**A framework to estimate the contribution of weeds to the delivery of ecosystem (dis)services in agricultural landscapes**

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**Appendix A**

**Methodology to estimate the flower and seed productions accounting for intraspecific variability (*i.e.* depending on growing conditions) : application to 155 weed species found in field edges and field cores of six crop types (winter wheat, winter barley, winter oilseed rape, winter mustard, spring barley and soybean).**

This appendix details the methodology used to estimate the production of flowers and seeds at different timings from early weed surveys (*i.e.* in March for winter crops, in April for spring crops and in June for summer crops) to the crop harvest, for the 155 studied weed species. The productions of flowers and seeds were computed separately in the edge and the core of fields of six crop types (winter wheat, winter barley, winter oilseed rape, winter mustard, spring barley and soybean). This methodology was based on a previous study (Yvoz et al., 2020), describing the phenological stage of 69 weed species every two to three weeks using a simplified BBCH scale (Hess et al., 1997), within 685 patches. For 43 out of 69 species, the flower production per plant at flowering was counted within the 685 patches. However, we did not observe the 69 species in all combinations of within-field location by crop type and we were lacking information for 86 of the 155 weed species studied.

In a way to implement values when data were missing, we estimated the flower and seed productions of missing species over time based on similarities (regarding their response to crop competition) with the studied weed species, using a multivariate approach. Three situations were found:

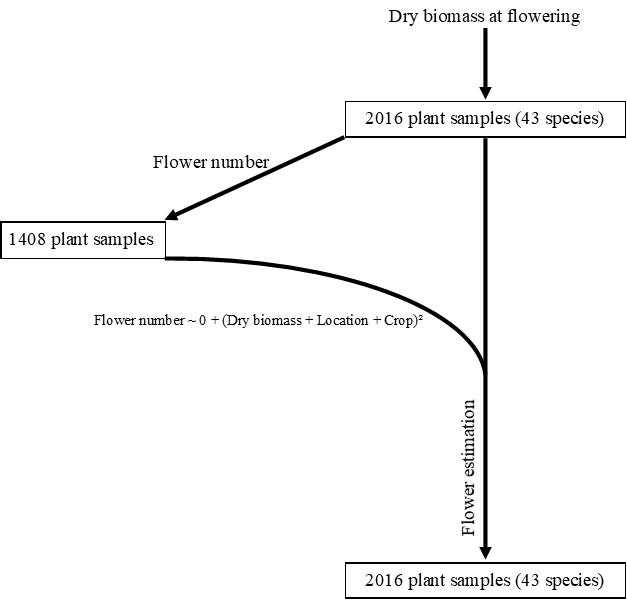
* Species with both the phenological profile and the flower number per plant in each growing condition were known from Yvoz et al., (2020), hereafter called **Type A** (N=43);
* Species with only the phenological profile known from Yvoz et al., (2020) but not the flower number, **Type B** (N=26);
* Species with all information missing, **Type C** (N=86).

We handled these three groups independently.

1. Estimation of the number of flowers per individual

Yvoz et al. (2020) sampled 2016 individual plants at flowering of **Type A** species within the 685 patches and weighted their dry biomass. We counted the total number of flowers (flowers plus fruits plus buds) for 1408 of the 2016 individual plants (Figure A.1). For each of the 1408 counted individuals, we regressed the flower number against the dry biomass at flowering, within-field location, crop type and their interactions (Eq. A.1, most complete model), using the *lm* function from the [lme4] package. Then, we generated all the submodels containing at least the dry biomass using the *dredge* function and selected the best model, *i.e.* with the lower AIC value using the *get.models* function from the [MuMIn] package (Table A.1). Using the function *predict*, the output of this step was the estimation of the flower production for the 2016 individual plants based on their dry biomass and considering their location within the 12 combinations of within-field location and crop type.

Flower number ~ 0 + (Dry biomass + Within-field Location + Crop type)² (Eq. A.1)

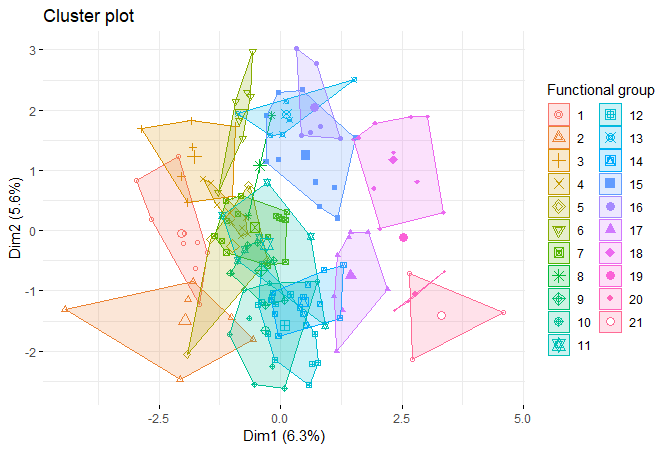


**Figure A.1:** Estimation of the flower number per individual plant sample based on the dry biomass at flowering.

1. Multivariate approach to identify the most similar weed species

To estimate the flower production of the **Type B** and **Type** C species, we first run a multivariate approach to identify the most similar **Type A** species. We selected 15 traits or biological characteristics (Table A.2) relevant to characterised species response to farming practices and crop competition (Gaba et al., 2017; Storkey et al., 2010; Yvoz et al., submitted), in addition to 12 variables describing the occurrence of weeds in each of the 12 combinations of within-field location by crop type.

