Achieving High Groundnut Yields

International Crops Research Institute for the Semi-Arid Tropics

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Abstract

An international workshop was held at the Shandong Peanut Research Institute, Laixi City, China, to review and document available technologies to achieve high groundnut yields, observe methods that have been developed and adopted in Shandong Province, and develop plans to achieve similar yields in other countries in Asia and elsewhere. Representatives from 13 provinces of China, India, Korea, Myanmar, The Philippines, Thailand, Vietnam, and Zimbabwe, and ICRISAT attended the meeting and toured areas of Shandong to see the technologies in practice. Papers on all aspects of groundnut production are included, with additional abstracts of poster papers, and summaries of Working Group discussions. All preliminary papers, abstracts, and discussion summaries are presented in English and Chinese.

为了总结花生高产技术，为了观摩山东省的花生高产措施，为了帮助亚洲其他国家及其他地区制定花生生产达到类似水平的发展规划，在位于中国莱西市的山东省花生研究所召开了一次花生高产国际学术研讨会.

来自于印度、韩国、缅甸、菲律宾、泰国、越南、津巴布韦、半干旱所及中国的 13 个省（市、自治区）的代表参加了会议，会议期间还参观了山东的花生高产技术.

本文集包括会上宣读的有关花生生产各个方面的论文、会议交流论文的摘要、及分组讨论记要. 所有论文、摘要和分组讨论记要都有中文及英文件.

Note-There is an error in the footnotes on the first page of each paper in these proceedings. The sequence of the editors in the citations should be as printed above.

Achieving High Groundnut Yields

Proceedings of an International Workshop

25-29 August 1995
Shandong Peanut Research Institute (SPRI)
Laixi, Shandong, China

Edited by

C L L Gowda, S N Nigam, C Johansen, and C Renard

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1996

Co-sponsors

Shandong Academy of Agricultural Sciences (SAAS)

Chinese Academy of Agricultural Sciences (CAAS)

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Organizing Committee

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Welcome Address

Lin Donghai[1]

On behalf of the Government of Qingdao City, I would like to extend the warmest welcome to the scientists from abroad and at home. I also wish to express my ardent welcome to the distinguished guests from the Chinese Academy of Agricultural Sciences, the Government of Shandong Province, and the Shandong Agricultural Department.

Qingdao City is the main groundnut-growing region in Shandong Province. Groundnut seed oil production in four of the five cities administered by Qingdao City is among the first eleven in China, and of these, Pingdu is ranked first. Held in Qingdao this workshop will make a great difference to the progress of groundnut production in our region. Please feel free to give us your kind advice. At the same time, I hope that new and everlasting cooperation is established between Qingdao and the research institutions and scientists abroad and at home. I welcome every scientist and friend to help groundnut production, and to travel in Qingdao.

I wish the International Workshop on Achieving High Groundnut Yields complete success.

欢 迎 词

林东海[1]

我代表青岛市人民政府对来自海内外的科学家表示最热烈地欢迎！对来自中国农业科学院、山东省政府和山东省农业厅的贵宾们表示热烈地欢迎！

青岛市是山东省的花生主产区．全市所辖5个县级市中有4个名列全国县级油料总产前11位．其中青岛市的平度市位居全国第一．此次研讨会在青岛召开，相信必定会对青岛的花生生产起到巨大的推动作用．我衷心希望国内外的专家学者能给我们留下宝贵的意见．同时，我也希望通过这次会议，青岛与国内外农业研究机构之间、与各位专家之间建立起永久的友好合作关系，并欢迎各位专家和朋友来青岛旅游观光．

祝大会圆满成功！

1．青岛市人民政府副秘书长，中国，青岛 266071．

Welcome Address

Wang Dagang[1]

The International Workshop on Achieving High Groundnut Yields is being held here in Laixi with the support of the Chinese Academy of Agricultural Sciences (CAAS) and cosponsorship of the Shandong Academy of Agricultural Sciences (SAAS) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). On behalf of SAAS and myself, I wish to extend a very warm and hearty welcome to the scientists from ICRISAT, India, Korea, Myanmar, Philippines, Thailand, Vietnam, and Zimbabwe, and from 13 provinces of China. I would also like to express my ardent thanks to our guests from CAAS, the Government of Shandong Province, and from Qingdao, Pingdu, Zhaoydan, and Laixi Cities for their attendance and earnest support to the workshop.

