Supplementary Information

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**Figure S1**: Germination results of field collected *Centaurea diffusa* seed. Seed was collected between 2001 and 2008, but no significant effect of age was detected on germination rate, and no sample bias between ranges is apparent. Germination rate is percent of seeds that germinated per maternal plant for wild collected seed. Sample size as follows: Invasive = 135, Native = 152, field collected mothers.

**Table S1**: Native *Centaurea diffusa* population information.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Population ID | Latitude | Longitude | Voucher Accession | Included in the following experiments (treatments) |
| BG001 | 43.38194 | 28.4575 | V236763 | B, M |
| GR001 | 40.15667 | 22.54806 | V236766 | B |
| GR002 | 40.62139 | 23.07861 | V232702, V236769 | B, M |
| GR003 | 40.85083 | 25.79306 | V232674, V236768 | B |
| HU001 | 47.64194 | 18.7825 | V236764 | B |
| RO001 | 44.11028 | 28.63694 | V236767 | B |
| RO002 | 43.90243 | 28.57392 | V232701 | B |
| RO003 | 44.38967 | 28.52664 | V232721, V232723 | B |
| RO004 | 45.57618 | 29.51805 | V232699, V232732, V232724 | B |
| RO005 | 45.49786 | 27.91181 | V232686, V232683 | B |
| RU001 | 51.38333 | 56.8 |  | B |
| RU002 | 49.17917 | 53.24226 |  | B (hndf) |
| RU003 | 38.1625 | 54.8 |  | B |
| RU004 | 60.16667 | 55.01667 |  | B (chndf) |
| RU005 | 49.18767 | 53.25347 |  | B (ecndf) |
| RU008 | 44.05 | 43.06 | V232687 | B, M |
| TR001 | 41.75111 | 27.24778 | V236765 | B, M |
| TR003 | 38.76722 | 37.00389 |  | B |
| TR004 | 38.36722 | 42.77361 |  | B |
| TR005 | 39.7825 | 41.07361 |  | B (chndf) |
| UA001 | 48.10067 | 37.81611 | V232729 | B |
| UA002 | 48.15233 | 37.84058 | V232684 | B (chndf) |
| UA003 | 50.48075 | 30.48631 | V232717 - V232720 | B  |
| UA004 | 48.64603 | 30.77508 | V232728 | B |
| UA005 | 47.862 | 38.46069 | V232700, V232725 | B |
| UA006 | 45.70833 | 33.34972 |  | B (chndf) |
| UA007 | 48.09222 | 30.74972 | V232703, V232726 | B (non-destructive early control only) |
| UA008 | 46.75722 | 32.76611 |  | B (chndf) |

Populations are included in all treatments and analyses in a given experiment unless otherwise stated. All populations in a given experiment were included in non-destructive early control measurements (number of basal leaves, area of longest leaf). Experiments are indicated by an upper-case letter and treatments and analyses are indicated by a lower-case letter as in the following code: broad common garden (B), maternal effects common garden (M), early control measurements that required destructive sampling such as biomass (e), control (c), herbivory (h), nutrient deficiency (n), drought (d), flood (f). Vouchers are located in the UBC Herbarium.

**Table S2**: Invasive *Centaurea diffusa* population information.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Population ID | Latitude | Longitude | Voucher Accession | Included in the following experiments (analyses) |
| CA001 | 49.01494 | -122.882 | V232677- V232679, V232704 - V232706 | B, M |
| CA006 | 49.320181 | -119.630 |  | Weevils only |
| CA007 | 49.2961 | -118.474 |  | B (chn), Weevils |
| CA008 | 49.01208 | -118.646 | V232722 | B, Weevils |
| US001 | 45.61523 | -120.788 | V232694 - V232697 | B, M |
| US002 | 46.18227 | -118.826 | V232669 - V232671 | B, M |
| US003 | 46.60415 | -116.642 |  | B, M |
| US011 | 43.38553 | -106.937 |  | B (hndf) |
| US012 | 40.52815 | -104.849 |  | B (chndf) |
| US013 | 40.5612 | -104.865 | V232713 - V232716, V232680 - V232682 | B (non-destructive early control only) |
| US014 | 40.12227 | -101.28 | V232730, V232698 | B |
| US015 | 42.72536 | -118.001 | V232672 | B |
| US017 | 40.42111 | -122.555 |  | B (non-destructive early control only) |
| US018 | 43.54677 | -118.914 |  | B (nd) |
| US020 | 46.98399 | -119.58 |  | B (chndf) |
| US021 | 46.617 | -110.092 |  | B (cnd) |
| US022 | 45.74515 | -119.785 |  | B |
| US023 | 39.22428 | -103.122 |  | B (chndf) |
| US026 | 40.37191 | -104.473 | V232733 | B (chdf) |

Populations are included in all treatments and analyses in a given experiment unless otherwise stated. All populations in a given experiment were included in non-destructive early control measurements (number of basal leaves, area of longest leaf). Experiments are indicated by an upper-case letter and treatments and analyses are indicated by a lower-case letter as in the following code: broad common garden (B), maternal effects common garden (M), early control measurements that required destructive sampling such as biomass (e), control (c), herbivory (h), nutrient deficiency (n), drought (d), flood (f). Weevils were collected for the leaf choice trial from locations indicated by “Weevils.” Vouchers are located in the UBC Herbarium.