The 27 variables, structured into 4 groups (Table A.2), were submitted to a Multiple Factor Analysis (MFA) adapted to both qualitative and quantitative variables, using the *MFA* functions from the [FactoMineR] package. The output was then submitted to a Hierarchical Clustering Analysis (HCA) using the function *HCPC* from the [FactoMineR] package, ending in the identification of 21 species groups gathering from 1 to 15 species (Figure A.2).



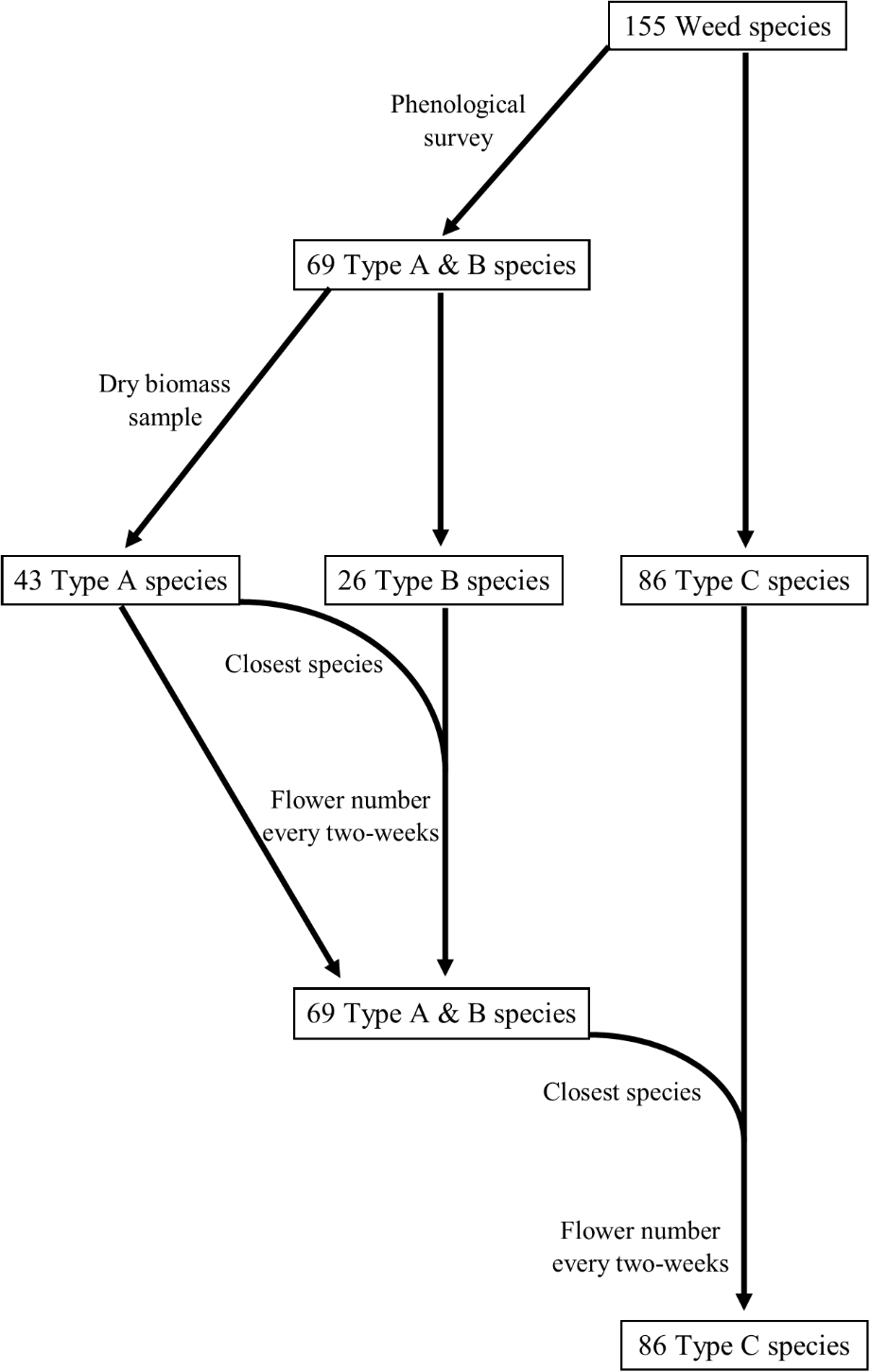
Species group

**Figure A.2:** Grouping of the 155 weed species in 21 species groups with a Hierarchical Clustering Analysis based on the output of the Multiple Factor Analysis carried out on the 27 variables (see Table A.2).

Then, we calculated the distance between each pair of species in the MFA space. For each species, we identified the closest species among the 43 **Type A** species and when possible, belonging to the same species group. Similarly, we identified the three closest species among the 69 **Type A** and **Type B** species, and when possible, belonging to the same species group. Results of the identified closest species are presented in Table A.3.

1. Distribution of the flower production over the crop season

The distribution of the flower production per individual every two weeks over the crop season was based on the results of the phenological survey described in Yvoz et al. (2020) and the counting of flowers per plant implemented in the same patches and described in Part 1. Following the framework presented in Figure A.3, we focused separately on the **Type A, Type B** and **Type C** species.



