

Regulation solution of water-fertilizer coupling for comprehensive growth of *Pinus massoniana* seedlings based on multi-level fuzzy evaluation and genetic algorithm

Yuanhong Fu, Guijie Ding*, Wenxuan Quan, Xizhou Zhao, Qinghong Tao

(Institute for Forest Resources and Environment of Guizhou/College of Forestry, Guizhou University, Guiyang 550025, Guizhou, China)

Abstract: **【Objective】** This study aims to explore the comprehensive regulatory of water-fertilizer coupling on the growth and development of *Pinus massoniana* seedlings, to understand how multiple factors of water and fertilizer affect the growth of seedlings and to quantify the water-fertilizer combination conducive to seedling comprehensive growth and the combined water-fertilizer application for the coordinated development of the environment and seedling quality. **【Method】** The experiment was carried out based orthogonal design of volumes water content (W_1 : 100% θ , $W_{0.5}$: 85% θ , $W_{0.5}$: 65% θ , W_{-1} : 45% θ ; θ : maximum volumetric water content), substrate available nitrogen (N_1 : 840, $N_{0.5}$: 420, N_0 : 210, $N_{-0.5}$: 105), phosphorus (P_1 : 128, $P_{0.5}$: 64, P_0 : 32, $P_{-0.5}$: 16), and potassium (K_1 : 936, $K_{0.5}$: 468, K_0 : 234, $K_{-0.5}$: 117, mg/kg-substrate). In addition, two control groups with sufficient water ($W_{0.5}$) no fertilization ($N_{-1}P_{-1}K_{-1}$) and mild water deficit (W_0 , 75% θ) moderate fertilization ($N_0P_0K_0$) were set. The multilevel fuzzy comprehensive evaluation (MFCE) model was used to comprehensively evaluate the four factors and 12 sub-factors for characterization of *P. massoniana* and the nondominated sorting genetic algorithm (NSGA-III) was utilized for multiple objective function optimization to achieve coordinated development of seedlings and reduce environmental pollution. **【Result】** The highest values of height, stem diameter, first-order lateral root number, photosynthetic rate, absorption of nitrogen and phosphorus, seedling quality indicators were observed under the $W_{85\% \theta} N_{420} P_{128} K_{234}$ treatment, while the root tip number, transpiration rate, *Chls*, potassium absorption were highest on the $W_{65\% \theta} N_{210} P_{128} K_{468}$ combination. The $W_{85\% \theta} N_{420} P_{128} K_{234}$ combination is most conducive to the comprehensive growth of the seedlings, followed by $W_{65\% \theta} N_{210} P_{128} K_{468}$, which are 1.401 to 141.413 times and 1.284 to 129.630 times higher than other water-fertilizer combinations, respectively. In terms of single-factor effects, the comprehensive growth index (CGI) of the seedlings followed a linear pattern with P and a downward-opening parabola with W, N, and K, peaking at 128 (P, 1), 235.725 (N, 0.06), 254.78 mg/kg-dry substrate (K, 0.04), 85% θ (W, 0.5). W-N and W-K had negative interaction effects on the growth of seedlings, while P-W, P-K, and N-K had the opposite effects. In terms of multi-factor coupling effects, adjusting the input of other elements had no positive impact on seedling growth, as long as the substrate $P \leq 32$ mg/kg-substrate. Whereas P was 128 mg/kg-dry substrate, the negative effects caused by low water could not be alleviated, even if moderate N and K levels were maintained if only W was below 45% θ . Redundancy analysis and partial least squares path modeling revealed that W and P had a direct and significant positive effect on the growth of seedlings, while N and K had a negative effect. 85-91.06% θ (W), 65.95-134.27 (N), 128 (P), and 215.87-234 mg/kg-dry substrate (K) were observed as combinations conducive to the growth of seedlings based on the MFCE model. W of 90.712% θ combined with the N, P, and K of 57.39, 88.397, and 123.084 mg/kg-dry substrate could obtain the coordinated development of environmental and seedling growth by NSGA-III. **【Conclusion】** P is the key driving factor affecting

the CGI of *P. massoniana* seedlings. Maintaining adequate moisture, appropriately reducing N and K applications, and increasing P fertilizer can help improve the quality of nursery stock and reduce environmental pollution. The test results have important guiding significance for water and fertilizer management in the growth process of *P. massoniana* seedlings.