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Plant VOCs emission: a new strategy of thermotolerance

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Abstract: Plant leaves may emit a substantial amount of **v**olatile **o**rganic **c**ompounds (VOCs) into the atmosphere, which include isoprene, terpene, alkanes, alkenes, alcohols, aldehydes, eters, esters and carboxylic acids. Furthermore, most of these compounds actively participate in tropospheric chemistry. Great progresses have been made in linking emission of these compounds to climate. However, the VOCs emission function in plant is still not clear. Recently, some evidence has emerged that the production and the emission of VOCs, such as isoprene and monoterpenes, which account for 80% of total VOCs, exhibit plant protection against high temperatures. These increases in VOCs emissions could contribute in a significant way to plant thermotolerance. This perspective summarizes some latest literatures regarding the VOCs emission-dependent thermoprotection in plant species subjected to high temperature stress, presents the achievement in studies concerning plant VOCs emission-dependent thermotolerance, and then exhibits the proposed mechanisms of such plant thermotolerance. Finally, open questions regarding the plant VOCs emission were shown, and the future researches were proposed.

Keywords: Volatile Organic Compounds (VOCs); Isoprene; Monoterpene; Photosynthesis; Thermotolerance; Thermoprotection
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Introduction

Plants, especially plant species grown in the tropical region, re-emit a substantial fraction of their assimilated carbon into the atmosphere as volatile organic compounds (VOCs). These VOCs represent a large carbon loss and can be up to 10% of that fixed by photosynthesis under stressful conditions and up to 100 g·C m^{-2} per year in some tropical ecosystems (Peňuelas & Llusià 2003). Moreover, at a global scale, the emissions of plant VOCs exceed by several-fold those emissions from anthropogenic sources (Peňuelas & Llusià 2004). Accordingly, the issue of plant VOCs emission attract scientist from all over the world, who can not help asking themselves such question that why plants emit such large amounts of VOCs? The question of VOCs emission function in plant always challenges scientists in past years. Recently, regarding the function of the plant VOCs emission, there have existed many hypotheses, such as plant thermotolerance, plant antioxidation, and plant protection against herbivore, which attempt to answer this question that why plant emit VOCs. However, plant VOCs emission-dependent thermotolerance against high temperature has received considerable attention in the past score years. To this day, there have been reports, showing that plant VOCs emissions can pay an important role in plant thermoprotection from high temperature. Consequently, researchers increasingly debate that, since plant VOCs emission exert thermoprotection from high temperature, whether or not can we make such a conclusion that plant VOCs emission is a new strategy of thermotolerance?

VOCs are produced in many different plant tissues and physiological processes. They are diverse, including isoprene, monoterpene, alkanes, alkenes, alcohols, esters, carbonyls and acids. However, of importance for atmospheric chemistry are mainly the more volatile compounds isoprene and monoterpene, both of which were often used to examine plant VOCs emission-dependent thermoprotection function in plant species. Actually, it was concluded that both isoprene and monoterpene account for 80% of total plant VOCs. Moreover, all the conclusions regarding plant VOCs emission thermoprotection in plant species derive from experimental results by fumigation with either isoprene or monoterpene.

Isoprene and monoterpene

Isoprene (2-methyl-1, 3-butadience) is emitted by a variety of plant species and exerts profound effects on atmospheric chemistry (Harley *et al*., 1999; Logan *et al*., 2000). However, not all plants emit isoprene. Most that do are woody in growth habit, and the species with the highest emission rates are found in the genera *Quercus* (oaks) and *Populus* (poplars) (Harley *et al*., 1999). Among conifers, only *Picea* (spruces) are emitters, and they emit at only moderate rates. The biochemical and physiological controls over the production of isoprene have received considerable attention in the past ten years because of the discovery of a novel biosynthetic pathway and the emergence of hypotheses concerning the possible adaptive role of isoprene during heat stress (Sharkey & Singsaas 1995; Singsaas *et al.*, 1997). This field is currently in a state of intellectual adjustment as biochemical discoveries are integrated with past experimental observations. Isoprene emission is different emission of the related and better known monoterpenes, isoprene emission requires de novo synthesis. However, emission of monoterpenes is, in most cases, from pools of hydrocarbon stored in resin ducts, glands, or trichome (Sharkey and Yeh 2001)