**Figure A.3:** Methodology used to estimate the production of flowers every two weeks for the 155 weed species.

* 1. Species with phenological survey and flower number (Type A species, N=43)

For the **Type A** species, we first linked each weed sample to the phenological survey at the patch scale, when possible. Otherwise, we linked the weed sample to the average phenological survey at the field or the crop type scale, distinguishing the two within-field locations. If no phenological survey was available at the crop type scale, we used the phenological survey of the closest crop type available (Table A.4). Similarly, if a phenological survey could not be associated with a flower sample at the patch scale, we linked it to the average flower number at the field, the crop type or the closest crop type scale, but always distinguishing the two within‑field locations. After linking together the phenological surveys and the weed samples, we assigned the flower number to each timing (every two weeks). For each species in all patches, we distributed equally the total number of flowers every two weeks when the plants were at flowering (stages D1 to D3). Then, we averaged for timing the flower numbers of all the patches at flowering for each combination of crop type and within-field location. Thus, we obtained the average number of flowers per plant at flowering for timing. We then multiplied this number by the proportion of patches at flowering at each timing, in a way to determine the average flower number per plant observed in the early weed survey.

* 1. Species with phenological survey but no flower number (Type B species, N=26)

For the **Type B** species, we first attributed the weed samples of the closest species among the 43 **Type A** species. However, the number of flowers per plant can highly vary by weed species and individual (related to its biomass). In order to account for these differences, we adjusted the flower numbers of the closest species using ratios extracted from the literature indicating the average number of flowers per plant. The ratio was computed as the average number of flowers of the **Type B** species divided by the average number of the **Type A** (Table A.5). Then, as done previously (section 3.1), we linked the attributed samples to the phenological surveys at the patch scale when possible, otherwise at the field or crop type scale. Then, we followed the same methodology as presented for the **Type A** species (section 3.1).

However, for some species of these two preceding species groups (**Type A & B**), flower production was lacking for few crop type by within-field location combinations observed in the weed surveys, but not in the phenological survey (Yvoz et al., 2020). In total, 204 combinations were lacking for these 69 species. To complete these combinations, we looked if they were filled in one of their 3 closest species (Table A.3). In that case, we used the flower production every two weeks of the closest species that we multiplied by the ratio of potential flower production. For 37 combinations, we did not find flower numbers within the 3 closest weed species. In that case, we used the flower production from the closest crop type with completed data (Table A.4).

* 1. Species without data (Type C, N=86)

For the 86 **Type C** species, we had neither phenological survey nor flower number. In that case, we directly took the flower number every two weeks from the 3 closest species. First, we attributed to each species the flower numbers estimated for the first closest species. After this step, data were still missing for 28 combinations of weed species, crop type and within-field location. We then looked for these combinations within the second and third closest surveyed species, allowing us to complete 23 combinations (Table A.3). Then, we multiplied these flower numbers by the ratio of potential flower production between the **Type C** species and the **Type A & B**. Finally, for the five combinations still missing, we attributed the flower production from the closest crop type, in the same within-field location (Table A.4).

1. Distribution of the seed production over the crop season

We used the same methodology than the flower production to estimate the seed production. We estimated separately the seed production for the **Type A**, the **Type B** and the **Type C** species. Firstly, we multiplied the estimated number of flowers from the 2016 samples by the average number of seeds per flower of the corresponding species (Table A.5). The number of seeds per flower was obtained from a literature research. Then, we estimated the distribution of the seed production over the fruiting period. Thus, we applied exactly the same methodology presented for the flower production, except that this time we equally distributed the number of seeds over the fruiting period (stages D3 to E2). Besides, the ratio of potential seed productions was here calculated as the average number of seed production of the **Type C and B** divided by the average number of the **Type A** species (Table A.5). We completed the missing combinations the same way as we did for the flower number. Finally, we calculated the average seed number per plant observed in the early weed survey, by multiplying the number of seeds per plant at fruiting by the proportion of plant fruiting every two weeks.

1. Conclusion

The methodology presented here allowed us to estimate the number of flowers and seeds produced every two weeks by the 155 weed species observed at early stage (often seedlings) in each combination of crop type and within-field location. It was a crucial step to assess the potential contribution of weed communities observed in the agricultural landscape to the provision of ecosystem services and harmfulness.

**Table A.1:** Best model (lowest AIC) and its Adjusted R-squared used to regress the flower production against the dry biomass at flowering of each of the 43 weed species (named according to their EPPO codes <https://gd.eppo.int/>). Nb\_flowers: Flower number, Biomass: Weed dry biomass at flowering, Location: Within-field location.

