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A trait-based analysis to assess the ability of cover plants to control weeds in a tropical island

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Highlights:

- 46 cover plants species performance were assessed in Reunion Island over three years
- Plant height and leaf appearance rate were traits optimizing ground coverage
- Weed control was similar between pure and mixture of cover plants
- Weed control was more efficient with species or mixture with high coverage, biomass and growth rate in height.

32 **Abstract:**

33 Cover plants have a high potential to manage weeds through competition for shared resources
34 in tropical agrosystems. Assessing the abilities of a large number of different plant species to
35 compete with weeds requires long-term experiments in different pedoclimatic environments.
36 Our study was based on a set of 10 trials including 46 species of cover plants and performed
37 from 2016 to 2018 in three sites in Reunion. Our aim was to identify and measure plant traits
38 that optimize plant coverage and weed control by cover plants under tropical climate. We
39 characterized two traits of interest (a soil coverage efficiency index and a coverage growth rate)
40 using a hierarchical clustering analysis and compared them between plant area of origin, life
41 cycle or growth habit. The ability for cover plant to cover efficiently and rapidly the soil
42 increased with growth rate in height and leaf appearance rate while tends to decrease with
43 thermal time for emergence. Accordingly, weed control efficiency (low weed coverage and dry
44 mass) was strongly correlated and increasing with cover plant growth rate in coverage, height
45 and biomass. The characterization of plant species using functional traits enabled to identify
46 cover plants which could be used in tropical agrosystems as an alternative to herbicides.
47 Assuming that the spatial and temporal combinations with the main crop will determine the
48 performances of the system, we discussed a trait-based methodology to identify the cover plants
49 adapted to sugarcane agrosystems in Reunion.

50 **Keywords:** cover crops; companion crops; green manures; weeds; Reunion; sugarcane

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61 **1. Introduction**

62 Weeds are a main biotic constraint to tropical agriculture (FAO, 2017). Weeds can induce a
63 loss of yields in terms of quality and quantity, as well as increasing the crop production costs
64 (Oerke, 2006; FAO, 2017). Not only, weeds are in competition with main crop for several
65 resources, such as light, water or nutrients (Cordeau and Moreau, 2017), but they are alternative
66 hosts for crop pests and pathogens (FAO, 2017). In most of tropical areas (except for Sudanese
67 and Sahelian climates), weeds grow fast all year thanks to a favorable climate, which may
68 strongly compete with main crop. Therefore, large amounts of chemical inputs, among which
69 herbicides represent a large proportion of the active ingredients, are used (Oerke and Dehne,
70 2004).

71 In tropical agrosystems, the use of cover or companion plants to control weeds can be one of
72 the solutions to help reduce herbicide inputs (e.g. Bhaskar et al., 2018; Mennan et al., 2000;
73 Ranaivoson et al., 2018) before planting (Lu et al., 2000) or during crop growth as intercrop
74 (Vandermeer, 1992). These plants are being increasingly used in innovative cropping systems
75 to favour biological regulation and to deliver agro-ecosystem services such as weed, pest or
76 erosion control (Altieri et al., 2011; Koohafkan et al., 2012; Snapp et al., 2005). Due to the large
77 game of cover plant available, the choice of a plant to deliver these services is crucial because
78 the spatial and temporal combinations with the main crop will determine the performances of
79 the system (Malezieux et al., 2009).

80 The biological regulation mechanisms of weeds using cover plants are complex. They can be
81 direct through competition for resources, allelopathy or a physical barrier to germination and
82 emergence (Médiène et al., 2011; Teasdale et al., 2007), and indirect e.g. through seed predators
83 or fungi responsible for damping-off (Cordeau and Moreau, 2017). In intensive tropical
84 agrosystem, the hypothesis of competition especially for light is mainly put forward in
85 biological regulation. The other resources are seldom limiting for plant growth (high
86 fertilization rates, high rainfall or irrigation). The ability of a plant species to compete for light
87 may result from the ability to access to light for the plant itself (e.g. overgrowth ability) or to
88 reduce access to light by its neighbours (e.g. shading). Assessing the efficiency of the processes
89 of light interception, light conversion, and carbon use may be challenging when studying a large
90 range of cover plants.

91 Trait-based approaches, which originated in the field of comparative functional ecology, have
92 a high potential to identify the most suitable plants and traits to control weeds (e.g. Damour et

93 al., 2016, 2014). These approaches are based on the use of functional traits, i.e. morpho-physio-
94 phenological features, which are measurable at the plant or group of plants level, and which
95 have an impact on plant performances (Violle et al., 2007). Traits can be considered as an
96 indicator of plant-driven processes and make it possible to compare wide ranges of cover crops.
97 Although trait-based approaches have been extensively used in natural ecosystems, applications
98 of these approaches to agrosystems are still currently increasing (Damour et al., 2016, 2014;
99 Garnier and Navas, 2012; Tardy et al., 2015; Tixier et al., 2011).

100 In Reunion, weeds pressure is a main constraint for agriculture. Initiated in 2008 and 2018, the
101 Ecophyto I and II programs aim to reduce the use of herbicides by 50% by 2025 in the French
102 agricultural sector. In the island, sugarcane, the first agro-industrial sector, plays an important
103 economic, societal and environmental role covering more than 50% of agricultural land
104 (Agreste, 2016). One of the main constraints of this crop is weeds: it's the first crop production
105 in Reunion consuming herbicides (Antoir et al., 2016). Indeed, diseases and pests are mainly
106 managed by varietal selection, except the larva of *Hoplochelus marginalis*, controlled by the
107 fungi *Beauveria brongniartii* in biological control (Mouret et al., 2017). In this context, cover
108 plants have a strong potential for the sugarcane sector.

109 The aim of this study was to investigate the trait-based characterization of a large range of cover
110 plants in order to assess their ability to control weeds in tropical agrosystems, using the case
111 study of Reunion. The objectives of this study were to identify among a wide variety of cover
112 plant species, i) the species most suitable for tropical climatic conditions in terms of soil cover,
113 ii) the species traits able to maximize soil cover and iii) to assess the ability of cover plants and
114 traits to control weed growth.

115 To answer these questions, we combined a set of 10 field experiments conducted in Reunion
116 from 2016 to 2018. Six of them were collection management experiments, to assess the cover
117 plants performance in response to local climate (i.e. weeds were controlled manually). In the
118 other four experiments, the ability of cover plants to control weed were assessed.

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123 2. Materials and methods

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125 2.1. Trials description

126 The trials described in this study were located in three experimental stations in Reunion from
127 2016 to 2018 between February and June (warm season and beginning of the cool season). The
128 trials localization and description are detailed in Table 1. Two main types of trials were
129 performed: the collection management trials and the weed control trials. In the collection trials,
130 cover plants were grown without competition with weeds to assess their ability to grow in local
131 climates. A manual weed control was performed after sowing and during the trial duration. Four
132 collection trials were performed in La Mare (50 m asl), one in Bassin Plat (160 m asl) and one
133 in Colimaçons (800 m asl). Each trial included pure cover plant plots of 12 or 16 m². Growth
134 duration of cover plants ranged from 2.5 to 4 months depending on trials. In the weed control
135 trials, no weed control was performed after sowing to assess the competition between cover
136 plants and weeds. Four trials were performed in La Mare and Bassin Plat with plots from 20 to
137 100 m². Grow duration of cover plants was 2 months. In all weed control trials, each plot was
138 associated with an adjacent control plot of natural weed flora. Dominant weed flora presented
139 in these sites are described in Table S4. In all sites, daily average temperature (T_{MEAN}) were
140 measured. Five of the trials were fertilized while the other five were not fertilized. The fertilizer
141 applications are described in Table 1. All trials were irrigated (except for Colimaçons which
142 present precipitation $> 120 \text{ mm month}^{-1}$ during the growth period). Before sowing, a tillage has
143 been carried out and herbicide was applied prior sowing. Seeds were sown manually following
144 lines spaced by 40cm. Seeds density are indicated in Table S2. Sowing density for each species
145 are described in Table S2 and were determined on the basis of bibliography, advice from
146 suppliers and internal expertise.

Table 1. Cover crop collection and weed control trials. The cover crop species used in the different trials are listed in Table S1. For each trial, the site, latitude, longitude, altitude, soil type, year, average temperature (T_{MEAN}), number of species, plot area, sowing date, trial duration, fertilization regime are indicated.

| Trial type | Site | Latitude | Longitude | Altitude | Soil type | Year | T_{MEAN} | Number of species (+ mixture) | Plot area (x repetition) | Sowing date (dd/mm) | Duration | Fertilization (kg ha ⁻¹) | Manual weed control | Trial ID |
|--------------|-------------|----------|-----------|----------|------------------|------|----------------------|-------------------------------|--------------------------|-------------------------|------------|--------------------------------------|---------------------|----------|
| Collection | La Mare | -20.9 | 55.53 | 50 m | Leptic cambisol | 2016 | 23.0 | 33 | 16 m ² (x1) | 30/03 | 3.5 months | NPK (36-82-60) | yes | 1 |
| | | | | | | 2017 | 23.2 | 28 | | 13/04 | 4 months | no | | 2 |
| | | | | | | 2018 | 22.7 | 26 | | 27/04 | 4 months | | | 3 |
| | Bassin Plat | -21.32 | 55.49 | 160 m | Cambisol andique | 2016 | 24.0 | 19 | 16 m ² (x1) | 04/03 | 2.5 months | NPK (36-77-48) | | 4 |
| | Colimaçon | -21.13 | 55.3 | 800 m | Brun andique | 2016 | 20.5 | 18 | 16 m ² (x1) | 16/03 | 2.5 months | | | 5 |
| | La Mare | -20.9 | 55.53 | 50 m | Leptic cambisol | 2018 | 25.7 22.0 23.6 | 16 | 12 m ² (x1) | 20/02 12/04 13/06 | 3 months | no | | 6 |
| Weed control | La Mare | -20.9 | 55.53 | 50 m | Leptic cambisol | 2016 | 24.1 | 6 (+9) | 36 m ² (x1) | 04/04 | 2 months | NPK (30-80-60) | no | 7 |
| | | | | | | 2016 | 24.4 | 8 | 100 m ² (x1) | 31/03 | | | | 8 |
| | | | | | | 2017 | 24.2 | 6 (+6) | 20 m ² (x4) | 13/04 | | | | 9 |
| | Bassin Plat | -21.32 | 55.49 | 160 m | Cambisol andique | 2017 | 25.3 | 4 (+3) | 24 m ² (x4) | 03/03 | no | 10 | | |

147 **2.2. Cover plant species**

148 A total of 46 cover plant species were tested in the different trials. The detail of cover plant
 149 species used in each experiment is presented in Table S1 and S2. These species included
 150 Asteraceae (n=2), Brassicaceae (n=3), Fabaceae (n=32), Poaceae (n=8) and Polygonaceae
 151 (n=1) plants. Among them, we have 21 temperate and 25 tropical species. The majority of
 152 species were annual (n=35) or perennial (n=8), and 1 biennial and 2 vivacious were
 153 characterized. The growth habit (creeping, erected or twining) are detailed in Table S1. Among
 154 weed control trials, 18 cover plant mixtures were also tested (Table 1), the list of mixture are
 155 detailed in Table S3 and included two species each time.