Monoterpenes constitute a major fraction of the plant VOCs emitted from vegetation (Guenther *et al*., 1995) and serve a wide range of functions in plant. In particular, the conifers, mint, citrus, and composite families accumulate these substances in ducts, glands and cavities. These isoprenoids are considered a means of defence against insects, fungi, herbivores and other plant species. When volatilized, monoterpenes can be signals for pollinators

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and conspecific herbivores, and can also mediate tritrophic interactions (Harborne, 1991). However, recent observations indicate that leaves of several tree species, such as the evergreen sclerophyllous holm oak (*Quercus ilex*), emit large amounts of monoterpenes despite the absence of storage pools (Loreto *et al*., 1998a). As demonstrated for isoprene (Sharkey & Yeh, 2001), this monoterpene emission is largely associated with photosynthesis. It is stimulated by light, declines in the dark, and is inhibited in the absence of atmospheric CO_2 (Loreto *et al*., 1996a,b). The physiological function of the emission of nonstored monoterpenes from certain plant species is a matter of debate and an important topic of current research on biosphere-atmosphere exchange. In this respect, one of the most fascinating hypotheses is that monoterpenes may protect leaves against high-temperature damage (Sharkey & Singsaas, 1995; Loreto *et al*., 1998a; Delfine *et al*., 2000; Peñuelas & Llusià 2002). Even though this phenomenon has been demonstrated for several species, clear-cut evidence for the proposed mechanisms of this profound effect has not been achieved (Sharkey & Yeh, 2001).

The thermotolerance hypothesis

Sharkey and Singsaas (1995) were the first people to propose that isoprene has a thermotolerance function. Holding leaves in darkness or in a nitrogen atmosphere to control endogenous isoprene synthesis, researchers assessed damage to photosynthesis as the temperature at which chlorophyll fluorescence increased (Seemann *et al*., 1984). Singsaas *et al*., (1997) showed that adding isoprene to an air stream (or nitrogen gas) that passed over these leaves could increased the temperature at which damage occurred from as low as 35 ºC to as high as 45ºC. These experiments indicated that isoprene was having some effect on the temperature tolerance of photosynthesis. Actually, earlier work had already suggested that isoprene biosynthesis was linked to photorespiration (Jones & Rasmussen 1975). However, subsequent results with *Populus tremuloides* (Monson & Fall 1989), or *Arundo donax* (Hewitt *et al*., 1990), among others, did not find such a relationship. Nevertheless, the most recent studies have not just focused on photorespiration as an alternative source of carbon for isoprenoid biosynthesis when photosynthesis is limited.

Fortunately, direct tests of the thermotolerance hypothesis became possible when it was discovered that fosmidomycin, an inhibitor of the isoprene synthesis pathway (Zeidler *et al*., 1998) was highly specific and did not inhibit photosynthesis (Sharkey *et al*., 2001). Following three heat spikes (2min at 42 ºC), photosynthesis at 30℃ was inhibited by one-third when leaves were able to make isoprene but by two-thirds when isoprene production was inhibited. Exogenous isoprene given to fosmidomycin-fed leaves could restore thermotolerance (Sharkey *et al*., 2001). The latest research (Peňuelas *et al*., 2005) reports that isoprene fumigation of *Quercus ilex*, which normally does not emit isoprene, result in substantial thermotolerance between 35 and 45 ºC, and photosynthesis at 50 ºC was depressed to the same degree in both treatments. Velikova and Loreto report that exposing leaves of *Phragmites australis* to 38 ºC for 90 min caused a greater reduction in photosynthesis when isoprene synthesis was inhibited by fosmidomycin, than when it was not (Velikova & Loreto 2005). In addition, photosynthesis recovered more when the leaf temperature was returned to the pre-stress level of 30℃ when isoprene was present than when it was inhibited (Sharkey 2005). Thermotolerance is much easier to see during the recovery from heat stress than during the initial heat stress episode (Sharkey *et al*., 2001; Velikova & Loreto 2005). Isoprene-induced thermotolerance is very fast (Singsaas & Sharkey 1998; Singsaas *et al*., 1999) compared with changes in xanthopyll (Havaux *et al*., 1996) or fatty acid composition of thylakoid (Murakami *et al*., 2000). These results show that isoprene synthesis and emission provide tolerance of short high-temperature episodes. In fact, so far the thermotolerance hypothesis for isoprene emission function now has substantial support, given three independent reports using different species and methods (Sharkey *et al*., 2001; Peñuelas *et al*., 2005; Velikova & Loreto 2005)