|  |  |  |
| --- | --- | --- |
| **Weed Species** | **Best model selected to estimate flower number** | **Adjusted R²** |
| ACHMI | Nb\_flowers ~ 0 + Biomass+ Crop\_type | 0.89 |
| AETCY | Nb\_flowers ~ 0 + Biomass + Crop\_type + Crop\_type:Biomass | 0.99 |
| ALOMY | Nb\_flowers ~ 0 + Biomass + Crop\_type | 0.67 |
| AMASS | Nb\_flowers ~ 0 + Biomass | -86.86 |
| ANGAR | Nb\_flowers ~ 0 + Biomass + Crop\_type + Location + Crop\_type:Biomass + Biomass:Location | 0.83 |
| ANRCA | Nb\_flowers ~ 0 + Biomass | 0.78 |
| AVEFA | Nb\_flowers ~ 0 + Biomass + Crop\_type + Crop\_type:Biomass | 0.98 |
| BROSPP | Nb\_flowers ~ 0 + Biomass + Location + Biomass:Location | 0.91 |
| CAPBP | Nb\_flowers ~ 0 + Biomass | 0.98 |
| CENCY | Nb\_flowers ~ 0 + Biomass | 0.90 |
| CHEAL | Nb\_flowers ~ 0 + Biomass + Location + Biomass:Location | 0.99 |
| CIRAR | Nb\_flowers ~ 0 + Biomass + Crop\_type + Location | 1.00 |
| CONAR | Nb\_flowers ~ 0 + Biomass + Location + Biomass:Location | 0.50 |
| ECHCG | Nb\_flowers ~ 0 + Biomass | -23.14 |
| EPHEX | Nb\_flowers ~ 0 + Biomass | 0.52 |
| EPHHE | Nb\_flowers ~ 0 + Biomass + Crop\_type + Crop\_type:Biomass | 0.85 |
| EROCI | Nb\_flowers ~ 0 + Biomass | 0.76 |
| FUMOF | Nb\_flowers ~ 0 + Biomass | 0.93 |
| GALAP | Nb\_flowers ~ 0 + Biomass | 0.87 |
| GERDI | Nb\_flowers ~ 0 + Biomass | 0.86 |
| GERPU | Nb\_flowers ~ 0 + Biomass | 0.99 |
| GERRT | Nb\_flowers ~ 0 + Biomass + Location | 0.99 |
| HERSP | Nb\_flowers ~ 0 + Biomass | -81.23 |
| LAMPU | Nb\_flowers ~ 0 + Biomass | 0.90 |
| MATSPP | Nb\_flowers ~ 0 + Biomass | 0.98 |
| MELAL | Nb\_flowers ~ 0 + Biomass | 0.17 |
| MERAN | Nb\_flowers ~ 0 + Biomass + Location | 0.05 |
| MYOAR | Nb\_flowers ~ 0 + Biomass | 0.77 |
| PAPRH | Nb\_flowers ~ 0 + Biomass | 0.84 |
| PLALA | Nb\_flowers ~ 0 + Biomass | 0.35 |
| POLAV | Nb\_flowers ~ 0 + Biomass | 0.72 |
| POLCO | Nb\_flowers ~ 0 + Biomass | 0.80 |
| POLLA | Nb\_flowers ~ 0 + Biomass | 0.88 |
| POLPE | Nb\_flowers ~ 0 + Biomass | 0.51 |
| SCAPV | Nb\_flowers ~ 0 + Biomass | 0.48 |
| SENVU | Nb\_flowers ~ 0 + Biomass + Location | 0.94 |
| SOLNI | Nb\_flowers ~ 0 + Biomass | 0.78 |
| SONAS | Nb\_flowers ~ 0 + Biomass + Crop\_type + Location + Crop\_type:Location + Biomass:Location | 0.82 |
| STEME | Nb\_flowers ~ 0 + Biomass + Crop\_type + Crop\_type:Biomass | 0.96 |
| TAROF | Nb\_flowers ~ 0 + Biomass + Crop\_type + Location + Crop\_type:Biomass + Crop\_type:Location | 0.78 |
| VERHE | Nb\_flowers ~ 0 + Biomass + Crop\_type + Location + Biomass:Location | 0.86 |
| VERPE | Nb\_flowers ~ 0 + Biomass | 0.88 |
| VIOSS | Nb\_flowers ~ 0 + Biomass + Location | 0.70 |

**Table A.2:** Variables used for the trait-based approach to identify the closest species in the multivariate space, *i.e.* the most similar species regarding its response to farming practices and crop competition (groups 1 and 2), growth cycle (group 3) and distribution between crop type and within-field locations (group 4).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Trait/Biological characteristic** | **Unit** | **Group** | **Type of data** | **Mean [min-max]** | **Source** |
| Ellenberg.L |  | 1 | Quantitative | 7.1 [4-9] | Baseflor  (Julve, 1998) |
| Ellenberg.N |  | 1 | Quantitative | 6.2 [1-9] | Baseflor  (Julve, 1998) |
| Height | cm | 1 | Quantitative | 79 [12-250] | (Mamarot and Rodriguez, 2014; TelaBotanica, 2020) |
| Leaf dry matter content (LDMC) | mg/g | 1 | Quantitative | 183 [84-408] | LEDA Traitbase  (Kleyer et al., 2008) |
| Seed mass | mg | 1 | Quantitative | 2.81 [0.01-33.5] | Seed information database  (Kew, 2020) |
| Specific leaf area (SLA) | mm²/mg | 1 | Quantitative | 25.2 [8.6-65.1] | LEDA Traitbase  ([Kleyer et al., 2008](#_ENREF_2)) |
| Botanical family |  | 2 | Qualitative | 36 families | (TelaBotanica, 2020) |
| Botanical order |  | 2 | Qualitative | 22 orders | (TelaBotanica, 2020) |
| Growth form |  | 2 | Qualitative | Rosette, Hemirosette, Erosulate | BiolFlor (Klotz et al., 2002) |
| Life cycle duration |  | 2 | Qualitative | Annual, Biannual, Perennial | BiolFlor (Klotz et al., 2002) |
| Leaf type |  | 2 | Qualitative | Grass, Forb | BiolFlor (Klotz et al., 2002) |
| Flowering onset |  | 3 | Quantitative | 5.1 [1-8]  Month number from January (1) to December (12) | (Mamarot and Rodriguez, 2014; TelaBotanica, 2020) |
| Flowering end |  | 3 | Quantitative | 8.9 [3-12]  Month number from January (1) to December (12) | (Mamarot and Rodriguez, 2014; TelaBotanica, 2020) |
| Germination onset |  | 3 | Quantitative | 3.4 [1-9]  Month number from September (1) to August (12) | (Mamarot and Rodriguez, 2014; TelaBotanica, 2020) |
| Germination end |  | 3 | Quantitative | 9.2 [4-12]  Month number from September (1) to August (12) | (Mamarot and Rodriguez, 2014; TelaBotanica, 2020) |
| Frequency of occurrence in the 12 combinations of crop by within-field location |  | 4 | Quantitative | 0.08 [0-1] | Weed survey carried out on the Fénay platform from 2008 to 2013 |

