2216   csvENVw+GENw:labL6            0.078    0.0713 805    1.09  0.2764
2217   csvENVw:labL7                 0.276    0.1554 805    1.78  0.0757
2218   csvENVb:labL7                 0.233    0.1554 805    1.50  0.1338
2219   csvGENw:labL7                -0.021    0.1554 805   -0.14  0.8917
2220   csvGENb:labL7                -0.117    0.1623 805   -0.72  0.4717
2221   csvENVw+GENw:labL7            0.070    0.1554 805    0.45  0.6501
2222   csvENVw:labL8                -0.014    0.0789 805   -0.18  0.8575
2223   csvENVb:labL8                 0.011    0.0789 805    0.14  0.8875
2224   csvGENw:labL8                -0.004    0.0789 805   -0.05  0.9613
2225   csvGENb:labL8                 0.038    0.0789 805    0.49  0.6272
2226   csvENVw+GENw:labL8           -0.046    0.0789 805   -0.58  0.5643
2227   csvENVw:labL9                -0.169    0.0705 805   -2.40  0.0168
2228   csvENVb:labL9                -0.234    0.0705 805   -3.32  0.0009
2229   csvGENw:labL9                -0.257    0.0705 805   -3.64  0.0003
2230   csvGENb:labL9                -0.151    0.0705 805   -2.14  0.0325
2231   csvENVw+GENw:labL9           -0.141    0.0705 805   -2.00  0.0461
2232   csvENVw:labL10                0.040    0.0787 805    0.51  0.6080
2233   csvENVb:labL10                0.021    0.0787 805    0.26  0.7925
2234   csvGENw:labL10               -0.041    0.0787 805   -0.52  0.5998
2235   csvGENb:labL10               -0.077    0.0787 805   -0.98  0.3261
2236   csvENVw+GENw:labL10          -0.001    0.0787 805   -0.02  0.9851
2237   csvENVw:labL11                0.027    0.0665 805    0.40  0.6891
2238   csvENVb:labL11                0.076    0.0648 805    1.18  0.2391
2239   csvGENw:labL11                0.021    0.0648 805    0.32  0.7479
2240   csvGENb:labL11               -0.020    0.0648 805   -0.30  0.7635
2241   csvENVw+GENw:labL11           0.001    0.0648 805    0.02  0.9856
2242   csvENVw:labL12                0.028    0.0701 805    0.40  0.6895
2243   csvENVb:labL12               -0.013    0.0721 805   -0.17  0.8624
2244   csvGENw:labL12               -0.082    0.0701 805   -1.17  0.2441
```

```
2245   csvGENb:labL12                -0.102    0.0721 805   -1.41  0.1585
2246   csvENVw+GENw:labL12           -0.005    0.0721 805   -0.07  0.9432
2247   csvENVw:labL13                 0.096    0.0510 805    1.89  0.0592
2248   csvENVb:labL13                 0.080    0.0510 805    1.57  0.1170
2249   csvGENw:labL13                -0.023    0.0510 805   -0.46  0.6473
2250   csvGENb:labL13                 0.023    0.0510 805    0.45  0.6520
2251   csvENVw+GENw:labL13            0.046    0.0510 805    0.90  0.3690
2252   csvENVw:labL14                 0.046    0.0590 805    0.78  0.4358
2253   csvENVb:labL14                 0.038    0.0602 805    0.63  0.5301
2254   csvGENw:labL14                -0.022    0.0590 805   -0.37  0.7114
2255   csvGENb:labL14                -0.007    0.0590 805   -0.11  0.9101
2256   csvENVw+GENw:labL14            0.018    0.0590 805    0.30  0.7647
2257   legumesBM:csvENVw:labL2        0.099    0.0969 805    1.02  0.3072
2258   legumesBM:csvENVb:labL2        0.075    0.0969 805    0.77  0.4422
2259   legumesBM:csvGENw:labL2       -0.027    0.0969 805   -0.28  0.7793
2260   legumesBM:csvGENb:labL2        0.089    0.0969 805    0.91  0.3613
2261   legumesBM:csvENVw+GENw:labL2   0.043    0.0969 805    0.44  0.6598
2262   legumesBM:csvENVw:labL3       -0.057    0.1117 805   -0.51  0.6106
2263   legumesBM:csvENVb:labL3        0.012    0.1084 805    0.11  0.9089
2264   legumesBM:csvGENw:labL3        0.000    0.1068 805    0.00  0.9975
2265   legumesBM:csvGENb:labL3        0.059    0.1068 805    0.56  0.5787
2266   legumesBM:csvENVw+GENw:labL3   0.016    0.1082 805    0.15  0.8800
2267   legumesBM:csvENVw:labL4        0.050    0.1012 805    0.49  0.6208
2268   legumesBM:csvENVb:labL4       -0.110    0.1012 805   -1.09  0.2755
2269   legumesBM:csvGENw:labL4       -0.040    0.1012 805   -0.40  0.6909
2270   legumesBM:csvGENb:labL4       -0.065    0.1023 805   -0.63  0.5282
2271   legumesBM:csvENVw+GENw:labL4  -0.139    0.1012 805   -1.38  0.1692
2272   legumesBM:csvENVw:labL5        0.047    0.1031 805    0.46  0.6474
2273   legumesBM:csvENVb:labL5        0.027    0.1040 805    0.26  0.7937
2274   legumesBM:csvGENw:labL5        0.116    0.1040 805    1.12  0.2635
2275   legumesBM:csvGENb:labL5        0.048    0.1031 805    0.47  0.6416
2276   legumesBM:csvENVw+GENw:labL5   0.032    0.1031 805    0.31  0.7563
2277   legumesBM:csvENVw:labL6        0.021    0.0979 805    0.22  0.8276
2278   legumesBM:csvENVb:labL6       -0.016    0.0979 805   -0.16  0.8716
2279   legumesBM:csvGENw:labL6        0.110    0.0979 805    1.13  0.2602
2280   legumesBM:csvGENb:labL6        0.080    0.0995 805    0.80  0.4241
2281   legumesBM:csvENVw+GENw:labL6   0.042    0.0987 805    0.43  0.6690
2282   legumesBM:csvENVw:labL7       -0.200    0.2019 805   -0.99  0.3214
2283   legumesBM:csvENVb:labL7       -0.038    0.2060 805   -0.19  0.8532
2284   legumesBM:csvGENw:labL7        0.099    0.1991 805    0.49  0.6208
2285   legumesBM:csvGENb:labL7        0.137    0.2046 805    0.67  0.5019
2286   legumesBM:csvENVw+GENw:labL7  -0.005    0.2060 805   -0.02  0.9801
2287   legumesBM:csvENVw:labL8        0.057    0.1061 805    0.54  0.5889
2288   legumesBM:csvENVb:labL8       -0.106    0.1061 805   -1.00  0.3194
2289   legumesBM:csvGENw:labL8       -0.016    0.1061 805   -0.15  0.8814
2290   legumesBM:csvGENb:labL8       -0.071    0.1061 805   -0.67  0.5054
2291   legumesBM:csvENVw+GENw:labL8  -0.099    0.1061 805   -0.94  0.3485
2292   legumesBM:csvENVw:labL9        0.190    0.1204 805    1.58  0.1153
2293   legumesBM:csvENVb:labL9        0.181    0.1231 805    1.47  0.1408
2294   legumesBM:csvGENw:labL9        0.181    0.1269 805    1.42  0.1548
2295   legumesBM:csvGENb:labL9        0.090    0.1204 805    0.74  0.4575
2296   legumesBM:csvENVw+GENw:labL9   0.156    0.1204 805    1.29  0.1959
2297   legumesBM:csvENVw:labL10       0.021    0.1175 805    0.18  0.8556
2298   legumesBM:csvENVb:labL10      -0.054    0.1175 805   -0.46  0.6472
2299   legumesBM:csvGENw:labL10       0.033    0.1175 805    0.28  0.7797
2300   legumesBM:csvGENb:labL10       0.084    0.1175 805    0.72  0.4729
2301   legumesBM:csvENVw+GENw:labL10 -0.009    0.1175 805   -0.07  0.9404
2302   legumesBM:csvENVw:labL11       0.152    0.0961 805    1.58  0.1142
2303   legumesBM:csvENVb:labL11      -0.025    0.0949 805   -0.27  0.7896
2304   legumesBM:csvGENw:labL11       0.027    0.0949 805    0.28  0.7761
2305   legumesBM:csvGENb:labL11       0.118    0.0949 805    1.24  0.2149
2306   legumesBM:csvENVw+GENw:labL11  0.197    0.0958 805    2.06  0.0399
2307   legumesBM:csvENVw:labL12       0.171    0.1099 805    1.56  0.1202
```

