Natural selection and outbreeding depression suggest adaptive differentiation in the invasive range of a clonal plant

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Supplementary tables

**Table S1.** Floral and vegetative characteristics of individuals from the F2 generation resulting from three different crosses between introduced and native populations of *Mimulus guttatus*. All crosses had an individual from an introduced perennial population (DBL) as the maternal parent in the F1. The paternal parent of each of the three crosses was either a native perennial (ALASKA), a native annual (LMC), or another introduced perennial (COL). The F2 was generated by self-fertilisation of a single F1 individual from each cross. Cross types as follows: *native-annual* (DBL × LMC)*;* *native-perennial* (DBL × ALASKA); *introduced-perennial,* (DBL × COL). Mean ± SE (number of individuals). Values calculated using only individuals that flowered. The statistics including all individuals are provided in the Supplementary Material (Supplemental Table S5).

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| Cross type | Days to flower | Plant height (cm) | Flowering node | Corolla width (mm) | Corolla height (mm) | Corolla tube (mm) | Leaf width (mm) | Leaf length (mm) | Stem thickness (mm) | Stolons at first flower | Lateral (clonal) spread (cm) | Flower number | Fruit number | Daily floral display |
| Native-annual | 24.92 ± 0.341 (374) | 18.773 ± 0.281 (374) | 4.352 ± 0.047 (372) | 23.971 ± 0.178 (373) | 22.555 ± 0.154 (373) | 18.311 ± 0.108 (373) | 25.182 ± 0.46 (361) | 37.216 ± 0.755 (361) | 3.305 ± 0.072 (369) | 0.056 ± 0.02 (378) | 5.012 ± 0.538 (378) | 51.164 ± 1.63 (378) | 42.238 ± 1.443 (378) | 2.813 ± 0.097 (378) |
| Native-perennial | 29.074 ± 0.413 (349) | 16.577 ± 0.298 (346) | 5.512 ± 0.066 (346) | 26.595 ± 0.164 (345) | 23.112 ± 0.151 (344) | 19.083 ± 0.109 (344) | 27.16 ± 0.43 (327) | 42.752 ± 0.74 (327) | 4.008 ± 0.068 (337) | 3.537 ± 0.073 (356) | 67.872 ± 0.988 (356) | 19.211 ± 1.172 (356) | 18.843 ± 1.147 (356) | 0.842 ± 0.047 (356) |
| Introduced-perennial | 34.62 ± 0.411 (379) | 17.502 ± 0.272 (378) | 5.675 ± 0.039 (378) | 28.115 ± 0.166 (379) | 24.791 ± 0.151 (379) | 19.939 ± 0.088 (379) | 32.189 ± 0.569 (366) | 58.616 ± 1.118 (366) | 5.348 ± 0.102 (376) | 0.907 ± 0.063 (387) | 43.76 ± 0.827 (387) | 67.452 ± 2.748 (387) | 59.63 ± 2.443 (387) | 2.497 ± 0.105 (387) |

**Table S2.** Cross-specific vital rates for *Mimulus guttatus* estimated in an experimental F2 field population in the introduced range in Scotland. *G* = germination rate, *Gr* = proportion of individuals that flowered, *Sw* = mean number of individuals that survived winter, *Sn* = mean number of individuals that survived summer, *C* = mean number of clones, *Sd* = mean number of seeds per fruit, *F* = mean number of fruits, *D* = seed bank survival, *A* = recruitment rate. The values for *D*, and *A* were obtained from previous demographic analyses of *Mimulus* in the native range, as they could not be estimated in our study. The values used here (*D* = 0.534 [23] and *A* = 0.00238 [24] were set the same across all F2 crosses. Mean ± SE (sample size). Cross types as follows: *native-annual* (DBL × LMC)*;* *native-perennial* (DBL × ALASKA); *introduced-perennial,* (DBL × COL).

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Cross type | *Gr* | *F* | *Sd* | *G* | *Sn* | *Sw* | *C* |
| Native-annual | 0.997 ± 0.003 (396) | 41.256 ± 1.447 (387) | 266.976 ± 38.01 (15) | 0.665 ± 0.029 (20) | 0.737 ± 0.022 (396) | 0.671 ± 0.028 (292) | 2.25 ± 0.643 (24) |
| Native-perennial | 0.92 ± 0.014 (389) | 16.982 ± 1.072 (395) | 675.995 ± 40.148 (15) | 0.925 ± 0.016 (20) | 0.98 ± 0.007 (396) | 0.943 ± 0.012 (388) | 9.417 ± 0.868 (24) |
| Introduced-perennial | 0.987 ± 0.006 (392) | 58.275 ± 2.429 (396) | 705.799 ± 55.536 (15) | 0.93 ± 0.018 (20) | 0.987 ± 0.006 (396) | 0.985 ± 0.006 (391) | 8.609 ± 0.735 (23) |