**Table A.3:** Identification of the closest species in the multivariate space (Figure A.2) having information on the flower number (**Type A**) and the three closest species with information on the phenological development (**Type A & B**). Species are named according to their EPPO codes <https://gd.eppo.int/>

| **Weed species of interest** | **Closest species having information on biomass (Type A)** | **Closest species having information on the phenological development (Type A & B)** | | |
| --- | --- | --- | --- | --- |
| **1st closest weed species** | **1st closest weed species** | **2nd closest weed species** | **3rd closest weed species** |
| ACHMI | ACHMI | CENJA | HERSP | DAUCA |
| AETCY | AETCY | GALAP | SONAS | RUMCR |
| AGIEU | ACHMI | PTLRE | CENJA | ACHMI |
| AGRRE | BROSPP | LOLSS | BROSPP | ALOMY |
| AGSST | ALOMY | LOLSS | ALOMY | POATR |
| ALLSS | ACHMI | ACHMI | PTLRE | CENJA |
| ALOMY | ALOMY | BROSPP | LOLSS | AGRRE |
| AMASS | AMASS | POLPE | POLLA | CHEAL |
| AMBEL | CIRAR | CIRAR | PICHI | PAVSA |
| AMIMA | POLCO | POLCO | CHEAL | ATXPA |
| ANGAR | ANGAR | KICSP | POLAV | POLCO |
| ANRCA | ANRCA | TAROF | MATSPP | GALMO |
| ANTAR | PLALA | PLALA | MELAL | TAROF |
| APHAR | EROCI | EROCI | PTLRE | GERRT |
| ARBTH | MYOAR | MYOAR | VERHE | CAPBP |
| ARFLA | CONAR | CONAR | CAGSE | PAVSA |
| ARISE | ANRCA | ANRCA | TAROF | MATSPP |
| ARREL | BROSPP | AGRRE | CRXSS | LOLSS |
| ARTVU | CIRAR | CIRAR | PAVSA | DAUCA |
| ATHOR | ANGAR | ANGAR | KICSP | EPHEX |
| ATXPA | CHEAL | CHEAL | POLLA | POLPE |
| AVEFA | AVEFA | AGRRE | BROSPP | ALOMY |
| BARSPP | EROCI | CVPSS | EROCI | SCAPV |
| BIDTR | CHEAL | CHEAL | SOLNI | POLLA |
| BROSPP | BROSPP | ALOMY | LOLSS | AGRRE |
| CAGSE | CONAR | CONAR | ECHCG | PICHI |
| CAPBP | CAPBP | PAPRH | MYOAR | VERHE |
| CARHI | EROCI | EROCI | CVPSS | MYOAR |
| CENCY | CENCY | SCAPV | VICSA | PAPRH |
| CENJA | ACHMI | ACHMI | LACSE | HERSP |
| CENSC | ACHMI | CENJA | ACHMI | LACSE |
| CERSPP | TAROF | TAROF | MELAL | ANRCA |
| CHEAL | CHEAL | POLLA | ATXPA | POLPE |
| CHEHY | SOLNI | SOLNI | POLCO | POLAV |
| CHEPO | POLLA | POLLA | CHEAL | POLCO |
| CHNMI | ANGAR | KICSP | ANGAR | ATXPA |
| CIRAR | CIRAR | ATXPA | PICHI | CHEAL |
| CIRVU | HERSP | LACSE | PICHI | PAVSA |
| CLVVT | ACHMI | ACHMI | GALMO | HERSP |
| CNSRE | TAROF | TAROF | ANRCA | GALMO |
| CONAR | CONAR | CAGSE | CIRAR | RUMCR |
| COPSQ | TAROF | TAROF | ANRCA | MATSPP |
| CRXSS | ALOMY | AGRRE | LOLSS | ALOMY |
| CVPSS | EROCI | EROCI | SCAPV | CENCY |
| CZRVA | EROCI | EROCI | CVPSS | ANRCA |
| DACGL | BROSPP | LOLSS | AGRRE | BROSPP |
| DAUCA | HERSP | HERSP | PAVSA | LACSE |
| DIWSI | ACHMI | LACSE | PAVSA | PICHI |
| ECHCG | ECHCG | CONAR | AMASS | ATXPA |
| EHIVU | EROCI | CVPSS | EROCI | SCAPV |
| EPHEX | EPHEX | MERAN | VIOSS | EPHHE |
| EPHFA | VIOSS | APHAR | VIOSS | EROCI |
| EPHHE | EPHHE | VIOSS | MERAN | CAPBP |
| EPHPE | EPHHE | EPHHE | VIOSS | EPHEX |
| EPHPL | EROCI | APHAR | EROCI | VIOSS |
| EPIAD | ACHMI | ALLSS | ACHMI | CENJA |
| EQUAR | EQUAR | PTLRE | CENJA | ACHMI |
| ERISU | HERSP | LACSE | PICHI | PAVSA |
| EROCI | EROCI | ANRCA | APHAR | MYOAR |
| ERPVE | EROCI | EROCI | CVPSS | MYOAR |
| ERXCA | CIRAR | CIRAR | CENJA | PAVSA |
| FESSPP | ALOMY | PTLRE | CRXSS | AGRRE |
| FUMOF | FUMOF | SENVU | LAPCO | GALAP |
| GALAP | GALAP | LAPCO | FUMOF | SENVU |
| GALMO | MATSPP | MATSPP | MELAL | URTDI |
| GERCO | GERDI | GERDI | GERPU | GERRT |
| GERDI | GERDI | GERRT | GERPU | GERMO |
| GERMO | GERPU | GERPU | GERRT | GERDI |
| GERPU | GERPU | GERDI | GERRT | GERMO |
| GERRO | GERRT | GERMO | GERRT | GERPU |