**Table S3**: Test statistics for all traits measured in broad common garden, from range differentiation models of phenotype of *Centaurea diffusa*, grown in a common garden.

|  |  |  |
| --- | --- | --- |
| Broad Common Garden | *Fixed effects* | *Random effects* |
| Origin | Latitude | Origin\*Latitude | Populations | Maternal lines | Populations within each Origin |
| *Trait* | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** |
| *Germination* |  |  |  |  |  |  |
| Seed weight by family | 1.38 (1) | 0.11 (1) | 1.02 (1) | 76.54 (1) \*\*\* | -- | 0.54 (2) |
| *Early Control* |  |  |  |  |  |  |
| Shoot mass | 2.57(1) | 10.80 (1) \*\*\* | 0.05 (1) | 13.10 (1) \*\*\* | 14.31 (1) \*\*\* | 0.57(4) |
| Root mass | 0.58 (1) | 12.31 (1) \*\*\* | 1.12 (1) | 13.43 (1) \*\*\* | 7.79 (1) \*\* | 3.95 (4) |
| Root crown diameter | 3.05 (1) . | 3.86 (1) \* | 0.61 (1) | 18.97 (1) \*\*\* | 3.69 (1) . | 0.30 (4) |
| Area of longest leaf | 0.34 (1) | 3.14 (1) . | 0.25 (1) | 96.67 (1) \*\*\* | 59.04 (1) \*\*\* | 2.82 (4) |
| Number of basal leaves | *nt* | *nt* | 6.23 (1) \* | 160.9 (1) \*\*\* | 8.78 (1) \*\* | 1.19 (4) |
| *Control* |  |  |  |  |  |  |
| Shoot mass | 0.18 (1) | 5.99 (1) \* | 0.06 (1) | 49.74 (1) \*\*\* | 2.90 (1) . | 4.81 (4) |
| Root mass | 3.31 (1) . | 4.90 (1) \* | 0.11 (1) | 41.15 (1) \*\*\* | 0.23 (1) | 3.86 (4) |
| Root crown diameter | 0.05 (1) | 9.64 (1) \*\* | 0.08 (1) | 48.89 (1) \*\*\* | 5.49 (3) | 18.22 (4) \*\* |
| Area of longest leaf | 1.25 (1) | 8.90 (1) \*\* | 0.29 (1) | 3.82 (1) . | 7.78 (1) \*\* | 9.48 (4) . |
| Number of basal leaves | 13.08 (1) \*\*\* | 5.91 (1) \* | 1.50 (1) | 66.22 (1) \*\*\* | 257.29 (3) \*\*\* | 37.14 (4) \*\*\* |
| Bolting status at harvest | *nt* | *nt* | 7.14 (1) \*\* | 0.57 (1) | 10.71 (1) \*\*\* | 4.07 (4) |