```
legumesBM:csvENVb:labL12       0.178    0.1112 805    1.60  0.1109
legumesBM:csvGENw:labL12       0.201    0.1099 805    1.83  0.0674
legumesBM:csvGENb:labL12       0.254    0.1112 805    2.29  0.0225
legumesBM:csvENVw+GENw:labL12  0.243    0.1112 805    2.19  0.0289
legumesBM:csvENVw:labL13       0.037    0.0787 805    0.47  0.6368
legumesBM:csvENVb:labL13      -0.025    0.0787 805   -0.32  0.7492
legumesBM:csvGENw:labL13       0.092    0.0787 805    1.16  0.2452
legumesBM:csvGENb:labL13       0.032    0.0787 805    0.41  0.6843
legumesBM:csvENVw+GENw:labL13  0.106    0.0787 805    1.35  0.1790
legumesBM:csvENVw:labL14       0.018    0.0909 805    0.20  0.8436
legumesBM:csvENVb:labL14      -0.039    0.0917 805   -0.43  0.6675
legumesBM:csvGENw:labL14       0.098    0.0909 805    1.08  0.2791
legumesBM:csvGENb:labL14       0.047    0.0909 805    0.51  0.6083
legumesBM:csvENVw+GENw:labL14  0.009    0.0909 805    0.10  0.9232

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-2.1971 -0.6441 -0.0995  0.5854  2.6829

Number of Observations: 974
Number of Groups: 2
```

Model for PC2 (PC2)

```
anova(mpc2)
                numDF denDF F-value p-value
(Intercept)         1   839    6.03  0.0143
legumes             1   839  988.88  <.0001
csv                 5   839   22.56  <.0001
lab                13   839  513.83  <.0001
legumes:csv         5   839   11.79  <.0001
legumes:lab        13   839   28.22  <.0001
csv:lab            65   839    2.77  <.0001
legumes:csv:lab    65   839    1.65  0.0014
summary(mpc2)
Linear mixed-effects model fit by REML
 Data: reproz
   AIC  BIC logLik
  1965 2897   -785

Random effects:
 Formula: ~1 | block
        (Intercept) Residual
StdDev:       0.036    0.358

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * legumes
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B  L6*BM
1.000 0.845  1.288  1.355  1.415  1.397  1.149  0.882  1.202  1.152  3.578  2.197
L9*B  L9*BM  L10*B L10*BM  L11*B L11*BM  L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.203  1.384 1.299  1.405 1.046  1.239  2.230  1.673  1.169  0.990  1.302  1.228
L7*B  L7*BM   L8*B  L8*BM
3.623  2.622  1.576  1.995
Fixed effects: PC2 ~ legumes * csv * lab
                            Value Std.Error  DF t-value p-value
(Intercept)                 -0.80     0.148 839   -5.40  0.0000
legumesBM                   -0.77     0.191 839   -4.04  0.0001
csvENVw                     -0.03     0.207 839   -0.15  0.8802
csvENVb                      0.07     0.207 839    0.35  0.7281
csvGENw                     -0.96     0.207 839   -4.64  0.0000
```

csvGENb	-0.48	0.207	839	-2.31	0.0213
csvENVw+GENw	-0.50	0.207	839	-2.41	0.0163
labL2	1.39	0.238	839	5.85	0.0000
labL3	1.91	0.253	839	7.53	0.0000
labL4	2.07	0.223	839	9.32	0.0000
labL5	1.49	0.229	839	6.54	0.0000
labL6	-0.54	0.543	839	-0.99	0.3244
labL7	1.86	0.229	839	8.13	0.0000
labL8	0.60	0.240	839	2.51	0.0122
labL9	0.45	0.212	839	2.13	0.0335
labL10	1.34	0.357	839	3.74	0.0002
labL11	4.08	0.225	839	18.15	0.0000
labL12	3.91	0.240	839	16.29	0.0000
labL13	2.03	0.549	839	3.70	0.0002
labL14	3.15	0.273	839	11.55	0.0000
legumesBM:csvENVw	0.31	0.271	839	1.14	0.2548
legumesBM:csvENVb	0.09	0.271	839	0.33	0.7414
legumesBM:csvGENw	0.81	0.271	839	2.99	0.0029
legumesBM:csvGENb	0.30	0.271	839	1.10	0.2699
legumesBM:csvENVw+GENw	0.11	0.271	839	0.41	0.6815
legumesBM:labL2	-0.59	0.334	839	-1.78	0.0761
legumesBM:labL3	-0.22	0.348	839	-0.63	0.5261
legumesBM:labL4	-0.05	0.285	839	-0.18	0.8535
legumesBM:labL5	-0.25	0.310	839	-0.81	0.4208
legumesBM:labL6	0.83	0.643	839	1.29	0.1984
legumesBM:labL7	-1.87	0.329	839	-5.69	0.0000
legumesBM:labL8	-0.43	0.339	839	-1.27	0.2048
legumesBM:labL9	0.23	0.305	839	0.76	0.4455
legumesBM:labL10	-1.79	0.450	839	-3.98	0.0001
legumesBM:labL11	-1.01	0.294	839	-3.43	0.0006
legumesBM:labL12	-0.94	0.324	839	-2.89	0.0040
legumesBM:labL13	-1.94	0.681	839	-2.84	0.0046
legumesBM:labL14	-0.69	0.418	839	-1.65	0.0998
csvENVw:labL2	0.01	0.337	839	0.03	0.9790
csvENVb:labL2	-0.20	0.337	839	-0.58	0.5612
csvGENw:labL2	-0.38	0.337	839	-1.12	0.2627
csvGENb:labL2	-0.36	0.337	839	-1.07	0.2860
csvENVw+GENw:labL2	-0.18	0.337	839	-0.53	0.5984
csvENVw:labL3	-0.21	0.358	839	-0.58	0.5641
csvENVb:labL3	0.08	0.358	839	0.23	0.8160
csvGENw:labL3	-0.29	0.358	839	-0.80	0.4259
csvGENb:labL3	-0.12	0.358	839	-0.33	0.7430
csvENVw+GENw:labL3	-0.35	0.358	839	-0.97	0.3343
csvENVw:labL4	-0.32	0.315	839	-1.02	0.3072
csvENVb:labL4	-0.19	0.315	839	-0.62	0.5384
csvGENw:labL4	0.28	0.315	839	0.89	0.3752
csvGENb:labL4	0.03	0.315	839	0.09	0.9248
csvENVw+GENw:labL4	-0.46	0.315	839	-1.47	0.1407
csvENVw:labL5	0.30	0.323	839	0.93	0.3501
csvENVb:labL5	0.18	0.323	839	0.57	0.5694
csvGENw:labL5	0.21	0.323	839	0.65	0.5148
csvGENb:labL5	-0.24	0.323	839	-0.75	0.4548
csvENVw+GENw:labL5	-0.29	0.323	839	-0.89	0.3742
csvENVw:labL6	0.21	0.768	839	0.27	0.7895
csvENVb:labL6	-0.65	0.768	839	-0.85	0.3942
csvGENw:labL6	-0.30	0.768	839	-0.39	0.6947
csvGENb:labL6	0.58	0.768	839	0.75	0.4531
csvENVw+GENw:labL6	-0.12	0.768	839	-0.16	0.8712
csvENVw:labL7	-0.30	0.323	839	-0.93	0.3511
csvENVb:labL7	-0.24	0.323	839	-0.74	0.4583
csvGENw:labL7	0.83	0.323	839	2.57	0.0104
csvGENb:labL7	0.16	0.323	839	0.49	0.6234
csvENVw+GENw:labL7	-0.15	0.323	839	-0.46	0.6459