| GERRT | GERRT | GERDI | GERPU | GERMO |
| GLEHE | LAMPU | VERAR | LAMPU | VERPE |
| HERSP | HERSP | DAUCA | ACHMI | PAVSA |
| HMAHI | PLALA | ALLSS | PLALA | TAROF |
| HOLMO | BROSPP | POATR | LOLSS | BROSPP |
| HYPPE | ALOMY | PTLRE | APHAR | URTDI |
| KICSP | ANGAR | ANGAR | POLAV | POLCO |
| KNAAR | ACHMI | ALLSS | ACHMI | CENJA |
| LACSE | HERSP | PAVSA | DAUCA | PICHI |
| LAMAM | VERPE | VERPE | VERAR | LAMPU |
| LAMPU | LAMPU | VERPE | STEME | VERAR |
| LAPCO | FUMOF | FUMOF | GALAP | SENVU |
| LEGSPP | MYOAR | MYOAR | CAPBP | PAPRH |
| LINVU | PLALA | PLALA | GALMO | KICSP |
| LITAR | EROCI | EROCI | CVPSS | ANRCA |
| LOLSS | BROSPP | AGRRE | BROSPP | POATR |
| LTHTU | HERSP | HERSP | DAUCA | ACHMI |
| MALSI | SONAS | CAGSE | SONAS | CONAR |
| MATSPP | MATSPP | GALMO | MELAL | ANRCA |
| MEDSPP | CENCY | VICSA | CENCY | SCAPV |
| MELAL | MELAL | MATSPP | GALMO | URTDI |
| MENSU | ANGAR | KICSP | ANGAR | POLPE |
| MERAN | MERAN | EPHHE | EPHEX | VIOSS |
| MYOAR | MYOAR | PAPRH | VERHE | CAPBP |
| OXASS | LAMPU | LAMPU | VERPE | POATR |
| PAPRH | PAPRH | MYOAR | CAPBP | VERHE |
| PAVSA | HERSP | DAUCA | LACSE | PICHI |
| PICEC | MATSPP | MATSPP | MELAL | GALMO |
| PICHI | HERSP | PAVSA | LACSE | DAUCA |
| PLALA | PLALA | TAROF | VERAR | VERHE |
| PLAMA | PLALA | PLALA | VERAR | TAROF |
| PLAME | PLALA | PLALA | TAROF | VERAR |
| POAAN | GERRT | POATR | LOLSS | GERRT |
| POAPR | ALOMY | AGRRE | CRXSS | LOLSS |
| POATR | BROSPP | LOLSS | BROSPP | AGRRE |
| POLAM | CIRAR | CIRAR | ATXPA | CONAR |
| POLAV | POLAV | POLCO | POLLA | ATXPA |
| POLCO | POLCO | POLAV | CHEAL | ATXPA |
| POLLA | POLLA | POLPE | CHEAL | ATXPA |
| POLPE | POLPE | POLLA | CHEAL | ATXPA |
| PTLAN | ACHMI | PTLRE | URTDI | GALMO |
| PTLRE | PLALA | URTDI | APHAR | GALMO |
| RANRE | PLALA | PLALA | MELAL | URTDI |
| RAPRA | VIOSS | VIOSS | EPHHE | EPHEX |
| RESLU | MATSPP | MATSPP | GALMO | ANRCA |
| RUBSS | ACHMI | PTLRE | CRXSS | CENJA |
| RUMCR | SONAS | SONAS | GALAP | AETCY |
| RUMOB | SONAS | SINAR | SONAS | AETCY |
| SAMEB | CIRAR | CIRAR | PAVSA | DAUCA |
| SANMI | EROCI | APHAR | EROCI | PTLRE |
| SAWOF | MATSPP | MATSPP | GALMO | ANRCA |
| SCAPV | SCAPV | CENCY | VICSA | ANRCA |
| SENVI | CIRAR | CIRAR | ATXPA | POLPE |
| SENVU | SENVU | FUMOF | GALAP | SINAR |
| SETPU | ECHCG | ECHCG | CRXSS | AGRRE |
| SETVI | ECHCG | ECHCG | CRXSS | AGRRE |
| SHRAR | ANRCA | ANRCA | TAROF | URTDI |
| SILVU | MATSPP | GALMO | MATSPP | TAROF |
| SINAR | SENVU | SENVU | GALAP | FUMOF |
| SLYMA | CENCY | VICSA | CENCY | SCAPV |
| SOLNI | SOLNI | CHEAL | POLLA | CHEHY |
| SONAR | CIRAR | CIRAR | PICHI | ATXPA |
| SONAS | SONAS | RUMCR | AETCY | GALAP |
| SONOL | AETCY | RUMCR | AETCY | SONAS |
| STAAN | ANGAR | KICSP | ANGAR | VERAR |
| STEME | STEME | VERPE | LAMPU | VERAR |
| SXFTR | PLALA | ALLSS | CVPSS | PLALA |
| TAROF | TAROF | ANRCA | MATSPP | MELAL |
| THLAR | GERPU | GERMO | GERPU | GERDI |
| THLPE | EROCI | EROCI | CVPSS | APHAR |
| TOISPP | CENCY | CENCY | SCAPV | VICSA |
| TRFCA | EROCI | APHAR | EROCI | CENJA |
| TRFPR | CENCY | CENCY | SCAPV | VICSA |
| TRFRE | GERDI | GERDI | GERRT | GERPU |
| TROSPP | ACHMI | ACHMI | CENJA | PAVSA |
| TUSFA | PLALA | ALLSS | PLALA | TAROF |
| URTDI | MELAL | GALMO | MELAL | MATSPP |
| VEBOF | ACHMI | PTLRE | GALMO | URTDI |
| VERAR | VERPE | VERPE | LAMPU | PLALA |
| VERHE | VERHE | MYOAR | PAPRH | CAPBP |
| VERPE | VERPE | LAMPU | VERAR | STEME |
| VERPO | VERPE | VERAR | VERPE | LAMPU |
| VICSA | SCAPV | SCAPV | CENCY | ALOMY |
| VIOSS | VIOSS | EPHHE | CAPBP | GALAP |
| VLLSS | MYOAR | MYOAR | PAPRH | VERHE |

