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“绿肥果茶园”新理念、效应及应用

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摘要: 我国果园和茶园 (果茶园) 普遍立地条件差，加之清耕粗放管理且过度依赖化肥，导致土壤及养分流失严重，引发果茶园土壤退化，果品和茶叶品质下降。果茶园里种植利用绿肥，不仅为果茶园提供大量有机肥源，还兼具生物耕作、绿色覆盖等功能，有效保障果品、茶叶的稳产提质。绿肥是高品质果茶园管理的核心配套技术，更是未来我国果业、茶业提质增效的首选路径。基于此，本文提出了将绿肥作为我国果茶园建设基本配置的“绿肥果园、绿肥茶园”新理念，并综述了绿肥果茶园的综合效应。运用绿肥果茶园理念与实践，果实、茶叶产量稳定，果品可溶性固形物、维生素 C 含量和糖酸比均提高；土壤物理性状明显改善，有机质和速效养分含量增加；土壤温度和湿度更适宜，水土和养分流失减少，杂草及害虫得到抑制。我国果茶园面积 1640 万 hm^2，现有绿肥果茶园面积约为 121 万 hm^2，仅占果茶园总面积的 7%，因此，推广绿肥果茶园的空间和潜力巨大。我国绿肥果茶园的应用，主要有北方落叶果园的绿肥覆盖循环利用和南方果茶园的冬绿肥覆盖免耕压草、冬夏绿肥周年覆盖等方式。北方落叶果园多选择抗旱抗寒能力较强的毛叶苕子、箭筈豌豆等豆科作物，以及十字花科的二月兰、油菜，或者禾本科的鼠茅草、黑麦草等。南方果茶园主要选择毛叶苕子、光叶苕子、紫云英、箭筈豌豆、山黧豆等豆科作物作为冬绿肥。未来，应从绿肥种质资源创新，绿肥−果树及茶树一体化养分和水分管理，土壤和果品及茶叶品质指标体系构建，模式优化与配套机械化技术，“绿肥+”果品及茶叶产业化路径建设等方面，构建绿肥果茶园技术与理论体系，推进绿肥果茶园建设。

关键词: 绿肥果茶园；应用方式；未来技术与理论体系

Green manuring orchards and tea gardens: concept, effects, and application

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Abstract: Fruit orchards and tea gardens in China are often established in sites with poor field conditions, farmed by clean tillage, and are popularly and excessively reliant on chemical fertilizers, leading to severe soil and nutrient losses, as well as soil degradation and decline of fruit and tea quality. Utilizing green manures in fruit orchards and tea gardens not only provide a large amount of organic matter but also act as biological tillage and green cover, ensuring the steady production and quality improvement of fruits and tea. As the core supporting technology for high-quality orchards or gardens, green manuring should be the most preferred path for China to improve the quality and efficiency of fruit and tea industry in future. Here, we introduce the concept of “green manuring orchard, green manuring tea garden” that takes green manuring as a fundamental component in establishing orchards and tea gardens. Green manuring improves the stability of fruit and tea yields, increases soluble solids, vitamin C content, and the sugar/acidity ratio in fruits; improves the physical properties as well as organic matter and available nutrients in garden soils; enhances the suitability of soil temperature and humidity for

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fruit and tea trees, reduces the losses of water, soil and nutrients, and suppresses weeds and pests. The area of orchards and tea gardens in China is about 16.4 million hectares, in which only about 1.21 million hectares are currently managed by green manuring, accounting for only 7% of the total area of fruit tea gardens, and there is a vast space and potential for the promotion of green manure fruit tea gardens. The main practices for green manuring orchards and tea gardens in China include the multi-years' coverage and recycling utilization method for northern deciduous orchards, and the winter coverage - no-tillage grass suppression method and the annual green manure coverage method for southern orchards and gardens. Deciduous orchards in the north China often choose leguminous crops with strong drought and cold resistance, such as hairy vetch and common vetch, as well as cruciferous plants like February orchid and rapeseed, or gramineous crops like *Fescue* grass and ryegrass. Fruit and tea gardens in southern China mainly select leguminous crops such as hairy vetch, smooth vetch, milk vetch, common vetch, and peavine as winter green manure. The technical and theoretical system for green manuring orchards and tea gardens is mainly expected as follows: the innovation of germplasms for green manure crops, the integrated management of soil, nutrients, and water for green manure together with trees, the quality evaluation indicator systems for fruit and tea products, and the industry pathways for "green manure +" fruit and tea.