```
csvENVw:labL8                  -0.36     0.339 839   -1.08  0.2823
csvENVb:labL8                  -0.65     0.339 839   -1.91  0.0565
csvGENw:labL8                   0.37     0.339 839    1.10  0.2717
csvGENb:labL8                  -0.21     0.339 839   -0.62  0.5377
csvENVw+GENw:labL8             -0.81     0.339 839   -2.39  0.0172
csvENVw:labL9                   0.43     0.299 839    1.45  0.1479
csvENVb:labL9                   0.28     0.299 839    0.92  0.3571
csvGENw:labL9                   0.63     0.299 839    2.12  0.0341
csvGENb:labL9                   0.25     0.299 839    0.83  0.4063
csvENVw+GENw:labL9              0.02     0.299 839    0.08  0.9373
csvENVw:labL10                 -0.05     0.505 839   -0.11  0.9142
csvENVb:labL10                 -0.26     0.505 839   -0.51  0.6090
csvGENw:labL10                  0.28     0.505 839    0.56  0.5747
csvGENb:labL10                 -0.17     0.505 839   -0.34  0.7352
csvENVw+GENw:labL10            -0.04     0.505 839   -0.08  0.9336
csvENVw:labL11                 -0.59     0.318 839   -1.84  0.0655
csvENVb:labL11                 -0.30     0.318 839   -0.95  0.3405
csvGENw:labL11                  1.09     0.318 839    3.43  0.0006
csvGENb:labL11                  0.32     0.318 839    1.01  0.3126
csvENVw+GENw:labL11             0.11     0.318 839    0.34  0.7318
csvENVw:labL12                 -0.61     0.339 839   -1.79  0.0745
csvENVb:labL12                 -0.51     0.339 839   -1.49  0.1355
csvGENw:labL12                  0.59     0.339 839    1.74  0.0827
csvGENb:labL12                  0.39     0.339 839    1.14  0.2566
csvENVw+GENw:labL12             0.15     0.339 839    0.45  0.6548
csvENVw:labL13                 -0.70     0.777 839   -0.90  0.3661
csvENVb:labL13                 -0.23     0.777 839   -0.30  0.7630
csvGENw:labL13                  0.29     0.777 839    0.37  0.7118
csvGENb:labL13                 -0.71     0.777 839   -0.91  0.3636
csvENVw+GENw:labL13            -0.51     0.777 839   -0.65  0.5153
csvENVw:labL14                 -0.45     0.386 839   -1.16  0.2481
csvENVb:labL14                 -0.59     0.386 839   -1.54  0.1246
csvGENw:labL14                 -0.32     0.386 839   -0.83  0.4094
csvGENb:labL14                 -0.44     0.386 839   -1.15  0.2493
csvENVw+GENw:labL14            -0.81     0.386 839   -2.09  0.0366
legumesBM:csvENVw:labL2         0.08     0.472 839    0.17  0.8668
legumesBM:csvENVb:labL2         0.21     0.472 839    0.45  0.6514
legumesBM:csvGENw:labL2         0.83     0.472 839    1.76  0.0786
legumesBM:csvGENb:labL2         1.11     0.472 839    2.35  0.0191
legumesBM:csvENVw+GENw:labL2    1.28     0.472 839    2.71  0.0070
legumesBM:csvENVw:labL3        -0.75     0.492 839   -1.52  0.1298
legumesBM:csvENVb:labL3        -0.49     0.492 839   -1.01  0.3150
legumesBM:csvGENw:labL3         0.12     0.492 839    0.24  0.8106
legumesBM:csvGENb:labL3        -0.11     0.492 839   -0.22  0.8229
legumesBM:csvENVw+GENw:labL3    0.67     0.492 839    1.36  0.1747
legumesBM:csvENVw:labL4        -0.05     0.403 839   -0.12  0.9058
legumesBM:csvENVb:labL4         0.16     0.403 839    0.40  0.6860
legumesBM:csvGENw:labL4        -0.39     0.403 839   -0.96  0.3359
legumesBM:csvGENb:labL4        -0.03     0.403 839   -0.07  0.9457
legumesBM:csvENVw+GENw:labL4    0.59     0.403 839    1.47  0.1430
legumesBM:csvENVw:labL5        -0.46     0.438 839   -1.04  0.2970
legumesBM:csvENVb:labL5        -0.26     0.438 839   -0.59  0.5525
legumesBM:csvGENw:labL5        -0.39     0.438 839   -0.89  0.3718
legumesBM:csvGENb:labL5        -0.08     0.438 839   -0.18  0.8535
legumesBM:csvENVw+GENw:labL5    0.25     0.438 839    0.56  0.5753
legumesBM:csvENVw:labL6        -0.63     0.909 839   -0.69  0.4918
legumesBM:csvENVb:labL6         0.54     0.909 839    0.60  0.5512
legumesBM:csvGENw:labL6        -0.75     0.909 839   -0.82  0.4111
legumesBM:csvGENb:labL6        -0.93     0.909 839   -1.02  0.3057
legumesBM:csvENVw+GENw:labL6    0.01     0.909 839    0.01  0.9955
legumesBM:csvENVw:labL7        -0.63     0.466 839   -1.36  0.1753
legumesBM:csvENVb:labL7        -0.31     0.466 839   -0.67  0.5037
legumesBM:csvGENw:labL7        -0.40     0.466 839   -0.86  0.3893
```

```
legumesBM:csvGENb:labL7         0.20     0.466 839    0.44  0.6607
legumesBM:csvENVw+GENw:labL7    0.97     0.466 839    2.08  0.0378
legumesBM:csvENVw:labL8        -0.15     0.479 839   -0.31  0.7554
legumesBM:csvENVb:labL8         0.51     0.479 839    1.06  0.2881
legumesBM:csvGENw:labL8        -0.41     0.479 839   -0.86  0.3903
legumesBM:csvGENb:labL8         0.70     0.479 839    1.47  0.1418
legumesBM:csvENVw+GENw:labL8    1.14     0.479 839    2.39  0.0172
legumesBM:csvENVw:labL9        -0.82     0.431 839   -1.90  0.0579
legumesBM:csvENVb:labL9        -0.57     0.431 839   -1.32  0.1866
legumesBM:csvGENw:labL9        -0.81     0.431 839   -1.88  0.0608
legumesBM:csvGENb:labL9        -0.28     0.431 839   -0.66  0.5113
legumesBM:csvENVw+GENw:labL9   -0.07     0.431 839   -0.16  0.8696
legumesBM:csvENVw:labL10       -0.09     0.637 839   -0.14  0.8890
legumesBM:csvENVb:labL10        0.15     0.637 839    0.24  0.8085
legumesBM:csvGENw:labL10        0.51     0.637 839    0.80  0.4226
legumesBM:csvGENb:labL10        0.40     0.637 839    0.63  0.5316
legumesBM:csvENVw+GENw:labL10   1.68     0.637 839    2.63  0.0086
legumesBM:csvENVw:labL11        0.42     0.416 839    1.01  0.3110
legumesBM:csvENVb:labL11        0.26     0.416 839    0.62  0.5330
legumesBM:csvGENw:labL11       -0.83     0.416 839   -1.99  0.0474
legumesBM:csvGENb:labL11       -0.05     0.416 839   -0.11  0.9113
legumesBM:csvENVw+GENw:labL11   0.33     0.416 839    0.80  0.4264
legumesBM:csvENVw:labL12        0.40     0.458 839    0.87  0.3872
legumesBM:csvENVb:labL12        0.18     0.458 839    0.40  0.6916
legumesBM:csvGENw:labL12       -0.35     0.458 839   -0.76  0.4460
legumesBM:csvGENb:labL12       -0.32     0.458 839   -0.71  0.4802
legumesBM:csvENVw+GENw:labL12   0.29     0.458 839    0.64  0.5231
legumesBM:csvENVw:labL13        1.50     0.963 839    1.55  0.1205
legumesBM:csvENVb:labL13        1.23     0.963 839    1.28  0.2022
legumesBM:csvGENw:labL13        0.00     0.963 839    0.00  0.9999
legumesBM:csvGENb:labL13        1.45     0.963 839    1.51  0.1317
legumesBM:csvENVw+GENw:labL13   2.65     0.963 839    2.75  0.0061
legumesBM:csvENVw:labL14        0.66     0.591 839    1.12  0.2624
legumesBM:csvENVb:labL14        0.65     0.591 839    1.10  0.2723
legumesBM:csvGENw:labL14       -0.60     0.591 839   -1.02  0.3074
legumesBM:csvGENb:labL14        0.24     0.591 839    0.41  0.6840
legumesBM:csvENVw+GENw:labL14   0.05     0.591 839    0.08  0.9332

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-3.2963 -0.5815  0.0528  0.6596  3.1293

Number of Observations: 1008
Number of Groups: 2
```

Detailed model outputs from Supplementary Table S3

Model for shoot biomass (shootbm)

```
anova(m1)
                  numDF denDF F-value p-value
(Intercept)           1   955   76.70  <.0001
mixture               1   955 1843.37  <.0001
het                   5   955    9.10  <.0001
setup                 1    12    2.99  0.1094
mixture:het           5   955   12.41  <.0001
mixture:setup         1   955  209.81  <.0001
het:setup             5   955   23.31  <.0001
mixture:het:setup     5   955    7.34  <.0001
```

```
summary(m1)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  2868 3132  -1380

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:        1.66

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:       0.442    0.165

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture

 Parameter estimates:
  L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
 1.000  5.483  0.979 18.348  5.569  6.876  6.235  4.325  4.737  3.093  1.941
 L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B L9*BM  L10*B L10*BM  L11*B L11*BM
 2.175  1.831 27.137  2.977  4.069  1.253 8.022  3.997 14.183 10.006  5.615
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
11.360  5.856 18.913  2.602 10.150 54.072