It is well known that groundnut is one of the world's staple oil and industrial crops. Therefore, achieving high groundnut yields plays a very important role in the improvement of human nutrition. But there is a great imbalance in groundnut productivity between countries and regions, and between areas within China. Our province, Shandong, is the main groundnut producing-area in China and ranks first in terms of area sown (74 000 ha), yield (3.5 t ha^{-1}), and output. Our experimental results show that the groundnut yield potential can be as high as 10.5 t ha^{-1}. It is possible to realize higher and higher yields and total production by closing the gap between farmers' fields and our experimental fields. I am convinced that this situation is the same all over the world.

The scientists here are specialists, well-experienced in basic groundnut research and technology transfer. Today you have happily gathered under the same roof to exchange ideas, and to learn how to help each other. I am sure that this will promote the progress of the science and technology of groundnut production in the world. This workshop will also bring about a great advance in groundnut production in Shandong. We will learn much from you. We thank you for your attendance, and wish the International Workshop on Achieving High Groundnut Yields complete success.

1. Professor, General Director, Shandong Academy of Agricultural Sciences (SAAS), Jinan 250100, People's Republic of China.

欢 迎 词

王大刚[1]

这次在莱西召开的国际花生高产学术研讨会，是在中国农业科学院的支持和指导下，由山东省农业科学院和国际半干旱热带地区作物研究所共同主办的．我代表山东省农业科学院，对来自国际半干旱热带地区作物研究所、印度、印尼、韩国、缅甸、菲律宾、泰国、越南和津巴布韦以及中国 13 个省（市、自治区）的科学家，表示热烈地欢迎！对来自中国农业科学院、山东省政府、青岛市政府、平度市政府、招远市政府和莱西市政府的贵宾们表示热烈地欢迎！对他们给予研讨会的大力支持表示衷心地感谢！

大家知道，花生是世界上食用油料和原料作物之一，发展花生生产对改善人类营养具有重要的作用，但是，世界上生产花生的国家和地区以及中国的不同地区，其生产水平很不平衡．就中国来说，山东省是花生主产区，常年种植面积 74 万公顷，产量在平均每公顷 3.5 吨左右．有研究表明，花生最高产量可达每公顷 10.5 吨，因此，提高花生生产量仍有很大潜力．我相信，世界其他地区的情况大致如此．

出席这次会议的各位科学家，都是在花生科学和技术研究方面积累了丰富经验的专家，今天大家欢聚一堂，相互交流经验，取长补短，必将有利于推动国际花生科学技术的进步和生产的发展．这次研讨会也必将对山东省的花生科学技术和生产的发展起到很大的促进作用，我们将从中学到许多好经验。感谢各位的光临，祝国际花生高产学术研讨会开得圆满成功！

1　山东省农业科学院院长，研究员，中国，济南，250100

Inaugural Address

Shao Guifang[1]

The first session of the International Workshop on Achieving High Groundnut Yields has convened in Laixi City, Shandong Province. This will be a very significant workshop for China, and especially for Shandong Province in terms of promoting groundnut research, technology exchange, international exchange, and cooperation. On behalf of the People's Government of Shandong Province, I would like to take this opportunity to extend my warm welcome to the scientists and experts who have come from ICRISAT Asia Center, India, Indonesia, The Philippines, Myanmar, South Korea, Thailand, Vietnam, Zimbabwe, and the Chinese Academy of Agricultural Sciences, as well as to those who have come here from other provinces of China.

Shandong is one of the biggest agricultural provinces. As a major economic crop, groundnut production has played a very important role in our province's agriculture. The Government of Shandong Province has constantly paid much attention to groundnut production, and has implemented a series of policies to support research and its application. These policies integrate agriculture, science, and education. By making the best use of all advantages, a steady increase of groundnut production has been guaranteed. The large Shandong variety groundnut enjoys a very good name in international markets. It is a traditional export commodity of which 200 000 tons are exported each year. In recent years, in addition to meeting the demands of our own province, we have also taken on the responsibility of supplying the product to such other cities as Beijing, Tianjin, and Shanghai.

At present, we still need to improve both the quality and quantity of groundnuts in our province. I am sure that after this meeting groundnut research and production will be greatly enhanced. The meeting will also result in advances in this area in every groundnut-producing country in the world. I wish the workshop success, and convey my good wishes to all participants. I also hope that everyone here will make greater progress in their work, and contribute more to all mankind.

