New Development of Test and Statistics of Genetic Breeding In Forest Trees

林木遗传育种中试验统计法新进展

——齐明·编著——

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前言

林木遗传育种理论的发展与林木遗传改良实践有着密切的关系。在这里，田间试验及其统计分析是联系林木遗传育种理论与林木遗传改良实践的桥梁。因为田间试验是林木遗传改良工作不可缺少的环节，并为林木遗传改良提供研究手段，统计分析则是服务于林木遗传改良目的达到的有效工具。人们在林木遗传改良实践活动中发现有关试验设计与统计分析问题，便为我们提出理论上的研究课题。而这一系列问题的解决，不仅促进了理论的向前发展，而且又为林木田间试验提供设计上的原理与方法，从而更有力地服务于林木遗传改良工作的需要。

过去，在林木遗传改良实践活动中，曾由于缺乏正确的理论指导，给林木遗传改良工作带来了严重失误：有时试验费力不少，所获得的试验资料价值不大；有时获得了试验数据，又缺乏正确的数学方法进行分析。此时获得的试验结果：①选出的优良品系，在生产实践中，表现出“异化”现象；②采用获得的不正确的遗传参数信息，来制定出的遗传改良方案，欠科学，结果浪费国家钱财。

这些失误在很大程度上是由于采用了不正确的统计分析方法。在林木遗传育种中，经常碰到不平衡不规则的试验数据，而林木遗传育种领域中，采用的统计分析方法多来自于动物、农作物，特别是农作物遗传育种。然而林木自身的特点以及林木遗传育种对统计分析结果的要求，与动物、农作物遗传育种有较大的不同，林木遗传育种学对若干参数的需求，需要以单株观察值来进行统计分析。来自农作物遗传育种，以小区平均值为基础的统计方法都要推倒，因为它无法获得林木遗传育种所需诸多参数，无以达到林木遗传育种的目的。同时在林木遗传育种中，试验结果总是获得非平衡资料，因此，所有的传统的平衡方差分析模式都要修改。

随着线性模型理论的完善和计算机技术的发展，线性模型理论在动物、

农作物遗传育种中得到了广泛的应用。国内外甚至掀起了一股否定传统方差分析理论的思潮。笔者认为，近代线性模型理论对于动物、农作物遗传育种是一种很好的方法。但是，我们应看到，由于林木自身的特点和林木遗传育种独有的需求，近代线性模型理论在林木遗传育种的应用，也应与林木遗传育种具体实践相结合。在林木遗传育种中，广义的方差分析是打不倒的，尤其是在处理林木田间子代试验的非平衡资料时。因为在随机模型条件下，广义的方差分析有合理的期望均方结构和精确的因子调节系数，从而可以估计处理的无偏遗传力及遗传变异；在固定模型条件下，它可以获得处理效应的变异性、成活率等信息，而这是线性模型理论所不具有的。目前，我们应促进广义的方差分析与近代线性模型理论的融合，使之发挥各自的优势，更好地为林木遗传育种服务。

笔者长期奋战在林木遗传改良第一线，经过反复钻研，结合林木的特点，结合林木遗传育种试验的目的，在忠实于统计原理的基础上，对来自动物、农作物育种中，处理不平衡试验资料的统计方法进行消化、吸收、改进，提出了转化分析法的理论，并就林木统计遗传学中一些常见的模型，加以改进，详细地论述了各模型的分析方法。然后利用杉木遗传改良中获得的数据资料，对这些方法进行检验，发现其分析效果十分理想，得到的遗传参数与国际上著名林木遗传学家的结果十分一致。本书是理论研究，也是经验总结，是方法创新，也是技术组装。

本书收集了作者关于林木遗传育种中不规则、不平衡子代试验资料的处理原理、方法和处理技术方面的研究成果，同时吸收了国内外线性模型方面的最新研究成果。着力阐明了非平衡数据分析时，构建线性模型的科学性，切实解决了林木遗传育种中三大块试验类型(田间试验、配合力测试、品种评选和基因型稳定性评价)中试验资料的统计分析方法和田间试验设计技术。以服务于林木遗传育种目的为前提，研究非平衡状态下，诸多参数科学的、合理的和精确的估计方法。本研究吸收了传统的统计分析方法的精华，并与近代线性模型理论相结合，发挥各自的优势，使研究结果具有统计效率高(获得的信息多)和参数精确性好的特点，可以克服负的方差分量和遗传相关系数大于1的现象。由于在今后相当长的一段时间内，常规的林木遗传育种仍然是林木遗传改良的主要途径，因此目前出版一本有关《林木遗传育种中试验统计法新进展》，对林木遗传改良实践有着十重要的实践意义。