The recognition that monoterpene synthesis increases dramatically at high temperatures and that this can cause them to build to high concentrations in tissues led to the hypothesis that emitted monoterpene may protect plants from temperature. To study thermotolerance caused by monoterpenes, Loreto *et al*., (1998b) fumigated terpene-emitting *Quercus ilex* leaves with a mixture of five monoterpenes during heat treatments and showed a significant stimulation of photosynthesis at high temperatures over unfumigated leaves. To complement the studies with *Quercus ilex*, Delfine *et al*., (2000) have tested whether terpene fumigation affects thermotolerance in a species that does not itself make terpenes, *Quercus suber*, by fumigation with a mixture of monoterpenes. They first showed that fumigation with exogenous terpenes resulted in increased terpene levels inside the leaves, and then demonstrated a significant increase in photosynthesis at elevated temperatures. This is more evident when leaves were given more than one high temperature treatment. Thus, researchers conclude that thermotolerance could be increased in a non-emitting species by fumigating with exogenous monoterpenes. Furthermore, monoterpene emitted in a light-dependent manner also provide the same type of thermotolerance as isoprene. Recent research shows a possible link of both monoterpene emission and monoterpene synthesis with photorespiration (Peňuelas & Llusià 2002). Peňuelas and Llusià have shown the formation of monoterpenes might depend on photorespiratory activity, and that under non-photorespiratory conditions monoterpene seem to replace photorespiration in providing protection against high temperatures (Peňuelas & Llusià 2002). Repeated cycles of high-temperature stress give reduced recovery in leaves without isoprene and monoterpene, although leaves with isoprene or monoterpene maintain high rates of photosynthesis, especially after repeated periods of high temperature (Delfine *et al*., 2000; Loreto *et al*., 1998b; Sharkey *et al*., 2001). More and more evidence show VOCs emission may protects plant from high temperature stress, which plant species, especially tropical plant species, often suffer from. However, the really intrinsic mechanism of plant VOCs emission-dependent thermotolerance is still poorly understood to this day. So this issue deserves comprehensive research.

The proposed mechanisms of thermotolerance

What is the intrinsic mechanism of the plant VOCs emissions providing thermotolerance? Speculation concerning the mechanism by which isoprene protects against short high-temperature episodes depends upon characteristics of the high temperature damage. An attractive idea for which data exists is that thylakoid membranes become leaky at moderately high temperature (Bukhov *et al*., 1999; Pastenes & Horton 1996). Isoprene could reside in the thylakoid membrane for a short time and enhance hydrophobic interactions. It could even block the formation of water channels because of the large volume of the double bonds. Another alternative is that high temperature excursions could allow large membrane-bound protein complexes (e.g. photosystem II) to fragment. Isoprene could enhance hydrophobic interactions within either membranes or protein complexes. Because each excursions to high temperature cloud result in more nonbilayer structures or more disrupted protein complexes, repeated high temperature episodes would progressively reduce the photosynthetic capacity. As leaves can be subject to dozens of high-temperature episodes each day (Singsaas *et al*., 1999; Singsaas & Sharkey 1998), the increased recovery from each episode afforded by isoprene could become very important to the plant. However, the above mentioned mechanisms for plant VOCs emissions thermoprotection has not received direct evidence.