Key words: green manuring orchards and tea gardens; application methods; future of the technical and theoretical system

1　我国果品、茶叶种植的基本现状

果业、茶业是我国国民经济和百姓生活的重要基础性行业，在当前全面推进乡村振兴中更是发挥着极为重要的作用。近年来，我国果园和茶园 (以下称果茶园) 发展迅速。2022 年，全国果园面积约为 1301 万 hm^2、茶园面积 339 万 hm^2，果品产量约 3.13 亿 t、茶叶产量约 334 万 t[1]。由于耕地资源有限，我国果茶园的发展策略是“上山下滩”，大多建在一般种植业不便利用的山地丘陵等立地条件较差的区域。不仅如此，我国果茶园普遍存在化学肥料投入过量、有机肥源不足等问题[2]。我国果园氮、磷、钾肥过量施用现象严重，化肥用量是世界平均水平的 2 倍[3]，柑橘园中过量施用氮、磷、钾肥的面积分别占柑橘园总面积的 57.3%、76.6% 和 69.1%[4]。我国茶园年均养分 ($N+P_2O_5+K_2O$) 投入总量达 796 kg/hm^2，其中有机养分仅占养分总投入量的 15%，高达 36% 的茶园化肥过量施用[5−6]，茶园氮肥农学效率和氮肥偏生产力普遍偏低，并呈逐年下降的趋势[7]。长期过量施肥下，果茶园土壤性状变差[2]，深层剖面硝态氮和有效磷累积，淋溶风险高[8]，亟需优化施肥与管理方法。

长期以来，我国绝大多数果茶园等经济林园习惯采用地表清耕管理方式，蓄水固土效果差、养分固持能力弱[9]，容易导致果茶园土壤有机养分加速消耗和流失，引发土壤退化等问题，导致果品、茶叶的品质下降[10−11]。以幼龄茶园为例，清耕管理下的地表径流量和泥沙流失量相较行间绿肥种植高出 63.6% 以上，总氮和总磷流失量分别增加 63.4% 和 60.7% 以上[11]。随着人力成本提高，一些地区转向依靠大量施用草甘膦等除草剂控制杂草或者任由杂草滋生，导致果园生态环境恶化，引发果树叶片和果实变小，株体干枯病和腐烂病多发，甚至苗期树体死亡等不良反应[12]，果实单果重、维生素 C 和可溶性固形物含量下降[13]，严重威胁果品安全和园地质量。

2　果茶园发展绿肥的必要性与“绿肥果茶园”理念

现阶段，我国果品、茶叶总体呈供过于求状态。2022 年我国人均水果占有量达 196 kg，但人均消费量仅为 54.7 kg[1]。如何实现果品、茶叶的提质增效，是新时代果、茶产业发展的重要要求。良好的养分供给和土壤性状是高品质果品和茶叶的基本保障。当前果茶园养分和土壤管理的主要手段是增施有机肥，然而受有机肥源数量和施用成本等条件限制，我国果茶园的有机肥投入严重不足，有机肥养分投入仅占果茶园养分总投入量的 7.0%[8]，增加果茶园的有机肥投入必须寻求新的路径。不仅如此，我国果茶园整体立地条件较差，土壤性状也需要良好的耕作措施来维持。