156
 157 **Table 2.** Traits and variables measured in the trials and used in the study. The identification of each
 158 trials (Trial ID) where measurements were made was indicated. 0-1 indicated that the variable values
 159 ranged from 0 to 1.

| | Index | Units | Description | Trial ID |
|--------------|----------|----------------------|---|----------------|
| Plant traits | COVEFF | 0-1 | Coverage efficiency over the growth period | All trial |
| | COVRATE | % d ⁻¹ | Growth rate in coverage per day between sowing and maximum coverage | All trial |
| | HRATE | cm d ⁻¹ | Growth rate in height per day since emergence | 1,2,4,5,6,9,10 |
| | LeafRATE | leaf d ⁻¹ | Leaf appearance rate per day | 1,2,4,5,6,9,10 |
| | EmergSDD | °d | Thermal time for emergence since planting | 1,2,4,5 |
| | FLOSDD | °d | Thermal time for flowering since planting | 1,2,4,5 |
| | ABVDM | kgDM m ⁻² | Aboveground dry mass at the end of the trial | 9,10 |
| Weed control | WCECOV | 0-1 | Weed control efficiency index based on weed coverage | 7,8,9,10 |
| | WCEDM | 0-1 | Weed control efficiency index based on weed dry mass | 9,10 |

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166 2.3. Measurements

167 Cover crop traits and phenology were measured in the different trials (Table 2). Ground
168 coverage by plants was measured in each plot weekly using a visual notation method described
169 in Table S5 and used in previous studies (Mansuy et al., 2019; Mathieu & Marnotte, 2000;
170 Marnotte et al., 1984). This method allows to assess the soil coverage of individual species in
171 multi-species crop (e.g. cover plant and weeds). Between two dates of measurements, coverage
172 (Cov, %) was linearly extrapolated each day. Then, we calculated an index of coverage
173 efficiency (COV_{EFF}) over the growth based on the area under the curve of the daily dynamics of
174 plant coverage:

$$175 \quad Cov_{EFF} = \frac{\sum_1^n Cov(i)}{n * 100\%}$$

176 Where Cov(i) was the plant coverage at day i and n the number of days of growth. The
177 maximum coverage (COV_{MAX}, %) was defined at the maximum over growth. A growth rate in
178 coverage per day (COV_{RATE}, % d⁻¹) was calculated between sowing up to reaching the maximum
179 coverage. Additionally, for each species, the height and number of leaves of 5 individuals per
180 plot were measured weekly and averaged per date. From these measurements, a growth rate in
181 height (H_{RATE}, cm d⁻¹) and a leaf appearance rate (Leaf_{RATE}, n d⁻¹) were calculated from
182 emergence to flowering as the slope between plant height or leaf number and the number of day
183 since planting. Considering phenology measurements, the thermal times for emergence
184 (Emerg_{SDD}, °d) and flowering (Flos_{SDD}, °d) were calculated as the sum of daily T_{MEAN} from
185 sowing to the state were 50% of plant emerged or flowered. Finally, to measure aboveground
186 dry masses (ABV_{DM}) in weed control trials, all weeds and cover plants in three 50x50cm square
187 in each plot were sampled and dried at 60°C over 2 days at the end of the experiment.

188 Additionally to cover plant traits, we assessed two weed control efficiency indices in terms of
189 weed coverage (WCE_{COV}) and biomass (WCE_{DM}) in the weed control trials. Similarly to cover
190 plants, a coverage efficiency index for weed over time (Cov_{Weed}) was calculated in each plot of
191 each trial. Then for each plot with cover plants, we assessed the WCE_{COV} as follows:

$$192 \quad WCE_{COV} = 1 - \frac{Cov_{Weed,cp}}{\langle Cov_{Weed,pure} \rangle}$$

193 With Cov_{Weed,cp} the weed coverage efficiency index in plot with cover plants and $\langle Cov_{Weed,pure} \rangle$
194 the average weed coverage efficiency index in control plots (pure weeds) among each trials.

195 Similarly, the WCE_{DM} was calculated based on final weed dry mass (DM_{Weed}) in control and
196 plot with cover crops:

$$197 \quad WCE_{DM} = 1 - \frac{DM_{Weed,cp}}{\langle DM_{Weed,pure} \rangle}$$

198 With $DM_{Weed,cp}$ the aerial weed dry mass in plot with cover plants and $\langle DM_{Weed,pure} \rangle$ the
199 average aerial weed dry mass in control plots among each trials. In case of mixture (Table S3),
200 an average trait among cover plants was calculated as the mean of trait value per species
201 weighted by the final coverage of each species. All experimental data are available online on
202 CIRAD dataverse (<http://dx.doi.org/10.18167/DVN1/HA0V2G>).

203 **2.4. Data analyses**

204 First a principal component analysis (PCA) was performed on all plant traits in the collection
205 trials to assess if plant behavior was different depending on temperature and fertilization
206 regimes (R package FactoMineR and missMDA). As no effect of fertilization regime and
207 temperature were identified (Fig. S1), we considered all trials as a pool in the following
208 analyses. Secondly, a hierarchical clustering analysis was performed on the average COV_{EFF} and
209 COV_{RATE} of cover plants in the collection management trials, to assess species ability to cover
210 the soil and create clusters of similar behavior (R package FactoMineR). Comparison of mean
211 between clusters of type of plants were tested using the non-parametric Dunn test (R package
212 dunn.test). Finally, correlation between individual traits were assess with a Spearman
213 correlation (ρ_{SPEAR} , R package Hmisc and corrplot). For visual purpose, polynomial smooth
214 regressions were added in the figures using the loess R function. All data analyses were
215 performed with R 3.4 (R Development Core Team, 2017).

216

217 **3. Results:**

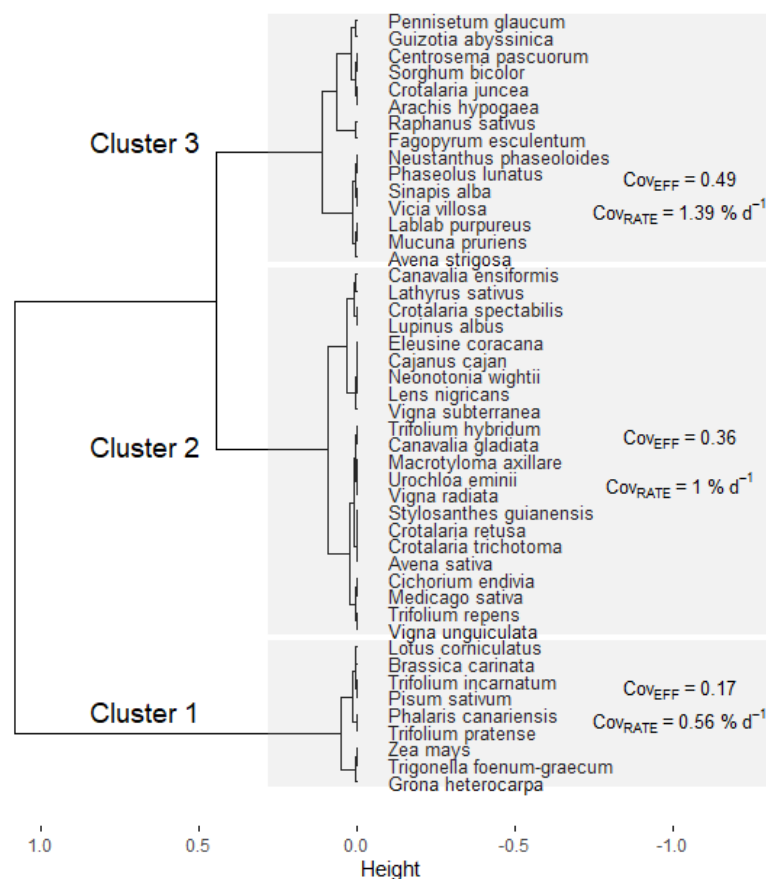
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219 **3.1. Coverage dynamics in the collection trials**

220 Based on a PCA performed on plant traits in the different trials, no effects of fertilisation regime
221 or average temperature during growth were found (Fig. S1). To compare plant species, a
222 hierarchical clustering on plant coverage efficiency (COV_{EFF}) and the coverage rate (COV_{RATE})
223 allowed to separate three clusters of cover plants (Fig. 1). They described a gradient of cover

224 plant potential in terms of coverage. Average Cov_{EFF} were 0.18, 0.36 and 0.49 in the clusters 1,
 225 2 and 3 respectively and average Cov_{RATE} were 0.56, 1.00 and 1.39 % d^{-1} in the clusters 1, 2
 226 and 3, respectively (Table 3). The details of species composition of each cluster were given in
 227 Fig. 1.

228 Cov_{EFF} and Cov_{RATE} were similar among temperate and tropical species (Fig. 2a,b).
 229 Additionally, annual species showed a higher Cov_{RATE} than perennial species by 10% (Fig. 2d),
 230 while Cov_{EFF} was similarly whatever plant life cycle (Fig. 2c). Depending of species family,
 231 the Fabaceae showed lower Cov_{RATE} than Asteraceae by 30%, while no difference in Cov_{EFF}
 232 was found among species family (Fig. 2c,g). Considering the shape of plant, the twining species
 233 showed the highest Cov_{EFF} , in comparison to erected and creeping species (Fig. 2e). Cov_{RATE}
 234 was similar among growth habit (1.15 % d^{-1}) in average, except than twining plants showed a
 235 higher Cov_{RATE} than creeping plants by 30% (Fig. 2h).



236
 237 **Fig. 1.** Hierarchical clustering analysis on plant coverage efficiency (Cov_{EFF} , %) and coverage rate
 238 (Cov_{RATE} , % d^{-1}) per cover plant species used in the 6 collection trials described in Table 1. Three clusters
 239 were defined and the average Cov_{EFF} and Cov_{RATE} per cluster is indicated.