Interestedly, Singsaas (2000) proposed that the intrinsic mechanism of VOCs emission-dependent thermotolerance is the same as that of xanthophyll-induced thermotolerance. The ion permeability of the thylakoid membranes increases at high temperature. This is compensated for by increasing cyclic photophosphorylation around photosystem II (Bukhov *et al*., 1999). If temperature continues to rise, the cyclic photophosphorylation cannot keep up with the proton leakage and the transmembrane gradient drops, causing a reduction in ATP synthesis. This can inhibit RuBP regeneration and lower the Rubisco activation state (Robinson & Portis 1988). Reducing proton leakage will delay this chain of events. When zeaxanthin is present in the membranes, proton leakage is reduced at high temperatures (Tardy & Havaux 1997). One hypothesis is that zeaxanthin may act as a solute in the membrane, which stabilizes its structure at high temperature. Since VOCs are extremely hydrophobic molecules and partition into membranes, they could have similar membrane-stabilizing properties. Nevertheless, the proposed mechanisms of the VOCs emission-dependent thermotolerance have not been widely accepted to this day. Thereby, investigators need much more evidences to reveal the intrinsic mechanism of VOCs emission-dependent thermotolerance.

Conclusions and open questions

In conclusion, among the great variety of likely plant VOCs emissions functions in plants, most recent reports show that plant VOCs emissions could protect plants against high temperatures. Some reports even show that the process of plant VOCs emissions providing thermotolerance is linked to photorespiration (Peňuelas and Llusià, 2002; 2005). The importance of the work by Peňuelas and Llusià is its contribution to our understanding of the possible physiological mechanisms underlying VOCs-related thermotolerance. It demonstrates that photorespiration seems to be necessary to avoid photochemical damage most notably under high temperature conditions. When fumigated with VOCs under nonphotorespiratory conditions, VOCs emission seems to replace photorespiration in the protection against high temperatures. Here, it is emphasized that achievements regarding VOCs emissions thermotolerance function in plant species were obtained from experiments of little plant species, which is either emitter or nonemitter fumigated with VOCs, thus strong and positive evidences will be needed to further assess the plant VOCs emissions-induced thermotolerance.

Inevitably, many questions about VOCs relationships with plant remain to be solved, especially, regarding plant VOCs emission-dependent thermoprotection. Do plants always protect themselves from over-heating by producing and emitting VOCs? Are there species characteristics, physiological states or environmental conditions that determine this photoprotection? Do the VOCs-emitting plant species tolerate higher temperature than the non-VOCs-emitting plant species?

From the evolutional standpoint, since VOCs emission protects plant from high temperature, why do some plant species emit neither isoprene nor monoterpene, which were dominant VOCs and confirmed to exhibit thermotolerance of photosynthesis in leaves exposed to high temperature? Why do some plant species “lose” function of VOCs emission-dependent thermoprotection during the course of long-term evolution, and what environmental factors might make them “lose” such function?

Additionally, how to link the VOCs emission-dependent thermotolerance to the well-known xanthophyll cycle-induced thermotolerance? What roles will the two processes pay in VOCs-emitting plant species subjected to high temperature stress? Which process is more sensitive to high temperature stress? Whether or not the two processes independently function in the different high temperature stress stage? Finally, how does photorespiration affect VOCs synthesis? Which are the intrinsic molecular mechanisms and the interactions involved? To what extent might VOCs emissions directly cool the plant through physiological or evaporative effects?

Future research

From a physiological standpoint, the most important next step is to clone the VOCs, especially isoprene and monoterpene, synthase gene and study its regulation and effects of environment on regulation. This step will answer question about metabolic regulation and provide tools for the further study of the regulation of VOCs emission capacity. After getting more information from this step, we can understand how environmental factors affect VOCs emission, and then according to global variation of environment, we might estimate the amount of emission of VOCs in the future.

Although there are many reports, people still poorly understand the intrinsic mechanism, thereby, studies are still needed on the underlying mechanisms by which VOCs emissions can protect plant species against high temperature. Actually, whether plant VOCs emission is a new strategy of thermotolerance will depend on a clear understanding of its mechanism. Why do some plant species “lose” such function during the course of evolution, whether are there another strategy of thermotolerance in non-emitters replacing the VOCs emission? Whether are emitter greater thermotolerant than non-emitter? The answers of these questions also depend on the understanding mechanism of VOCs emission-dependent thermotolerance. Furthermore, these studies could lead to new discoveries concerning the effect of high temperature on photosynthesis and thylakoid membranes.