生草覆盖是国外果茶园普遍采用的生产方式，套种绿肥是人工生草的主要手段[14−15]。绿肥由于其强大的有机转化归还能力和生物耕作效应，是改善经

济林园土壤性状的高效措施。种植并利用绿肥不仅为果茶园增辟有机肥源、改善土壤养分循环，也能对土壤进行生物耕作、提升绿色覆盖，是园地土壤改良、生态环境改善的最有效手段。我国科学工作者长期坚持推行果园绿肥、茶园绿肥，在20世纪90年代，就已经形成了一系列技术方法，也证明了绿肥在果茶园里的良好作用。近些年也有大量研究证实，果茶园种植利用绿肥作物，能够改善土壤质量，提升果品、茶叶品质，保障果茶园的可持续生产[16−21]。鉴于绿肥在果茶园中的良好效果，结合我国果茶园的立地条件较差、有机肥源不足、土壤质量低下等因素，为满足果茶业的高质量发展需求，我们认为，采用绿肥技术是未来我国果茶园的必由之路。

尽管果茶园种植利用绿肥的作用明显，但是我国果茶园绿肥的发展依然处于初级阶段，并且推行缓慢。限制果茶园绿肥发展的主要因素，除了绿肥模式不完善、机械化手段不配套等技术问题，更重要的是种植户和行业管理部门对果茶园绿肥的效应认识不足、重视不够等理念问题。因此，有必要思考影响果茶园绿肥发展的内在原因，通过技术优化和理念创新指导绿肥服务于现代果茶业的发展。

基于此，我们于2021年提出了“绿肥果园、绿肥茶园”(绿肥果茶园)的新理念。绿肥果茶园是指利用绿肥技术，将绿肥作为果茶园建设的基本配置，保障果园、茶园的可持续利用和发展。新理念突出以绿肥技术来实现果园、茶园的提质增效，是主动适应新时代农业高质量发展的机制创新。发展好绿肥果茶园，利用绿肥为果树、茶树提供有机养分、增加绿色覆盖、压制杂草、改善生态环境、实现生物耕作，为果品和茶叶生产创造良好的土壤、养分、生态环境，进而保障高品质果品和茶叶的生产。

3 绿肥果茶园效应

3.1 提升果品、茶叶产量及品质

根据全球果园已经公开发表的数据分析，豆科绿肥可提升果实产量7.5%[19]。南非柑橘园间作豆科绿肥，柑橘产量提高7.6%～64.0%[22]。欧洲橄榄园种植豆科绿肥，橄榄果实的含水率和单果重提高，果实产量显著提升31.6%[23]。四川丘陵柑橘园种植利用豆科绿肥，使柑橘产量提高13.6%～34.9%，以间作南选山黧豆和光叶苕子效果最佳[24]。四川大渡河干暖河谷地区间作紫云英、毛叶苕子、紫花苜蓿、白三叶草，均显著提高柑橘的产量和单果重，其中以紫云英增产效果最佳[25]。落叶果园间作绿肥在不同程度上也可提升猕猴桃园[26]、苹果园[27]和芒果园[28]的果实产量。福建茶园间作爬地兰和威恩圆叶决明，能够促进茶树生长和鲜叶产量[29]。

绿肥果园在改善果园生态环境、提高果品产量的同时，提升了果实的品质[24, 30]。综合全球范围的研究表明，绿肥果园的果品可溶性固形物、糖含量和维生素C含量分别平均提高了6.7%、6.8%和16.0%，果实酸度降低了11.9%[19]。表1列出了我国山东苹果园、湖北柑橘园、四川柑橘园、贵州猕猴桃园，地中海地区葡萄园、葡萄牙东北部橄榄园，以及江苏和湖南茶园的研究结果，均表明间作绿肥有提高果实、茶叶品质的效应[23−24, 31−36]。

3.2 培育健康土壤

3.2.1 改善土壤物理性状　绿肥果茶园中，绿肥生长产生的有机体和根系的生物耕作作用，会明显促进土壤团聚体的形成，有利于改善土壤物理性状[37]。湖南柑橘园，绿肥覆盖后土壤容重降低0.02～1.11 g/cm^3，土壤总孔隙度提高0.86%～4.71%[38]。福建龙眼园，种植绿肥后0—40 cm土层的土壤容重降低0.68%，总孔隙度提高1.19%[39]。重庆柑橘园，绿肥覆盖增加了30～150 μm孔隙和土壤颗粒的数量，且豆科绿肥比非豆科绿肥具有更大的孔隙连贯度和颗粒结构，利用绿肥5年后，提高了>0.25 mm各粒级团聚体的比例和土壤团聚体的平均重量直径、几何平均直径，降低了土壤分形维数。江西柑橘园，黑麦草和白三叶覆盖下土壤>0.25 mm水稳性团聚体含量分别增加15.51%和12.19%[40]。