本书共分4个部分：第1部分，转化分析法的理论基础；第2部分，转化

分析法各论，以及以转化分析法为基础，对林木遗传育种中的其他遗传参数统计法进行了更新；第3部分，试验林数据处理技术的比较评价；第4部分，转化分析法应用举例。这4个部分是有机一体，具有严密的内在的逻辑性，都是围绕对林木遗传育种中规则不规则、平衡非平衡资料，进行科学分析和采用更先进技术这一中心，进行论证。

本书的读者需具备如下背景知识：数量遗传学和林木遗传育种学；数理统计学和多元统计；线性代数和线性模型理论；田间试验设计；自然辩证法等。

本书在一定范围内，可作为林木遗传育种工作者和林木遗传改良方向研究生的工具书、参考书。本书可为他们指引一种正确的统计方法，来处理林木遗传改良和林木遗传育中采集到的试验数据，从而获得正确的结果，并制订出科学周密的遗传改良方案，节约人力、物力、财力，早出成果，为林木遗传育种服务。

由于作者水平有限，本书中如有不妥之处，欢迎广大读者批评指正。

齐　明

中国林业科学研究院亚热带林业研究所

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PREFACE

There were very close relationships between theoretical development of genetic breeding and genetic improvement practices of forest trees. Here, field test and statistical analysis play the bridge's role linking genetic theoretical progress to genetic improvement action. Because field test of forest trees were essential ties of its genetic improvement programmes and provided research means for genetic improvement practice of forest trees . Statistical analysis methods and techniques were effective tools serving goals of genetic improvement of forest trees. Some problems about test designs and statistical analysis having been found in genetic improvement practice will become our research items of quantitative genetics. But these problems have been solved, this not only will promote statistical theory forward, but also provided the bases for test design of forest tree thus, arriving to goals of genetic breeding of forest trees with great efforts.

In the past, due to lack correct theory of statistical genetics, serious faults had been made in genetic improvement of forest tree: some times, much more manpower, material resource and lands spending on the field test, but trial data have little value; some times, people have get test data, but short of correct statistical methods and techniques, at last, (1) some better strains having been selected behave bad in forestry practice; (2) genetic improvement programmes made according to incorrect genetic parameters cause enormous losses for forestry, and waste much more money and times.

In the domain of genetic breeding of forest trees, unbalanced or irregular test data always were met, almost statistical analysis methods used by workers of genetic breeding of forest trees were from genetic breeding of animal and crop. But there were great differences in many aspects among trees and animal as well as crop. Great differences among demands of genetic breeding of forest trees on statistical parameters and those of animal as well as crop were existed also. Statistical genetic parameters in forest trees need the analysis methods that individual value as basic units of statistical analysis. Plot mean value method from genetic breeding of crop must be pushed over. Because many genetic parameters acquiring from plot mean value method did not achieve the goals of field test of forest trees. At same time, unbalanced test data always be get from balanced test design, so all the balanced AOV models must be revised and perfected.

With perfection of linear model theory and popularizing of computer techniques, linear model theory was widely used in genetic breeding of animal and crop. And more, trend of thoughts that deny AOV theory had been raised at home and abroad. But the author thinks that linear model theory is very good method for genetic breeding of animal and crop . So we should know that there are great differences among forest trees and animal as well as crop, requirement of

forest trees on genetic parameters has obvious differences with that of animal and crop. So application of linear theory in genetic breeding of trees must be combined with specific conditions of genetic breeding of forest trees.

In genetic breeding of forest trees, broad sense AOV method should not be denied. Because under random model, broad sense AOV method has reasonable expected mean structure and exact regulation coefficient. Information about heritability and genetic variation of treatments can be estimated; under fixed model, CV of treatments, survival rate of strains to be tested can be acquired. But these information can not be got by linear model theory . At present, we should combined broad sense AOV with linear model theory together, utilization of their advantage themselves in order to serve genetic improvement of forest trees.