1. Deputy Governor, Shandong Province, Jinan, Shandong, China.

开 幕 祝 词

邵桂芳[1]

第一届国际花生高产学术研讨会在山东省莱西市召开，这对扩大我国、特别是山东省花生高产研究与技术推广方面的国际影响，促进国际间的交流与合作，具有十分重大的意义。对此，我代表山东省人民政府，对来自国际半干旱研究所、印度、印度尼西亚、菲律宾、缅甸、韩国、津巴布韦、越南、泰国以及中国农业科学院、国内13个省市的与会者、专家，表示热烈地欢迎。

山东是一个农业大省，花生做为主要经济作物，在农业生产中占有举足轻重的地位。山东省政府历来重视花生生产，在研究、推广等方面制定了一系列扶持政策，实行了农科教一体化，集中人、财、物力保证了花生产量的持续提高。山东大花生在国际市场上享有盛誉，是传统的出口商品，每年出口20万吨。近几年，除满足本省城乡人民的需要外，还担负着向京、津、沪等大城市的供应任务。

目前，山东花生生产，无论在产量方面还是在质量方面，都需要有一个新的提高，我相信，这次会议必将促进我省花生研究与生产的全面发展，必将促进世界各国花生研究与生产的全面发展。在此，我以良好的愿望，预祝会议圆满成功！祝愿大家在各自的事业中做出更大成绩，造福于人类！

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1. 山东省副省长，中国，山东济南。

Opening Speech

Zhu Dewei[1]

I should like to declare the International Workshop on Achieving High Groundnut Yields open. First of all, I should like to express my heartfelt congratulations on the convening of this workshop on behalf of the Chinese Academy of Agricultural Sciences (CAAS) and on my own behalf, and to extend a warm welcome to Drs Renard, and Gowda, and the other ICRISAT scientists, and to the representatives from India, Indonesia, Korea, Myanmar, The Philippines, Thailand, Vietnam, and Zimbabwe as well as to the Chinese scientists from more than 10 provinces, municipalities and autonomous regions. I should also like to express my sincere thanks to the host organization-the Shandong Academy of Agricultural Sciences (SAAS).

China is a major groundnut-producing country. The groundnut-producing area in China is about 3 035 600 hectares, and it is ranked second in the world after India. The groundnut-growing area in Shandong ranks first in China in terms of unit yield, and the average annual total yield. Therefore, it is of great significance that this workshop is being held here in Shandong.

The cooperation between China and ICRISAT started in the early 1980s. In 1988 CAAS and ICRISAT signed an Agreement of Cooperation when the two parties agreed to collaborate on groundnut, sorghum, minor millets, chickpea, and pigeonpea. In recent years, their mutual efforts have made great achievements in scientific cooperation. China has received several thousand germplasm accessions of groundnut and sorghum from ICRISAT that have enriched the Chinese genebanks. A number of promising varieties of sorghum and groundnut that involve ICRISAT materials have been released in China. The popularization of these varieties will promote Chinese production of sorghum and groundnut in China.

In the past, more than 70 Chinese scientists have visited ICRISAT to attend training courses or workshops, and to conduct collaborative research. ICRISAT has educated a large number of young Chinese groundnut and sorghum scientists who now play an important role in Chinese agricultural research.

Last year, CAAS and ICRISAT signed a new Agreement of Collaboration. It covers 21 projects of which 11 are on groundnut. These projects, combined with key national programs, are supported by the germplasm and by funding. In future we will further strengthen and broaden the collaboration between China and ICRISAT, so that we will be able to make a greater contribution to agricultural research and to production in China and the world.

I wish the workshop success, and our friends a pleasant stay in Shandong.

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1. First Vice-President, Chinese Academy of Agricultural Sciences (CAAS), 30 Baishiqiao Road, Beijing, China.