3.2.2 促进土壤养分循环、改善土壤生物性状　种植利用绿肥是增加经济林园土壤碳输入、提高土壤有机质含量的重要措施[41]。一项涵盖国内不同土壤类型绿肥果园的研究表明，豆科绿肥通过促进微生物残体碳的积累提升了土壤稳定性有机碳的固持，土壤有机碳总量和矿物结合态有机碳含量分别提升了23.3%和25.1%[20]，土壤有机质储量平均增加22%[42]。绿肥覆盖使巴西热带地区的橄榄园土壤碳库管理指数从21增加到48[43]。

绿肥可有效提高果园土壤养分含量，且豆科绿肥对氮素营养的提升效应更显著。三峡库区柑橘园中光叶苕子、毛叶苕子、箭筈豌豆、白三叶、紫云英和鼠茅草等绿肥盛花期的生物量和氮养分累积量分别在11～24 t/hm^{2}和35～97 kg/hm^2[44]。重庆柑橘

表 1　绿肥对果品、茶叶品质的影响

Table 1　Effects of green manuring on the quality of fruit and tea products

研究区域 Research area	作物 Crop	绿肥种类 Green manure species	品质效应 Quality effect	参考文献 Reference
山东省新泰市 Xintai, Shandong	苹果 Apple	毛叶苕子 Hairy vetch	可溶性固形物和维生素C含量分别增加14.9%和9.3%，可滴定酸降低20.2%。The content of soluble solids and vitamin C increased by 14.9% and 9.3%, while the titratable acidity decreased by 20.2%.	[31]
湖北省武汉市 Wuhan, Hubei	柑橘 Citrus	百喜草 *Paspalum natatum*	座果率提高14.6%、柠檬酸降低7.9%、可溶性固形物增加7.5%。Fruit set rate increased by 14.6%, citric acid decreased by 7.9%, and the content of soluble solids increased by 7.5%.	[32]
四川省南充市 Nanchong, Sichuan	柑橘 Citrus	南选山黧豆、光叶紫花苕和白三叶 Peavine, smooth vetch, and write clover	果实维生素C含量分别提高0.11、0.28和0.15 mg/kg，可溶性固形物分别增加1.9%、0.9%和1.0%。The vitamin C content in the fruit increased by 0.11, 0.28, and 0.15 mg/kg, and the soluble solids increased by 1.9%, 0.9%, and 1.0%.	[24]
贵州省贵阳市 Guiyang, Guizhou	猕猴桃 Kiwi fruit	黑麦草、箭筈豌豆 Ryegrass, common vetch	可溶性固形物、维生素C和可溶性糖分别提高3.03%～8.43%、9.75%～18.92%和4.60%～19.17%。The content of soluble solids, vitamin C, and soluble sugars increased by 3.03% to 8.43%, 9.75% to 18.92%, and 4.60% to 19.17%.	[33]
地中海地区 Mediterranean region	葡萄 Grape	豌豆 Pea	可溶性固形物提高3.6%。The soluble solids increased by 3.6%.	[34]
葡萄牙东北部 Northeastern Portugal	橄榄 Olive	11种豆科绿肥混播 11 species of legume green manure mixed sowing	橄榄中油橄榄素、毛蕊花糖苷、咖啡酸和表儿茶素浓度提升。The concentrations of oleuropein, verbascoside, caffeic acid, and epicatechin in olives are enhanced.	[23]
江苏省南京市 Nanjing, Jiangsu	茶 Tea	大豆 Soybean	茶树鲜叶中可溶性糖、氨基酸含量分别提高84.6%和84.4%。The content of soluble sugars and amino acids in fresh tea leaves increased by 84.6% and 84.4%.	[35]
湖南省益阳市 Yiyang, Hunan	茶 Tea	紫云英、肥田萝卜、绿肥油菜 Milk vetch, radish, and rapeseed	茶叶氨基酸含量增加7.49%～84.92%，茶叶酚氨比值降低0.34～6.72。The amino acid content in tea leaves increased by 7.49% to 84.92%, and the phenol-amine ratio decreased by 0.34 to 6.72.	[36]