| Bolting date | 1.59 (1) | 3.54 (1) . | 0.005 (1) | 154.7 (1) \*\*\* | 184.2 (1) \*\*\* | 9.25 (4) . |
| *Nutrient* |  |  |  |  |  |  |
| Shoot mass | 3.22 (1) . | 3.83 (1) \* | <0.01 (1) | 15.96 (1) \*\*\* | 0.05 (1) | 2.30 (4) |
| Root mass | 3.30 (1) . | 7.84 (1) \*\* | 0.68 (1) | 42.65 (1) \*\*\* | 0.14 (1) | 5.43 (4) |
| Root crown diameter | 0.89 (1) | 2.83 (1) . | <0.01 (1) | 26.05 (1) \*\*\* | 0.68 (1) | 9.10 (4). |
| Area of longest leaf | 0.71 (1) | 2.05 (1) | <0.01 (1) | 7.97 (1) \*\* | <0.01 (1) | 0.23 (4) |
| Number of basal leaves | 1.97 (1) | 3.71 (1) . | 2.44 (1) | 62.57 (1) \*\*\* | 48.11 (3) \*\*\* | 10.33 (4) \* |
| *Herbivory* |  |  |  |  |  |  |
| Root mass | 4.33 (1) \* | 15.82 (1) \*\*\* | 0.06 (1) | 13.04 (1) \*\*\* | <0.01 (1) | 0.84 (4) |
| Root crown diameter | 0.81 (1) | 14.66 (1) \*\*\* | 0.21 (1) | 10.85 (1) \*\*\* | <0.01 (1) | 2.22 (4) |
| Number of basal leaves | 5.91 (1) \* | 13.46 (1) \*\*\* | 0.02 (1) | 166.6 (1) \*\*\* | 237.03 (3) \*\*\* | 20.54 (4) \*\*\* |
| Bolting status at harvest | *nt* | *nt* | 14.46 (1) \*\*\* | <0.01 (1) | 0.32 (1) | 6.24 (4) |
| Bolting date | 1.91 (1) | 5.34 (1) \* | <0.01 (1) | 53.36 (1) \*\*\* | 80.88 (1) \*\*\* | 8.03 (4) . |
| *Drought* |  |  |  |  |  |  |
| Date of 1st wilt | 4.76 (1) \*  | 6.34 (1) \* | 0.50 (1) | 2.12 (1) | 0.27 (1) | 3.71 (4) |
| Date of total wilt | 1.31 (1) | 7.68 (1) \*\* | 1.19 (1) | 1.11 (1) | <0.01 (1) | 3.41 (4) |
| Death date | 2.68 (1) | 12.46 (1) \*\*\* | 0.16 (1) | <0.01 (1) | <0.01 (1) | <0.01 (4) |
| *Flood* |  |  |  |  |  |  |
| Date of 1st yellow leaf | 0.38 (1) | 0.63 (1) | 0.06 (1) | <0.01 (1) | <0.01 (1) | <0.01 (4) |
| Root death date | 2.58 (1) | 17.87 (1) \*\*\* | 0.36 (1) | <0.01 (1) | 0.04 (1) | 0.64 (4) |
| Death date | 0.80 (1) | 7.06 (1) \*\* | 0.01 (1) | 7.01 (1) \*\* | 3.68 (1) . | 2.06 (4) |