开 幕 词

朱德蔚[1]

我高兴地宣布，国际花生高产学术研讨会开幕！首先，我代表中国农业科学院以及我个人对这次研讨会的召开表示热烈地祝贺！对Renard博士、Gowda博士和国际半干旱热带地区作物研究所的其他科学家们，以及来自印度、印度尼西亚、韩国、缅甸、菲律宾、泰国、越南、津巴布韦和来自中国十几个省(市、自治区)的代表们表示热烈地欢迎！对会议的组织者——山东省农业科学院表示衷心地感谢！

中国是主要的花生生产国，花生面积约为3035600公顷，在世界上仅次于印度列第二位，山东省的花生单产和总产在中国列第一位，此次研讨会在山东召开具有重大意义.

中国与国际半干旱热带地区作物研究所的合作始于八十年代初，中国农业科学院与国际半干旱所在1988年签订了合作协议，双方同意合作研究花生、高粱、珍珠粟、鹰嘴豆和木豆。近几年来，在双方的共同努力下，合作研究取得了很大的成绩，从国际半干旱所得到的几千份花生和高粱种质资源丰富了中国的基因库，包括国际半干旱所的材料在内的大量有前途的花生和高粱品种，已经在中国推广，这必将提高中国高粱和花生的产量

迄今已有70多位参加培训和研讨会及进行合作研究的中国科学家访问了国际半干旱所，半干旱所所培养的大量的在花生和高粱方面的青年科学家，现在正在中国的农业研究方面发挥重要作用.

去年，中国农业科学院和国际半干旱热带地区作物研究所签署了新的合作协议，在所有的21个项目中，花生占了11项，这些项目与国家重点项目一起得到了种质和资金方面的支持。将来我们会进一步加强与国际半干旱所的合作，以便为中国和世界农业的研究与生产做出更大的贡献！

祝研讨会圆满成功！祝朋友们在山东过得愉快！

1 中国农业科学院常务副院长，中国，北京白石桥路30号

Keynote Address

C Renard[1]

During July 1994, the Director General of ICRISAT, Dr J G Ryan signed a Work Plan with the Chinese Academy of Agricultural Sciences (CAAS). This signing coincided with a Cereals and Legumes Asia Network (CLAN) Working Group Meeting on Bacterial Wilt of Groundnut that also involved a training course on the disease, and workshop that brought together 39 participants from Australia, China, Indonesia, Malaysia, Thailand, UK, Vietnam, FAO, and ICRISAT. The resulting proceedings contained abstracts in Chinese - the first ICRISAT proceedings to carry that language- made possible through the collaboration of groundnut scientists in China. The training course participants contributed to another ICRISAT first; during their laboratory work they used a draft technical manual, and made comments on its practicality and usefulness. These comments helped ICRISAT scientists to revise and publish it as the first in a new ICRISAT series of technical manuals, designed to pass on practical knowledge of technologies developed at ICRISAT in collaboration with National Agricultural Research Systems (NARS) and mentor institutions.

The proposal to hold a workshop at international level on achieving high groundnut yields to be held in China was made during that time.

When Drs J G Ryan, Y L Nene, and C L L Gowda put forward the idea that other countries in Asia would benefit from the experience of the groundnut production technology practiced in China, it was welcomed, and Shandong Academy of Agricultural Sciences (SAAS), and CAAS agreed to co-sponsor the present workshop.

In March 1995, when Professor Gai Shuren, Director, and Mr Wang Caibin, Assistant Director and Researcher from the Shandong Peanut Research Institute (SPRI) at Laixi visited ICRISAT Asia Center, we discussed and finalized the plans for the present workshop.

Groundnut is a major crop in Asia and is cultivated on 8.5 million ha in India, and 3.0 million ha in China. But the total production in India (7.4 million t in 1993) is slightly less than that in China (8.1 million t). China has been able to achieve average yields of 2.71 t ha^{-1} compared to the 0.9 t ha^{-1} achieved in India.

China's groundnut production is comparable to that obtained in some other countries. Korea, for example, is producing 2.8 t ha^{-1}, more than the average yield of 2.28 t ha^{-1} obtained in the USA.