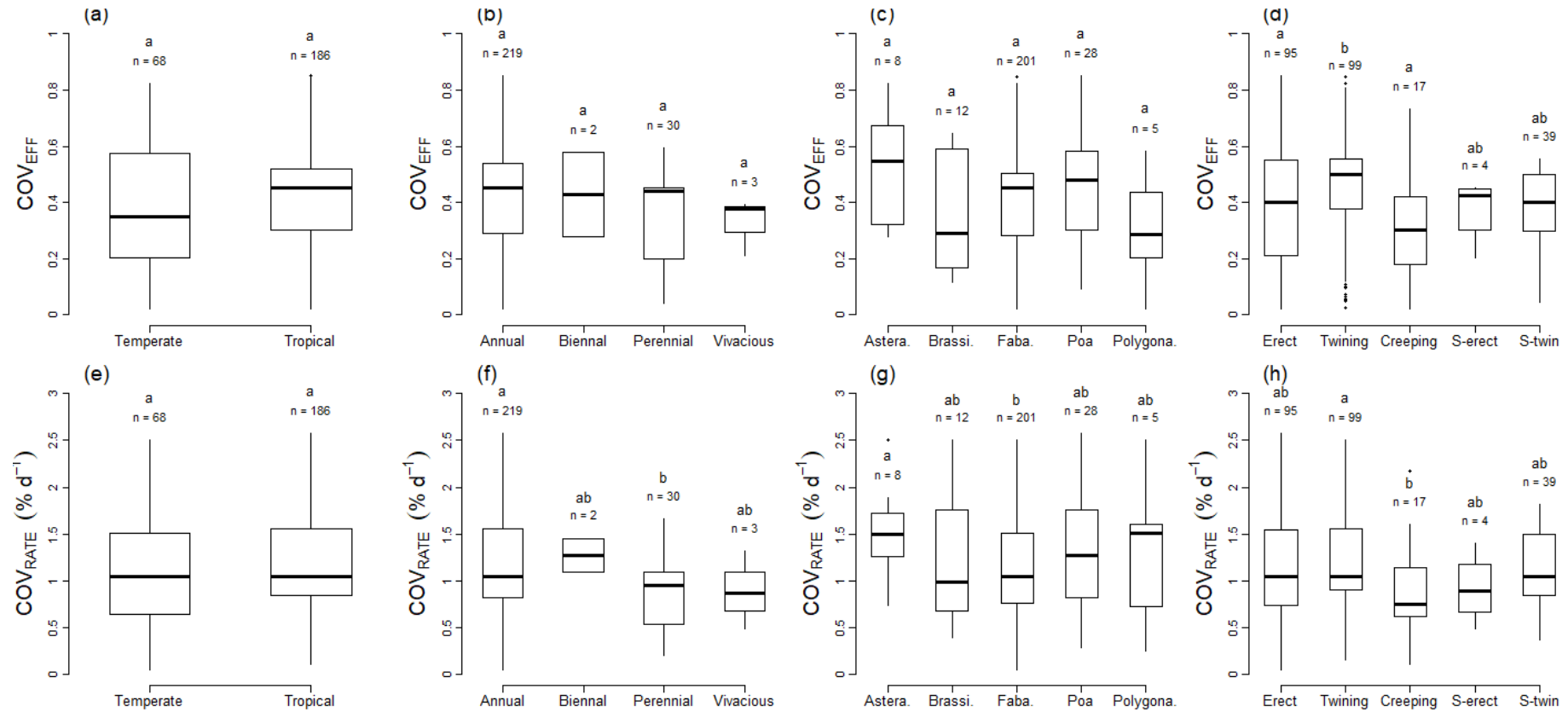


Fig. 2. Coverage efficiency (COV_{EFF}) and coverage rate (COV_{RATE}) of cover plant species used in the collection trials depending on area of origin (a,e), life cycle (b,f), species family (c,g) and growth habit (d,h). Plant families were abbreviated for Asteraceae (Astera.), Brassicaceae (Brassic.), Fabaceae (Faba.), Poaceae (Poa.) and Polygonaceae (Polygona.). Growth habits were abbreviated for erected (Erect), semi-erected (S-erect) and semi-twining (S-twin) plants. The differences between factors were tested using a Dunn test and indicated by letters a and b. The number of sample within each category is indicated by “n”.

239 3.2. Correlation between plant traits and coverage

240 At the cluster level, the two clusters with the highest coverage efficiency and coverage rate
 241 (clusters 2 and 3) also showed the highest growth rate in height with 0.78 cm d^{-1} in average
 242 (Table 3). $\text{Leaf}_{\text{RATE}}$ was higher by 18% in the cluster 3 than in the cluster 2. Considering thermal
 243 time for emergence and flowering, no difference among cluster were found. The average
 244 $\text{Emerg}_{\text{SDD}}$ and Flo_{SDD} were 170 and $1420 \text{ }^\circ\text{d}$, respectively.

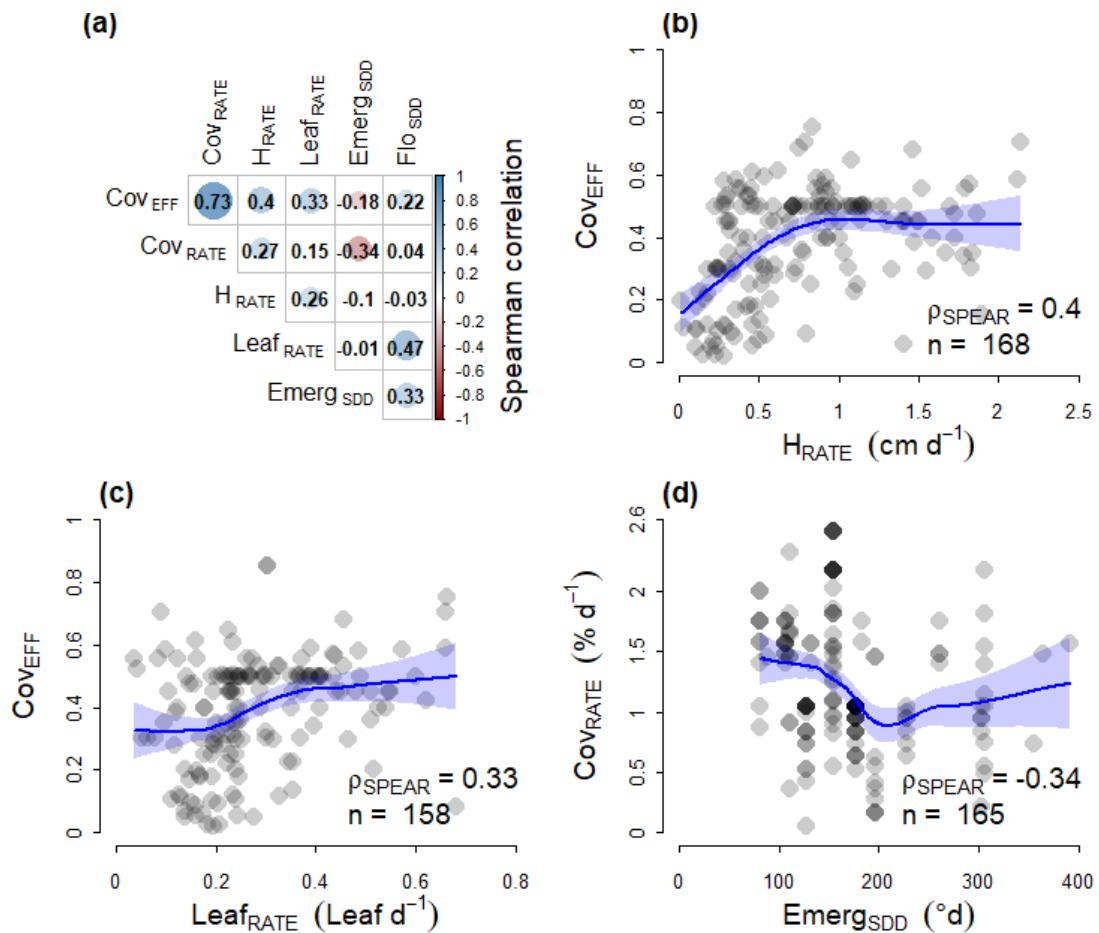
245 At the species levels (Fig. 3), correlations were found between the two indices of coverage
 246 performance Cov_{EFF} and Cov_{RATE} ($\rho_{\text{SPEAR}}=0.73$; $p<0.001$). Additional correlations were found
 247 between coverage performance and other plant traits. On one hand, Cov_{EFF} was positively
 248 correlated with H_{RATE} , $\text{Leaf}_{\text{RATE}}$ and Flo_{SDD} and negatively correlated with $\text{Emerg}_{\text{SDD}}$ (Fig.
 249 3b,c). On the other hand, Cov_{RATE} was positively correlated with H_{RATE} and negatively with
 250 $\text{Emerg}_{\text{SDD}}$ (Fig. 3d). In particular, Cov_{EFF} reached its maximum values for H_{RATE} higher than
 251 0.8 cm d^{-1} (Fig 3b). Cov_{EFF} slightly increased with $\text{Leaf}_{\text{RATE}}$ and reached maximum values for
 252 $\text{Leaf}_{\text{RATE}}$ higher than 0.4 leaf d^{-1} (Fig 3c). Highest Cov_{RATE} were also found for $\text{Emerg}_{\text{SDD}}$ lower
 253 than $150 \text{ }^\circ\text{d}$ (Fig. 3d). Moreover, additional significant correlations between plant traits were
 254 found (Fig. 3a). Flo_{SDD} was highly correlated with $\text{Leaf}_{\text{RATE}}$ ($\rho_{\text{SPEAR}} = 0.47$) and less with
 255 $\text{Emerg}_{\text{SDD}}$ ($\rho_{\text{SPEAR}} = 0.33$). $\text{Leaf}_{\text{RATE}}$ and H_{RATE} were also slightly correlated ($\rho_{\text{SPEAR}} = 0.26$)

256

257 **Table 3.** Coverage efficiency (Cov_{EFF}), growth rate in coverage (Cov_{RATE}), height (H_{RATE}), leaf appearance
 258 rate ($\text{Leaf}_{\text{RATE}}$), thermal time for flowering (Flo_{SDD}) and emergence ($\text{Emerg}_{\text{SDD}}$) depending of the species
 259 cluster obtained in Fig 1. The differences between clusters were tested using a Dunn test and indicated
 260 by letters a,b,c when p value < 0.025. The number of sample within each group is indicated by “n”.

| Species cluster | Cov_{EFF} (0-1) | Cov_{RATE} (% d^{-1}) | H_{RATE} (cm d^{-1}) | $\text{Leaf}_{\text{RATE}}$ (leaf d^{-1}) | Flo_{SDD} ($^\circ\text{d}$) | $\text{Emerg}_{\text{SDD}}$ ($^\circ\text{d}$) |
|-----------------|------------------------------------|--|--|---|---|---|
| Cluster 1 | 0.18 ± 0.13 a (n=14) | 0.56 ± 0.33 a (n=14) | 0.29 ± 0.21 a (n=7) | 0.37 ± 0.27 ab (n=7) | 1163 ± 14 a (n=2) | 191 ± 79 a (n=4) |
| Cluster 2 | 0.36 ± 0.17 b (n=125) | 1.00 ± 0.45 b (n=125) | 0.73 ± 0.43 b (n=86) | 0.33 ± 0.34 a (n=85) | 1497 ± 433 a (n=71) | 176 ± 68 a (n=86) |
| Cluster 3 | 0.49 ± 0.19 c (n=115) | 1.39 ± 0.57 c (n=115) | 1.02 ± 0.93 b (n=80) | 0.39 ± 0.33 b (n=80) | 1353 ± 393 a (n=63) | 162 ± 57 a (n=75) |

261



262

263 **Fig 3.** Spearman correlation (ρ_{SPEAR}) between cover plant traits in the collection trials (a). Significant
 264 positive and negative correlations were presented with blue and red circle, respectively. Relation
 265 between coverage efficiency (Cov_{EFF}) and height growth rate (H_{RATE}) and leaf appearance rate (Leaf_{RATE})
 266 are detailed in (b) and (c). Relation between coverage rate (Cov_{RATE}) and thermal time for emergence
 267 (Emerg_{SDD}) is presented in (d). In each case, the number of sample is indicated (n) and a smooth
 268 regression were added using a polynomial smooth regression (blue line) with standard deviation (light
 269 blue).