Results are presented from restricted maximum likelihood (REML) models. Where no random effects were significant, generalized linear models (GLM) were used to test fixed effects. Significance of term indicated by symbol: ., *P* < 0.1; \*, *P* < 0.05; \*\*, *P* < 0.01; \*\*\*, *P* < 0.001. (df) = degrees of freedom. χ2 = chi-squared test statistic. *Nt* = Not tested, due to significant interaction term.**Table S4**: Means and confidence intervals for all traits estimated from range differentiation models of phenotypes of *Centaurea diffusa* grown in a common garden.

|  |  |  |  |
| --- | --- | --- | --- |
| Broad Common Garden |  | *Origin* |  |
|  |  | Native | Invasive |  |
| *Trait* | *Distribution and model* | **Estimate** | **CI** | **Estimate** | **CI** | ***P*** |
| *Early Control* |  |  |  |  |  |  |
| Shoot mass (g) | Gaussian, REML | 0.41 | 0.36 – 0.45 | 0.48 | 0.40-0.55 |  |
| Root mass (g) | Gaussian (loge), REML | 0.25 | 0.20 – 0.31 | 0.29 | 0.20 – 0.43 |  |
| Root crown diameter (mm) | Gaussian, REML | 3.40 | 3.14 – 3.67 | 3.88 | 3.44 – 4.31 | . |
| Area of longest leaf (cm2) | Gaussian, REML | 45.18 | 42.13 – 48.23 | 46.67 | 42.60 – 50.74 |  |
| Number of basal leaves | Poisson, REML | 9.83 | 9.28 – 10.41 | 9.60 | 8.90 – 10.36 | [\*] |
| *Control* |  |  |  |  |  |  |
| Shoot mass (g) | Gaussian, REML | 3.13 | 2.87 – 3.39 | 3.23 | 2.88 – 3.60 |  |
| Root mass (g) | Gaussian (loge), REML | 1.40 | 1.17 – 1.68 | 1.84 | 1.44 – 2.37 | . |
| Root crown diameter (mm) | Gaussian, REML | 7.80 | 7.38 – 8.22 | 7.87 | 7.59 – 8.14 |  |
| Area of longest leaf (cm2) | Gaussian, REML | 148.43 | 140.44 – 156.43 | 155.85 | 144.71 – 166.99 |  |
| Number of basal leaves | Poisson, REML | 12.43 | 11.04 – 13.99 | 16.28 | 15.31 – 17.32 | \*\*\* |
| Bolting status at harvest (%) | Binomial, REML | 24.30 | 17.49 – 32.69 | 2.07 | 0.62 – 6.76 | [\*\*] |
| Bolting date | Poisson, REML | 58.13 | 51.59 – 65.49 | 74.42 | 51.88 – 106.76 |  |
| *Nutrient* |  |  |  |  |  |  |
| Shoot mass (g) | Gaussian, REML | 1.29 | 1.19 – 1.39 | 1.44 | 1.30 – 1.57 | . |
| Root mass (g) | Gaussian (loge), REML | 2.55 | 2.23 – 2.92 | 3.14 | 2.60 – 3.79 | . |
| Root crown diameter (mm) | Gaussian, REML | 5.58 | 5.33 – 5.82 | 5.78 | 5.43 – 6.12 |  |
| Area of longest leaf (cm2) | Gaussian, REML | 69.66 | 63.98 – 75.33 | 73.75 | 65.67 – 81.86 |  |
| Number of basal leaves | Poisson, REML | 14.45 | 13.04 – 16.01 | 15.79 | 14.79 – 16.87 |  |
| *Herbivory* |  |  |  |  |  |  |
| Root mass (g) | Gaussian (loge), REML | 1.03 | 0.88 – 1.21 | 1.37 | 1.09 – 1.72 | \* |
| Root crown diameter (mm) | Gaussian, REML | 6.81 | 6.52 – 7.09 | 7.03 | 6.62 – 7.45 |  |
| Number of basal leaves | Poisson, REML | 21.58 | 19.26 – 24.18 | 25.71 | 23.82 – 27.74 | \* |
| Bolting status at harvest (%) | Binomial, GLM | 26.71 | 20.17 – 34.47 | 6.45 | 2.44 – 15.97 | [\*\*\*] |
| Bolting date | Poisson, REML | 44.55 | 38.81 – 51.14 | 63.08 | 39.64 – 100.40 |  |
| *Drought* |  |  |  |  |  |  |
| Date of 1st wilt | Poisson, GLM | 3.73 | 3.43 – 4.05 | 3.14 | 2.76 – 3.58 | \* |
| Date of total wilt | Poisson, GLM | 6.13 | 5.74 – 6.54 | 5.73 | 5.20 – 6.31 |  |
| Death date | Poisson, GLM | 12.82 | 12.25 – 13.41 | 11.98 | 11.21 – 12.82 |  |
| *Flood* |  |  |  |  |  |  |
| Date of 1st yellow leaf | Poisson, GLM | 6.47 | 6.07 – 6.90 | 6.23 | 5.63 – 6.90 |  |
| Root death date | Poisson, GLM | 16.27 | 15.33 – 17.26 | 17.67 | 16.29 – 19.17 |  |
| Death date | Poisson, REML | 18.06 | 17.08 – 19.08 | 18.90 | 17.41 – 20.52 |  |

Least squares (LS) means from restricted maximum likelihood (REML) models which include origin and all significant terms (interactions were excluded). Where no random effects were significant, LS means are estimated from generalized linear models (GLM). Significance of origin term (or origin\*latitude in square brackets []) indicated in right-most column: ., *P* < 0.1; \*, *P* < 0.05; \*\*, *P* < 0.01; \*\*\*, *P* < 0.001. CI = 95% confidence interval. Loge indicates natural log transformation of data. *Nt* = Not tested, due to significant interaction term.

**Table S5**: Means and confidence intervals for all traits estimated from range differentiation models of phenotypes of *Centaurea diffusa* grown in a common garden, after one generation.