Fixed effects: shootbm ~ mixture * het * setup
                                              Value Std.Error  DF t-value p-value
(Intercept)                                    2.79     0.701 955    3.98  0.0001
mixtureBM                                      4.71     0.195 955   24.21  0.0000
hetENVw                                       -0.14     0.091 955   -1.55  0.1204
hetENVb                                       -0.05     0.091 955   -0.57  0.5712
hetGENw                                        0.52     0.091 955    5.77  0.0000
hetGENb                                        0.43     0.091 955    4.72  0.0000
hetENVw+GENw                                   0.61     0.091 955    6.77  0.0000
setupgrowth_chamber                           -0.30     0.923  12   -0.32  0.7524
mixtureBM:hetENVw                             -0.87     0.206 955   -4.23  0.0000
mixtureBM:hetENVb                             -0.24     0.206 955   -1.15  0.2488
mixtureBM:hetGENw                             -0.70     0.206 955   -3.41  0.0007
mixtureBM:hetGENb                             -0.42     0.206 955   -2.04  0.0413
mixtureBM:hetENVw+GENw                        -1.37     0.206 955   -6.66  0.0000
mixtureBM:setupgrowth_chamber                 -2.51     0.225 955  -11.16  0.0000
hetENVw:setupgrowth_chamber                    0.21     0.109 955    1.96  0.0501
hetENVb:setupgrowth_chamber                    0.04     0.109 955    0.38  0.7014
hetGENw:setupgrowth_chamber                   -0.52     0.109 955   -4.73  0.0000
hetGENb:setupgrowth_chamber                   -0.40     0.109 955   -3.68  0.0002
hetENVw+GENw:setupgrowth_chamber              -0.38     0.109 955   -3.50  0.0005
mixtureBM:hetENVw:setupgrowth_chamber          1.03     0.258 955    4.01  0.0001
mixtureBM:hetENVb:setupgrowth_chamber          0.06     0.257 955    0.22  0.8260
mixtureBM:hetGENw:setupgrowth_chamber         -0.01     0.257 955   -0.05  0.9576
mixtureBM:hetGENb:setupgrowth_chamber         -0.06     0.257 955   -0.24  0.8127
mixtureBM:hetENVw+GENw:setupgrowth_chamber     0.85     0.257 955    3.31  0.0010

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-2.9236 -0.7399  0.0667  0.8455  3.6711

Number of Observations: 1005
Number of Groups:
            lab block %in% lab
             14             28
```

Model for shoot biomass (rootbm)

```
anova(m2)
                  numDF denDF F-value p-value
(Intercept)           1   939  114.19  <.0001
mixture               1   939  705.35  <.0001
het                   5   939   20.91  <.0001
setup                 1    12    7.35  0.0189
mixture:het           5   939    3.30  0.0059
mixture:setup         1   939   30.33  <.0001
het:setup             5   939    5.59  <.0001
mixture:het:setup     5   939    1.03  0.3993

summary(m2)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  1633 1896   -763

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:        0.52

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:        0.15     0.23

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.00   1.34   1.08   0.92   1.81   2.00   0.55   0.76   2.12   1.84   9.85   L
6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
5.12   1.41   6.57   2.71   2.79    1.23   2.09  3.85   3.49   1.38   1.26
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.78   1.51   4.69   5.13   0.96  10.27

Fixed effects: rootbm ~ mixture * het * setup
                                          Value Std.Error  DF t-value p-value
(Intercept)                                0.83     0.223 939     3.7  0.0002
mixtureBM                                  0.58     0.061 939     9.4  0.0000
hetENVw                                   -0.19     0.054 939    -3.5  0.0004
hetENVb                                   -0.06     0.054 939    -1.1  0.2759
hetGENw                                    0.24     0.055 939     4.3  0.0000
hetGENb                                    0.11     0.054 939     2.1  0.0360
hetENVw+GENw                               0.16     0.054 939     2.9  0.0035
setupgrowth_chamber                        0.54     0.298  12     1.8  0.0964
mixtureBM:hetENVw                          0.07     0.086 939     0.8  0.4455
mixtureBM:hetENVb                         -0.07     0.086 939    -0.9  0.3845
mixtureBM:hetGENw                         -0.10     0.087 939    -1.2  0.2332
mixtureBM:hetGENb                         -0.11     0.086 939    -1.3  0.1952
mixtureBM:hetENVw+GENw                    -0.16     0.086 939    -1.8  0.0683
mixtureBM:setupgrowth_chamber              0.27     0.114 939     2.4  0.0189
hetENVw:setupgrowth_chamber                0.33     0.095 939     3.5  0.0006
hetENVb:setupgrowth_chamber                0.08     0.095 939     0.9  0.3865
hetGENw:setupgrowth_chamber                0.11     0.096 939     1.1  0.2690
hetGENb:setupgrowth_chamber                0.07     0.095 939     0.7  0.4548
hetENVw+GENw:setupgrowth_chamber           0.24     0.095 939     2.6  0.0109
mixtureBM:hetENVw:setupgrowth_chamber      0.04     0.160 939     0.2  0.8078
mixtureBM:hetENVb:setupgrowth_chamber      0.15     0.159 939     1.0  0.3297
mixtureBM:hetGENw:setupgrowth_chamber     -0.19     0.159 939    -1.2  0.2370
```

```
mixtureBM:hetGENb:setupgrowth_chamber       0.05     0.159 939     0.3  0.7714
mixtureBM:hetENVw+GENw:setupgrowth_chamber -0.04     0.159 939    -0.3  0.7933

Standardized Within-Group Residuals:
   Min     Q1    Med     Q3    Max
-2.968 -0.678 -0.028  0.692  4.380

Number of Observations: 989
Number of Groups:
           lab block %in% lab
            14             28
```

Model for shoot biomass (seedbm)

```
                  numDF denDF F-value p-value
(Intercept)           1   947   28.74  <.0001
mixture               1   947  729.57  <.0001
het                   5   947   39.52  <.0001
setup                 1    12    1.34  0.2696
mixture:het           5   947   21.51  <.0001
mixture:setup         1   947   87.11  <.0001
het:setup             5   947   22.70  <.0001
mixture:het:setup     5   947    0.82  0.5347
```

```
summary(m3)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  1047 1311   -470

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:        0.59

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:       0.071     0.19

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture

 Parameter estimates:
  L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.00   0.53   1.26   0.21   7.29   2.05   2.21   1.00   4.19   1.17   1.02
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
0.69   6.42   1.32   1.27   1.19   2.00   1.34 7.91   1.23   9.03   2.84
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
8.05   2.24   1.18   0.56   5.99   2.95


Fixed effects: seedbm ~ mixture * het * setup
                                            Value Std.Error  DF t-value p-value
(Intercept)                                  1.76      0.25 947     7.1  0.0000
mixtureBM                                   -0.77      0.06 947   -12.1  0.0000
hetENVw                                     -0.06      0.09 947    -0.7  0.4776
hetENVb                                     -0.01      0.09 947    -0.1  0.9036
hetGENw                                     -0.31      0.09 947    -3.6  0.0003
```

```
hetGENb                                    -0.11      0.09 947    -1.3  0.2068
hetENVw+GENw                               -0.31      0.09 947    -3.6  0.0004
setupgrowth_chamber                        -0.57      0.33  12    -1.7  0.1096
mixtureBM:hetENVw                           0.05      0.09 947     0.6  0.5566
mixtureBM:hetENVb                          -0.02      0.09 947    -0.2  0.8256
mixtureBM:hetGENw                           0.23      0.09 947     2.5  0.0113
mixtureBM:hetGENb                           0.11      0.09 947     1.2  0.2155
mixtureBM:hetENVw+GENw                      0.26      0.09 947     2.9  0.0035
mixtureBM:setupgrowth_chamber               0.32      0.08 947     3.8  0.0002
hetENVw:setupgrowth_chamber                 0.17      0.11 947     1.5  0.1257
hetENVb:setupgrowth_chamber                 0.05      0.11 947     0.5  0.6219
hetGENw:setupgrowth_chamber                -0.25      0.11 947    -2.3  0.0229
hetGENb:setupgrowth_chamber                -0.26      0.11 947    -2.4  0.0156
hetENVw+GENw:setupgrowth_chamber           -0.17      0.11 947    -1.6  0.1164
mixtureBM:hetENVw:setupgrowth_chamber      -0.10      0.12 947    -0.8  0.3989
mixtureBM:hetENVb:setupgrowth_chamber       0.00      0.12 947     0.0  0.9681
mixtureBM:hetGENw:setupgrowth_chamber       0.06      0.12 947     0.5  0.5952
mixtureBM:hetGENb:setupgrowth_chamber       0.11      0.12 947     1.0  0.3318
mixtureBM:hetENVw+GENw:setupgrowth_chamber -0.04      0.12 947    -0.4  0.7064
```

Model for shoot biomass (totalbm)

```
summary(m4)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  3736 4000  -1814

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:        2.64

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:       0.786    0.362

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  2.915  1.078  0.676  4.465  3.862  7.152  3.382  2.568  1.760  7.745
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
5.606  2.353 12.988  3.091  4.315  1.288  5.097 3.742  3.770  8.312  2.815
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
10.039  2.986  3.333  4.700  4.710 37.184
Fixed effects: totalbm ~ mixture * het * setup
                                           Value Std.Error  DF t-value p-value
(Intercept)                                 7.20     1.112 958    6.48  0.0000
mixtureBM                                   1.33     0.173 958    7.67  0.0000
hetENVw                                    -0.04     0.205 958   -0.18  0.8550
hetENVb                                    -0.01     0.205 958   -0.07  0.9462
hetGENw                                     0.79     0.205 958    3.85  0.0001
hetGENb                                     0.58     0.205 958    2.81  0.0051
hetENVw+GENw                                0.65     0.205 958    3.15  0.0017
setupgrowth_chamber                        -1.60     1.469  12   -1.09  0.2984
mixtureBM:hetENVw                           0.04     0.243 958    0.16  0.8708
mixtureBM:hetENVb                          -0.05     0.243 958   -0.19  0.8487
mixtureBM:hetGENw                          -0.79     0.243 958   -3.26  0.0011
mixtureBM:hetGENb                          -0.74     0.243 958   -3.02  0.0026
mixtureBM:hetENVw+GENw                     -0.45     0.243 958   -1.85  0.0640
```