**Table S3.** Elasticities (*eij*) for stage transitions estimated in the F2 generation of three crosses in native and introduced *Mimulus guttatus*. Elasticities represent the proportional sensitivity of population growth rate to small changes in the each transition rate. Higher values indicate larger effects of changing a particular transition rate on population fitness (λ). Notice that the transition rate *P31* (seed to rosette) is set to zero based on the life cycle model used here and in Peterson et al. [14]. Cross types as follows: *native-annual* (DBL × LMC)*;* *native-perennial* (DBL × ALASKA); *introduced-perennial,* (DBL × COL).

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| --- | --- | --- | --- | --- |
| Cross type |  |  |  |  |
| Native-annual |  | **seedt** | **seedlingt** | **rosettet** |
|  | **seedt+1** | 0.0001 | 0.0078 | 0.0007 |
|  | **seedlingt+1** | 0.0085 | 0.8242 | 0.0755 |
|  | **rosettet+1** | 0.0000 | 0.0762 | 0.0070 |
| Native-perennial | | **seedt** | **seedlingt** | **rosettet** |
|  | **seedt+1** | 0.0000 | 0.0006 | 0.0003 |
|  | **seedlingt+1** | 0.0009 | 0.4995 | 0.2065 |
|  | **rosettet+1** | 0.0000 | 0.2068 | 0.0855 |
| Introduced-perennial |  | **seedt** | **seedlingt** | **rosettet** |
|  | **seedt+1** | 0.0000 | 0.0003 | 0.0000 |
|  | **seedlingt+1** | 0.0003 | 0.8204 | 0.0850 |
|  | **rosettet+1** | 0.0000 | 0.0851 | 0.0088 |

**Table S4.** Pearson’s correlation coefficients of 13 traits measured in 1,121 F2 individuals derived from three crosses between native and introduced populations of *Mimulus guttatus*.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Days to flower** | **Plant height** | **Flowering node** | **Corolla width** | **Corolla height** | **Corolla tube** | **Leaf width** | **Leaf length** | **Stem thickness** | **Clonal spread** | **Flower number** | **Fruit number** | **Floral display** |
| **Stolons** | 0.08 | -0.03 | 0.29 | 0.23 | 0.08 | 0.14 | 0.17 | 0.15 | 0.18 | 0.69 | -0.16 | -0.12 | -0.24 |
| **Days to flower** |  | -0.06 | 0.57 | 0.20 | 0.17 | 0.06 | 0.10 | 0.11 | 0.13 | 0.24 | -0.10 | -0.08 | -0.22 |
| **Plant height** |  |  | 0.21 | 0.38 | 0.36 | 0.41 | 0.56 | 0.53 | 0.50 | 0.00 | 0.40 | 0.4 | 0.45 |
| **Flowering node** |  |  |  | 0.41 | 0.26 | 0.25 | 0.22 | 0.28 | 0.31 | 0.44 | -0.01 | 0.03 | -0.13 |
| **Corolla width** |  |  |  |  | 0.77 | 0.61 | 0.47 | 0.54 | 0.54 | 0.39 | 0.23 | 0.27 | 0.11 |
| **Corolla height** |  |  |  |  |  | 0.59 | 0.39 | 0.43 | 0.45 | 0.21 | 0.24 | 0.26 | 0.17 |
| **Corolla tube** |  |  |  |  |  |  | 0.45 | 0.51 | 0.50 | 0.25 | 0.28 | 0.3 | 0.22 |
| **Leaf width** |  |  |  |  |  |  |  | 0.87 | 0.78 | 0.26 | 0.55 | 0.56 | 0.52 |
| **Leaf length** |  |  |  |  |  |  |  |  | 0.85 | 0.29 | 0.61 | 0.63 | 0.51 |
| **Stem thickness** |  |  |  |  |  |  |  |  |  | 0.33 | 0.53 | 0.54 | 0.44 |
| **Clonal spread** |  |  |  |  |  |  |  |  |  |  | -0.09 | -0.04 | -0.25 |
| **Flower number** |  |  |  |  |  |  |  |  |  |  |  | 0.97 | 0.82 |
| **Fruit number** |  |  |  |  |  |  |  |  |  |  |  |  | 0.80 |

