In the low control efficacy level as reflected by the 2018 reproduction potentials, waterhemp population densities were projected to increase rapidly in all rotations, but most quickly in the 2-year rotation ( and ) and slowest in the 4-year rotation ( and ) (Figure ?? and Table 1).

The alfalfa phase of the 4-year rotation (A4) offered opportunities for decreasing , which was not possible in any other crop phases in the three examined rotations. However, the declines in phase-wise in A4 ( and ) were not strong enough to deplete seed replenishment occurring in the corn phase (, and ), soybean phase (, and ), and oat phase (, and ).

### Scenario 2

Unlike Scenario 1’s dynamics, the differences in the absolute value of the elasticity of to the first-ranked and second-ranked groups of parameters were multiple orders of magnitude. The seed producing parameters were ranked higher in all crop environments (crop species in each rotation).

The elasticity of ’s to fecundity rates, as a group, were ranked first in all crop phases (Figure 2). The elasticity of ’s to cohort one fecundity were the highest in C2 (4.02 x and 3.44 x ), S3 (1.33 x and 1.61 x ), and O4 (682.28 and 1531.97) phases. The elasticity of ’s elasticity to cohort two fecundity were the highest in S2 (1.82 x and 1.39 x ), C3 (2.22 x and 5.69 x ), O3 (76673.94 and  
62845.84), C4 (5.84 x and 1.01 x ), S4 (5.74 x and 2.17 x ), and A4 (1850.3 and 156.54) phases.

The second-ranked group of demographic parameters to differed by rotation and crop phase. In the 2-year rotation, the second-ranked group of parameters in contribution to the elasticity of were both pre-planting tillage-induced seed movement and overwinter seed survival. In the 3-year rotation, no clear pattern of the second-ranked group of parameters in contribution to elasticity of was observed: overwinter survival rate of the top stratum seeds in C3, non-germinating seeds in the top stratum in S3, and overwinter survival rate of the bottom stratum seeds in O3. In the 4-year rotation, the second-ranked group of parameters in contribution to elasticity of was overwinter seed survival in the warm-season crop phase and non-germinating seeds in the top stratum in the cool-season crop phases.

Table 1: Population growth rate under high control efficacy condition.

|  |  | lambda | | phase wise lambda in | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Rotation | Corn weed management | annualized | rotation wise | corn | soybean | oat | alfalfa |
| 2-year | conventional | 59.35 | 3,523.00 | 26.01 | 135.85 |  |  |
| 2-year | low | 333.30 | 111,091.72 | 587.80 | 188.96 |  |  |
| 3-year | conventional | 48.37 | 113,185.49 | 14.59 | 3,575.02 | 2.55 |  |
| 3-year | low | 28.46 | 23,058.69 | 11.38 | 1,864.89 | 1.48 |  |
| 4-year | conventional | 14.65 | 46,092.47 | 29.68 | 773.71 | 6.54 | 0.57 |
| 4-year | low | 10.50 | 12,141.08 | 87.27 | 92.07 | 12.80 | 0.53 |