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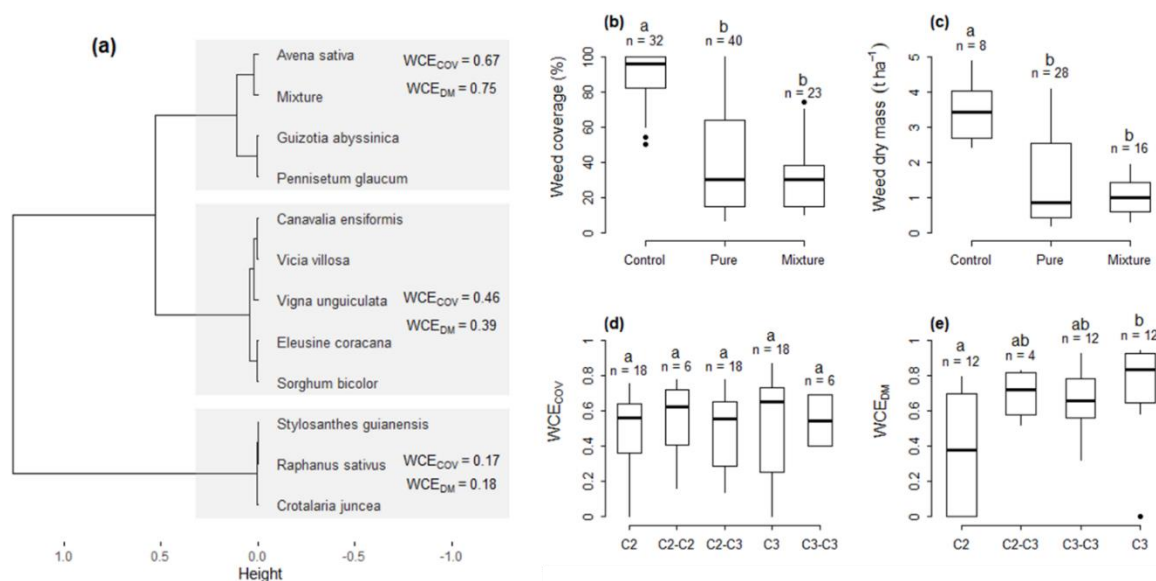
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3.3. Weed control and pure vs mixture cover plants

277 Weed control was assessed through the calculation of two weed control efficiency indices based
 278 on weed coverage (WCE_{COV}) and dry mass (WCE_{DM}). In average, cover plants in pure and
 279 mixture stands both successfully controlled weeds. Plots with cover plants showed lower weed
 280 coverage and weed dry mass by 69% and 74%, respectively (Fig 4b,c). Nevertheless, the
 281 variability of weed control was much lower in mixture ($sd = 17.7\%$ and 0.5 t ha^{-1}) than in pure
 282 stand ($sd = 29.4\%$ and 1.2 t ha^{-1} for coverage and dry mass, respectively). Only species of cluster
 283 2 and 3 were tested in the weed control trials and both clusters showed a similar WCE_{COV} (0.5)
 284 over the experiment, even in mixture (Fig. 4d). However, average WCE_{DM} was higher by 119%
 285 in plots with cluster 3 species that in plots and with cluster 2 (Fig 4e). The mixture of cluster 2
 286 and cluster 3 species showed an intermediate WCE_{DM} . The clustering analysis on average
 287 WCE_{COV} and WCE_{DM} (Fig. 4a) showed that the plant with highest weed control were mixture,
 288 *Avena sativa*, *Guizotia abyssinica* and *Pennisetum glaucum*. On the contrary, *Stylosanthes*
 289 *guianensis*, *Raphanus sativus* and *Crotalaria juncea* failed to control weed. Other species (Fig.
 290 4a) presented intermediate weed control efficiency.



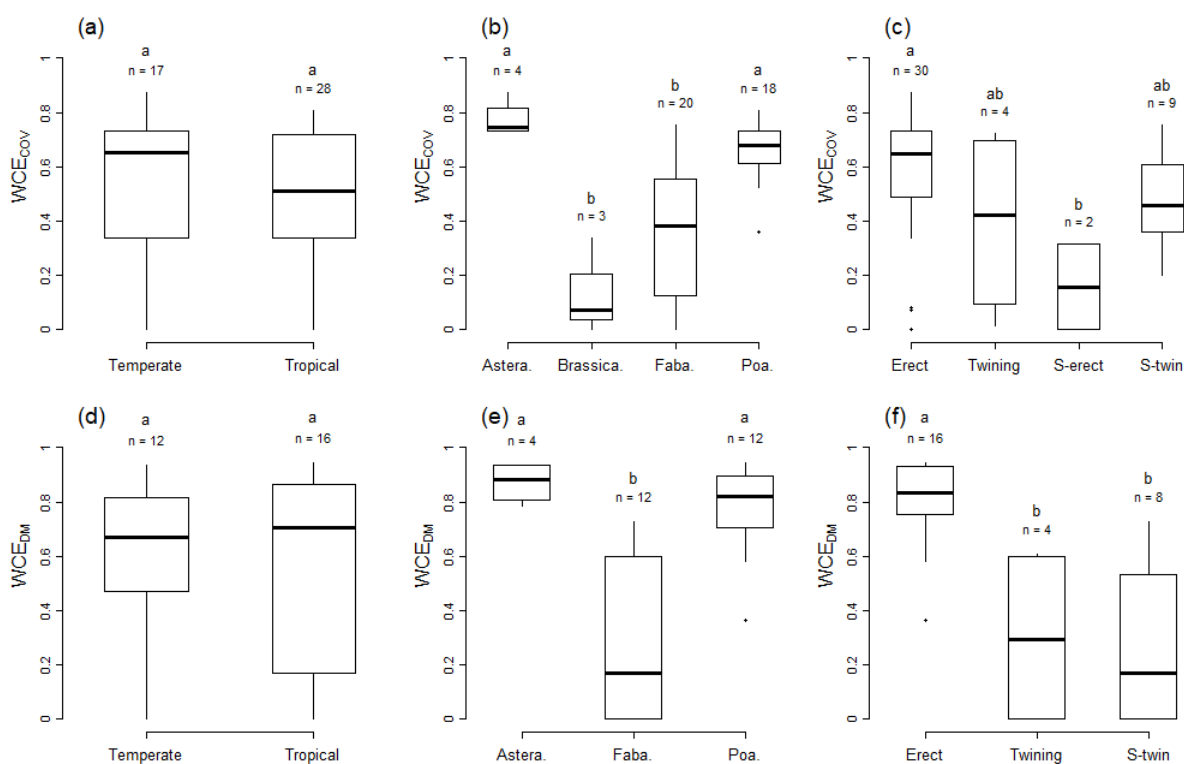
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292 **Fig. 4.** Hierarchical clustering analysis on weed control efficiency in terms of weed coverage (WCE_{COV})
 293 and dry mass (WCE_{DM}) per cover plant species or mixture used in the weed control trials (a). Change in
 294 WCE_{COV} and WCE_{DM} are presented depending on type of plot (control, pure or mixture of cover plants,
 295 b,c) and plant clusters defined in Fig1 (d,e). Mixture of plants from the same cluster are indicated by
 296 'C2-C2' and 'C3-C3' while a mixture with plants from clusters 2 and 3 is indicated by 'C2-C3'. The
 297 difference between factors were tested using a Dunn test and indicated by letters a,b. The number of
 298 sample within each category is indicated by "n".

299 **3.4. Weed control and plant traits**

300 Among these species, the highest WCE_{COV} and WCE_{DM} were found for Asteraceae and Poaceae
 301 species ($WCE_{COV} = 0.69$ and $WCE_{DM} = 0.83$), while weed control remained low for Fabaceae
 302 species ($WCE_{COV} = 0.38$ and $WCE_{DM} = 0.17$, Fig. 5b,e). Twining (and to a lesser extent semi-
 303 twining) species showed a lower weed control than erected species (Fig. 5 c,d). WCE_{COV} and
 304 WCE_{DM} were lower by 35% and 65% for twining species compared to erected species. The area
 305 of origin (temperate or tropical) had no impact on WCE_{COV} and WCE_{DM} (Fig. 5a,d).

306



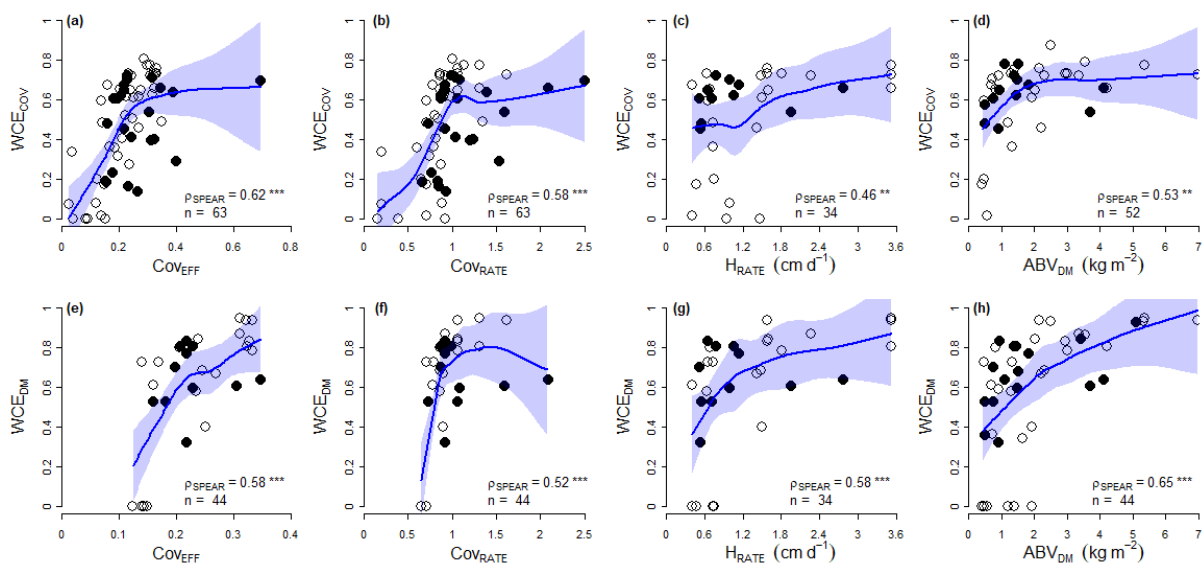
307

308 **Fig. 5.** Weed control efficiency based on weed coverage (WCE_{COV}) or dry mass (WCE_{DM}) depending on
 309 area of origin (a,d), species family (b,e) and growth habit (c,f). Only pure crop plots from the weed
 310 control trials are represented. Species family were abbreviated for Asteraceae (Asteraceae), Brassicaceae
 311 (Brassicaceae), Fabaceae (Fabaceae) and Poaceae (Poaceae). Growth habits were abbreviated for erected (Erect),
 312 semi-erected (S-erect) and semi-twining (S-twin) plants. The difference between factors were tested
 313 using a dunn test and indicated by letters a and b. The number of sample within each category is
 314 indicated by "n".

315

316 In terms of traits, WCE_{COV} and WCE_{DM} were positively correlated with coverage performance
 317 (COV_{EFF} and COV_{RATE}) but also with two plant traits (Fig. 6): H_{RATE} and plant dry mass
 318 (ABV_{DM}). In each correlation, WCE_{COV} reached its maximum values for $COV_{EFF} > 0.3$, COV_{RATE}
 319 $> 1\% d^{-1}$, $H_{RATE} > 1.8\text{ cm d}^{-1}$ and $ABV_{DM} > 2\text{ kg m}^{-2}$. WCE_{DM} had a similar response to plant
 320 traits. Correlation between weed coverage efficiency and leaf appearance rate was also tested
 321 but no significant correlations were found: spearman correlations were equal to -0.32 ($p=0.07$,
 322 $n=34$) and -0.17 ($p=0.37$, $n=34$) for WCE_{COV} and WCE_{DM} , respectively.

323



324

325 **Fig. 6.** Change in weed control efficiency based on weed coverage (WCE_{COV}) and dry mass (WCE_{DM})
 326 depending on cover plant traits: coverage efficiency (COV_{EFF} , a,e), growth rate in coverage (COV_{RATE} , b,c),
 327 growth rate in height (H_{RATE} , e,g) and aerial dry mass (ABV_{DM} , d,h). The number of sample (n) and the
 328 spearman correlation coefficient (ρ_{SPEAR}) were indicated. Polynomial smooth regression between weed
 329 coverage and plant traits were added (blue line) with standard deviation (light blue). Pure and mixture
 330 cover plant were indicated by white and black points, respectively.

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336 4. Discussions

337 4.1. Cover plant performance and weed control

338 The increasing interest of producers and researchers in cover plants might have been
339 encouraged by the many positive aspects which are attributed to cover cropping. In particular,
340 cover plants provide direct weed control during their establishment by competing with weeds
341 for light, water, nutrients and space (Blanco-Cadi et al., 2015), as well as releasing
342 allelochemical compounds into the environment (Gfeller et al., 2018). Additionally, cover plant
343 residues retained on the soil surface can directly limit germination and growth of weeds in the
344 following cash crop (Mirsky et al. 2011; Ryan et al. 2011; Teasdale and Mirsky 2015). Most
345 importantly, they can help prevent the buildup of weed plant populations and therefore reduce
346 future weed pressure.