The area under groundnut in China increased by 50.5% between 1970 and 1983. During that time the production increased by 124.3%, and the average yield by 48.3%. The major factors responsible for that jump include the agricultural reforms that started in the late 1970s, the adoption of improved varieties, changes

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主 题 讲 话

C Renard[1]

1994年7月，国际半干旱热带地区作物研究所所长J G Ryan博士与中国农业科学院签署了合作工作计划。签署计划时恰逢亚洲禾谷类和豆类协作网花生青枯病工作组会议及青枯病培训班开班，39名来自澳大利亚、中国、印度、印度尼西亚、马来西亚、泰国、英国、越南、联合国粮农组织和国际半干旱热带地区作物研究所的人员参加了会议，会议论文集中首次使用了中文摘要，这与中国科学家的合作是分不开的，这也是国际半干旱所首次在研讨会论文集中使用汉语。培训班学员为半干旱所所做的另一项贡献是，他们在实验室工作中应用了一套新的操作技术，并对这一套技术的有效性和可操作性进行了评价，这些评价有助于国际半干旱所的科学家修改现有技术，并在新的半干旱所的系列技术手册中将其发表。

在中国召开一次国际水平的花生高产学术研讨会的建议就是那时提出的。

J G Ryan博士、Y L Nene博士和C L L Gowda博士认为，亚洲其他国家将从中国花生生产实践经验中获益，这一想法得到了普遍的欢迎，山东省农业科学院和中国农业科学院同意协助主办这次研讨会。

1995年3月，山东省花生研究所所长盖树人研究员和王才斌先生访问了国际半干旱所亚洲中心，我们讨论并确定了这次研讨会的具体计划。

花生在亚洲是一种主要的作物，印度栽培面积850万公顷，中国300万公顷，但印度的总产量(1993年740万吨)比中国(810万吨)略少，中国的平均产量达每公顷2.71吨，而印度为0.9吨每公顷。

中国的花生生产水平与韩国等国的水平相当，韩国的平均单产为每公顷2.8吨，比美国的每公顷2.28吨还要高。

从1970年到1983年，中国的花生面积增长了50.5%，这期间产量增长了124.3%，平均产量增长了48.3%。造成这种增长的主要原因是七十年代末期开始的农业改革、采用新品种、一年两作的新种植制度、使用地膜、窄畦栽培、增加种植密度、肥料的合理利用和有效的病虫害防治方法。这些新技术已经推广到农户。山东和江苏的花生产量高于平均水平，在一些地方获得了每公顷11吨的产量。

食品和安全饮用水是人类的首要需要，当我们谈到食品时，我们首先想到的是生产的数量，但质量也是必须的。我要告诉你们的是在亚洲和非洲的许多国家中，人们的膳食中油脂和蛋白质的摄取量不足或低于最低需要量，花生可以提供食品和食用油，这些必须的油脂和蛋白质是解决人口健康问题的一个重要方面。

亚洲和非洲的大多数国家需要增加农业产品和产量，以适应人口发展和(或)国际市场的需要。我们来山东这里学习其花生高产生产技术的第一手资料，也帮助传播山东省和中国其他地区以及亚洲其他国家的有关技术。我们的共同目标是应用可用技术架起潜在的和实际的产量间的桥梁。在许多地方，现有产量水平应该能够提高2－3倍。在大多数农业系

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1 国际半干旱热带地区作物研究所亚洲地区执行所长
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in cropping systems that made it possible to grow two crops in a year, the use of polythene film mulching, narrow bed cultivation, increasing plant density, rational use of fertilizers, and effective control of pests and diseases. These new techniques have been effectively extended to farmers' fields. The yields in Shandong and Jiangsu are well above average, and in some places up to 11 t ha^{-1} are obtained.

Food and safe drinking water are first among the hierarchical needs of human beings. When talking of food, we think first of the quantity produced. But quality is just as essential. I do not have to tell you that lipids and proteins are qualitative elements missing or below the minimum threshold in the diets of people living in many countries in Asia and Africa. In that respect groundnut provides food and edible oil, a major part of these essential lipids and proteins needed for the well-being of the populations in question.

Most countries in Asia and Africa need to increase their agricultural production and productivity to meet the requirements of their growing populations and/or the demands of international markets. We are here to learn at first hand about the high yield groundnut production technology in Shandong, and also to help disseminate this technology, and the technologies from other Asian countries and other parts of China.

Our common objective is to bridge the gap between potential and actual yields with the available technologies. The existing yields can be doubled or tripled in many situations, and a combination of location-specific technologies, timely delivery of appropriate inputs, and better marketing will allow us to tap the untapped reservoir which exists in most farming systems.

We also should look at upgrading the biological potential of wasted land, i.e., rehabilitating degraded land in Asia. We should encourage the introduction of ecologically sound practices in agriculture, because the sustainability of production systems is essential if productivity is to increase in the long term.

