**File S1. Detailed description of the variables.**

## Description of the traits

Traits related to vigour after sowing:

*Days from sowing to emergence:* Number of days between the sowing of the plot and the start of emergence. Recorded only at PO in 2015 (***DES\_po15***)

*Vigour after sowing:* Visual score performed two months after sowing on a scale of 1 (small and/or necrotized and/or chlorotic plants) to 9 (strong green plants, very good size, difficult to pull out). Recorded in 2015 at the three trial locations (***VAS-lu15***, ***VAS\_me15*** and ***VAS\_po15***).

*Regularity after sowing*: Visual score performed two months after sowing and proportional to the percentage of emerged plants on a scale of 1 (no emergence) to 9 (full stand, 100% plants emerged). Recorded in 2015 at the three locations (***RAS\_lu15***, ***RAS\_me15*** and ***RAS\_po15***).

Morphology of plants and sward density:

*Leaf lamina width:* Visual score performed during spring growth before fertile stem elongation on a scale of 1 (very thin) to 9 (very large). Recorded at PO in 2016 (***LMW\_po16***), ME in 2016 (***LMW\_me16***) and LU in 2017 (***LMW\_lu17***).

*Growth habit:* Visual score recorded on a scale of 1 (most erect) to 9 (most prostrate) in spring 2016 at LU and PO. Because of high correlation between the two locations, only average values of populations over locations (***GRH\_avg***) were used in data analyses (see ‘*Computation of mean values and elaborate variables*’).

*Sward density*: Visual score recorded in the early spring to assess density of vegetative tillers on a scale of 1 (very poor density, few tillers, ground largely visible) to 9 (very dense, many tillers, no visible ground). Recorded in April 2017 at LU (***DVG\_04\_lu17***).

Traits related to phenology:

*Percentage of plants heading in first year*: Visual score reporting the density of elongated fertile (bearing spike) stems the year of sowing (*i.e.* without vernalization) on a scale of 1 (no fertile stem) to 9 (100% plants with fertile stems). Recorded in 2015 at LU (***HFY\_lu15***) and PO (***HFY\_po15***).

*Heading date:* In spring after a vernalisation period, date when at least 20 spikes are arising at the top of tiller sheath in a micro-sward. This date was converted into growing-degree-days (GDD) with a base temperature of 0°C starting from the first day when daily minimum temperature and incident shortwave global radiation do not fall anymore below 0°C and 60 W m-2, respectively (*i.e.* from the start of vegetative spring growth). Recorded in 2016 at LU and PO (***HEA\_lu16*** and ***HEA\_po16***) and in 2017 at LU and PO (***HEA\_lu17*** and ***HEA\_po17***). Note that these four heading dates were highly correlated (correlations higher than 0.90).

*Aftermath heading*: After the cut of the first spring wave of elongated fertile stems, visual score reporting the intensity of afterwards recurring fertile stem elongation on a scale of 1 (no fertile stem) to 9 (100% plants with fertile stems). Recorded in 2016 and 2017 at LU, ME and PO (***AHD\_lu16***, ***AHD\_lu17***, ***AHD\_me16***, ***AHD\_me17***, ***AHD\_po16*** and ***AHD\_po17***).

Investment in sexual reproduction:

*Density of elongated fertile stems*: Visual score recorded for the first spring wave of elongated fertile stems on a scale of 1 (no fertile stem) to 9 (maximum observed density of tillers with elongated fertile stem). Recorded in 2017 at LU (***DST\_lu17***) and PO (***DST\_po17***).

*Straw height*: Length in cm of one average elongated fertile stem per micro-sward (from ground to base of spike). Recorded at LU in 2017 (***HST\_lu17***).

*Spike length* (LSP): Length in mm of one average spike per micro-sward. Recorded at LU in 2017 (***LSP\_lu17***).

*Spikelet length* (LSL): Length in mm of a spikelet from one average spike per micro-sward. Recorded at LU in 2017 (***LSL\_lu17***).

*Spikelet count* (NSL): Number of spikelets from one average spike per micro-sward. Recorded at LU in 2017 (***NSL\_lu17***).