347 In intensive tropical agrosystem, the hypothesis of competition especially for light is mainly
348 put forward in weed regulation as the other resources are seldom limiting for plant growth (high
349 fertilization rates, high rainfall or irrigation). As a sequence, we choose to focus in this study
350 on the coverage growth rate ($COVRATE$) to identify species with early canopy closure and the
351 coverage efficiency over time ($COVEFF$) to optimize ground cover over many months. Our results
352 highlight how weed control by cover plant was improved with species with high coverage rate
353 at the beginning of the growth and high coverage efficiency over time. Such observations
354 confirm previous conclusion that species with early canopy closure generally show better weed
355 suppression (Baraibar et al., 2018; Hayden et al., 2012). Additionally, in our study, cover plant
356 with higher biomass also showed higher weed control, highlighting the role of competition for
357 resources. High biomass production can increase the effect of competition (den Hollander et
358 al., 2007; Tobin et al., 2012) and many studies highlighted this relation between cover plants
359 biomass and weed control (e.g. Bhaskar et al., 2018; Florence et al., 2019; Osipitan et al., 2019;
360 Schappert et al, 2019). Nevertheless, cover plant biomass is not always a good predictor of
361 weed control (Baraibar et al., 2018; Kunz et al., 2016) which make some authors like Dorn et
362 al. (2015) suggesting that rapid plant development after sowing is more important than the final
363 biomass.

364 Some studies suggest that increased cover crop diversity results in greater weed suppression
365 (Akemo et al. 2000; Brennan and Smith 2005; Lawson et al. 2015), while others are more
366 nuanced (Baraibar et al., 2018; Finney et al., 2016; Schappert et al., 2019; Smith et al., 2014).
367 In our study, weed control efficiency was similar between pure and mixture cover plants

368 species. Nevertheless, while mixtures were always efficient, the variability of weed control by
369 pure cover plants was very large. In particular, stands of single cover plant species might not
370 be able to buffer rapidly changing environmental conditions. Therefore, many studies have
371 investigated the adaptability of mixtures (Hajjar et al., 2008; Tilman et al., 2001). In average,
372 mixtures are not as effective as the best performing single sown cover plants in the literature.
373 Nevertheless, species combinations increased resilience against weather conditions, an
374 advantage to achieving efficient weed control over a long-term period.

375 In the objectives of identifying cover plant species adapted to new environment, assessing the
376 efficiency of weed control may be challenging when studying a large range of cover plants and
377 mixtures, particularly due to the variability of plant performance with soil and climate
378 variability. In addition, plant traits could be considered as indicators of plant-driven processes
379 and make it possible to compare wide ranges of cover crops.

380

381 **4.2. Plant traits and weed control**

382 Trait-based approaches have a high potential to identify the most suitable plants and traits to
383 control weeds (e.g. Damour et al., 2016, 2014). These approaches are based on the use of
384 functional traits, i.e. morpho-physio-phenological features, which are measurable at the plant
385 or group of plants level, and which have an impact on plant performances (Violle et al., 2007).
386 Compared to the range of trait values measured in wild species worldwide in the TRY database
387 (Kattge et al., 2011), measurements of cover plant traits are still limited (Damour et al., 2016,
388 2014; Garnier and Navas, 2012; Tardy et al., 2015; Tixier et al., 2011).

389 Plants which invest carbohydrates in a support structure to grow in height are erected plant
390 species in our study. By re-using the terminology of Tardy et al. (2015), these species have a
391 “shading” competition strategy, with no physical action on neighbours. Their ability to develop
392 support structures in height allows them to be in the top layers of the canopy, and therefore to
393 increase access to light and to shade neighbouring plants. On the contrary, plants which invest
394 in leaf production with rapid growth can be either creeping or twining species. They have an
395 “obstruction” competition strategy conferred by their ability to cover the soil and to avoid the
396 germination and the emergence of weeds. When they are twining species, they also can smother
397 weeds but also the main crop (Teasdale 1996).

398 While all species with high coverage and biomass succeeded in controlling weeds, our results
399 highlight how the ‘shading’ strategy appeared more efficient than the ‘obstruction’ strategy in
400 our tropical conditions. The positive correlation between height and plant coverage was also
401 observed in previous studies in tropical conditions (Tardy et al., 2015). In temperate conditions,
402 it was also observed that tall grasses (Poaceae) like cereals are highly weed suppressive due to
403 their rapid growth rate (Brennan and Smith, 2005; Dorn et al., 2015; Finney et al., 2015; Hayden
404 et al., 2012). Previous studies highlighted how Poaceae were often more efficient to control
405 weeds than Fabaceae legume species (Baraibar et al., 2018; Brainard et al., 2011; Ofori and
406 Stern, 1987), similarly to our results. Nevertheless, soil cover by Poaceae and Fabaceae species
407 were similar in our study, suggesting additional mechanisms involved in weed control. The low
408 weed control by Poacea could be explained a low competitiveness for soil resources. Legumes
409 are known to have less developed roots than grasses. Previous studies have shown that the speed
410 of progression of deep roots as well as root density are lower in legumes than in cereals (Corre-
411 Hellou et al., 2007; Greenwood et al., 1982; Thorup-Kristensen, 2001).

412

413 **4.3. Trait-based selection in Reunion**

414 While the use of species with shading competition strategies could be very efficient to control
415 weeds in crop rotations (Liebman and Dyck, 1993), their ability to be in the top layer in the
416 canopy could have detrimental effects on main crop yield in crop mixtures. In that second case,
417 it is necessary to find a trade-off between the ability of the cover plant to compete with weeds
418 for light and their impact on main crop.

419 In Reunion, sugarcane plantations represent more than 50% of agricultural land (Agreste, 2016)
420 and one of the main constraints of this crop is weeds management. As an alternative to
421 herbicides, the use of cover plants is currently investigated in both rotation and intercropping
422 (Christina et al., 2018; Mansuy et al., 2019). As a semi-perennial crop, sugarcane is planted
423 every seven years in average. The use of erected species with high coverage and biomass, like
424 *Pennisetum glaucum* or *Guizotia abyssinica* are particularly adapted to the short periods (3-4
425 months) before replanting. Depending on sowing season, *Avena sativa* has also shown high
426 weed control in this study.

427 Moreover, to reduce quantitatively the use of herbicide, sugarcane intercropping with cover
428 plants is worthy investigating because rotation only occurs once seven years. Despite being

429 considered a giant grass, sugarcane have a relatively slow growth rate the first three months
430 after harvest, which make it sensitive to competition with weeds (Marion and Marnotte, 1992).
431 To avoid competition, the choice should more focus on particular creeping or twining species
432 which still showed high competition with weeds. In our study, *Vigna unguiculata* and
433 *Canavalia ensiformis* have shown relatively high coverage and efficient weed control, despite
434 having low growth rate in height. Such Fabaceae species have also the advantage to fix nitrogen
435 from the atmosphere to deliver it to the main crop when it decomposes. Moreover, despite being
436 semi-twining species, lianas were not observed in our climatic conditions for these two species.

437 The use of cover plants in rotation or intercropping with sugarcane is an increasing practices
438 worldwide (Soares et al., 2017 in Brazil; Ali et al., 2018 and Teshome et al., 2015 in Africa;
439 Paungfoo-Lonhienne et al., 2017 in Australia; Hemwong et al., 2009 in Asia). As cover plant
440 performance will strongly vary with climatic conditions, the species selection performed in this
441 study will only be valid in similar climatic areas. Nevertheless, the selection of traits that
442 improve weed control should not depend on local climatic variability, highlighting the high
443 potential of trait-based approaches to identify the most suitable plants and traits to control
444 weeds.

445

446 **5. Conclusion**

447 Our study aimed to identify cover plant species and traits which optimize ground coverage and
448 weed control in tropical agrosystems, based on a set of ten trials performed in Reunion Island.
449 Little differences were found in terms of ground coverage depending on the life cycle, the
450 species family. Nevertheless, the ability for cover plant to cover efficiently and rapidly the soil
451 increased with growth rate in height or leaf appearance rate while tended to decrease with
452 thermal time for emergence. While no difference of weed control were observed between pure
453 and mixture of cover plants, weed control was more efficient with species or mixture with high
454 growth rate in height or high aboveground biomass. Based on a trait-selection, we aimed to
455 identify adapted to crop rotation or intercropping in the case of sugarcane plantations in
456 Reunion, as an alternative to herbicides. While trait-based selection of cover plants appeared
457 promising, weed traits will also influence plant-weed interactions. Consequently, future
458 researches should focus on weed traits and their link with the harmfulness of natural flora.

459

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467

468 **References**

- 469 Agreste, 2016. Réunion : enquête pratiques culturales canne – Le désherbage de la canne à sucre (No. 101). Daaf.
- 470 Akemo, M.C., Regnier, E.E., Bennett, M.A., 2000. Weed Suppression in Spring-Sown Rye (*Secale cereale*): Pea
471 (*Pisum sativum*) Cover Crop Mixes. *Weed Technology* 14, 545–549.
- 472 Ali, M.A., Abd El-Lattie, E.A., Gad, A.A., Mekky, M.S., 2018. Study Impact of Integration Between Cover Crop
473 and Weed Control Treatments on Weeds and Improved Sugarcane Productivity. *Assiut Journal of Agricultural
474 Sciences* 49, 32–43. <https://doi.org/10.21608/ajas.2018.26821>
- 475 Altieri, M.A., Lana, M.A., Bittencourt, H.V., Kieling, A.S., Comin, J.J., Lovato, P.E., 2011. Enhancing Crop
476 Productivity via Weed Suppression in Organic No-Till Cropping Systems in Santa Catarina, Brazil. *Journal of
477 Sustainable Agriculture* 35, 855–869. <https://doi.org/10.1080/10440046.2011.588998>
- 478 Antoir, J., Goebel, F.R., Le Bellec, F., Esther, J.J., Maillary, L., Mansuy, A., Marion, D., Marnotte, P., Martin, J.,
479 Rossolin, G., Vincenot, D., 2016. Les bonnes pratiques de désherbage de la canne à sucre – Ile de La Réunion
480 2016. à sucre – Ile de La Réunion 2016. C.
- 481 Baraibar, B., Hunter, M.C., Schipanski, M.E., Hamilton, A., Mortensen, D.A., 2018. Weed Suppression in Cover
482 Crop Monocultures and Mixtures. *Weed Science* 66, 121–133. <https://doi.org/10.1017/wsc.2017.59>
- 483 Bhaskar, V., Bellinder, R.R., DiTommaso, A., Walter, M.F., 2018. Living mulch performance in a tropical cotton
484 system and impact on yield and weed control. *Agriculture (Switzerland)* 8, 1–17.
485 <https://doi.org/10.3390/agriculture8020019>
- 486 Blanco- Canqui, H., Shaver, T.M., Lindquist, J.L., Shapiro, C.A., Elmore, R.W., Francis, C.A., Hergert, G.W.,
487 2015. Cover Crops and Ecosystem Services: Insights from Studies in Temperate Soils. *Agronomy Journal* 107,
488 2449–2474. <https://doi.org/10.2134/agronj15.0086>
- 489 Brainard, D.C., Bellinder, R.R., Kumar, V., 2011. Grass–Legume Mixtures and Soil Fertility Affect Cover Crop
490 Performance and Weed Seed Production. *Weed Technology* 25, 473–479. [https://doi.org/10.1614/WT-D-10-
00134.1](https://doi.org/10.1614/WT-D-10-
491 00134.1)
- 492 Brennan, E.B., Smith, R.F., 2005. Winter Cover Crop Growth and Weed Suppression on the Central Coast of
493 California. *wee* 19, 1017–1024. <https://doi.org/10.1614/WT-04-246R1.1>
- 494 Christina, M., Marnotte, P., Renaud, B., Marin, Y., Courtois, J., Virama, M., Chabanne, A., 2018. Crop cover
495 selection to improve weed control in multi-species agrosystems in Reunion Island. Presented at the 18th European
496 Weed Research Society Symposium: New approaches for smarter weed management, Agricultural Institute of
497 Slovenia, Ljubljana, Slovenia.
- 498 Cordeau, S., Moreau, D., 2017. Gestion des adventices au moyen des cultures intermédiaires multi-services:
499 potentiels et limites. *Innovations Agronomiques* 62, 1–14.
- 500 Corre-Hellou, G., Brisson, N., Launay, M., Fustec, J., Crozat, Y. 2007. Effect of root depth penetration on soil
501 nitrogen competitive interactions and dry matter production in pea– barley intercrops given different soil nitrogen
502 supplies. *Field Crops Research*, 103:76- 85.