We should promote cooperation between scientists, extension staff, and farmers. I am told that the increase in groundnut production here in Shandong is partly attributable to effective cooperation involving several thousand farmers. That close interaction of researcher-extension-farmers needs to be understood by others so that they can follow some of these principles.

We also understand that Chinese scientists have conducted several basic and strategic research studies on the physiology of groundnut without using sophisticated equipment. This is another area where we can learn from them.

During these few days, we will listen to and learn from each other, and at the end we hope to be better able to contribute to the improvement in quality and quantity of food production in the different countries assembled here.

统中，综合利用适合本地的技术、适时适当的投入、好的市场形势，将使我们发挥出前所未有的生产潜力。

我们也应看到提高荒地比如在亚洲复垦瘠薄地的生产潜力，我们鼓励在农业中引入生态实践，因为要使生产力在一个长时期一直提高，生产系统的可持续性是必须的。

我们将鼓励科学家、雇员和生产主之间的合作，我得知山东花生生产的增长部分归功于包括几千农民的有效合作。研究者、推广者和农户之间的紧密联系应被其他地区所理解并加以学习。

我们也知道，中国的科学家在缺少尖端仪器设备的情况下，完成了一些花生生理方面的基本的战略性的研究工作，这是我们可以向他们学习的另一领域。

在这几天里我们将互相学习，会议结束之后，我们希望集中在这里的各国的科学家能为提高本国食品生产的质量和产量更好地工作。

Objectives of the Meeting

C L L Gowda[1]

On behalf of the Cereals and Legumes Asia Network (CLAN), I would like to extend my hearty welcome to all the distinguished guests and participants at this meeting.

I would like to briefly mention CLAN and its role in facilitating collaborative research and technology exchange in Asia. CLAN is a research and technology exchange network formed by Asian scientists. All countries in Asia are invited to become members of the network that is currently active in Bangladesh, China, India, Indonesia, Myanmar, Nepal, Pakistan, The Philippines, Sri Lanka, Thailand, and Vietnam. All scientists and administrators in Asia, and those in regional and international institutions interested in CLAN priority crops (sorghum, pearl millet, chickpea, pigeonpea, and groundnut) are invited to become cooperators. These cooperators participate in collaborative research by agreeing to commit themselves to share their research resources and results.

This is one way of joining hands to tackle common problems; by pooling resources to overcome funding constraints, to reduce costs, and increase the cost-effectiveness of research endeavors. ICRISAT provides the facilities and funding to host the CLAN Coordination Unit. Additional support funding for in-country research, training activities, meetings, etc., comes from such other donors as the Asian Development Bank (ADB), the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP).

As indicated earlier, one of CLAN's major activities is to share and exchange research information and technology. This workshop is one such event.

The idea for organizing the workshop originated almost 14 months ago, when ICRISAT's Deputy Director General Dr Y L Nene visited the Shandong Peanut Research Institute (SPRI). He was impressed by the high yield technology developed and extended by SPRI in Shandong Province. During discussions with Professor Gai Shuren, Director of SPRI, a general plan to organize a meeting at Laixi was formulated to provide an opportunity for scientists from other countries in Asia and Africa to observe the technology used in China, and to exchange information on the high yield technologies used in their countries. I am very glad that we are now assembled here to do this for our mutual benefit.

The specific objectives of the workshop are:

- To review and document available technologies to achieve high groundnut yields,
- To observe the technologies that have been developed and adopted in Shandong Province, and
- To develop plans to achieve high groundnut yields in other countries in Asia and beyond.

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会 议 目 标

C L L Gowda[1]

我代表亚洲禾谷类和豆类协作网，对这次会议的各位来宾和与会者表示热烈地欢迎！

我想首先简要介绍一下亚洲禾谷类和豆类协作网与它在亚洲合作研究和技术交流中的作用．亚洲禾谷类和豆类协作网是由亚洲科学家组成的一个合作研究和技术交流的协作网，所有亚洲国家都被邀请参加该协作网，现有孟加拉国、中国、印度、印度尼西亚、缅甸、尼泊尔、巴基斯坦、菲律宾、斯里兰卡、泰国和越南等成员．所有对该协作网所研究的作物（高粱、珍珠粟、鹰嘴豆、木豆和花生）感兴趣的亚洲和其他地区及国际机构的科学家和管理者都被邀请成为其中的成员，这些成员参加合作研究并共享资源和成果．