**Table A.4:** Proximity between crop types used to estimate the phenological surveys and flower and seed productions within a weed species.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Crop of interest** | **1st closest crop** | **2nd closest crop** | **3rd closest crop** | **4th closest crop** |
| Winter wheat | Winter barley | Spring barley | Winter oilseed rape | Winter mustard |
| Winter barley | Winter wheat | Spring barley | Winter oilseed rape | Winter mustard |
| Winter mustard | Winter oilseed rape | Winter wheat | Winter barley | Spring barley |
| Winter oilseed rape | Winter mustard | Winter wheat | Winter barley | Spring barley |
| Spring barley | Winter barley | Winter wheat | Winter oilseed rape | Winter mustard |
| Soybean | - | - | - | - |

**Table A.5:** Average number of flowers per plant and number of seeds per flower extracted from the literature for the 155 studied weed species. Species are named according to their EPPO codes <https://gd.eppo.int>

| **Weed species** | **Flower unit** | **Average flower number/**  **plant** | **Seed number/**  **flower** |  | **Weed species** | **Flower unit** | **Average flower number/**  **plant** | **Seed number/**  **flower** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ACHMI | Flower head | 120 | 20 |  | LACSE | Flower head | 526.32 | 19 |
| AETCY | Umbel | 1.32 | 455 |  | LAMAM | Single flower | 50 | 4 |
| AGIEU | Single flower | 25 | 2 |  | LAMPU | Single flower | 150 | 4 |
| AGRRE | Spicklet | 20 | 5 |  | LAPCO | Flower head | 30.95 | 21 |
| AGSST | Spicklet | 200 | 1 |  | LEGSPP | Single flower | 19.47 | 81 |
| ALLSS | Single flower | 12.5 | 2 |  | LINVU | Single flower | 54.22 | 166 |
| ALOMY | Ear | 28.85 | 150 |  | LITAR | Single flower | 46.75 | 4 |
| AMASS | Single flower | 19905 | 1 |  | LOLSS | Spicklet | 215.57 | 7 |
| AMBEL | Flower head | 251.8 | 10 |  | LTHTU | Single flower | 75 | 2 |
| AMIMA | Flower head | 3.75 | 2000 |  | MALSI | Single flower | 50 | 14 |
| ANGAR | Single flower | 30 | 30 |  | MATSPP | Flower head | 44.67 | 150 |
| ANRCA | Umbel | 23.48 | 230 |  | MEDSPP | Single flower | 11.25 | 8 |
| ANTAR | Flower head | 45.68 | 77.5 |  | MELAL | Single flower | 55.81 | 215 |
| APHAR | Single flower | 300 | 1 |  | MENSU | Single flower | 50 | 4 |
| ARBTH | Single flower | 173.06 | 33 |  | MERAN | Single flower | 286 | 1 |
| ARFLA | Flower head | 112.33 | 73 |  | MYOAR | Single flower | 212.5 | 4 |
| ARISE | Single flower | 100 | 15 |  | OXASS | Single flower | 12 | 50 |
| ARREL | Spicklet | 250 | 1 |  | PAPRH | Single flower | 14.71 | 1360 |
| ARTVU | Flower head | 20000 | 10 |  | PAVSA | Umbel | 2.67 | 592 |
| ATHOR | Single flower | 16.7 | 150 |  | PICEC | Flower head | 17.17 | 36 |
| ATXPA | Single flower | 3050 | 1 |  | PICHI | Flower head | 28.92 | 50 |
| AVEFA | Spicklet | 195.2 | 2.5 |  | PLALA | Single flower | 6.67 | 1500 |
| BARSPP | Single flower | 423.08 | 13 |  | PLAMA | Inflorescence | 4.93 | 2030 |
| BIDTR | Flower head | 12.10 | 83 |  | PLAME | Single flower | 5.13 | 1950 |
| BROSPP | Spicklet | 58 | 7 |  | POAAN | Ear | 4.74 | 95 |
| CAGSE | Single flower | 93.75 | 4 |  | POAPR | Ear | 1.6 | 130 |
| CAPBP | Single flower | 840 | 25 |  | POATR | Ear | 2.31 | 130 |
| CARHI | Single flower | 13.15 | 20 |  | POLAM | Single flower | 150 | 1 |
| CENCY | Flower head | 32.86 | 35 |  | POLAV | Single flower | 163 | 1 |
| CENJA | Flower head | 30.29 | 35 |  | POLCO | Single flower | 350 | 1 |
| CENSC | Flower head | 22.99 | 87 |  | POLLA | Single flower | 825 | 1 |