注：品质效应结果以清耕为对照。

Note: Quality effect are results compared with clean tillage

园，黑麦草、毛叶苕子和三叶草连续种植 5 年后，土壤全氮含量分别提高 19.5%、40.5% 和 33.4%，其中土壤有机氮和无机氮含量分别提高 0.10～0.30 g/kg 和 7.7～15.7 mg/kg，毛叶苕子效果最佳。山东绿肥苹果园行间种植绿肥，0—20 cm 土层土壤无机氮、微生物量氮及有机氮组分中的酸解氨态氮、酸解未知态氮和非酸解性氮含量均显著提高[45]。海南在椰子园间作柱花草后，土壤全氮、铵态氮、硝态氮含量分别提高 55.2%、75.7% 和 67.3%，土壤有机氮组分含量提高 33.4%～102.2%[46]。河北梨园种植利用 8 年黑麦草还田后，土壤有机质、碱解氮、有效磷、速效钾含量，以及土壤铁、锌的有效性显著提高[47]。江苏茶园，间作大豆有效提升土壤肥力，土壤有机质、全氮、无机氮和速效钾含量分别提高了 41.9%、74.2%、54.7% 和 72.7%，且土壤 pH 值达到 5.1，比清耕茶园升高了 0.2 个单位，缓解了茶园土壤酸化[35]。

果茶园种植利用绿肥，可有效改善土壤微生物组成、活性等生物性状。陕西苹果园，覆盖黑麦草和白三叶显著提高了 0—40 cm 土层土壤酶活性[48]。日本柚园和坚果园，行间种植蚕豆可以在短期内提高土壤微生物生长并促进菌根真菌形成，提高果树根系菌根真菌侵染率和孢子数量[49]。湖北猕猴桃园，绿肥种植提高土壤微生物的代谢活性和功能多样性，增强对 D-甘露醇等糖类、L-精氨酸等氨基酸类、γ-羟丁酸等羧酸类、4-羟基苯甲酸等酚酸类碳源底物的利用能力[50]。江苏茶园，间作大豆、紫云英，通过提高土壤碳循环相关酶活性和功能基因丰度，土壤多功能性抵抗力提高 25.7%[51]。

3.3　优化园地生态环境

3.3.1　调控土壤温度和湿度　　土壤温度和湿度是

影响果树生长和果品品质形成的重要环境因子，绿肥覆盖可有效降低土壤水分无效蒸发，调节土壤耕层温湿度状况，改善果树生长微环境，促进果树生长[52−53]。在干旱地区，绿肥对果园土壤温湿度的改善效果更显著。在新疆干旱区苹果园，绿肥覆盖后土壤湿度提高了 7.2%，0—5、5—10 和 10—15 cm 土层温度较清耕分别降低了 3.8℃、3.6℃ 和 3.1℃[54]。在川渝极端高温干旱气候条件下，绿肥覆盖柑橘园土壤温度显著低于清耕，土壤湿度增加 3.1%～17.0%，柑橘日灼果的比例大幅度降低，有效保证了果树保果稳果。福建丘陵山地茶园，夏季高温干旱时期，茶园套种圆叶决明使土壤 0—20 cm 的含水量提高 21.8%，空气温度日变化幅度降低 5.1℃，空气湿度日均值提高 3.9%[55]。在全球气候变暖和极端高温天气频发的背景下，绿肥通过降低土壤温度、提升土壤湿度，调控果园地表微生态环境的作用更加凸显。