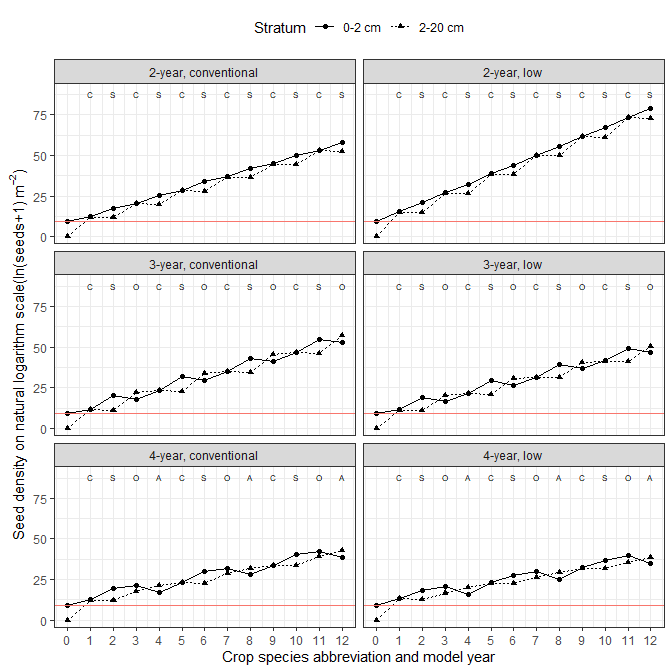


Figure 1: Scenario 1: Changes of natural-logarithm of seed densities in two soil strata after 12 model years in three rotations (2-year, 3-year, and 4-year) crossed with two corn weed management programs (conventional and low herbicide). Seed densities were natural-logarithm transformed because of scales. The model started at year 0 with 10000 and 0 seeds per squared meter in the top (0 - 2 cm) and bottom (2 - 20 cm) strata, respectively. The red horizontal line shows the number of seeds at the top stratum at the beginning of the model clock. The annualized population growth rates are followed by their variances in brackets. The model years’ are labelled with the main crop species names’ abbreviations: C - corn, S - soybean, O - oat, and A - alfalfa.

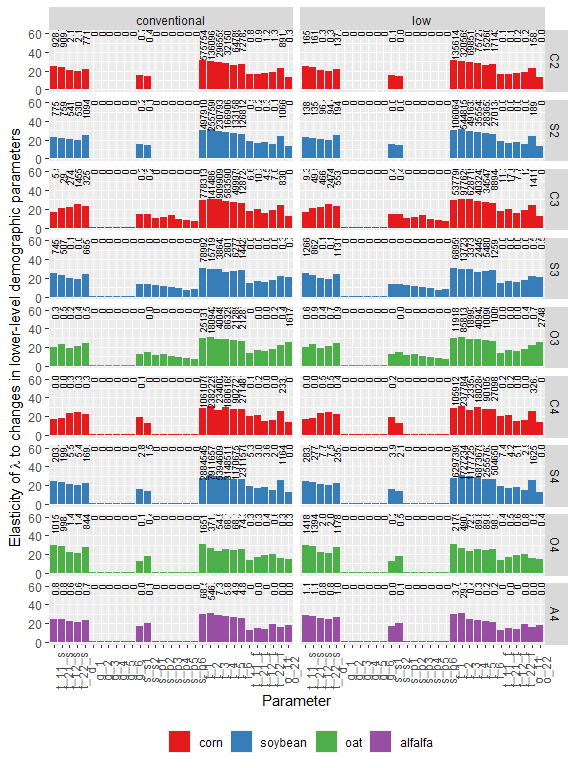


Figure 2: Scenario 2: Elasticity of annualized population growth rates to changes in lower-level demographic parameters. Bar height represents parameter’s ranking. Each bar is labeled with the absolute value of the contribution of the parameter to elasticity of annualized population growth rates (zeros on top of some of the medium height bars were due to rounding). Crop identities are color-coded by crop species. From left to right of the x-axis, the sub-annual demographic parameters are: t\_11\_s - probability that a seed at the 0-2 cm soil stratum stay at that statum after pre-planting tillage; t\_21\_s - probability that a seed at the 2-20 cm soil stratum move to the 0-2 cm soil stratum after pre-planting tillage; t\_12\_s - probability that a seed at the 0-2 cm soil stratum move to the 2-20 cm stratum after pre-planting tillage; and t\_22\_s - probability that a seed in the 2-20 cm soil stratum stay at that statum after pre-planting tillage; d - the probability that a seed is not germinating; g\_1 through g\_6: the probabiblites that a seed emerge to seedling cohorts 1 through 6; s\_s1 and s\_s2 - the survival rate of seeds in the 0-2 cm and 2-20 cm soil strata in the cropped season; s\_p1 through s\_p6: the probability that seedling cohorts 1 through 6 reach reproductive maturity; f\_1 through f\_6 - the fecundity rates of mature plant cohorts 1 through 6; t\_11\_f - probability that a seed in the 0-2 cm soil stratum stay at that statum after post-harvest tillage; t\_21\_f - probability that a seed in the 2-20 cm soil stratum move to the 0-2 cm soil stratum after post-harvest tillage; t\_12\_f - probability that a seed in the 0-2 cm soil stratum move to the 2-20 cm stratum after post-harvest tillage; and t\_22\_f - probability that a seed in the 2-20 cm soil stratum stay at that statum after post-harvest tillage; o\_11 and o\_12 - overwiter survival rates in the 0 - 2 cm and 2 - 20 cm soil strata.