**Table S5.** Floral and vegetative characteristics individuals from the F2 generation resulting from three different crosses between introduced and native population of *Mimulus guttatus*. All crosses had an individual from an introduced population (DBL) as the maternal parent in the F1. The paternal parent of the each of the three crosses were a native, perennial (ALASKA), a native, annual (LMC), or another introduced perennial (COL). The F2 was generated from a single F1 individual in each cross. Cross types as follows: *native-annual* (DBL × LMC)*;* *native-perennial* (DBL × ALASKA); *introduced-perennial,* (DBL × COL). Mean ± SE (number of individuals). Values calculated using all available plants, including those that did not flower.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cross type | Days to flower | Plant height (cm) | Flowering node | Corolla width (mm) | Corolla height (mm) | Corolla tube (mm) | Leaf width (mm) | Leaf length (mm) | Stem thickness (mm) | Stolons at first flower | Lateral (clonal) spread (cm) | Flower number | Fruit number | Daily floral display |
| Native-annual | 24.847 ± 0.334 (386) | 18.675 ± 0.277 (386) | 4.337 ± 0.046 (383) | 23.921 ± 0.174 (385) | 22.494 ± 0.152 (385) | 18.277 ± 0.106 (385) | 25.075 ± 0.452 (372) | 37.113 ± 0.747 (372) | 3.293 ± 0.071 (381) | 0.053 ± 0.02 (396) | 4.802 ± 0.516 (396) | 50.365 ± 1.637 (384) | 41.578 ± 1.446 (384) | 2.748 ± 0.095 (396) |
| Native-perennial | 29.046 ± 0.412 (351) | 16.562 ± 0.297 (348) | 5.51 ± 0.065 (347) | 26.595 ± 0.164 (345) | 23.112 ± 0.151 (344) | 19.083 ± 0.109 (344) | 27.146 ± 0.429 (328) | 42.73 ± 0.738 (328) | 4.003 ± 0.068 (338) | 3.467 ± 0.072 (396) | 66.446 ± 0.977 (389) | 17.314 ± 1.095 (395) | 16.982 ± 1.072 (395) | 0.766 ± 0.044 (395) |
| Introduced-perennial | 34.62 ± 0.411 (379) | 17.502 ± 0.272 (378) | 5.675 ± 0.039 (378) | 28.115 ± 0.166 (379) | 24.791 ± 0.151 (379) | 19.939 ± 0.088 (379) | 32.189 ± 0.569 (366) | 58.616 ± 1.118 (366) | 5.348 ± 0.102 (376) | 0.894 ± 0.062 (396) | 43.691 ± 0.823 (392) | 65.919 ± 2.733 (396) | 58.275 ± 2.429 (396) | 2.454 ± 0.104 (394) |

**Table S6.** Standardised linear (β) and quadratic (γ) selection gradients estimated in the F2 generation of three crosses of *Mimulus guttatus* in a field population in central Scotland (Stirling). The subscript indicated the paternal parent of each cross: ALASKA = Alaskan Peninsula, U.S.A. (native-perennial); COL = Coldstream, Scotland (introduced-perennial); LMC = California, U.S.A. (native-annual) All crosses had the same maternal parent (DBL, Dunblane, Scotland). The coefficients were estimated from a full model including all analysed traits and their quadratic terms. The statistical significance of individual coefficients indicates whether they are different from zero assuming a t distribution of the full model. Linear selection gradients were calculated in a model with linear terms only. \* P < 0.05; \*\* P < 0.01; \*\*\* P <0.001.

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| --- | --- | --- | --- | --- | --- | --- |
| Trait | βALASKA | γALASKA | βCOL | γCOL | βLMC | γLMC |
| Flowering time | -0.041\*\* | 0.016 | -0.042\*\*\* | -0.014 | -0.024 | -0.008 |
| Flowering node | -0.060\*\*\* | 0.007 | 0.007 | -0.012 | 0.005 | -0.014 |
| Daily floral display | 0.306\*\*\* | -0.036\*\*\* | 0.099\*\*\* | 0.002 | 0.139\*\*\* | 0.020 |
| Corolla width | 0.019 | -0.195\*\*\* | 0.013 | -0.053\*\*\* | 0.041\*\*\* | -0.063\*\*\* |
| Corolla tube | 0.022\* | 0.007 | 0.015 | -0.015 | -0.015 | -0.005 |
| Leaf width | 0.030\* | -0.019 | 0.022\* | -0.016 | -0.018 | -0.009 |
| Plant height | 0.074\*\*\* | -0.020 | 0.039\*\*\* | -0.027\*\* | 0.012 | -0.027\* |
| Number of stolons | 0.018 | -0.004 | 0.028\* | -0.011 | 0.081\* | -0.153 |
| Lateral spread | 0.036\* | 0.001 | 0.038\* | -0.100\*\*\* | 0.046 | -0.162\* |