503 Damour, G., Dorel, M., Quoc, H.T., Meynard, C., Risède, J.M., 2014. A trait-based characterization of cover plants
504 to assess their potential to provide a set of ecological services in banana cropping systems. *European Journal of*
505 *Agronomy* 52, 218–228. <https://doi.org/10.1016/j.eja.2013.09.004>

506 Damour, G., Guérin, C., Dorel, M., 2016. Leaf area development strategies of cover plants used in banana
507 plantations identified from a set of plant traits. *European Journal of Agronomy* 74, 103–111.
508 <https://doi.org/10.1016/j.eja.2015.12.007>

509 den Hollander, N.G., Bastiaans, L., Kropff, M.J., 2007. Clover as a cover crop for weed suppression in an
510 intercropping design: II. Competitive ability of several clover species. *European Journal of Agronomy* 26, 104–
511 112. <https://doi.org/10.1016/j.eja.2006.08.005>

512 Dorn, B., Jossi, W., Heijden, M.G.A. van der, 2015. Weed suppression by cover crops: comparative on-farm
513 experiments under integrated and organic conservation tillage. *Weed Research* 55, 586–597.
514 <https://doi.org/10.1111/wre.12175>

515 FAO, 2017. Plant Production and Protection Division Integrated Weed Management [WWW Document]. fao.org.
516 URL [http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-](http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-ecosystems/integrated-weed-management/en/)
517 [ecosystems/integrated-weed-management/en/](http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-ecosystems/integrated-weed-management/en/) (accessed 5.18.20).

518 Finney, D.M., White, C.M., Kaye, J.P., 2016. Biomass Production and Carbon/Nitrogen Ratio Influence
519 Ecosystem Services from Cover Crop Mixtures. *Agronomy Journal* 108, 39–52.
520 <https://doi.org/10.2134/agronj15.0182>

521 Florence, A.M., Higley, L.G., Drijber, R.A., Francis, C.A., Lindquist, J.L., 2019. Cover crop mixture diversity,
522 biomass productivity, weed suppression, and stability. *PLoS ONE* 14, 1–18.
523 <https://doi.org/10.1371/journal.pone.0206195>

524 Garnier, E., Navas, M.-L., 2012. A trait-based approach to comparative functional plant ecology: concepts,
525 methods and applications for agroecology. A review | SpringerLink. *Agronomy for Sustainable Development* 32,
526 365:399. <https://doi.org/10.1007/s13593-011-0036-y>

527 Gfeller, A., Herrera, J.M., Tschuy, F., Wirth, J., 2018. Explanations for *Amaranthus retroflexus* growth
528 suppression by cover crops. *Crop Protection* 104, 11–20. <https://doi.org/10.1016/j.cropro.2017.10.006>

529 Greenwood, DJ, Gerwitz, A, Stone, DA, Barnes, A. 1982. Root development of vegetable crops. *Plant and Soil*,
530 68:75-96.

531 Hajjar, R., Jarvis, D.I., Gemmill-Herren, B., 2008. The utility of crop genetic diversity in maintaining ecosystem
532 services. *Agriculture, Ecosystems & Environment* 123, 261–270. <https://doi.org/10.1016/j.agee.2007.08.003>

533 Hayden, Z.D., Brainard, D.C., Henshaw, B., Ngouajio, M., 2012. Winter Annual Weed Suppression in Rye–Vetch
534 Cover Crop Mixtures. *Weed Technology* 26, 818–825. <https://doi.org/10.1614/WT-D-12-00084.1>

535 Hemwong, S., Toomsan, B., Cadisch, G., Limpinuntana, V., Vityakon, P., Patanothai, A., 2009. Sugarcane residue
536 management and grain legume crop effects on N dynamics, N losses and growth of sugarcane. *Nutrient Cycling*
537 *in Agroecosystems* 83, 135–151. <https://doi.org/10.1007/s10705-008-9209-8>

538 Kattge, J., Bönisch, G., Díaz, S., Lavorel, S., Prentice, I.C., et al. 2019. TRY plant trait database – enhanced
539 coverage and open access. *Global Change Biology* in press. <https://doi.org/10.1111/gcb.14904>

540 Koochafkan, P., Altieri, M.A., Gimenez, E.H., 2012. Green Agriculture: foundations for biodiverse, resilient and
541 productive agricultural systems. *International Journal of Agricultural Sustainability* 10, 61–75.
542 <https://doi.org/10.1080/14735903.2011.610206>

543 Kunz, C., Sturm, D.J., Varnholt, D., Walker, F., Gerhards, R., 2016. Allelopathic effects and weed suppressive
544 ability of cover crops. *Plant, soil and environment* 62, 60–66.

545 Lawson, A., Cogger, C., Bary, A., Fortuna, A.-M., 2015. Influence of Seeding Ratio, Planting Date, and
546 Termination Date on Rye-Hairy Vetch Cover Crop Mixture Performance under Organic Management. *PLoS ONE*
547 10, e0129597. <https://doi.org/10.1371/journal.pone.0129597>

548 Liebman, M., Dyck, E., 1993. Crop-Rotation and Intercropping Strategies for Weed Management. *Ecol. Appl.* 3,
549 92–122. <https://doi.org/10.2307/1941795>

550 Lu, Y.-C., Watkins, K.B., Teasdale, J.R., Abdul-Baki, A.A., 2000. Cover crops in sustainable food production.
551 *Food Reviews International* 16, 121–157. <https://doi.org/10.1081/FRI-100100285>

552 Malézieux, E., Crozat, Y., Dupraz, C., Laurans, M., Makowski, D., Rapidel, B., Tourdonnet, S.D., Mal, E., Crozat,
553 Y., Dupraz, C., Laurans, M., Makowski, D., 2009. Mixing plant species in cropping systems : concepts , tools and
554 models . A review To cite this version : Review article Mixing plant species in cropping systems : concepts , tools
555 and models . *Agronomy for Sustainable Development* 29, 43–62. <https://doi.org/10.1051/agro:2007057>

556 Mansuy, A., Marmotte, P., Martin, J., Roux, E., Chouteau, R., Wilt, M., Soubadou, G., 2019. CanécoH : mise au
557 point de leviers pour une Canne à sucre économe en Herbicide à La Réunion. *Innovations Agronomiques* 76, 103–
558 119. <https://doi.org/10.15454/tskwve>

559 Marion, D., Marnotte, P., 1991. Harmfulness of weed coverage on sugarcane. Presented at the 1. Rencontres
560 Internationales en Langue Francaise sur la Canne a Sucre., Montpellier, France, 10-15 Jun.

561 Marnotte, P., 1984. Influence des facteurs agroécologiques sur le développement des mauvaises herbes en climat
562 tropical humide. Presented at the 7ème Coll. Int. Ecol. Biol. et Syst. des mauvaises herbes, COLUMA-EWRS,
563 Paris, pp. 183–189.

564 Mathieu, B., Marnotte, P., 2000. L'enherbement des sols à Muskuwaari au Nord-Cameroun. Presented at the
565 Eleventh international conference on weed biology, AFPP, INRA, Dijon, France, pp. 151–158.

566 Médiène, S., Valantin-Morison, M., Sarthou, J.-P., de Tourdonnet, S., Gosme, M., Bertrand, M., Roger-Estrade,
567 J., Aubertot, J.-N., Rusch, A., Motisi, N., Pelosi, C., Doré, T., 2011. Agroecosystem management and biotic
568 interactions: a review. *Agronomy Sust. Developm.* 31, 491–514. <https://doi.org/10.1007/s13593-011-0009-1>

569 Mennan, H., Jabran, K., Zandstra, B.H., Pala, F., 2020. Non-Chemical Weed Management in Vegetables by Using
570 Cover Crops: A Review. *Agronomy-Basel* 10, 257. <https://doi.org/10.3390/agronomy10020257>

571 Mirsky, S.B., Curran, W.S., Mortenseny, D.M., Ryany, M.R., Shumway, D.L., 2011. Timing of Cover-Crop
572 Management Effects on Weed Suppression in No-Till Planted Soybean using a Roller-Crimper. *Weed Science* 59,
573 380–389. <https://doi.org/10.1614/WS-D-10-00101.1>

574 Mouret, N., Martin, P., Roux, E., Goebel, F.-R., 2017. Multi-scale Evaluation of the Impacts of *Beauveria* sp.
575 (Ascomycota: Hypocreales) Used to Control the White Grub *Hoplochelus marginalis* (Fairmaire) (Coleoptera:
576 Scarabaeidae) on Sugarcane in Réunion. *Sugar Tech* 19, 592–598. <https://doi.org/10.1007/s12355-017-0526-6>

577 Oerke, E.C., 2006. Crop losses to pests. *Journal of Agricultural Science* 144, 31–43.
578 <https://doi.org/10.1017/S0021859605005708>

579 Oerke, E.C., Dehne, H.W., 2004. Safeguarding production - losses in major crops and the role of crop protection.
580 *Crop Prot.* 23, 275–285. <https://doi.org/10.1016/j.cropro.2003.10.001>

581 Ofori, F., Stern, W.R., 1987. Cereal–Legume Intercropping Systems - ScienceDirect. *Advances in Agronomy* 41,
582 41–90.

583 Osipitan, O.A., Dille, A., Assefa, Y., Radicetti, E., Ayeni, A., Knezevic, S.Z., 2019. Impact of Cover Crop
584 Management on Level of Weed Suppression: A Meta-Analysis. *Crop Sci.* 59, 833–842.
585 <https://doi.org/10.2135/cropsci2018.09.0589>

586 Paungfoo-Lonhienne, C., Wang, W., Yeoh, Y.K., Halpin, N., 2017. Legume crop rotation suppressed nitrifying
587 microbial community in a sugarcane cropping soil. *Sci Rep* 7, 16707. [https://doi.org/10.1038/s41598-017-17080-](https://doi.org/10.1038/s41598-017-17080-z)
588 [z](https://doi.org/10.1038/s41598-017-17080-z)

589 R Development Core Team, 2017. R: A language and environment for statistical computing. R Foundation for
590 Statistical Computing, Vienna, Austria.

591 Ranaivoson, L., Naudin, K., Ripoche, A., Rabeharisoa, L., Corbeels, M., 2018. Is mulching an efficient way to
592 control weeds? Effects of type and amount of crop residue in rainfed rice based cropping systems in Madagascar.
593 *Field Crops Research* 217, 20–31. <https://doi.org/10.1016/j.fcr.2017.11.027>

594 Ryan, M.R., Curran, W.S., Grantham, A.M., Hunsberger, L.K., Mirsky, S.B., Mortensen, D.A., Nord, E.A.,
595 Wilson, D.O., 2011. Effects of Seeding Rate and Poultry Litter on Weed Suppression from a Rolled Cereal Rye
596 Cover Crop. *Weed Science* 59, 438–444. <https://doi.org/10.1614/WS-D-10-00180.1>

597 Schappert, A., Schumacher, M., Gerhards, R., 2019. Weed control ability of single sown cover crops compared to
598 species mixtures. *Agronomy* 9. <https://doi.org/10.3390/agronomy9060294>

599 Smith, R.G., Atwood, L.W., Warren, N.D., 2014. Increased Productivity of a Cover Crop Mixture Is Not
600 Associated with Enhanced Agroecosystem Services. *PLOS ONE* 9, e97351.
601 <https://doi.org/10.1371/journal.pone.0097351>

602 Snapp, S.S., Swinton, S.M., Labarta, R., Mutch, D., Black, J.R., Leep, R., Nyiraneza, J., O'Neil, K., 2005.
603 Evaluating cover crops for benefits, costs and performance within cropping system niches. *Agron. J.* 97, 322–332.