这是携手解决共同问题的一条途径，是集中资源克服资金短缺，减少花费和增加研究效率的一种努力．国际半干旱热带地区作物研究所为协作网的合作单位提供设备和资金，对国内研究、培训活动、会议等的另外资助资金来源于象亚洲开发银行、联合国粮农组织、联合国开发计划署等的捐赠．

如前所述，协作网的一个主要活动是分享和交流研究信息和技术．这也是此次研讨会的宗旨．

组织这次研讨会的最初想法产生于14个月以前，当国际半干旱热带地区作物研究所执行所长 Y L Nene 博士访问山东省花生研究所的时候提出来的，他被山东省花生研究所在山东省的高产技术发展和推广深深地打动了，通过与山东省花生研究所所长董树人研究员讨论，形成了一个在莱西组织一次会议的大体计划，这一计划为来自亚洲和非洲的科学家提供了一次实地观摩中国高产技术应用的机会，并且交流他们各自国家高产技术信息．我很高兴我们集中在这里做对我们双方都有益的事情．

这次研讨会的主要目标是：

. 综述花生高产的适用技术．

. 参观山东省花生高产的发展和应用技术．

. 提出亚洲其他国家和其他地区花生高产和发展计划．

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Country Status Reports

Present Situation and Prospects for Groundnut Production in China

Gai Shuren, Wang Caibin, Yu Shanlin, Zhang Jimin, Zuo Xueqing, Wan Shubo, Tao Shouxiang, Wang Chuantang, and Qiu Ruorai[1]

Abstract

Groundnut is a very important oilseed crop in China; production has increased rapidly in recent years. During the first 4 years of the 1990s, the annual average area (3 035 600 ha), yield (2.2 t ha^{-1}), and production (6 761 000 t), have all set records. Domestic consumption of crushed and edible groundnut increases year by year. The main groundnut-producing areas are Shandong, Henan, Guangdong, Hebei, and Guangxi. In China groundnut is grown as a sole or an intercrop in spring, summer, and autumn. The key factors contributing to increased production are an increase in the cropping area as a result of incentives to producers, and the development and application of new achievements in science and technology that have resulted in increased yields. Despite the constraints, groundnut production in China shows great potential for further development.

花生是中国主要的油料作物．近年来中国花生生产发展较快．九十年代前4年年均面积、单产和总产均创历史最高水平，分别达到303.56万公顷 2227公斤/公顷和676.1万吨．榨油和食用花生的国内消费量逐年上升．花生主产区有山东、河南、广东、河北和广西等．主要种植季节和方式有春播、夏播、秋植，单作或套种．关键增产因素，一是生产者积极性提高，面积扩大；二是科技新成果开发应用，单产提高．尽管目前仍存在一些制约因素，但中国花生生产进一步发展的潜力很大．

Introduction

Groundnut has a long history of cultivation in China. According to the records the Chinese people began to cultivate groundnut in 1368 (between the end of the Yuan and the beginning of the Qing dynasties), i.e., about 600 years ago. Groundnut is now one of the main cash and oil crops in China, occupying a very important place in oil crop production.

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Gai Shuren, Wang Caibin, Yu Shanlin, Zhang Jimin, Zuo Xueqing, Wan Shubo, Tao Shouxiang, Wang Chuantang, and **Qiu Ruorui.** 1996. Present situation and prospects for groundnut production in China. (In En. Summary in Ch.) Pages 17-26 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

The area under groundnut in China accounts for about 25% of all oil crops, and its production for about 40% of oil crops. Since 1978, groundnut production in China has developed rapidly. This paper retraces the history of groundnut production in China, especially its development since 1980, and summarizes Chinese experience and lessons, to increase groundnut production in the future.

General Situation

The Course of Development

There were three significant periods in the development of groundnut production in China (Table 1). Since the foundation of the People's Republic of China, the first period was from 1950 to 1959 when the production of groundnut was restored and began to increase; the second period from 1960 to 1979 when production began to decrease and fluctuate; and the third period from 1980 to 1993 when production began to develop rapidly.

Yield and Production

In recent years there has been rapid expansion of cultivated area, and increases in yield and production (Table 2). Table 3 shows that the annual cultivated area, yield, and production from 1990-93 were about 10.9%, 22.2% and 35.5% higher than those of the 1980s and set records in China.