|  |  |  |
| --- | --- | --- |
| Maternal Common Garden | *Origin* |  |
|  |  | Native | Invasive |  |
| *Trait* | *Distribution and model* | **Estimate** | **CI** | **Estimate** | **CI** | ***P*** |
| *Germination* |  |  |  |  |  |  |
| Seed count by family | Poisson, REML | 3.35 | 2.56 – 4.38 | 7.21 | 5.48 – 9.48 | \*\* |
| Rate by family (% of global average seed count) | Poisson, GLM | 59.19 | 51.05 – 68.62 | 79.85 | 71.16 – 89.59 | \*\* |
| Average germination date by family | Gaussian, GLM | 2.36 | 2.21 – 2.51 | 2.07 | 1.94 – 2.20 | \* |
| Average seed weight by family (mg) | Gaussian, GLM | 1.00 | 1.00-1.00 | 1.00 | 1.00 – 1.00 |  |
| *Early Control* |  |  |  |  |  |  |
| Shoot mass (g) | Gaussian, GLM | 0.88 | 0.73 – 1.03 | 1.24 | 1.10 – 1.38 | \*\*\* |
| Root crown diameter (mm) | Gaussian, GLM | 5.05 | 4.64 – 5.47 | 4.85 | 4.46 – 5.24 |  |
| Area of longest leaf (cm2) | Gaussian, REML | 56.04 | 40.96 – 71.11 | 75.80 | 60.88 – 90.73 | \* |
| Number of basal leaves | Poisson, REML | 15.06 | 13.09 – 17.33 | 14.76 | 12.83 – 17.00 | [\*] |
| *Control* |  |  |  |  |  |  |
| Shoot mass (g) | Gaussian, GLM | 3.37 | 3.11 – 3.63 | 3.79 | 3.52 – 4.05 | \* |
| Root crown diameter (mm) | Gaussian, REML | 0.88 | 0.70 – 1.06 | 0.87 | 0.78 – 0.96 |  |
| Area of longest leaf (cm2) | Gaussian, GLM | 102.48 | 90.06 – 114.89 | 120.97 | 109.19 – 132.74 | [\*] |
| Number of basal leaves | Poisson, REML | 11.74 | 8.51 – 16.21 | 20.41 | 14.81 – 28.14 | \* |
| Specific leaf area (mm2/mg) | Gaussian (loge), GLM | 175.53 | 162.0 – 190.2 | 169.73 | 157.6 – 182.8 |  |
| Bolting status at harvest (%) | Binomial, GLM | 75.09 | 54.53 – 88.34 | 7.57 | 2.51 – 20.67 | [\*] |
| Bolting date | Poisson, REML | 59.61 | 53.63 – 66.25 | 71.27 | 61.81 – 82.16 | . |
| *Nutrient* |  |  |  |  |  |  |
| Shoot mass (g) | Gaussian, GLM | 1.66 | 1.30 – 2.02 | 1.97 | 1.61 – 2.33 |  |
| Root crown diameter (mm) | Gaussian, GLM | 0.70 | 0.59 – 0.81 | 0.75 | 0.64 – 0.86 |  |
| Area of longest leaf (cm2) | Gaussian, GLM | 56.45 | 41.76 – 71.13 | 82.74 | 68.05 – 97.42 | \*\* |
| Number of basal leaves | Poisson, REML | 20.74 | 15.82 – 27.20 | 17.51 | 13.29 – 23.07 |  |
| *Herbivory* |  |  |  |  |  |  |
| Root crown diameter (mm) | Gaussian, GLM | 0.88 | 0.62 – 1.13 | 1.04 | 0.79 – 1.30 |  |
| Number of basal leaves | Poisson, REML | 31.84 | 24.80 – 40.88 | 32.32 | 25.15 – 41.54 |  |
| Bolting status at harvest (%) | Binomial, GLM | 84.70 | 36.30 – 98.18 | 0.44 | 0.01 – 24.82 | [\*\*] |
| *Drought* |  |  |  |  |  |  |
| Date of 1st wilt | Poisson, GLM | 2.00 | 1.34 – 2.98 | 1.25 | 0.75 – 2.07 |  |
| Date of total wilt | Poisson, GLM | 4.17 | 3.16 – 5.50 | 3.83 | 2.87 – 5.12 |  |
| Death date | Poisson, GLM | 8.17 | 6.70 – 9.95 | 7.00 | 5.65 – 8.67 |  |
| *Flood* |  |  |  |  |  |  |
| Date of 1st yellow leaf | Poisson, GLM | 6.50 | 5.21 – 8.12 | 6.00 | 4.76 – 7.56 |  |
| Root death date | Poisson, GLM | 11.67 | 9.23 – 14.75 | 12.14 | 9.82 – 15.02 |  |
| Death date | Poisson, GLM | 13.5 | 11.57 – 15.75 | 13.67 | 11.73 – 15.93 |  |

Least squares (LS) means from restricted maximum likelihood (REML) models which include origin and all significant terms (interactions were excluded). Where no random effects were significant, LS means are estimated from generalized linear models (GLM). Significance of origin term (or origin\*latitude in square brackets []) indicated in right-most column: ., *P* < 0.1; \*, *P* < 0.05; \*\*, *P* < 0.01; \*\*\*, *P* < 0.001. CI = 95% confidence interval. Loge indicates natural log transformation of data. *Nt* = Not tested, due to significant interaction term.

**Table S6:** Test statistics for all traits measured in maternal common garden from range differentiation models of phenotypes of *Centaurea diffusa* grown in a common garden, after one generation in the glasshouse.