Dynamics of vegetative spring growth:

Vegetative spring growth was monitored in 2016 and 2017 in each of the three trial locations from the start of spring growth to a couple of weeks before spike emergence (heading) in ME and to a couple of weeks after spike emergence in LU and PO (the trial was cut before spike emergence in ME). The monitoring was carried out by measuring the micro-sward canopy height (CH) once a week. To measure the canopy height, an ‘herbometre®’ tool ***(ARVALIS)*** was used. It is a ruler along which a plate runs; the plate was left to lean on the canopy and the canopy height was measured (in mm) as the distance from the ground to the plate. This tool is used to estimate biomass yield on grasslands (Powell 1974). We assessed the correlation between CH before cut and the cut dried aerial biomass for 30 micro-swards per location (3 replicates 10 populations) at one cutting date per location in 2016 (Table S1-T1) and found that it ranged from 0.80 to 0.86.

**Table S1-T1**: Relationship between canopy height and plot dry weight

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location and date of cut** | **Growth period** | **Mean plot dry weight (tons/hectare)** | **Plot dry weight genetic (inter-population) standard deviation** | **Plot dry weight residual standard deviation** | **H² (Analogous to broad sense heritability) of plot dry weight** | **Canopy height measure date** | | **Correlation between canopy height and plot dry weight** |
| ME 09/05/16 | From start of spring | 3.74 | 1.48 | 0.92 | 0.93 | 03/05/2016 | 0.86 | | |
| PO 11/07/16 | From 01/06 | 3.35 | 1.29 | 0.43 | 0.97 | 11/07/2016 | 0.89 | | |
| LU 26/07/16 | From 08/06 | 1.14 | 0.59 | 0.57 | 0.76 | 25/06/2016 | 0.80 | | |

At each measurement date, the canopy height of a given micro-sward was recorded twice at two different positions in the micro-sward. A Schnute growth model (Schnute 1981) was afterwards fitted to model the spring growth of each population for each combination of location and year using the six observations available for a population at a given measurement date. The growth curves were fitted in the time interval running from the start of spring growth to spike emergence date of populations at LU and PO and to the date of end of weekly measurements at ME. These models were used to predict the canopy heights of populations at several thermal time dates (one predicted value per population for each combination of location and year). The predicted canopy heights illustrated in Figure S1-F1 were as follows:

- canopy height at 300 GDD after the start of spring growth in 2016 and 2017 at LU, PO and ME (***CHs300\_lu16***, ***CHs300\_lu17***, ***CHs300\_po16***, ***CHs300\_po17, CHs300\_me16*** and ***CHs300\_me17***)

- canopy height at 500 GDD after the start of spring growth in 2016 and 2017 at LU, PO and ME (***CHs500\_lu16***, ***CHs500\_lu17***, ***CHs500\_po16***, ***CHs500\_po17, CHs500\_me16*** and ***CHs500\_me17***)

- canopy height at 300 GDD before spike emergence (heading) date in 2016 and 2017 at LU and PO (***CH300h\_lu16***, ***CH300h\_lu17***, ***CH300h\_po16*** and ***CH300h\_po17***)

- canopy height at 400 GDD before spike emergence (heading) date in 2016 and 2017 at LU and PO (***CH400h\_lu16***, ***CH400h\_lu17***, ***CH400h\_po16*** and ***CH400h\_po17***)

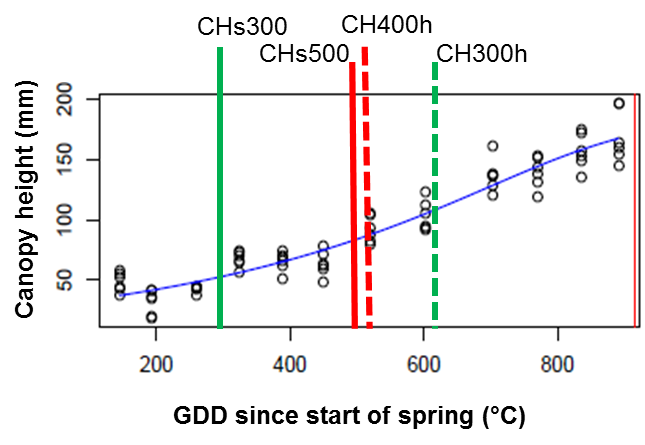


Figure S1-F1: Illustration of the Schnute derived canopy height variables for a population observed at LU in 2017 whose heading date was of 964 GDD.

Summer and autumn growth variables:

*Summer canopy height*: Canopy height (in mm) after a summer period measured with the herbometre® as previously described for the monitoring of the dynamics of spring growth. Recorded in 2016 at LU and ME (***SMH\_lu16*** and ***SMH\_me16***) and in 2017 at ME and PO (***SMH\_me17*** and ***SMH\_po17***).

