

ABSTRACT

Early selection of superior genotypes is critical in *Eucalyptus* hybrid breeding programs to accelerate genetic gain and enhance resource efficiency. This study investigates the genetic relationship between nursery phenotypes and early field growth performance in a hybrid clonal population of *E. pellita* × *E. grandis*. A total of 623 hybrid clones were assessed for seven nursery traits: seedling height, collar diameter, leaf number, branch number, main root number, root quadrant, and root dry weight. Following on, field performance was evaluated at 12 months for height, diameter at breast height, and volume. Genetic parameters were estimated using Best Linear Unbiased Prediction (BLUP), Pedigree-based BLUP (ABLUP), and Single-step Genomic BLUP (ssGBLUP), with Principal Component Analysis (PCA) used to reduce phenotypic dimensionality. Multivariate mixed models and Spearman rank correlations were applied to explore trait relationships across pedigree hierarchies and species contributions. Results demonstrated strong correlations between root and shoot traits, with PCA identifying key axes related to seedling vigor, root architecture, and canopy structure. Incorporating genomic data into ssGBLUP models improved genetic parameter estimation, highlighting the impact of non-additive genetic variance. Multivariate analysis revealed strong correlations within nursery traits and moderate correlations between nursery and early field traits. Spearman rank analysis showed that root-related traits, particularly in *E. grandis*, were strongly linked to field performance, while *E. pellita* exhibited trade-offs between certain traits and field growth. Gradient boosting machine analysis confirmed that *E. pellita* influences nursery phenotypes, while *E. grandis* excels in early field growth, with ABLUP and ssGBLUP models showing slightly improved accuracy. These findings underscore the operational value of integrating genomic and nursery phenotypic data for efficient screening and selection in *Eucalyptus* hybrid breeding, providing a cost-effective strategy for improving plantation productivity in tropical environments.

Keywords: *Eucalyptus pellita* × *E. grandis* hybrids, Nursery traits, Genetic correlations, ssGBLUP vs ABLUP, Early field growth performance

Seleksi awal genotipe unggul sangat penting dalam program pemuliaan hibrida *Eucalyptus* untuk mempercepat kemajuan genetik dan meningkatkan efisiensi sumberdaya. Penelitian ini menyelidiki hubungan genetik antara fenotipe pembibitan dan kinerja pertumbuhan awal di lapangan pada populasi klon hibrida *E. pellita* × *E. grandis*. Sebanyak 623 klon hibrida dinilai untuk tujuh karakter pembibitan: tinggi semai, diameter pangkal batang, jumlah daun, jumlah cabang, jumlah akar utama, kuadran akar, dan berat kering akar. Selanjutnya, kinerja pertumbuhan awal di lapangan dievaluasi pada umur 12 bulan untuk tinggi, diameter setinggi dada, dan volume. Parameter genetik diestimasi menggunakan Best Linear Unbiased Prediction (BLUP), Pedigree-based BLUP (ABLUP), dan Single-step Genomic BLUP (ssGBLUP), dengan Principal Component Analysis (PCA) digunakan untuk mereduksi dimensionalitas fenotipik. Model campuran multivariat dan korelasi rank Spearman diterapkan untuk mengeksplorasi hubungan karakter lintas hierarki silsilah dan kontribusi spesies. Hasil menunjukkan korelasi kuat antara karakter akar dan pucuk, dengan PCA mengidentifikasi sumbu-sumbu kunci yang terkait dengan vigor semai, arsitektur akar, dan struktur tajuk. Pengintegrasian data genomik ke dalam model ssGBLUP meningkatkan estimasi parameter genetik, menyoroti dampak ragam genetik nonaditif. Analisis multivariat mengungkapkan korelasi kuat dalam karakter pembibitan dan korelasi sedang antara karakter pembibitan dan pertumbuhan awal di lapangan. Analisis rank Spearman menunjukkan bahwa karakter terkait akar, khususnya pada *E. grandis*, berkaitan erat dengan kinerja pertumbuhan awal di lapangan, sedangkan *E. pellita* menunjukkan trade-off antara karakter tertentu dan pertumbuhan awal di lapangan. Analisis gradient boosting machine mengkonfirmasi bahwa *E. pellita* mempengaruhi fenotipe pembibitan, sedangkan *E. grandis* unggul dalam pertumbuhan awal di lapangan, dengan model ABLUP dan ssGBLUP menunjukkan sedikit peningkatan akurasi. Temuan ini menekankan nilai operasional dari pengintegrasian data genomik dan fenotipik pembibitan untuk skrining dan seleksi yang efisien dalam pemuliaan hibrida *Eucalyptus*, menyediakan strategi cost-effective untuk meningkatkan produktivitas hutan tanaman di lingkungan tropis.

Kata kunci: Hibrida *Eucalyptus pellita* × *E. grandis*, Karakter pembibitan, Korelasi genetik, ssGBLUP vs ABLUP, Kinerja pertumbuhan awal di lapangan