And finally, regarding relationship between the emission of VOCs and climate, whether the increased plant VOCs emissions will cool or warm the environment needs to be determined. Whether the increases in both CO_2 concentration and N deposition enhance VOCs emissions from ecosystem or not needs to be examined. The accurate estimation of VOCs emissions from global ecosystem with progressive increases in global temperature is also needed to forecast the interaction effects of plant VOCs emission on global environment. Therefore, investigators may make an effort to investigate the above issues.

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下相比，由于开顶箱的限制，其内的湍流交换表现出了十分独特的属性。开顶箱内大多数湍流统计量表现出十分清晰的日进程。湍流近似为各向同性，并在各个方向表现出很强的相关性。气团的时空结构呈现出与开顶箱形状类似的柱状结构。开顶箱内热力驱动的连续交换过程时常受到外部大尺度气团的入侵，从而表现出较强的间歇性。图 3 表 4 参 16。

关键词：开顶箱；湍流强度；时间与长度尺度；间歇性；热力作用

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澳大利亚新南威尔士州台地上桉树的衰落/张艳华，孙立夫（绍兴文理学院，生命科学学院，绍兴 312000，中国），Ken C. Hodgkinson（澳大利亚联邦科学与工业研究组织，可持续生态系统部，堪培拉 2601，澳大利亚）//Journal of Forestry Research.–2005, 16(4): 306–310.

桉属植物是澳大利亚景观中的主要的乡土植物类群。在欧洲人定居澳大利亚以后，新南威尔士州台地的桉树急剧减少，桉树更新停滞，景观生态系统很难恢复到原初状态。本文介绍了桉树和乡土灌木减少的历史背景，分析了在这一地区幼苗更新减少的原因主要是由于开垦、放牧、火烧、外来物种竞争、枯萎、昆虫和干旱等，总结了桉树更新的可能条件，如幼苗存活的合适条件、充足的种子供应、避免捕食、适当的萌发条件、无放牧环境、机械处理、杂草控制、火烧系统和疾病控制等，借以建议在该地区应怎样保护和促进桉树的更新。参 26。

关键词：桉树；衰落；更新

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可燃物分类与卫星遥感制图/田晓瑞（中国林科院森林保护研究所,北京 100091），DOUGLAS J. MCRAE（加拿大林务局大湖林业中心,苏圣玛丽 P6A 2E5，加拿大），舒立福，王明玉（中国林科院森林保护研究所，北京 100091）//Journal of Forestry Research.–2005, 16(4): 311–316.

本文总结了当前一些国家火险等级系统或火行为预测系统采用的可燃物分类方法。加拿大森林火险等级系统把可燃物分成 5 组共 16 个类型；美国的国家火险等级系统中，可燃物模型分成 4 个植被组 20 个火行为可燃物模型；希腊的谱落米修斯系统把可燃物分成 7 类，而澳大利亚只采用 3 种可燃物类型：草地，干性桉树林和灌丛。制取可燃物图有 4 种途径：(1) 野外调查; (2) 直接勾绘; (3)间接制图方法; (4) 可燃物模型方法。卫星遥感技术是快速获得可燃物资料的一个途径，因为与传统的航空摄影和野外调查相比，时间和空间分别率足以满足可燃物制图更新的需要，利用卫星遥感方法获取数据更及时、高效。卫星传感器也能提供数字信息，这使得采用地理信息系统进行空间分析更加方便，也便于输入到火行为模型和火增长模型中。文中讨论了用于可燃物制图的卫星遥感方法。根据对国际上采用的可燃物制图技术的分析，建议中国在发展国家火险等级系统前要进行可燃物分类，促进林火管理技术的发展。表 4 参 35。

关键词：可燃物分类；可燃物制图；可燃物模型；火行为；火险

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3S 技术在中国湿地研究、调查与管理中的应用/崔丽娟（中国林科院湿地研究中心，国家林业局林木培育重点实验室，北京 100091），安娜·芭登博格(湿地国际-中国项目办，北京 100011)，张曼胤(东北师范大学，环境科学与工程系，长春 130024）//Journal of Forestry Research.–2005, 16(4): 317–322.