*Summer growth rate*: The preceding variable from which was subtracted the height just after the cut at the start of the summer period and which was then divided by the number of GDD between the date of cut preceding the canopy height measurement and the date of the canopy height measurement. Computed for the same combinations of locations and years as *summer canopy height* (***SGR\_lu16***, ***SGR\_me16***, ***SGR\_me17*** and ***SGR\_po17***).

*Autumn canopy height* (AMH): Canopy height (in mm) after a period of autumn growth measured with the herbometre® as previously described for the monitoring of the dynamics of spring growth. Recorded in 2017 at ME and PO (***AMH\_me17*** and ***AMH\_po17***).

*Autumn growth rate* (AGR): The preceding variable from which was subtracted the height just after the cut at the start of the autumn period and which was then divided by the number of GDD between the date of cut preceding the canopy height measurement and the date of the canopy height measurement. Computed for the same combinations of locations and year as *autumn canopy height* (***AGR\_me17*** and ***AGR\_po17***).

Dynamics of regrowth after cutting:

*Vigour after cutting*: Recovery after cutting scored one or two times a year from 1 (no regrowth) to 9 (strongest regrowth). Recorded at LU in 2016 and 2017 (***VAC\_lu16*** and ***VAC\_lu17***) and at PO in 2017 (***VAC\_po17***).

Abiotic stresses:

*Drought stress symptoms*: Visual score of susceptibility to drought recorded during a drought period and reporting the percentage of sere leaves on a scale of 1 (no damage, green growing plants) to 9 (all plants with completely sere foliage). Recorded in 2016 at LU and PO (***DRO\_lu16*** and ***DRO\_po16***).

*Winter damage*: Visual score of damage on plants at the end of the winter period on a scale of 1 (no damage, green plants) to 9 (all plants with necrotized foliage). Recorded at PO in 2016 and 2017 (***WID-po16*** and ***WID\_po17***).

Biotic stresses - Disease damages:

*Helmintosporium (*Dreschlera siccans*) susceptibility*: Visual score of *Helmintosporium* damages recorded after occurrence of the disease and reporting the proportion of foliage affected on a scale of 1 (no symptoms) to 9 (all plants with highly affected foliage). Recorded at LU in January and July 2016 (***DHE\_01\_lu16*** and ***DHE\_07\_lu16***) and in April 2017 (***DHE\_04\_lu17***).

*Black rust (*Puccinia graminis*) susceptibility*: Visual score of black rust damages recorded after occurrence of the disease and reporting the proportion of foliage affected on a scale of 1 (no symptoms) to 9 (all plants with highly affected foliage). Recorded at LU in 2015 and 2016. Average values of populations over recorded dates were computed and used in data analyses (***DRB\_lu1516***).

*Susceptibility to indeterminate diseases*: Visual score of damages caused by indeterminate diseases or mixtures of diseases recorded after their occurrence and reporting the proportion of foliage affected on a scale of 1 (no symptoms) to 9 (all plants with highly affected foliage). Recorded at LU in 2015, 2016 and 2017 (***DIS\_lu15***, ***DIS\_lu16*** and ***DIS\_lu17***), at ME in 2016 and 2017 (***DIS\_me16*** and ***DIS\_me17***) and at PO in 2015 and 2017 (***DIS\_po15*** and ***DIS\_po17***).

Dynamics of persistency over successive trial years:

A visual score of soil coverage by living plants was recorded in each location four months after sowing and then every couple of months. It was proportional to the soil surface covered by green plant material and was scored on a scale of 1 (no living plants on the micro-sward plot) to 9 (best soil coverage, *i.e.* micro-sward perfectly filled with strong living plants). To assess the dynamics of change in population persistency between two dates of record of soil coverage in a given location, we computed the difference between the soil coverage record of micro-swards at the late date and at the early date. This difference was considered as an indicator of population persistency over the targeted time span. Such differences were computed throughout targeted periods at the three trial locations as follows:

- throughout summers of 2015, 2016 and 2017 at LU (***SCD\_su15\_lu***, ***SCD\_su16\_lu*** and ***SCD\_su17\_lu***)

- throughout summer of 2017 at ME (***SCD\_su17\_me***)