```
mixtureBM:setupgrowth_chamber                1.31     0.273 958    4.82  0.0000
hetENVw:setupgrowth_chamber                  0.47     0.249 958    1.88  0.0602
hetENVb:setupgrowth_chamber                  0.18     0.249 958    0.71  0.4754
hetGENw:setupgrowth_chamber                 -1.14     0.249 958   -4.55  0.0000
hetGENb:setupgrowth_chamber                 -0.78     0.249 958   -3.11  0.0019
hetENVw+GENw:setupgrowth_chamber            -0.62     0.249 958   -2.47  0.0136
mixtureBM:hetENVw:setupgrowth_chamber        0.09     0.376 958    0.25  0.8049
mixtureBM:hetENVb:setupgrowth_chamber       -0.16     0.376 958   -0.42  0.6748
mixtureBM:hetGENw:setupgrowth_chamber        0.26     0.376 958    0.69  0.4935
mixtureBM:hetGENb:setupgrowth_chamber        0.61     0.376 958    1.63  0.1030
mixtureBM:hetENVw+GENw:setupgrowth_chamber -0.09     0.376 958   -0.25  0.8013

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-3.4575 -0.7405 -0.0443  0.7257  3.4425

Number of Observations: 1008
Number of Groups:
           lab block %in% lab
            14             28
```

Model for shoot to root biomass ratio (shoot.root)

```
anova(m5)
                   numDF denDF F-value p-value
(Intercept)            1   934  120.46  <.0001
mixture                1   934  706.29  <.0001
het                    5   934   21.00  <.0001
setup                  1    12    7.52  0.0178
mixture:het            5   934    3.32  0.0056
mixture:setup          1   934   30.37  <.0001
het:setup              5   934    5.57  <.0001
mixture:het:setup      5   934    1.00  0.4140

summary(m5)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  1583 1846   -737

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:        0.51

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:        0.14     0.23

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture

 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B  L6*BM
1.00   1.35   1.08   0.92   1.81   1.99   0.55   0.76   2.12   1.84   7.17   4.40
L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM  L12*B L12*BM
1.41   6.57   2.71   2.80   1.23   2.09 3.85   3.48   1.38   1.26   1.77   1.51
L13*B L13*BM  L14*B L14*BM
4.72   5.12   0.96  10.26


Fixed effects: shoot.root ~ mixture * het * setup
```

```
                                          Value Std.Error  DF t-value p-value
(Intercept)                                0.83     0.215 934     3.9  0.0001
mixtureBM                                  0.58     0.061 934     9.4  0.0000
hetENVw                                   -0.19     0.054 934    -3.5  0.0004
hetENVb                                   -0.06     0.054 934    -1.1  0.2761
hetGENw                                    0.24     0.055 934     4.3  0.0000
hetGENb                                    0.11     0.054 934     2.1  0.0361
hetENVw+GENw                               0.16     0.054 934     2.9  0.0035
setupgrowth_chamber                        0.52     0.289  12     1.8  0.0979
mixtureBM:hetENVw                          0.07     0.086 934     0.8  0.4452
mixtureBM:hetENVb                         -0.07     0.086 934    -0.9  0.3843
mixtureBM:hetGENw                         -0.10     0.087 934    -1.2  0.2335
mixtureBM:hetGENb                         -0.11     0.086 934    -1.3  0.1955
mixtureBM:hetENVw+GENw                    -0.16     0.086 934    -1.8  0.0684
mixtureBM:setupgrowth_chamber              0.27     0.114 934     2.4  0.0181
hetENVw:setupgrowth_chamber                0.33     0.095 934     3.5  0.0005
hetENVb:setupgrowth_chamber                0.08     0.095 934     0.9  0.3741
hetGENw:setupgrowth_chamber                0.11     0.096 934     1.1  0.2518
hetGENb:setupgrowth_chamber                0.07     0.095 934     0.7  0.4593
hetENVw+GENw:setupgrowth_chamber           0.25     0.095 934     2.6  0.0093
mixtureBM:hetENVw:setupgrowth_chamber      0.04     0.159 934     0.2  0.8238
mixtureBM:hetENVb:setupgrowth_chamber      0.15     0.158 934     1.0  0.3408
mixtureBM:hetGENw:setupgrowth_chamber     -0.18     0.159 934    -1.1  0.2554
mixtureBM:hetGENb:setupgrowth_chamber      0.05     0.159 934     0.3  0.7345
mixtureBM:hetENVw+GENw:setupgrowth_chamber -0.06     0.158 934    -0.4  0.7150

Standardized Within-Group Residuals:
   Min     Q1    Med     Q3    Max
-2.967 -0.690 -0.026  0.685  4.382

Number of Observations: 984
Number of Groups:
           lab block %in% lab
            14             28
```

Model for Brachypodium distachyon height (heightB)

```
anova(m6)
                   numDF denDF F-value p-value
(Intercept)            1   944  827.30  <.0001
mixture                1   944   30.90  <.0001
het                    5   944   20.16  <.0001
setup                  1    12    5.28  0.0404
mixture:het            5   944    1.70  0.1318
mixture:setup          1   944   10.92  0.0010
het:setup              5   944    3.37  0.0051
mixture:het:setup      5   944    2.58  0.0251
```

```
summary(m6)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  5659 5922  -2775

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:         3.6
```

```
 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:         1.6      5.1

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture

 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.00   0.92   0.19   0.48   0.49   1.10   1.03   1.32   0.44   0.56   0.69
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
0.43   0.51   0.71   1.12   0.81   0.78   1.00  0.71   0.83   0.40   0.58
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
0.52   0.51   1.84   1.85   0.64   4.00


Fixed effects: heightB ~ mixture * het * setup
                                               Value Std.Error  DF t-value p-value
(Intercept)                                       33      1.60 944    20.4  0.0000
mixtureBM                                         -2      0.73 944    -2.2  0.0299
hetENVw                                           -2      0.45 944    -4.3  0.0000
hetENVb                                           -2      0.45 944    -3.3  0.0010
hetGENw                                            1      0.45 944     1.7  0.0902
hetGENb                                            1      0.45 944     1.4  0.1537
hetENVw+GENw                                       1      0.45 944     1.2  0.2228
setupgrowth_chamber                               -5      2.14  12    -2.5  0.0299
mixtureBM:hetENVw                                  1      1.00 944     1.3  0.1959
mixtureBM:hetENVb                                  0      1.00 944     0.3  0.7301
mixtureBM:hetGENw                                  1      0.99 944     1.4  0.1567
mixtureBM:hetGENb                                  2      0.99 944     1.7  0.0820
mixtureBM:hetENVw+GENw                             2      1.00 944     1.7  0.0840
mixtureBM:setupgrowth_chamber                      0      1.01 944     0.4  0.6987
hetENVw:setupgrowth_chamber                        2      0.79 944     2.5  0.0113
hetENVb:setupgrowth_chamber                        1      0.79 944     1.5  0.1264
hetGENw:setupgrowth_chamber                        2      0.80 944     2.0  0.0504
hetGENb:setupgrowth_chamber                        0      0.79 944     0.3  0.7690
hetENVw+GENw:setupgrowth_chamber                   1      0.79 944     1.5  0.1217
mixtureBM:hetENVw:setupgrowth_chamber             -1      1.40 944    -0.8  0.4122
mixtureBM:hetENVb:setupgrowth_chamber              0      1.40 944    -0.3  0.7501
mixtureBM:hetGENw:setupgrowth_chamber             -4      1.40 944    -3.0  0.0032
mixtureBM:hetGENb:setupgrowth_chamber             -3      1.39 944    -2.1  0.0322
mixtureBM:hetENVw+GENw:setupgrowth_chamber        -2      1.40 944    -1.4  0.1493

Standardized Within-Group Residuals:
   Min     Q1    Med     Q3    Max
-2.898 -0.750  0.063  0.752  2.517

Number of Observations: 994
Number of Groups:
            lab block %in% lab
             14             28
```

Model for shoot N% (N.)