|  |  |  |
| --- | --- | --- |
| Maternal Common Garden | *Fixed effects* | *Random effects* |
| Origin | Latitude | Origin\*Latitude | Populations | Maternal lines | Populations within each Origin |
| *Trait* | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** |
| *Germination* |  |  |  |  |  |  |
| Seed count by family | 8.56 (1) \*\* | 2.91 (1) . | 2.09 (1) | 2.38 (1) | 79.57 (1) \*\*\* | 1.04 (4) |
| Rate by family | 10.73 (1) \*\* | 0.78 (1) | 0.85 (1) | <0.01 (1) | 2.99 (1) . | 0.86 (4) |
| Average germination date by family | 5.51 (1) \* | 5.56 (1) \* | 0.85 (1) | <0.01 (1) | <0.01 (1) | 9.04 (4) . |
| Average seed weight by family | 0.01 (1) | 0.24 (1) | 0.26 (1) | 1.30 (1) | <0.01 (1) | 0.06 (4) |
| *Early Control* |  |  |  |  |  |  |
| Shoot mass | 13.66 (1) \*\*\* | 1.40 (1) | 0.93 (1) | 0.14 (1) | 2.26 (1) | 3.39 (4) |
| Root crown diameter | 0.56 (1) | 0.34 (1) | <0.01 (1) | <0.01 (1) | <0.01 (1) | 3.31 (4) |
| Area of longest leaf | 4.76 (1) \* | 0.35 (1) | <0.01 (1) | 16.09 (1) \*\*\* | 38.54 (1) \*\*\* | 1.78 (4) |
| Number of basal leaves | *nt* | *nt* | 6.24 (1) \* | 1.45 (1) | 16.87 (1) \*\*\* | 0.05 (4) |
| *Control* |  |  |  |  |  |  |
| Shoot mass | 4.85 (1) \* | 3.12 (1) . | 0.32 (1) | 1.37 (1) | 0.29 (1) | 3.14 (4) |
| Root crown diameter | 0.08 (1) | 0.76 (1) | 0.44 (1) | 0.82 (1) | 12.88 (1) \*\*\* | 0.68 (4) |
| Area of longest leaf | 4.60 (1) \* | 1.79 (1)  | 4.28 (1) \* | 1.30 (1) | 0.52 (1) | 3.12 (4) |
| Number of basal leaves | 4.20 (1) \* | 0.64 (1) | 3.75 (1) . | 4.48 (1) \* | 215.7 (1) \*\*\* | 4.22 (4) |
| Specific leaf area | 0.38 (1) | <0.01 (1) | 2.76 (1) . | <0.01 (1) | 2.32 (1) | 1.43 (4) |
| Bolting status at harvest | *nt* | *nt* | 5.78 (1) \* | <0.01 (1) | 0.11 (1) | 0.68 (4) |
| Bolting date | 3.50 (1) . | <0.01 (1) | 0.26 (1) | 1.82 (1) | 55.18 (1) \*\*\* | 0.37 (4) |
| *Nutrient* |  |  |  |  |  |  |
| Shoot mass | 1.56 (1) | <0.01 (1) | 0.63 (1) | 1.30 (1) | <0.01 (1) | 0.08 (4) |
| Root crown diameter | 0.43 (1) | 1.42 (1) | 2.18 (1) | 0.24 (1) | 3.82 (1) . | 4.51 (4) |
| Area of longest leaf | 6.89 (1) \*\* | 1.12 (1)  | 1.32 (1) | 0.13 (1) | <0.01 (1) | 1.47 (4) |
| Number of basal leaves | 0.70 (1) | 0.90 (1) | 2.15 (1) | 7.72 (1) \*\* | 1.28 (1) | 0.33 (4) |
| *Herbivory* |  |  |  |  |  |  |
| Root crown diameter | 1.01 (1) | 0.04 (1) | 0.03 (1) | 0.36 (1) | <0.01 (1) | 1.34 (4) |
| Number of basal leaves | <0.01 (1) | 1.73 (1) | 0.63 (1) | 16.18 (1) \*\*\* | 63.44 (1) \*\*\* | 0.02 (4) |
| Bolting status at harvest | *nt* | *nt* | 7.34 (1) \*\* | <0.01 (1) | <0.01 (1) | <0.01 (4) |
| *Drought* |  |  |  |  |  |  |
| Date of 1st wilt | 2.10 (1) | 0.11 (1) | <0.01 (1) | <0.01 (1) | <0.01 (1) | 0.09 (4) |
| Date of total wilt | 0.17 (1) | 0.39 (1) | 0.73 (1) | <0.01 (1) | <0.01 (1) | <0.01 (4) |
| Death date | 1.08 (1) | 2.24 (1) | 0.57 (1) | <0.01 (1) | <0.01 (1) | <0.01 (4) |
| *Flood* |  |  |  |  |  |  |
| Date of 1st yellow leaf | 0.24 (1) | 0.46 (1) | <0.01 (1) | <0.01 (1) | <0.01 (1) | <0.01 (4) |
| Root death date | 0.06 (1) | 1.19 (1) | 0.18 (1) | <0.01 (1) | <0.01 (1) | <0.01 (4) |
| Death date | 0.01 (1) | 0.97 (1) | 0.14 (1) | <0.01 (1) | <0.01 (1) | <0.01 (4) |