604 Soares, M.B.B., Bianco, S., Finoto, E.L., Bolonhezi, D., Albuquerque, J. a. A., 2017. Phytosociological Study on
605 the Weed Communities in Green Sugarcane Field Reform Using Conservation Tillage and Oilseed Crops in
606 Succession. *Appl. Ecol. Environ. Res.* 15, 417–428. https://doi.org/10.15666/aeer/1503_417428

607 Tardy, F., Moreau, D., Dorel, M., Damour, G., 2015. Trait-based characterisation of cover plants' light competition
608 strategies for weed control in banana cropping systems in the French West Indies. *European Journal of Agronomy*
609 71, 10–18. <https://doi.org/10.1016/j.eja.2015.08.002>

610 Teasdale, J., Brandsater, L., Calegari, A., Skora Neto, F., 2007. Cover crops and weed management, in: *Non-
611 Chemical Weed Management: Principles, Concepts and Technology*. CABI, Wallingford, pp. 49–64.

612 Teasdale, J.R., Hatfield, J.L., Buhler, D.D., Stewart, B.A., 1996. Cover crops, smother plants, and weed
613 management. *Advances in Soil Science*.

614 Teasdale, J.R., Mirsky, S.B., 2015. Tillage and Planting Date Effects on Weed Dormancy, Emergence, and Early
615 Growth in Organic Corn. *Weed Science* 63, 477–490. <https://doi.org/10.1614/WS-D-14-00112.1>

616 Teshome, Z., Fantaye, A., Hagos, H., 2014. Effect of Nitrogen and Phosphorus on Yield Components, Yield and
617 Sugarcane Juice Quality parameters of Soybean-Sugarcane Intercropping at Tendaho Sugar Factory. *Biochem
618 Physiol* 4, 1000151. <https://doi.org/10.4172/2168-9652.1000151>

619 Thorup-Kristensen, K. 2001. Are differences in root growth of nitrogen catch crops important for their ability to
620 reduce soil nitrate-N content, and how can this be measured? *Plant and Soil*, 230:185-195.

621 Tilman, D., Reich, P.B., Knops, J., Wedin, D., Mielke, T., Lehman, C., 2001. Diversity and Productivity in a Long-
622 Term Grassland Experiment. *Science* 294, 843–845. <https://doi.org/10.1126/science.1060391>

623 Tixier, P., Lavigne, C., Alvarez, S., Gauquier, A., Blanchard, M., Ripoche, A., Achard, R., 2011. Model evaluation
624 of cover crops, application to eleven species for banana cropping systems. *European Journal of Agronomy* 34, 53–
625 61. <https://doi.org/10.1016/j.eja.2010.10.004>

626 Tobin, M.F., Wright, A.J., Mangan, S.A., Schnitzer, S.A., 2012. Lianas have a greater competitive effect than trees
627 of similar biomass on tropical canopy trees. *Ecosphere* 3, art20. <https://doi.org/10.1890/ES11-00322.1>

628 Vandermeer, J.H., 1992. *The Ecology of Intercropping*. Cambridge University Press.

629 Violle, C., Navas, M.-L., Vile, D., Kazakou, E., Fortunel, C., Hummel, I., Garnier, E., 2007. Let the concept of
630 trait be functional! *Oikos* 116, 882–892. <https://doi.org/10.1111/j.0030-1299.2007.15559.x>

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642 **Supplementary materials**

643 **Table S1.** List of cover plant species used in the different trials. The family, life cycle (A=annual,
 644 P=perennial, Bi=biennial, V=vivacious), area of origin (Tr=tropical, Tm=temperate) and the growth
 645 habit (E=erected, Cr=creeping, Tw=Twining) of each species are described.

| Family | Species | Cycle | Zone | Growth |
|--------------------------------------|---|-------|---------|---------|
| Asteraceae | <i>Cichorium endivia</i> L. | Bi | Tm | E |
| | <i>Guizotia abyssinica</i> (L.f.) Cass. | A | Tm | E |
| Brassicaceae | <i>Brassica carinata</i> A.Braun | A | Tm | E |
| | <i>Raphanus sativus</i> L. | A | Tm | E |
| | <i>Sinapis alba</i> L. | A | Tm | E |
| Fabaceae | <i>Arachis hypogaea</i> L. | A | Tr | Cr |
| | <i>Cajanus cajan</i> (L.) Huth | P | Tr | E |
| | <i>Canavalia ensiformis</i> (L.) DC. | A | Tr | semi-Tw |
| | <i>Canavalia gladiata</i> (Jacq.) DC. | A | Tr | semi-Tw |
| | <i>Centrosema pascuorum</i> Mart. ex Benth. | A | Tr | Tw |
| | <i>Crotalaria juncea</i> L. | A | Tr | E |
| | <i>Crotalaria retusa</i> L. | A | Tr | E |
| | <i>Crotalaria spectabilis</i> Roth | A | Tr | E |
| | <i>Crotalaria trichotoma</i> Bojer | A | Tr | E |
| | <i>Grona heterocarpa</i> (L.) H.Ohashi & K.Ohashi | A | Tr | Cr |
| | <i>Lablab purpureus</i> (L.) Sweet | A | Tr | Tw |
| | <i>Lathyrus sativus</i> L. | A | Tm | Tw |
| | <i>Lens nigricans</i> (M.Bieb.) Webb & Berthel. | A | Tm | Tw |
| | <i>Lotus corniculatus</i> L. | A | Tm | Cr |
| | <i>Lupinus albus</i> L. | A | Tm | E |
| | <i>Macrotyloma axillare</i> (E.Mey.) Verdc. | P | Tr | Tw |
| | <i>Medicago sativa</i> L. | P | Tm | E |
| | <i>Mucuna pruriens</i> (L.) DC. | A | Tr | Tw |
| | <i>Neonotonia wightii</i> (Wight & Arn.) J.A.Lackey | P | Tr | Tw |
| | <i>Neustanthus phaseoloides</i> (Roxb.) Benth. | P | Tr | Tw |
| | <i>Phaseolus lunatus</i> L. | A | Tr | Tw |
| | <i>Pisum sativum</i> L. | A | Tm | Cr |
| | <i>Stylosanthes guianensis</i> (Aubl.) Sw. | P | Tr | semi-E |
| | <i>Trifolium hybridum</i> L. | P | Tm | Cr |
| | <i>Trifolium incarnatum</i> L. | A | Tm | Cr |
| | <i>Trifolium pratense</i> L. | V | Tm | Cr |
| <i>Trifolium repens</i> L. | V | Tm | Cr | |
| <i>Trigonella foenum-graecum</i> L. | A | Tm | E | |
| <i>Vicia villosa</i> Roth | A | Tm | Tw | |
| <i>Vigna radiata</i> (L.) R.Wilczek | A | Tr | Tw | |
| <i>Vigna subterranea</i> (L.) Verdc. | A | Tr | Cr | |
| <i>Vigna unguiculata</i> (L.) Walp. | A | Tr | semi-Tw | |
| Poaceae | <i>Avena sativa</i> L. | A | Tm | E |
| | <i>Avena strigosa</i> Schreb. | A | Tm | E |
| | <i>Eleusine coracana</i> (L.) Gaertn. | A | Tr | E |
| | <i>Pennisetum glaucum</i> (L.) R.Br. | A | Tr | E |
| | <i>Phalaris canariensis</i> L. | A | Tm | E |
| | <i>Sorghum bicolor</i> (L.) Moench | A | Tr | E |
| | <i>Urochloa eminii</i> (Mez) Davidse | P | Tr | semi-E |
| <i>Zea mays</i> L. | A | Tr | E | |
| Polygonaceae | <i>Fagopyrum esculentum</i> Moench | A | Tm | E |

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647 *Crotalaria zanzibarica* Benth. synonym of *Crotalaria trichotoma* Bojer

648 *Desmodium heterocarpon* (L.) DC. synonym of *Grona heterocarpa* (L.) H.Ohashi & K.Ohashi

649 *Pueraria phaseoloides* (Roxb.) Benth. synonym of *Neustanthus phaseoloides* (Roxb.) Benth.

650 *Brachiaria decumbens* Stapf synonym of *Urochloa eminii* (Mez) Davidse

651 *Cenchrus americanus* (L.) Morrone synonym of *Pennisetum glaucum* (L.) R.Br.

652 **Table S2.** Species composition of each trials and sowing density for pure crops. The trial ID description
 653 are detailed in Table 1.

| Species | Collection trial ID | Weed control trial ID | Sowing density (kg/ha) |
|---|---------------------|-----------------------|------------------------|
| <i>Cichorium endivia</i> L. | 2,5 | | 7 |
| <i>Guizotia abyssinica</i> (L.f.) Cass. | 1,2,3,6 | 9 | 10 |
| <i>Brassica carinata</i> A.Braun | 6 | | 6 |
| <i>Raphanus sativus</i> L. | 1,2,3,4,5,6 | 10 | 10 |
| <i>Sinapis alba</i> L. | 3 | | 10 |
| <i>Arachis hypogaea</i> L. | 1,2,3, | | 150 |
| <i>Cajanus cajan</i> (L.) Huth | 1,2,3,6 | | 10 |
| <i>Canavalia ensiformis</i> (L.) DC. | 1,2,3,4,5,6 | 7,8,10 | 40 |
| <i>Canavalia gladiata</i> (Jacq.) DC. | 1,2,4 | | 40 |
| <i>Centrosema pascuorum</i> Mart. ex Benth. | 1,4 | | 15 |
| <i>Crotalaria juncea</i> L. | 1,2,3,4,5,6 | 7,8,9,10 | 40 |
| <i>Crotalaria retusa</i> L. | 1 | | 25 |
| <i>Crotalaria spectabilis</i> Roth | 1,3,4,5,6 | | 20 |
| <i>Crotalaria trichotoma</i> Bojer | 1,2,3,4,5 | | 25 |
| <i>Grona heterocarpa</i> (L.) H. Ohashi & K. Ohashi | 1 | | 20 |
| <i>Lablab purpureus</i> (L.) Sweet | 1,2,3,4,6 | | 50 |
| <i>Lathyrus sativus</i> L. | 1,4,5 | | 50 |
| <i>Lens nigricans</i> (M.Bieb.) Webb & Berthel. | 1 | | 80 |
| <i>Lotus corniculatus</i> L. | 2 | | 8 |
| <i>Lupinus albus</i> L. | 2 | | 150 |
| <i>Macrotyloma axillare</i> (E.Mey.) Verdc. | 1,5 | | 4 |
| <i>Medicago sativa</i> L. | 1,2,3,4,5 | | 25 |
| <i>Mucuna pruriens</i> (L.) DC. | 1,2,3,4,5 | | 35 |
| <i>Neonotonia wightii</i> (Wight & Arn.) J.A.Lackey | 1,2 | | 25 |
| <i>Neustanthus phaseoloides</i> (Roxb.) Benth. | 1,2 | | 20 |
| <i>Phaseolus lunatus</i> L. | 1,2,3,4,5 | | 80 |
| <i>Pisum sativum</i> L. | 6 | | 100 |
| <i>Stylosanthes guianensis</i> (Aubl.) Sw. | 1,2,4,5 | 7,8 | 8 |
| <i>Trifolium hybridum</i> L. | 3 | | 15 |
| <i>Trifolium incarnatum</i> L. | 3 | | 15 |
| <i>Trifolium pratense</i> L. | 3 | | 8 |
| <i>Trifolium repens</i> L. | 3 | | 10 |
| <i>Trigonella foenum-graecum</i> L. | 1,2, | | 35 |
| <i>Vicia villosa</i> Roth | 2,3,6 | 9 | 20 |
| <i>Vigna radiata</i> (L.) R.Wilczek | 1,2,3,4,5 | | 10 |
| <i>Vigna subterranea</i> (L.) Verdc. | 1,2,3,5 | | 90 |
| <i>Vigna unguiculata</i> (L.) Walp. | 1,2,3,4,5,6 | 9 | 15 |
| <i>Avena sativa</i> L. | 2,3,4,5,6 | 7,8,9 | 90 |
| <i>Avena strigosa</i> Schreb. | 2,3,6 | | 40 |
| <i>Eleusine coracana</i> (L.) Gaertn. | 1 | 8 | 3 |
| <i>Pennisetum glaucum</i> (L.) R.Br. | 1,2,3,4,5,6 | 7,8,9,10 | 20 |
| <i>Phalaris canariensis</i> L. | 1 | | 4 |
| <i>Sorghum bicolor</i> (L.) Moench | 1,2,4,5 | 7,8 | 11 |
| <i>Urochloa eminii</i> (Mez) Davidse | 1 | | 8 |
| <i>Zea mays</i> L. | 3 | | 15 |
| <i>Fagopyrum esculentum</i> Moench | 2,3,6 | | 40 |