```
anova(m7)
                  numDF denDF F-value p-value
(Intercept)           1   958 194.788  <.0001
mixture               1   958  54.143  <.0001
het                   5   958   0.754  0.5831
setup                 1    12  15.130  0.0021
```

```
mixture:het           5   958   1.283  0.2690
mixture:setup         1   958  35.934  <.0001
het:setup             5   958   0.911  0.4729
mixture:het:setup     5   958   3.768  0.0022
```

```
summary(m7)
Linear mixed-effects model fit by REML
 Data: reproz
  AIC BIC logLik
  128 393    -10

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:         0.3

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:        0.15     0.11

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture

 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.00   0.47   6.17   5.89   0.69   1.55   3.39   3.22   1.07   1.10   1.04
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
1.00   5.77   3.64   2.41   2.45   1.37   1.09  1.96   2.46   1.58   2.97
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
3.14   3.18   4.79   5.05   1.63   0.87

Fixed effects: N. ~ mixture * het * setup
                                                Value Std.Error  DF t-value p-value
(Intercept)                                      1.78     0.137 958    13.0  0.0000
mixtureBM                                       -0.32     0.057 958    -5.7  0.0000
hetENVw                                         -0.03     0.062 958    -0.5  0.6242
hetENVb                                         -0.07     0.062 958    -1.2  0.2273
hetGENw                                         -0.19     0.062 958    -3.0  0.0024
hetGENb                                         -0.12     0.062 958    -2.0  0.0510
hetENVw+GENw                                    -0.17     0.062 958    -2.8  0.0048
setupgrowth_chamber                             -0.86     0.178  12    -4.8  0.0004
mixtureBM:hetENVw                                0.02     0.078 958     0.2  0.8120
mixtureBM:hetENVb                                0.05     0.078 958     0.7  0.4972
mixtureBM:hetGENw                                0.23     0.078 958     3.0  0.0032
mixtureBM:hetGENb                                0.09     0.078 958     1.1  0.2729
mixtureBM:hetENVw+GENw                           0.26     0.078 958     3.3  0.0010
mixtureBM:setupgrowth_chamber                    0.29     0.062 958     4.7  0.0000
hetENVw:setupgrowth_chamber                      0.03     0.067 958     0.4  0.6533
hetENVb:setupgrowth_chamber                      0.06     0.067 958     0.9  0.3733
hetGENw:setupgrowth_chamber                      0.20     0.067 958     3.0  0.0025
hetGENb:setupgrowth_chamber                      0.16     0.067 958     2.3  0.0201
hetENVw+GENw:setupgrowth_chamber                 0.20     0.067 958     3.0  0.0032
mixtureBM:hetENVw:setupgrowth_chamber           -0.03     0.086 958    -0.4  0.7110
mixtureBM:hetENVb:setupgrowth_chamber           -0.05     0.086 958    -0.6  0.5403
mixtureBM:hetGENw:setupgrowth_chamber           -0.23     0.086 958    -2.7  0.0080
mixtureBM:hetGENb:setupgrowth_chamber           -0.14     0.086 958    -1.7  0.0925
mixtureBM:hetENVw+GENw:setupgrowth_chamber      -0.29     0.086 958    -3.4  0.0006


Standardized Within-Group Residuals:
   Min     Q1    Med     Q3    Max
```

```
-2.454 -0.735 -0.054  0.591  4.755

Number of Observations: 1008
Number of Groups:
           lab block %in% lab
            14             28
```

Model for shoot C% (C.)

```
anova(m8)
                   numDF denDF F-value p-value
(Intercept)            1   958 27558.9  <.0001
mixture                1   958   197.3  <.0001
het                    5   958     0.0  0.9998
setup                  1    12     5.0  0.0456
mixture:het            5   958     2.3  0.0425
mixture:setup          1   958    11.6  0.0007
het:setup              5   958     2.0  0.0699
mixture:het:setup      5   958     0.6  0.6643

summary(m8)
Linear mixed-effects model fit by REML
 Data: reproz
   AIC  BIC logLik
  2769 3033  -1331

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:        0.95

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:        0.25     0.71

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture

 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  0.962  0.774  1.394  1.408  1.259  1.187  0.931  1.053  0.641  2.364
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
2.177  0.425  0.646  1.053  0.886  0.815  0.522 1.235  1.895  1.089  1.513
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.459  1.725  7.686  4.144  0.935  1.022

Fixed effects: C. ~ mixture * het * setup
                                          Value Std.Error  DF t-value p-value
(Intercept)                               42.77    0.4212 958  101.56  0.0000
mixtureBM                                 -0.36    0.2041 958   -1.77  0.0770
hetENVw                                   -0.17    0.1848 958   -0.92  0.3579
hetENVb                                    0.13    0.1848 958    0.69  0.4879
hetGENw                                    0.32    0.1848 958    1.75  0.0801
hetGENb                                    0.14    0.1848 958    0.78  0.4344
hetENVw+GENw                               0.21    0.1848 958    1.14  0.2548
setupgrowth_chamber                        1.36    0.5499  12    2.46  0.0298
mixtureBM:hetENVw                          0.21    0.2865 958    0.73  0.4631
mixtureBM:hetENVb                          0.07    0.2865 958    0.25  0.8025
mixtureBM:hetGENw                         -0.08    0.2865 958   -0.30  0.7672
mixtureBM:hetGENb                         -0.09    0.2865 958   -0.32  0.7465
```

```
mixtureBM:hetENVw+GENw                       -0.21    0.2865 958   -0.74  0.4585
mixtureBM:setupgrowth_chamber                -0.10    0.2373 958   -0.41  0.6810
hetENVw:setupgrowth_chamber                   0.37    0.2213 958    1.66  0.0982
hetENVb:setupgrowth_chamber                  -0.10    0.2213 958   -0.46  0.6441
hetGENw:setupgrowth_chamber                  -0.18    0.2213 958   -0.83  0.4040
hetGENb:setupgrowth_chamber                  -0.09    0.2213 958   -0.39  0.6955
hetENVw+GENw:setupgrowth_chamber             -0.05    0.2213 958   -0.23  0.8152
mixtureBM:hetENVw:setupgrowth_chamber        -0.53    0.3327 958   -1.60  0.1097
mixtureBM:hetENVb:setupgrowth_chamber        -0.22    0.3327 958   -0.66  0.5066
mixtureBM:hetGENw:setupgrowth_chamber        -0.38    0.3327 958   -1.15  0.2490
mixtureBM:hetGENb:setupgrowth_chamber        -0.12    0.3327 958   -0.36  0.7168
mixtureBM:hetENVw+GENw:setupgrowth_chamber -0.22    0.3327 958   -0.65  0.5159

Standardized Within-Group Residuals:
   Min     Q1    Med     Q3    Max
-3.106 -0.653  0.024  0.696  2.988

Number of Observations: 1008
Number of Groups:
           lab block %in% lab
            14             28
```

Model for shoot delta ^{15}N (deltaN)

```
anova(m9)
                    numDF denDF F-value p-value
(Intercept)             1   913  49.368  <.0001
mixture                 1   913  56.153  <.0001
het                     5   913   8.067  <.0001
setup                   1    12   0.316  0.5843
mixture:het             5   913   6.384  <.0001
mixture:setup           1   913   4.615  0.0320
het:setup               5   913   6.760  <.0001
mixture:het:setup       5   913   1.565  0.1674
```

```
summary(m9)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  2304 2566  -1098

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:         1.8

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:        0.83     0.51

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture

 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.00   1.10   0.81   0.89   5.63   6.21   1.12   1.11   0.75   0.79   1.02
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
0.94   1.23   1.85   1.11   1.56   1.08   1.47  0.91   0.95   2.09   1.06
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
```

```
2.04   0.80   2.52   1.41   3.01   1.62

Fixed effects: deltaN ~ mixture * het * setup
                                          Value Std.Error  DF t-value p-value
(Intercept)                                 3.9      0.79 913     4.9  0.0000
mixtureBM                                  -0.1      0.16 913    -0.9  0.3798
hetENVw                                     0.1      0.18 913     0.6  0.5518
hetENVb                                     0.1      0.17 913     0.3  0.7707
hetGENw                                     0.3      0.17 913     1.7  0.0875
hetGENb                                    -0.1      0.17 913    -0.8  0.4252
hetENVw+GENw                                0.4      0.17 913     2.3  0.0226
setupgrowth_chamber                        -0.7      1.04  12    -0.7  0.5045
mixtureBM:hetENVw                          -0.2      0.22 913    -1.1  0.2512
mixtureBM:hetENVb                           0.0      0.22 913     0.0  0.9850
mixtureBM:hetGENw                           0.1      0.22 913     0.3  0.7642
mixtureBM:hetGENb                           0.4      0.22 913     1.8  0.0670
mixtureBM:hetENVw+GENw                     -0.4      0.22 913    -1.9  0.0533
mixtureBM:setupgrowth_chamber               0.0      0.19 913    -0.1  0.9372
hetENVw:setupgrowth_chamber                 0.6      0.21 913     2.8  0.0054
hetENVb:setupgrowth_chamber                 0.3      0.20 913     1.7  0.0935
hetGENw:setupgrowth_chamber                -0.2      0.21 913    -0.8  0.4319
hetGENb:setupgrowth_chamber                 0.4      0.20 913     1.8  0.0744
hetENVw+GENw:setupgrowth_chamber            0.3      0.21 913     1.5  0.1416
mixtureBM:hetENVw:setupgrowth_chamber      -0.2      0.27 913    -0.6  0.5798
mixtureBM:hetENVb:setupgrowth_chamber      -0.2      0.27 913    -0.8  0.4190
mixtureBM:hetGENw:setupgrowth_chamber       0.0      0.27 913    -0.2  0.8575
mixtureBM:hetGENb:setupgrowth_chamber      -0.6      0.27 913    -2.3  0.0246
mixtureBM:hetENVw+GENw:setupgrowth_chamber  0.0      0.27 913     0.2  0.8703