遥感技术(RS)、地理信息系统(GlS)、全球定位系统(GPS)在湿地调查和湿地管理方面有着非常重要的应用价值，比如在获取湿地的恢复、管理、可视化信息以及湿地水资源和社会经济资料方面。本文首先介绍了中国湿地的现状。然后描述了 3S 技术在湿地领域的应用，包括湿地的土地利用及其变化追踪，湿地演替过程，景观变化分析，洪水和湿地资源监测，空间定量分析与模型，生态系统服务评价，生态过程与风险评价，疾病控制，水质监测，污染监测，湿地水文，湿地地理信息系统等。第三，提出了目前 3S 技术的应用的限制和应有的发展方向。指出了中国在湿地研究和管理领域中由于先进技术知识和技巧的有限，对地理信息系统认识的不足和使用的能力的不够，使地理信息产出与决策之间的关系不清晰；还有在湿地研究方面缺少政策支持，缺少共享的地理信息系统数据。为了实现 3S 技术的真正应用，要实现湿地相关数据信息的可获得性，可靠性，一致性，连续性，由此相关的环境、政策规章和资金是必须的。参 38。

关键词：遥感技术；地理信息系统；全球定位系统；3S；湿地

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05-04-017

植物挥发性有机化合物的排放：一种新的抗热策略/陈军文（中国科学院西双版纳热带植物园，勐腊，云南，666303），曹坤芳(中国科学院研究生院，北京 100039) //Journal of Forestry Research.–2005, 16(4): 323–326.

许多植物能够产生和排放大量的挥发性有机化合物（Volatile Organic Compounds，VOC）。植物排放的 VOC 主要包括异戊二烯和单萜，它们占了植物排放的全部 VOC 80%以上。据估算，全球每年植物排放进入大气的 VOC 达到 1150 Tg C，中国全年植物 VOC 的排放量达 21 Tg C，在一些热带生态系统中，每年每平方米 VOC 的排放量甚至能达到 100 g C。VOC 的排放意味着植物光合作用固定碳的损耗。据研究，VOC 排放损耗的碳源能占植物光合作用固定碳的 10%，甚至更多。关于植物 VOC 排放的研究，人们着重关注的是两个问题，一是 VOC 排放对大气环境产生的影响，二是植物为什么要“浪费”通过光合作用固定的碳源。目前，科学家已经能证明 VOC 能影响大气中的氧化平衡、温室气体的浓度、以及

浮质的形成。对于植物为什么排放 VOC，科学家还没有取得共识，但有两种假说，一是抗热性假说，二是抗氧化性假说，常常用来解释植物排放 VOC 的生理生态原因。随着科学的发展，这两种假说得到了越来越多的证明。其中抗热性假说得到越来越多科学家的承认。本文将着重介绍近几年来植物 VOC 的排放与植物抗热性研究的一些最新的成果，并对下一步的研究作了相应的建议。参 33。

关键词：挥发性有机化合物；异戊二烯；单萜；抗热性；光合作用

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05-04-018

土壤微生物生物量及其影响因素研究/张江山（福建师范大学环境科学研究中心，福州 350007），郭剑芬，陈光水，钱伟（福建省亚热带资源与环境重点实验室，福州 350007）//Journal of Forestry Research.–2005, 16(4): 327–330.