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659 **Table S3.** Mixture of two species tested in the weed control trials. The trial ID description are detailed
 660 in Table 1. In case of mixture, sowing density was equal to half the density in pure crops.

| Species mixture | | Weed control trial ID |
|-----------------------------|--------------------------------|-----------------------|
| <i>Avena sativa</i> | <i>Canavalia ensiformis</i> | 7 |
| <i>Avena sativa</i> | <i>Crotalaria juncea</i> | 7,9 |
| <i>Avena sativa</i> | <i>Stylosanthes guianensis</i> | 7 |
| <i>Avena sativa</i> | <i>Vicia villosa</i> | 9 |
| <i>Avena sativa</i> | <i>Vigna unguiculata</i> | 9 |
| <i>Canavalia ensiformis</i> | <i>Pennisetum glaucum</i> | 10,7 |
| <i>Canavalia ensiformis</i> | <i>Raphanus sativus</i> | 10 |
| <i>Pennisetum glaucum</i> | <i>Crotalaria juncea</i> | 7,9,10 |
| <i>Pennisetum glaucum</i> | <i>Stylosanthes guianensis</i> | 7 |
| <i>Pennisetum glaucum</i> | <i>Vigna unguiculata</i> | 9 |
| <i>Guizotia abyssinica</i> | <i>Crotalaria juncea</i> | 9 |
| <i>Sorghum bicolor</i> | <i>Canavalia ensiformis</i> | 7 |
| <i>Sorghum bicolor</i> | <i>Crotalaria juncea</i> | 7 |
| <i>Sorghum bicolor</i> | <i>Stylosanthes guianensis</i> | 7 |

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677 **Table S4.** Weed flora in the sites with weed control trials (measured in 2017).

| Famille | Espèces | Bassin Plat | La Mare |
|----------------|---|-------------|---------|
| Aizoaceae | <i>Trianthema portulacastrum</i> L. | x | |
| Amaranthaceae | <i>Amaranthus</i> sp | x | x |
| Asteraceae | <i>Acanthospermum hispidum</i> DC. | x | |
| Asteraceae | <i>Bidens pilosa</i> L. | x | x |
| Cleomaceae | <i>Cleome viscosa</i> L. | | x |
| Commelinaceae | <i>Commelina benghalensis</i> L. | x | |
| Convolvulaceae | <i>Ipomoea eriocarpa</i> R.Br. | x | x |
| Convolvulaceae | <i>Ipomoea hederifolia</i> L. | | x |
| Convolvulaceae | <i>Ipomoea obscura</i> (L.) Ker-Gawler | x | x |
| Convolvulaceae | <i>Ipomoea triloba</i> L. | | x |
| Convolvulaceae | <i>Merremia aegyptia</i> (L.) Urb. | | x |
| Cyperaceae | <i>Cyperus rotundus</i> L. | x | x |
| Euphorbiaceae | <i>Euphorbia heterophylla</i> L. | x | x |
| Euphorbiaceae | <i>Euphorbia hirta</i> L. | x | x |
| Euphorbiaceae | <i>Euphorbia hyssopifolia</i> L. | x | x |
| Euphorbiaceae | <i>Phyllanthus amarus</i> Schumach. & Thonn. | x | |
| Fabaceae | <i>Desmanthus virgatus</i> (L.) Willd. | x | x |
| Fabaceae | <i>Mimosa pudica</i> L. | | x |
| Fabaceae | <i>Senna occidentalis</i> (L.) Roxb. | | x |
| Lamiaceae | <i>Leucas lavandulifolia</i> Sm. | x | |
| Malvaceae | <i>Malvastrum coromandelianum</i> (L.) Garcke | x | |
| Papaveraceae | <i>Argemone mexicana</i> L. | x | |
| Plantaginaceae | <i>Plantago lanceolata</i> L. | x | |
| Poaceae | <i>Brachiaria decumbens</i> Stapf | | x |
| Poaceae | <i>Dactyloctenium aegyptium</i> (L.) P.Beauv. | x | |
| Poaceae | <i>Eleusine indica</i> (L.) Gaertn. | x | |
| Poaceae | <i>Panicum maximum</i> Jacq. | x | |
| Portulacaceae | <i>Portulaca oleracea</i> L. | x | x |
| Sapindaceae | <i>Cardiospermum microcarpum</i> Kunth | x | x |
| Solanaceae | <i>Nicandra physalodes</i> (L.) Gaertn. | x | |
| Solanaceae | <i>Solanum americanum</i> Mill. | | x |

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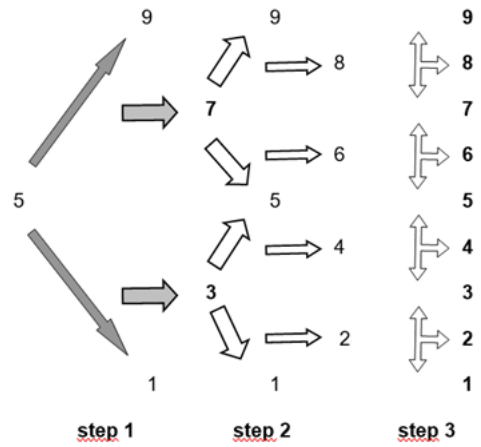
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685 **Table S5.** Visual notation methods to assess ground coverage by plants (weeds or cover plants).

| Notation | Equivalence in percentage | coverage |
|----------|---------------------------|---|
| 1 | 1 | Species present but rare |
| 2 | 7 | Less than one individual per m ² |
| 3 | 15 | At least one individual per m ² |
| 4 | 30 | 30 % of coverage |
| 5 | 50 | 50 % of coverage |
| 6 | 70 | 70 % of coverage |
| 7 | 85 | High coverage |
| 8 | 93 | Very little apparent soil |
| 9 | 100 | Full coverage |



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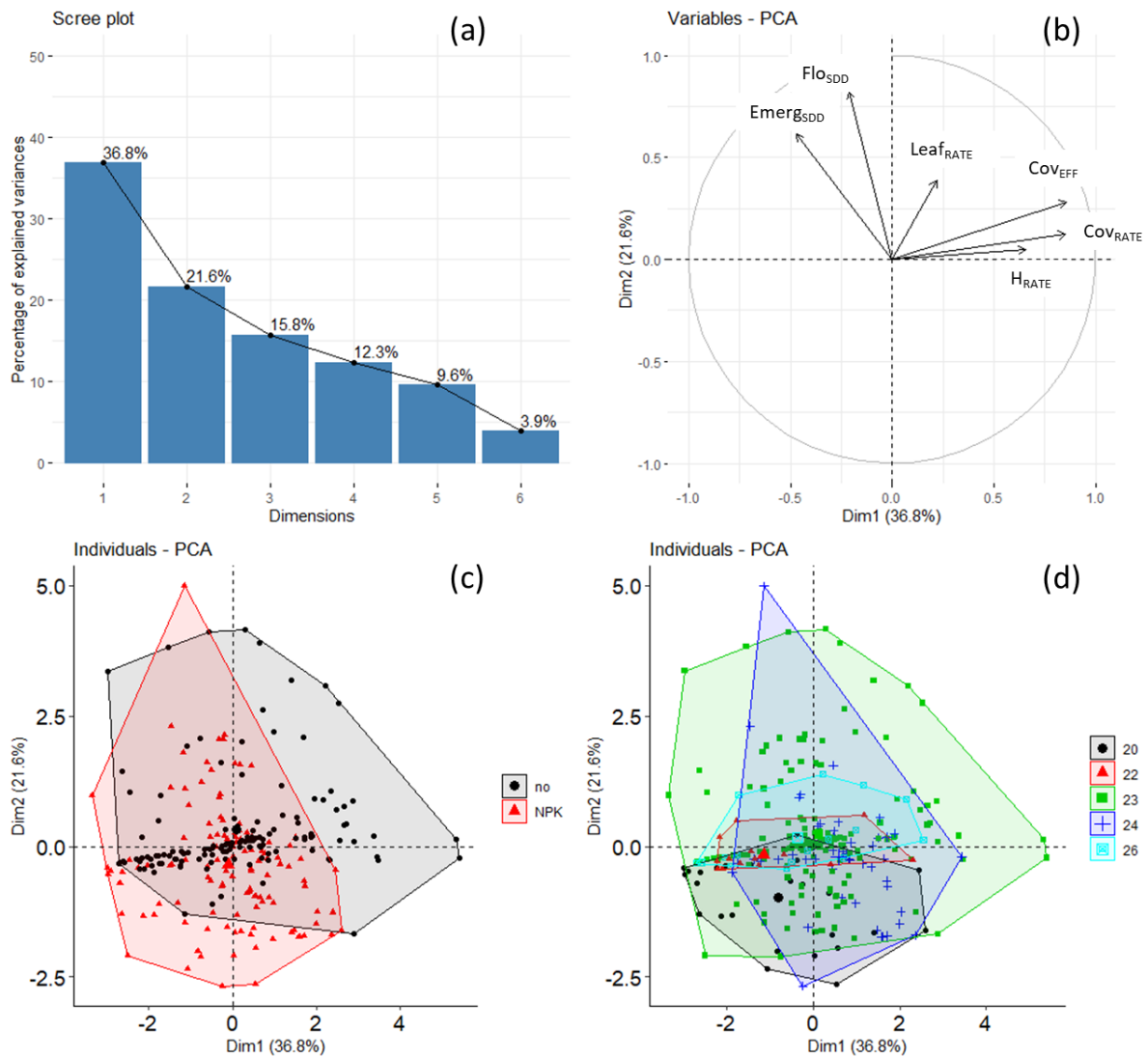
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694 **Figure S1.** Principal component analysis (PCA) of the collection trials dataset. The percentage
 695 of explained variances of each dimensions are shown in (a). The correlation plot (b) shows the
 696 contribution of each variable to the two first principal components (Dim1, Dim2). Cover plant
 697 traits were clustered as a function of fertilization regime (no fertilization or NPK fertilization,
 698 c) or as a function of average temperature during the growth (d). Data point with a larger size
 699 in (c) and (d) correspond to the barycenter of each cluster. The quantitative variables considered
 700 in the PCA are described in Table 2.

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