Standardized Within-Group Residuals:
     Min       Q1      Med       Q3      Max
-2.90862 -0.68204  0.00092  0.63948  3.52505

Number of Observations: 963
Number of Groups:
           lab block %in% lab
            14             28
```

Model for shoot delta ^{13}C (deltaC)

```
anova(m10)
                    numDF denDF F-value p-value
(Intercept)             1   923  8224.3  <.0001
mixture                 1   923    22.2  <.0001
het                     5   923    77.5  <.0001
setup                   1    12     0.6  0.4710
mixture:het             5   923     6.5  <.0001
mixture:setup           1   923    17.0  <.0001
het:setup               5   923     9.9  <.0001
mixture:het:setup       5   923     1.0  0.4279

summary(m10)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  1328 1590   -610

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:        1.31
```

```
 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:       0.224    0.295

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  1.633  1.005  1.092  0.952  0.915  1.639  1.721  1.260  0.998  1.399
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
1.679  1.159  1.302  1.645  1.398  1.223  1.511 1.081  0.988  1.714  1.537
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.747  1.678  2.280  2.968  2.279  1.368

Fixed effects: deltaC ~ mixture * het * setup
                                                Value Std.Error  DF t-value p-valu
e
(Intercept)                                   -32.07    0.542 923  -59.12  0.0000
mixtureBM                                       0.31    0.108 923    2.85  0.0045
hetENVw                                        -0.08    0.109 923   -0.77  0.4409
hetENVb                                        -0.11    0.110 923   -0.96  0.3367
hetGENw                                         0.76    0.111 923    6.76  0.0000
hetGENb                                         0.58    0.112 923    5.20  0.0000
hetENVw+GENw                                    1.01    0.111 923    9.03  0.0000
setupgrowth_chamber                            -0.33    0.716  12   -0.47  0.6493
mixtureBM:hetENVw                               0.19    0.152 923    1.23  0.2201
mixtureBM:hetENVb                               0.18    0.153 923    1.16  0.2480
mixtureBM:hetGENw                              -0.18    0.155 923   -1.17  0.2409
mixtureBM:hetGENb                              -0.29    0.154 923   -1.87  0.0619
mixtureBM:hetENVw+GENw                         -0.15    0.155 923   -0.99  0.3223
mixtureBM:setupgrowth_chamber                  -0.07    0.130 923   -0.51  0.6115
hetENVw:setupgrowth_chamber                     0.10    0.130 923    0.75  0.4554
hetENVb:setupgrowth_chamber                     0.16    0.131 923    1.23  0.2179
hetGENw:setupgrowth_chamber                    -0.15    0.133 923   -1.10  0.2704
hetGENb:setupgrowth_chamber                    -0.19    0.132 923   -1.47  0.1421
hetENVw+GENw:setupgrowth_chamber               -0.44    0.132 923   -3.34  0.0009
mixtureBM:hetENVw:setupgrowth_chamber          -0.24    0.183 923   -1.29  0.1960
mixtureBM:hetENVb:setupgrowth_chamber          -0.33    0.185 923   -1.79  0.0744
mixtureBM:hetGENw:setupgrowth_chamber          -0.19    0.186 923   -1.02  0.3062
mixtureBM:hetGENb:setupgrowth_chamber          -0.01    0.185 923   -0.06  0.9547
mixtureBM:hetENVw+GENw:setupgrowth_chamber     -0.18    0.186 923   -0.96  0.3396

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-3.0753 -0.6545  0.0148  0.6620  3.0739

Number of Observations: 973
Number of Groups:
           lab block %in% lab
            14             28
```

Model for evapotranspiration (finalET)

```
anova(m11)
                  numDF denDF F-value p-value
(Intercept)           1   952  106.13  <.0001
mixture               1   952  650.80  <.0001
het                   5   952    1.20  0.3049
setup                 1    12    0.09  0.7744
mixture:het           5   952    0.50  0.7771
mixture:setup         1   952  281.93  <.0001
```

```
het:setup             5   952   12.44  <.0001
mixture:het:setup     5   952    4.31  0.0007

summary(m11)
Linear mixed-effects model fit by REML
 Data: repro
   AIC  BIC logLik
  9374 9638  -4633

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:          51

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:        17.6     7.94

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  2.152  0.635  1.392  3.086 14.650  1.281  9.628  2.923  2.238  1.267
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
2.882  3.643  3.443  2.394  2.855  1.271  4.684 9.252  8.621  7.314  5.047
6.550  6.628  0.784  0.873  2.068 22.086
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM

Fixed effects: finalET ~ mixture * het * setup
                                          Value  Std.Error  DF t-value p-value
(Intercept)                              144.91    21.519 952   6.734  0.0000
mixtureBM                                 15.43     2.798 952   5.514  0.0000
hetENVw                                   -0.71     2.053 952  -0.344  0.7311
hetENVb                                   -2.96     2.053 952  -1.444  0.1491
hetGENw                                    2.02     2.053 952   0.986  0.3245
hetGENb                                   -0.68     2.053 952  -0.332  0.7401
hetENVw+GENw                               2.42     2.053 952   1.177  0.2393
setupgrowth_chamber                      -16.89    28.507  12  -0.592  0.5645
mixtureBM:hetENVw                         -6.63     3.906 952  -1.696  0.0901
mixtureBM:hetENVb                          3.76     3.906 952   0.962  0.3364
mixtureBM:hetGENw                         -2.81     3.909 952  -0.719  0.4725
mixtureBM:hetGENb                          4.27     3.906 952   1.094  0.2742
mixtureBM:hetENVw+GENw                    -2.90     3.906 952  -0.741  0.4586
mixtureBM:setupgrowth_chamber             30.32     5.029 952   6.030  0.0000
hetENVw:setupgrowth_chamber                3.20     3.453 952   0.926  0.3546
hetENVb:setupgrowth_chamber                6.28     3.453 952   1.820  0.0691
hetGENw:setupgrowth_chamber              -13.40     3.453 952  -3.879  0.0001
hetGENb:setupgrowth_chamber               -5.39     3.456 952  -1.559  0.1193
hetENVw+GENw:setupgrowth_chamber          -9.29     3.453 952  -2.690  0.0073
mixtureBM:hetENVw:setupgrowth_chamber     20.90     7.020 952   2.977  0.0030
mixtureBM:hetENVb:setupgrowth_chamber     -1.16     7.002 952  -0.166  0.8680
mixtureBM:hetGENw:setupgrowth_chamber     10.70     7.003 952   1.528  0.1267
mixtureBM:hetGENb:setupgrowth_chamber     -4.70     7.020 952  -0.670  0.5032
mixtureBM:hetENVw+GENw:setupgrowth_chamber 15.56    7.026 952   2.215  0.0270

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-2.7957 -0.6881  0.0316  0.8653  2.9818

Number of Observations: 1002
Number of Groups:
           lab block %in% lab
```

```
              14             28
```

Model for teabag litter decomposition (teabag)

```
anova(m12)
                    numDF denDF F-value p-value
(Intercept)             1   924  388.72  <.0001
mixture                 1   924    3.63  0.0570
het                     5   924    0.79  0.5601
setup                   1    12    0.03  0.8578
mixture:het             5   924    2.08  0.0662
mixture:setup           1   924    1.04  0.3092
het:setup               5   924    1.38  0.2279
mixture:het:setup       5   924    1.24  0.2863

summary(m12)
Linear mixed-effects model fit by REML
 Data: repro
    AIC   BIC logLik
  -1547 -1285    828

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:       0.112

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:       0.017   0.0775

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  1.074  1.439  1.400  1.434  1.414  1.124  1.203  1.300  1.011  1.172
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
0.882  3.364  2.152  1.440  1.292  1.635  1.796 1.290  1.323  1.011  0.949
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.189  1.429  0.519  0.538  0.797  0.959


Fixed effects: teabag ~ mixture * het * setup
                                          Value Std.Error  DF t-value p-value
(Intercept)                               0.585    0.047 924   12.32   0.000
mixtureBM                                 0.001    0.016 924    0.07   0.942
hetENVw                                   0.013    0.015 924    0.83   0.407
hetENVb                                   0.018    0.016 924    1.17   0.244
hetGENw                                  -0.019    0.016 924   -1.21   0.226
hetGENb                                   0.015    0.016 924    0.94   0.349
hetENVw+GENw                             -0.002    0.016 924   -0.12   0.901
setupgrowth_chamber                       0.016    0.064  12    0.25   0.804
mixtureBM:hetENVw                         0.021    0.023 924    0.92   0.355
mixtureBM:hetENVb                        -0.032    0.023 924   -1.38   0.168
mixtureBM:hetGENw                         0.026    0.023 924    1.15   0.251
mixtureBM:hetGENb                        -0.015    0.023 924   -0.67   0.502
mixtureBM:hetENVw+GENw                    0.027    0.023 924    1.16   0.244
mixtureBM:setupgrowth_chamber             0.021    0.026 924    0.80   0.422
hetENVw:setupgrowth_chamber              -0.021    0.026 924   -0.77   0.441
hetENVb:setupgrowth_chamber              -0.030    0.027 924   -1.13   0.258
hetGENw:setupgrowth_chamber              -0.001    0.027 924   -0.02   0.984
```