- throughout winters of 2015-16, 2016-17 and 2017-18 at LU (***SCD\_wi1516\_lu***, ***SCD\_wi1617\_lu*** and ***SCD\_wi1718\_lu***)

- throughout winter of 2016-17 at ME (***SCD\_wi1617\_me***)

- throughout winters 2015-16 and 2016-17 at PO (***SCD\_wi1516\_po*** and ***SCD\_wi1617\_po***)

- from end of spring 2015 to end of autumn 2018 at LU (***SCD\_15to18\_lu***)

- from end of spring 2015 to end of autumn 2017 at PO (***SCD\_15to17\_po***)

- from end of spring 2016 to end of autumn 2017 at ME (***SCD\_16to17\_me***)

Biochemistry of aerial biomass:

At the April and October cuts in 2017 at ME, fresh samples of aerial biomass were collected, dried down at 60°C for 72 h and ground to pass a 1 mm sieve. Ground samples were analysed by Near Infrared Reflectance Spectroscopy (NIRS) at ILVO to predict the following biochemical composition variables:

* *Acid Detergent Lignin* (ADL), *Acid detergent fibre* (ADF) and *neutral detergent fibre* (NDF) in dry matter (% DM) (Van Soest *et al.* 1991) (***ADL\_04\_me17*** and ***ADL\_10\_me17, ADF\_04\_me17*** and ***ADF\_10\_me17***, ***NDF\_04\_me17*** and ***NDF\_10\_me17***)
* *Crude protein* content (ISO derived method 5983-2) in % DM (***PRT\_04\_me17*** and ***PRT\_10\_me17***)
* *Water-soluble-carbohydrate* content in % DM (Wiseman *et al.* 1960) (***WSC\_04\_me17*** and ***WSC\_10\_me17***).
* Organic matter digestibility (De Boever *et al.* 1988) (**OMD\_04\_me17** and **OMD\_10\_me17**)
* *In vitro neutral detergent fibre degradability* (DNDF) as per Dolstra and Medema (1990) (***DNDF\_04\_me17*** and ***DNDF\_10\_me17***).

Leaf lamina biochemical traits:

A sunlit leaf lamina sample was collected on 30 plants per micro-sward at LU on April 2016. The 30 samples per micro-sward were pooled to a single batch which was dried, ground and analyzed by mass spectrometry (Flash 2000 Thermo-Fisher) at LU to predict the *nitrogen content of the dry leaf lamina tissue* (***NLI\_lu16***) and the *isotopic composition of 13C* (***13C\_lu16***).

Nitrogen content in sunlit leaf lamina was previously demonstrated to report the fulfillment of plant nitrogen need for optimal growth (Lemaire *et al.* 1997; Farruggia *et al.* 2004). Isotopic composition of 13C (13C) is considered as a marker of water use efficiency (Condon *et al.* 2002) and possibly of photosynthetic efficiency when water supply is not limiting (Condon *et al.* 2007).

## Computation of variables corrected for the heading date

Significant correlations were found between canopy height in spring and density of elongated fertile stems with heading date, but some variability for these traits was obvious at same heading earliness. To take into account this trend, we regressed the value of the populations for these traits in each environmental condition on the mean value of populations for heading date averaged over environments (***HEA\_avg***).

The Schnute (Schnute 1981) model-predicted canopy heights were thus regressed on average heading date (***HEA\_avg***) and regression residuals were kept as additional variables for downstream analyses. Those variables could be used to compare the spring aerial growths of populations with contrasted heading dates.

- resCHs300\_lu16, resCHs300\_lu17, resCHs300\_po16, resCHs300\_po17, resCHs300\_me16 and resCHs300\_me17

- resCHs500\_lu16, resCHs500\_lu17, resCHs500\_po16, resCHs500\_po17, resCHs500\_me16 and resCHs500\_me17

- resCH300h\_lu16, resCH300h\_lu17, resCH300h\_po16 and resCH300h\_po17

- resCH400h\_lu16, resCH400h\_lu17, resCH400h\_po16 and resCH400h\_po17

The scored value for density of elongated fertile stems at LU in 2017 for each micro-sward was regressed on average heading date (***HEA\_avg***) of the population sown within the micro-sward and the residuals (value obtained for each replicate of each population) were kept to form an additional variable (***resDST\_lu17***). Those residuals represent the degree of investment in sexual reproduction independently of heading earliness.

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