3.3.2 减少水土和养分流失　绿肥覆盖在阻控丘陵山地果茶园水土流失方面也具有重要意义。分析全球范围已发表的果园研究数据表明，绿肥覆盖平均可减少 48.5% 的径流、70.5% 的土壤侵蚀、53.4% 的氮素流失和 56.9% 的磷素流失[56]。与传统的清耕方式相比，山东苹果园间作鼠茅草能显著降低 93.5% 的地表径流量、90.0% 矿质氮径流损失，增加 69.9% 渗漏量[57]。福建蜜柚园，绿肥覆盖下土壤流失量仅为清耕处理的 2.7%，径流中各形态氮磷含量和流失量显著降低[58]。在三峡库区柑橘园，不同绿肥覆盖处理地表径流和壤中流流失量分别降低 14.49%～26.90% 和 17.00%～32.36%，随径流发生的氮素流失减少 13～27 kg/hm^2，其中以黑麦草和三叶草覆盖的阻控能力更强[59]。上海桃园，菊苣、紫花苜蓿和白三叶覆盖可分别显著减少 41.6%、35.0% 和 58.4% 的地表径流，且铵态氮、总氮和总磷流失量也显著降低，以白三叶效果最佳[60]。福建柑橘园，套种平托花生相比清耕，4 年累计地表径流次数减少 140 次、径流总量减少 11358 t/hm^2，且无泥沙流失[61]。广西坡度为 23° 的柑橘园种植绿肥，地表径流中总氮、总磷、铵态氮和硝态氮流失量分别比清耕减少了 24.6%、15.3%、10.0% 和 20.2%[62]。

3.3.3 抑制杂草及害虫　在落叶果园、常绿果树未形成郁闭前，种植绿肥能实现良好覆盖，高效抑制果茶园杂草。在江西果园的定位监测试验发现，覆盖绿肥后，春季杂草和秋季杂草密度仅为自然生草的 10.9%～24.3% 和 8.0%～24.2%，毛叶苕子抑制杂草效果最佳。天津桃园，二月兰翻压对艾蒿、卷耳、婆婆纳、马齿苋都有很强的防除效果，防除率分别达 86%、77%、72% 和 54% 以上[63]。四川柑橘园，山黧豆对稗草、马齿苋和升马唐的株防效分别为 66.2%、63.1% 和 62.2%，光叶苕子对空心莲子草、刺儿菜和牛筋草的株防效分别为 76.7%、80.6% 和 89.4%[24]。桃园间作黑麦草或白三叶草，可抑制杂草种子发芽，提高桃园收益[64]。据国家绿肥产业技术体系调研，绿肥覆盖平均减少除草剂施用 3 次，节约除草剂和喷药人工成本 900 元/hm^2；如果清耕果园采用人工除草，绿肥覆盖可节省人工费用 4500～7500 元/hm^2。

绿肥覆盖对害虫也有一定的防控作用。世界范围内绿肥苹果园中，绿肥作物显著增加了苹果园害虫的天敌数量，具有减少害虫的趋势[65]。不同类型的绿肥均显著提高了福建茶园中叶蝉天敌缨小蜂的种群数量[66]。智利梅园中绿肥丰富了寄生性天敌的多样性，寄生性天敌食物网的专业化程度更高[67]。甘肃苹果园间作油菜，通过提高瓢虫和草蛉等天敌数量，实现对苹果绣线菊蚜的生态防控[68]。间作铺地木兰和罗顿豆、圆叶决明和白三叶或者白三叶和平托花生，可以增强茶园生物的多样性，提高害虫天敌种类和个体数，更有效发挥天敌对有害生物的生态控制[69]。