```
hetGENb:setupgrowth_chamber                -0.011    0.026 924   -0.41   0.685
hetENVw+GENw:setupgrowth_chamber           -0.003    0.027 924   -0.11   0.910
mixtureBM:hetENVw:setupgrowth_chamber      -0.027    0.037 924   -0.73   0.464
mixtureBM:hetENVb:setupgrowth_chamber       0.026    0.037 924    0.70   0.487
mixtureBM:hetGENw:setupgrowth_chamber       0.003    0.037 924    0.08   0.935
mixtureBM:hetGENb:setupgrowth_chamber      -0.004    0.037 924   -0.10   0.919
mixtureBM:hetENVw+GENw:setupgrowth_chamber -0.059    0.037 924   -1.58   0.114

Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-2.3845 -0.7307 -0.0867  0.6559  3.6548

Number of Observations: 974
Number of Groups:
           lab block %in% lab
            14             28
```

Model for PC1 (PC1)

```
anova(mpc1)
                  numDF denDF F-value p-value
(Intercept)           1   958    0.74  0.3904
mixture               1   958 1002.71  <.0001
het                   5   958    9.43  <.0001
setup                 1    12    0.00  0.9456
mixture:het           5   958    2.84  0.0150
mixture:setup         1   958    2.31  0.1285
het:setup             5   958   15.65  <.0001
mixture:het:setup     5   958   10.03  <.0001
summary(mpc1)
Linear mixed-effects model fit by REML
 Data: reproz
   AIC  BIC logLik
  2440 2704  -1166

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:        1.22

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:       0.404    0.273

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | lab * mixture
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  2.080  4.275  0.625  2.832  2.355  2.812  2.075  2.121  1.191  5.095
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
2.909  1.649  7.677  2.450  2.589  0.908  3.260 3.604  2.383  2.286  2.172
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
2.583  2.442  2.757  6.640  2.124 19.900

Fixed effects: PC1 ~ mixture * het * setup
                                            Value Std.Error  DF t-value p-valu
e
(Intercept)                                -1.189     0.527 958   -2.25  0.0244
mixtureBM                                   1.740     0.146 958   11.94  0.0000
hetENVw                                    -0.607     0.169 958   -3.60  0.0003
```

```
hetENVb                                    -0.330     0.169 958   -1.95  0.0509
hetGENw                                     0.967     0.169 958    5.73  0.0000
hetGENb                                     0.591     0.169 958    3.51  0.0005
hetENVw+GENw                                0.755     0.169 958    4.48  0.0000
setupgrowth_chamber                         0.096     0.693  12    0.14  0.8922
mixtureBM:hetENVw                           0.577     0.190 958    3.03  0.0025
mixtureBM:hetENVb                           0.240     0.190 958    1.26  0.2072
mixtureBM:hetGENw                          -0.961     0.190 958   -5.05  0.0000
mixtureBM:hetGENb                          -0.612     0.190 958   -3.21  0.0014
mixtureBM:hetENVw+GENw                     -0.585     0.190 958   -3.07  0.0022
mixtureBM:setupgrowth_chamber              -0.348     0.184 958   -1.90  0.0579
hetENVw:setupgrowth_chamber                 0.868     0.190 958    4.56  0.0000
hetENVb:setupgrowth_chamber                 0.478     0.190 958    2.51  0.0122
hetGENw:setupgrowth_chamber                -0.859     0.190 958   -4.51  0.0000
hetGENb:setupgrowth_chamber                -0.522     0.190 958   -2.74  0.0062
hetENVw+GENw:setupgrowth_chamber           -0.419     0.190 958   -2.20  0.0280
mixtureBM:hetENVw:setupgrowth_chamber      -0.440     0.243 958   -1.81  0.0703
mixtureBM:hetENVb:setupgrowth_chamber      -0.348     0.243 958   -1.43  0.1518
mixtureBM:hetGENw:setupgrowth_chamber       0.880     0.243 958    3.63  0.0003
mixtureBM:hetGENb:setupgrowth_chamber       0.597     0.243 958    2.46  0.0142
mixtureBM:hetENVw+GENw:setupgrowth_chamber 0.529     0.243 958    2.18  0.0294


Standardized Within-Group Residuals:
    Min      Q1     Med      Q3     Max
-3.1176 -0.6583  0.0607  0.7984  3.1556

Number of Observations: 1008
Number of Groups:
           lab block %in% lab
            14             28
```

Model for PC2 (PC2)

```
anova(mpc2)
                   numDF denDF F-value p-value
(Intercept)            1   958    0.03  0.8607
mixture                1   958  588.49  <.0001
het                    5   958   28.11  <.0001
setup                  1    12   12.27  0.0044
mixture:het            5   958   10.12  <.0001
mixture:setup          1   958    6.59  0.0104
het:setup              5   958    1.42  0.2141
mixture:het:setup      5   958    1.42  0.2161
summary(mpc2)
Linear mixed-effects model fit by REML
 Data: reproz
   AIC  BIC logLik
  2029 2293   -960

Random effects:
 Formula: ~1 | lab
        (Intercept)
StdDev:       0.816

 Formula: ~1 | block %in% lab
        (Intercept) Residual
StdDev:       0.187    0.324

Variance function:
 Structure: Different standard deviations per stratum
```

```
 Formula: ~1 | lab * mixture
 Parameter estimates:
L1*B  L1*BM   L2*B  L2*BM   L3*B  L3*BM   L4*B  L4*BM   L5*B  L5*BM   L6*B
1.000  0.994  1.800  1.697  1.504  1.574  1.450  1.023  1.456  1.125  4.277
L6*BM   L7*B  L7*BM   L8*B  L8*BM   L9*B  L9*BM L10*B L10*BM  L11*B L11*BM
2.543  1.633  5.074  1.580  1.642  1.149  1.295 2.701  3.178  2.325  1.012
L12*B L12*BM  L13*B L13*BM  L14*B L14*BM
1.927  1.446  3.265  3.265  1.657  2.717

Fixed effects: PC2 ~ mixture * het * setup
                                                Value Std.Error  DF t-value p-valu
e
(Intercept)                                     1.897     0.353 958    5.38  0.0000
mixtureBM                                      -1.443     0.128 958  -11.23  0.0000
hetENVw                                        -0.414     0.144 958   -2.89  0.0040
hetENVb                                        -0.272     0.144 958   -1.89  0.0585
hetGENw                                        -0.789     0.144 958   -5.50  0.0000
hetGENb                                        -0.573     0.144 958   -3.99  0.0001
hetENVw+GENw                                   -0.825     0.144 958   -5.75  0.0000
setupgrowth_chamber                            -1.843     0.463  12   -3.98  0.0018
mixtureBM:hetENVw                               0.531     0.180 958    2.96  0.0032
mixtureBM:hetENVb                               0.393     0.180 958    2.19  0.0291
mixtureBM:hetGENw                               0.748     0.180 958    4.16  0.0000
mixtureBM:hetGENb                               0.596     0.180 958    3.32  0.0009
mixtureBM:hetENVw+GENw                          0.856     0.180 958    4.76  0.0000
mixtureBM:setupgrowth_chamber                   0.529     0.163 958    3.25  0.0012
hetENVw:setupgrowth_chamber                     0.417     0.174 958    2.40  0.0165
hetENVb:setupgrowth_chamber                     0.320     0.174 958    1.84  0.0662
hetGENw:setupgrowth_chamber                     0.088     0.174 958    0.51  0.6114
hetGENb:setupgrowth_chamber                     0.097     0.174 958    0.56  0.5757
hetENVw+GENw:setupgrowth_chamber                0.146     0.174 958    0.84  0.4021
mixtureBM:hetENVw:setupgrowth_chamber          -0.558     0.228 958   -2.45  0.0146
mixtureBM:hetENVb:setupgrowth_chamber          -0.424     0.228 958   -1.86  0.0632
mixtureBM:hetGENw:setupgrowth_chamber          -0.312     0.228 958   -1.37  0.1722
mixtureBM:hetGENb:setupgrowth_chamber          -0.357     0.228 958   -1.57  0.1176
mixtureBM:hetENVw+GENw:setupgrowth_chamber-0.456     0.228 958   -2.00  0.0458


Standardized Within-Group Residuals:
     Min       Q1      Med       Q3      Max
-3.96848 -0.67233 -0.00268  0.67480  3.44045

Number of Observations: 1008
Number of Groups:
           lab block %in% lab
            14             28
```

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