| CERSPP | Single flower | 76.21 | 62 |  | POLPE | Single flower | 800 | 1 |
| CHEAL | Single flower | 10080 | 1 |  | PTLAN | Single flower | 18.75 | 8 |
| CHEHY | Single flower | 6250 | 1 |  | PTLRE | Single flower | 18.75 | 8 |
| CHEPO | Single flower | 4000 | 1 |  | RANRE | Single flower | 7.5 | 20 |
| CHNMI | Single flower | 24.27 | 103 |  | RAPRA | Single flower | 62.5 | 8 |
| CIRAR | Flower head | 124.89 | 45 |  | RESLU | Single flower | 139.05 | 19 |
| CIRVU | Flower head | 16 | 250 |  | RUBSS | Single flower | 15.38 | 13 |
| CLVVT | Single flower | 802.27 | 22 |  | RUMCR | Single flower | 3711 | 1 |
| CNSRE | Single flower | 10 | 20 |  | RUMOB | Single flower | 7000 | 1 |
| CONAR | Single flower | 40 | 4 |  | SAMEB | Umbel | 0.64 | 647.5 |
| COPSQ | Single flower | 157.84 | 51 |  | SANMI | Inflorescence | 12 | 10 |
| CRXSS | Spicklet | 8 | 50 |  | SAWOF | Single flower | 16.96 | 50 |
| CVPSS | Flower head | 200 | 40 |  | SCAPV | Umbel | 7.5 | 20 |
| CZRVA | Single flower | 130.57 | 7 |  | SENVI | Flower head | 40.70 | 86 |
| DACGL | Spicklet | 59 | 5 |  | SENVU | Flower head | 95.56 | 45 |
| DAUCA | Umbel | 2.125 | 2000 |  | SETPU | Ear | 8.98 | 189.0625 |
| DIWSI | Single flower | 1.28 | 1892 |  | SETVI | Ear | 11.79 | 550 |
| ECHCG | Ear | 5 | 400 |  | SHRAR | Single flower | 77.5 | 2 |
| EHIVU | Single flower | 412.5 | 4 |  | SILVU | Single flower | 80.81 | 49.5 |
| EPHEX | Umbel | 18.75 | 24 |  | SINAR | Single flower | 312.5 | 8 |
| EPHFA | Umbel | 9.03 | 72 |  | SLYMA | Flower head | 2.30 | 63 |
| EPHHE | Umbel | 7.22 | 90 |  | SOLNI | Single flower | 161.07 | 56 |
| EPHPE | Umbel | 22.22 | 54 |  | SONAR | Flower head | 33.51 | 191 |
| EPHPL | Umbel | 7.22 | 90 |  | SONAS | Flower head | 41.43 | 140 |
| EPIAD | Single flower | 47.25 | 153 |  | SONOL | Flower head | 43.57 | 140 |
| EQUAR | None | 0 | 0 |  | STAAN | Single flower | 31.25 | 4 |
| ERISU | Flower head | 2244.90 | 49 |  | STEME | Single flower | 200 | 12 |
| EROCI | Single flower | 240 | 5 |  | SXFTR | Single flower | 3.89 | 284 |
| ERPVE | Single flower | 4 | 50 |  | TAROF | Flower head | 15.14 | 146 |
| ERXCA | Umbel | 18.09 | 47 |  | THLAR | Single flower | 179.45 | 11 |
| FESSPP | Ear | 2.21 | 210 |  | THLPE | Single flower | 197.4 | 10 |
| FUMOF | Single flower | 1600 | 1 |  | TOISPP | Umbel | 2.74 | 242.5 |
| GALAP | Single flower | 175 | 2 |  | TRFCA | Inflorescence | 4.77 | 30 |
| GALMO | Single flower | 867 | 2 |  | TRFPR | Single flower | 206 | 1 |
| GERCO | Single flower | 62.8 | 5 |  | TRFRE | Inflorescence | 5.71 | 105 |
| GERDI | Single flower | 150 | 5 |  | TROSPP | Flower head | 4.07 | 55 |
| GERMO | Single flower | 58 | 5 |  | TUSFA | Flower head | 11.67 | 300 |
| GERPU | Single flower | 105 | 5 |  | URTDI | Ear | 24.48 | 250 |
| GERRO | Single flower | 26.4 | 5 |  | VEBOF | Single flower | 101 | 4 |
| GERRT | Single flower | 105 | 5 |  | VERAR | Single flower | 81.13 | 15 |
| GLEHE | Single flower | 12.5 | 4 |  | VERHE | Single flower | 106.5 | 4 |
| HERSP | Umbel | 1.20 | 706.5 |  | VERPE | Single flower | 92.92 | 12 |
| HMAHI | Single flower | 28.8 | 1000 |  | VERPO | Single flower | 10 | 40 |
| HOLMO | Spicklet | 150 | 2 |  | VICSA | Single flower | 25 | 8 |
| HYPPE | Single flower | 118.11 | 127 |  | VIOSS | Single flower | 39 | 50 |
| KICSP | Single flower | 60.05 | 38 |  | VLLSS | Single flower | 140 | 1 |
| KNAAR | Flower head | 33.90 | 59 |  |  |  |  |  |

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