My humble self had worked hard at the first line of genetic improvement of forest trees for long time. Aiming at the features of forest trees and distinctive requirements of genetic breeding of trees, after though researching again and again, statistical analysis methods about unbalanced test data from animal and crop were digested, absorbed and improved, transformation analysis methods had been put forward on foundation of true to statistical genetics bases. And all classical models in genetic breeding of forest trees had been improved and perfected. Analysis methods and techniques of these models had been discussed . The new models had been examined by use unbalanced data in genetic breeding of Chinese fir, their analysis effects are very good, their genetic parameters from these models were as same as those of famous scholars on the world. The book *New Development of Test and Statistics of Genetic Breeding in Forest Trees* was new theoretical research, was experience summarization of genetic breeding of forest trees also; it was new analysis methods establishment, was combination of new analysis techniques recently also.

The readers need background knowledge as follows if they want to read the book: (1) quantitative genetics; (2) genetic breeding of forest trees; (3) mathematical statistics and Multivariate statistics; (4) Linear algebra and linear model theory; (5) Field test design of forest trees; (6) Dialectics of nature and so on.

To some extent, the book can be used as reference book for tree breeding workers, and for postgraduates in the scope of genetic improvement of forest trees. One correct analysis methods for treating test unbalanced data acquiring in genetic breeding and genetic improvement of forest trees can be attained. Genetic improvement schemes with science and with great cares can be worked out in order to serve the goals of genetic breeding of forest trees, saving manpower, material resources and lands, obtaining achievements early.

Owing to limits of theory level of my humble self, if there are some mistakes in the book, welcome to criticize and correct it.

Thanks a lot !

Qi Ming
Research Institute of Subtropical Forestry, CAF
2009, 7.5

ABSTRACT

There are a great differences in many aspects among forest and animal as well as crop. This makes forest genetic breeding science have distinctive demands not only on test design, but also on statistical analysis. At present, people still continue to use the statistical methods from genetic and breeding of animal and crop. However, this analysis methods not only have obvious defect, but also do not achieve the goal of field test of forest in practice. Genetic breeding science of forest trees needs to improve some statistical analysis methods from animal or crop.

Due to exist inevitably missing data, original field test always loses balance. Some experimental factors do not meet prerequisite suppose of the analysis of Variance, and the analysis of variance can't carry on general bases. According to some principle and basis of test design of forest, we can carry out some transformation on experiment design, solving the normal distribution problem of some factors meets the needs of analyses of variance. By means of the improved methods we can treat unbalanced data from experiment of forest genetic breeding. Transformation analyses supply tree progeny test with some principles of design: (1) The section of an area with even and identical environment was divided into one iteration. Size and shape of iteration was determined by environmental condition of test land. (2) Either complete block or incomplete block was used in different iterations. Size and shape of block in different iterations can be changed. (3) When part block was used in some one iteration, materials tested in different part blocks may be equal or unequal. (4) Plots among different repeats are changeable—plot. All these principles accord with the forest tree bases of field test design. At last, some problems about transformation analyses had been discussed and explained.

The book collects my research achievements about analysis principles, analysis methods analysis techniques of treatment regular or irregular, balanced or unbalanced test data in genetic breeding of forest trees, and collects newly research fruits on linear model theory at home and abroad. The book expounds deeply the scientific foundations constructing linear model at treatment of unbalanced test data. Statistical analysis principles, analysis methods of three great types of unbalanced test data (field test of progenies, combining ability trail, strain selection and evaluation on stability of genotypes) had been consummated or improved. Techniques of carrying out

field test designs of many kinds of progenies has been perfected also. Take attaining the goals of genetic breeding of forest trees as perquisite, scientific, rational and accurate estimations of many kinds of factor parameters has been studied, essence of traditional AOV methods had been absorbed, at same time, transformation analysis was combined with linear model theory, their advantages themselves can be brought into play. This makes its analysis results have higher efficiency, more accurate parameters, thus solves those problems that negative variance component and genetic relationship coefficient more than 1 were often met in genetic breeding of forest trees. Because conventional genetic breeding of trees still is a major way of genetic improvement of forest trees in future quite long period. The book *New Development of Test and Statistics of Genetic Breeding in Forest Trees* is edited and published, it has important practical meaning and theoretical value.

The book is divided by four sections. The first part is theoretical foundations of transformation analysis; The second part is transformation analysis of different models respectively. The three part is comparative evaluation of different analysis methods and techniques about unbalanced data of test plantations. The fourth part is some examples about applications of transformation analysis in genetic breeding of forest trees. Those four parts are an organic whole, they have close logicality. All the research works revolve round more scientific of unbalanced or irregular data analysis methods, all centre on proving advancement and reasonability of analysis techniques.

Key words: Genetic breeding; Forest tree; Unbalanced or irregular test data; Field test, analysis method and analysis technique; Quantitative genetic

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