土壤微生物生物量的养分贮量比土壤有机质的小，但它既是植物所需养分的有效来源，还是养分的临时贮库。本文根据国内外研究结果综述了一些影响土壤微生物生物量动态的因素。这些因素主要包括 C 和 N 的限制、残留物和营养物质的经营、植物种类、土壤质地、土壤湿度和温度等。通过细致分析，我们认为未来研究应着重于探讨土地利用变化对热带和亚热带土壤微生物生物量的影响。参 55。

关键词：微生物生物量；土壤；影响因素；研究进展

CLC number: S714.3; S154.3 Document Code: A

Article ID: 1007–662X(2005)02–0327–04

05-04-019

关于中国吉林省林业建设的思考/A. Mosseler, B. Pendrel, W. Wang（加拿大新布朗斯威克省弗雷德里克顿市加拿大林务局大西洋林业中心），牛延章（吉林省外国专家局,长春 130051），Y. S. Park（加拿大新布朗斯威克省弗雷德里克顿市加拿大林务局大西洋林业中心），高长启，宋丽文（吉林省林业科学研究院， 长春 130033）//Journal of Forestry Research.–2005, 16(4): 331–334.

本文回顾了吉林省的各种林业实践活动，重点强调了吉林省丰富的自然多样性和中国乡土物种的巨大潜力。作者认为适应与森林资源开发和生态建设相关的土地管理机构的需求，中国的研究人员应该将研究的重点更多地放在如何开发乡土种的潜力上。外来种的引进和试验应该仅限于严密的科学试验，同时在林业引进外来种之前应该事先与乡土种进行对比，包括潜在的外来侵入种和害虫的问题，以防产生有害的生态后果。作者还强调了保持可育的（例如：基因多样性和繁殖适合度）乡土种自然种群的重要性，因为只有这样才能保护中国珍惜的自然多样性，保持乡土种作为当地森林和生态建设的种源的潜力。参 4。

关键词：生物多样性保护；外来物种；森林恢复；乡土树种；森林类型，种群生存能力；水土保持

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05-04-020

角化细胞生长因子（KGF）研究中的若干问题/郑文静（东北林业大学野生动物资源学院遗传与分子生物学实验室，哈尔滨 150040），袁力（东北林业大学林学院，哈尔滨 150040），刘学东（东北林业大学野生动物资源学院遗传与分子生物学实验室，哈尔滨 150040；中国农业科学院畜牧研究所遗传资源实验室，北京 10094），郑冬（东北林业大学野生动物资源学院遗传与分子生物学实验室，哈尔滨 150040）//Journal of Forestry Research.–2005, 16(4):334–338.

角化细胞生长因子（KGF 或 FGF-7）是成纤维细胞生长因子（FGF）家族中的第七个成员，它介导多种组织中表（上）皮细胞增殖和分化。本文对 KGF 研究中如下几个问题进行了综述，（1）KGF 作用通路：已有实验表明在间充质－表皮相互作用中 KGF 主要通过的旁分泌通路进行调节，此时 KGF 表达受到反馈环调节，KGF 特别在肿瘤发生过程中通过自分泌途径进行功能调控；（2）细胞凋亡中的 KGF：少数研究近期揭示 KGF 基于自身促细胞分裂功能介导细胞存活，而且 KGF 通过 Nrf-2 通路抑制在 ROS 诱导的凋亡；（3）肿瘤发生中的 KGF：高表达的 KGF 促进肿瘤细胞和多种癌症的进展、扩散和侵染，并伴有自分泌通路替代旁分泌，另外很清楚的是 KGF 在乳腺癌进展过程中起早期信号作用；（4）KGF 临床应用和给药方法：KGF 已成功用于治疗多起放疗和化疗诱导的粘膜炎，并被研发成皮下注射药品（Palifermin），但是更有效的给药方法仍在研究之中。参 51。

关键词：角化细胞生长因子 (KGF 或 FGF-7)；旁分泌；自分泌；细胞凋亡；肿瘤发生；给药

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森林有害生物生态控制－森林有害生物控制的新策略/梁军，张星耀(中国林业科学研究院森林生态环境与保护研究所，北京 100091，中国)// Journal of Forestry Research.–2005, 16 (4): 339–342.

与有害生物综合管理和化学控制比较后，作者提出了森林有害生物控制新策略－森林有害生物生态控制。论文论述了森林有害生物控制策略发展的历史，概述了森林有害生物控制的概念和原则，讨论了森林有害生物控制的技术和方法，评价了森林有害生物生态控制及其适用条件。参 14。

关键词：森林有害生物生态控制；化学控制；有害生物综合管理；生态系统管理

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