Results are presented from restricted maximum likelihood (REML) models. Where no random effects were significant, generalized linear models (GLM) were used to test fixed effects. Significance of term indicated by symbol: ., *P* < 0.1; \*, *P* < 0.05; \*\*, *P* < 0.01; \*\*\*, *P* < 0.001. (df) = degrees of freedom. χ2 = chi-squared test statistic. *Nt* = Not tested, due to significant interaction term.**Table S7**: Z ratios and parameter estimates from explicit trade-off models *Centaurea diffusa* grown in a common garden which included a significant interaction between origin and control treatment performance (control shoot mass).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Explicit trade-off models | Sample size |  |  |  |  |
| *Trait* | *Coefficient* | *Invasive* | *Native* | **Estimate** | **SE** | **Z ratio** | ***P*** |
| Broad Common Garden |  |  |  |  |  |  |
| *Drought* |  |  |  |  |  |  |  |
| Days to first wilt | Invasive mean (intercept) | 65 | 145 | 0.32 | 0.53 | 0.61 |  |
|  | Difference in means |  |  | 1.44 | 0.56 | 2.58 | \*\* |
|  | Invasive slope over control shoot mass |  |  | 0.23 | 0.16 | 1.46 |  |
|  | Difference in slopes over control shoot mass |  |  | -0.38 | 0.17 | -2.24 | \* |
|  |  |  |  |  |  |  |  |
| Days to total wilt | Invasive mean (intercept) | 65 | 145 | 1.86 | 0.49 | 3.76 | \*\*\* |
|  | Difference in means |  |  | 0.93 | 0.41 | 2.24 | \* |
|  | Invasive slope over control shoot mass |  |  | 0.22 | 0.12 | 1.84 | . |
|  | Latitude |  |  | -0.02 | 0.01 | -2.43 | \* |
|  | Difference in slopes over control shoot mass |  |  | -0.26 | 0.13 | -2.07 | \* |
|  |  |  |  |  |  |  |  |
| Days to death | Invasive mean (intercept) | 65 | 145 | 2.33 | 0.27 | 8.63 | \*\*\* |
|  | Difference in means |  |  | 0.65 | 0.29 | 2.29 | \* |
|  | Invasive slope over control shoot mass |  |  | 0.04 | 0.08 | 0.54 |  |
|  | Difference in slopes over control shoot mass |  |  | -0.18 | 0.09 | -2.11 | \* |
| *Flood* |  |  |  |  |  |  |  |
| Days to death | Invasive mean (intercept) | 122 | 49 | 1.28 | 0.39 | 3.32 | \*\*\* |
|  | Difference in means |  |  | 1.01 | 0.32 | 3.17 | \*\* |
|  | Invasive slope over control shoot mass |  |  | 0.32 | 0.09 | 3.43 | \*\*\* |
|  | Latitude |  |  | 0.01 | 0.006 | 2.22 | \* |
|  | Difference in slopes over control shoot mass |  |  | -0.34 | 0.10 | -3.41 | \*\*\* |
| Maternal Common Garden |  |  |  |  |  |  |
| *Drought* |  |  |  |  |  |  |  |
| Days to total wilt | Invasive mean (intercept) | 12 | 12 | -3.06 | 2.20 | -1.39 |  |
|  | Difference in means |  |  | 5.35 | 2.31 | 2.32 | \* |
|  | Invasive slope over control shoot mass |  |  | 1.15 | 0.57 | 2.03 | \* |
|  | Difference in slopes over control shoot mass |  |  | -1.40 | 0.60 | -2.33 | \* |

Z ratios are presented from explicit trade-off models which include a significant interaction term, described in Table 3. Results are presented from restricted maximum likelihood (REML) models. Where no random effects were significant, generalized linear models (GLM) were used to test fixed effects. Models include all significant terms. All random effects were non-significant, except for days to death in the flood treatment of the broad common garden (maternal line: χ2 = 4.35 (1)\*; population: χ2 =4.51 (1)\*). Estimates and standard errors (SE) are untransformed. Significance of term indicated by symbol: ., *P* < 0.1; \*, *P* < 0.05; \*\*, *P* < 0.01; \*\*\*, *P* < 0.001. (df) = degrees of freedom. χ2 = chi-squared test statistic.