4 我国绿肥果茶园的主要应用方式

我国果园、茶园虽然分布广泛，但从种植利用绿肥的角度出发，可以从北方落叶果园和南方果茶园两大区域加以考虑，分别采取相应的绿肥利用方式[70]。

4.1 北方落叶果园

北方落叶果园多选择抗旱抗寒能力较强的毛叶苕子、箭筈豌豆等豆科绿肥，以及十字花科的二月兰、油菜，或者禾本科的鼠茅草、黑麦草等。黄淮海地区的果园可在 8 月至 9 月中旬前播种绿肥，西北地区果园则应 3 月底至 4 月初播种，可越冬的绿肥种类也可在 8 月底播种。绿肥于翌年 3—4 月返青并快速覆盖地表，4—5 月进入花期，6 月前后结荚、自然枯萎落籽。北方果园绿肥产籽量较高，自繁能力强，3～5 年内不需补播，可一次播种多年利用。

幼龄果园可采用周年绿肥轮作快速培肥模式，根据不同绿肥的生物学特性择机播种，如西北苹果园绿肥大豆−油菜轮作时，大豆应在 4 月下旬到 5 月上旬浅耕翻后播种，油菜于 8 月播种。

4.2　南方果茶园

南方果茶园主要选择毛叶苕子、光叶苕子、紫云英、箭筈豌豆、山黧豆等豆科作物作为冬绿肥。其中，毛叶苕子和箭筈豌豆一般用于江淮地区及长江以南的果、茶园，光叶苕子主要用于云南、贵州、四川、重庆、广西等地果茶园，山黧豆主要用于四川和重庆等地区，紫云英主要适宜地势相对平缓的果茶园。冬夏绿肥周年覆盖模式中，夏绿肥一般选择印度豇豆、乌豇豆、拉巴豆等绿肥种类。冬绿肥于 9—10 月、土壤墒情较好时播种。采用冬夏绿肥周年覆盖技术的果茶园，8—9 月降雨前后播种冬绿肥，翌年 5—6 月播种夏绿肥。

5　绿肥果茶园潜力及展望

我们提出了“绿肥内源驱动土壤健康”新观点[71]，指出绿肥有着自身明显的特色和优势，与商品有机肥、畜禽粪便等外源有机 (类) 肥料具有本质区别。绿肥是植入生产制度，通过其自身的生命活动，活化及固定环境养分并予以归还，为农田输入有机物，全方位深层次调节土壤性状[72−73]。这些性质也决定了发展绿肥技术是我国建设高品质果茶园的必然选择。

据国家绿肥产业技术体系调研，2017—2021 年，我国绿肥果茶园面积为 52 万～60 万 hm^2；2022 和 2023 年绿肥果茶园面积达到 108 万和 121 万 hm^2 (图 1，国家绿肥产业技术体系资料)。虽然在绿肥果茶园理念推动下，绿肥果茶园面积有所发展，但也仅占果茶园总面积的约 7.0%。

综上，我国发展绿肥果茶园，对果品、茶叶产业提质增效十分必要，且有巨大的发展空间。未来，绿肥果茶园研发的主要工作包括：1) 适宜果茶园的绿肥种质资源创新与配套技术；2) 绿肥果茶园适产优质的土壤、养分与水分综合调控技术；3) 建立绿肥果茶园的生态环境与产品品质评价指标体系；4) 适应绿肥种植利用农艺要求的果茶园模式构建与配套装备；5) “绿肥+”优质果品、茶叶产业化路径与产业经济。

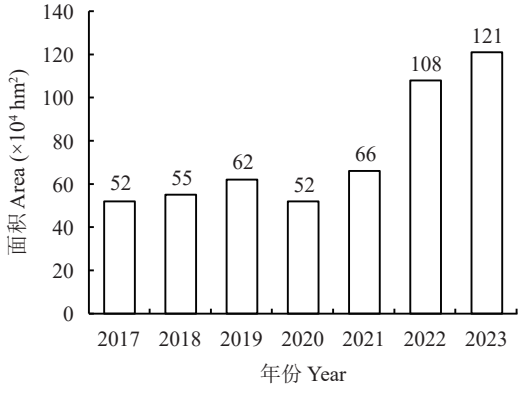

图 1　2017—2023 年我国绿肥果茶园面积

Fig. 1　The area of green manure orchards and tea gardens in China from 2017 to 2023

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