**Table S8**: Effect of origin, latitude, and constitutive defense on herbivore preference of *Centaurea diffusa* grown in a common garden, across two generations.

|  |  |  |
| --- | --- | --- |
| Leaf choice trials | *Fixed effects* | *Random effects* |
|  | Origin | Defense | Latitude | Populations | Maternal lines | Populations within Origin |
| *Trait* | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** | **χ2 (df) *P*** |
| Most preferred | 0.75 (1) | <0.01 (3) | 1.00 (1) | <0.01 (1) | <0.01 (1) | 0.32 (4) |
| Area consumed | 0.09 (1) | >250 (3) \*\*\* | 3.06 (1) . | 1.04 (1) | <0.01 (1) | 1.92 (4) |

Results are presented from restricted maximum likelihood (REML) models. Generation was included as a random effect, but was never significant. Where no random effects were significant, generalized linear models (GLM) were used to test fixed effects. Significance of term indicated by symbol: ., *P* < 0.1; \*, *P* < 0.05; \*\*, *P* < 0.01; \*\*\*, *P* < 0.001. (df) = degrees of freedom. χ2 = chi-squared test statistic.

**Table S9**: Z ratios and parameter estimates from range differentiation models of *Centaurea diffusa* grown in a common garden which included a significant interaction between origin and latitude.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Range differentiation models | Sample size |  |  |  |  |
| *Trait* | *Coefficients* | *Invasive* | *Native* | **Estimate** | **SE** | **Z ratio** | ***P*** |
| Broad Common Garden |  |  |  |  |  |  |  |
| *Early Control* |  |  |  |  |  |  |  |
| No. of basal leaves | Invasive mean (intercept) | 490 | 1045 | 0.29 | 0.50 | 0.58 |  |
|  | Difference in means |  |  | 1.51 | 0.57 | 2.64 | \*\* |
|  | Invasive slope over latitude |  |  | 0.04 | 0.01 | 3.91 | \*\*\* |
|  | Difference in slopes over latitude |  |  | -0.03 | 0.01 | -2.61 | \*\* |
| *Control* |  |  |  |  |  |  |  |
| Bolting status (harvest) | Invasive mean (intercept) | 125 | 261 | -25.67 | 17.19 | -1.44 |  |
|  | Difference in means |  |  | 32.03 | 17.95 | 1.78 | . |
|  | Invasive slope over latitude |  |  | 0.47 | 0.37 | 1.25 |  |
|  | Difference in slopes over latitude |  |  | -0.64 | 0.38 | -1.68 | . |
| *Herbivory* |  |  |  |  |  |  |  |
| Bolting status (harvest) | Invasive mean (intercept) | 62 | 146 | -172.96 | 242.39 | -0.71 |  |
|  | Difference in means |  |  | 173.31 | 242.40 | 0.72 |  |
|  | Invasive slope over latitude |  |  | 3.51 | 4.94 | 0.71 |  |
|  | Difference in slopes over latitude |  |  | -3.54 | 4.94 | -0.72 |  |
| Maternal Common Garden |  |  |  |  |  |  |
| *Early Control* |  |  |  |  |  |  |  |
| No. of basal leaves | Invasive mean (intercept) | 115 | 115 | 5.27 | 1.36 | 3.87 | \*\*\* |
|  | Difference in means |  |  | -4.80 | 1.80 | -2.67 | \*\* |
|  | Invasive slope over latitude |  |  | -0.05 | 0.03 | -1.89 | . |
|  | Difference in slopes over latitude |  |  | 0.11 | 0.04 | 2.68 | \*\* |
| *Control* |  |  |  |  |  |  |  |
| Area of longest leaf (cm2) | Invasive mean (intercept) | 50 | 45 | 624.06 | 210.21 | 2.97 | \*\* |
|  | Difference in means |  |  | -656.30 | 299.52 | -2.19 | \* |
|  | Invasive slope over latitude |  |  | -10.75 | 4.49 | -2.39 | \* |
|  | Difference in slopes |  |  | 13.91 | 6.73 | 2.07 | \* |
|  |  |  |  |  |  |  |  |
| Bolting status (harvest) | Invasive mean (intercept) | 55 | 56 | 9.53 | 16.04 | 0.59 |  |
|  | Difference in means |  |  | -39.85 | 19.61 | -2.03 | \* |
|  | Invasive slope over latitude |  |  | -0.24 | 0.34 | -0.70 |  |
|  | Difference in slopes over latitude |  |  | 0.96 | 0.43 | 2.22 | \* |
| *Herbivory* |  |  |  |  |  |  |  |
| Bolting status (harvest) | Invasive mean (intercept) | 12 | 12 | 28.68 | 62.74 | 0.46 |  |
|  | Difference in means |  |  | -1204 | 275700 | -0.004 |  |
|  | Invasive slope over latitude |  |  | -0.07 | 1.358 | -0.49 |  |
|  | Difference in slopes over latitude |  |  | 27.78 | 6355 | 0.004 |  |

Z ratios are presented from range differentiation models described in Tables S1 and S2 which include a significant interaction term. Results are presented from restricted maximum likelihood (REML) models. Where no random effects were significant, generalized linear models (GLM) were used to test fixed effects. Models include all significant terms. Estimates and standard errors (SE) are untransformed.