Main Production Regions

Groundnut can be grown in almost all the 28 provinces of China. There are two main regions of groundnut production that differ in their geographic locations,

Table 1. Development periods of groundnut production in China.

Period	Year	Area ('000 ha $year^{-1}$)	Yield (kg ha^{-1})	Production (million t)
Foundation of the P. R. China	1949	1254.4	1020	1.268
Restoration and increase	1950-59	2028.0	1200	2.434
Decrease and fluctuation	1960-79	1724.4	1118	1.928
Rapid development	1980-93	2886.2	2035	5.875

Table 2. Annual cultivated areas, production, and yield of groundnut in China, 1980-89.

Year	Area ('000 ha $year^{-1}$)	Yield (kg ha^{-1})	Production (million t)
1980	2339.1	1537.5	3.600
1981	2472.4	1545.0	3.826
1982	2416.3	1620.0	3.916
1983	2200.9	1792.5	3.951
1984	2421.5	1987.5	4.815
1985	3318.3	2010.0	6.664
1986	3253.5	1815.0	5.882
1987	3022.1	2040.0	6.171
1988	2976.6	1920.0	5.693
1989	2946.1	1820.2	5.363
mean (1980s)	2736.7	1822.7	4.988
mean (1970s)	1821.0	1221.9	2.225
% increase (1980s over 1970s)	50.3	49.2	1.242

Table 3. Annual cultivated area, yield, and production of groundnut in China, 1990-93.

Year	Area ('000 ha $year^{-1}$)	Yield (kg ha^{-1})	Production (million t)
1990	2907.1	2190.7	6.368
1991	2879.9	2190.0	6.303
1992	2975.9	2000.0	5.953
1993	3379.5	2491.5	8.420
Mean (1990-93)	3035.6	2227.2	6.761
Mean (1980s)	2736.7	1822.7	4.988
% Increase (1990-93 over 1980s)	10.9	22.2	35.5

soil types, and farming systems. The boundary between these two regions is the Yangtze River and latitude 30°N that divide the country into the northern and southern region of groundnut production. The northern region accounts for about 65% of the cultivated area and 70% of the total production in the country.

The main provinces of groundnut production in China include Shandong, Henan, Guangdong, Hebei, and Guangxi (Table 4). These five provinces accounted for about 67% of the annual cultivated area and 69% of the total production of the country in the 1980s.

Table 4. Annual cultivated area and production of groundnut in some main provinces of China in the 1980s.

	Area		Production	
Province	'000 ha	% of total	million t	% of total
Shandong	713.7	26.1	1.788	35.8
Henan	290.5	10.6	0.464	9.3
Guangdong	388.1	14.2	0.574	11.5
Hebei	283.6	10.4	0.439	8.8
Guangxi	157.7	5.8	0.182	3.6
Total	1833.6	67.1	3.447	69.0

Climate and Soil Conditions of the Groundnut Production Regions

Climatic conditions and soil types of the groundnut production regions are very diverse. In general, the mean daily temperature, the annual frost-free period, and the annual rainfall in the northern region are 4-17°C, 150-230 days, and 400-1000 mm respectively; and in the southern region 15-24°C, 230-300 days, and 800-2000 mm. The soil types in the northern region are mainly gravelly soil, and alluvial soils on the plain; and in the southern region red loam, yellow soil, alluvial sandy soil, and sandy soil.

Farming systems and cultivation of groundnut

Different farming systems result from various climatic conditions. Table 5 shows that the farming systems in the northern region of groundnut production are very different from those in the southern region. The cropping intensity in the southern region is much higher than in the northern region. The main systems include spring sowing, relay cropping, summer sowing, autumn sowing, and winter sowing.

Table 5. Groundnut cropping systems in the two main regions in China.

Region	Main crop rotation system	Main crops for rotation	Groundnut growing season	Sowing date (for groundnut)
The north	One crop a year	Wheat, maize	Spring sowing	20 Apr to 10 May
	Three crops in two years	Sweet potato, legumes, barley, cotton, etc.	Relay cropping with wheat	10 Apr to 20 May
	Two crops a year	Sweet potato, legumes, barley, cotton, etc.	Summer sowing	10 Jun to 30 Jun
The south	• Irrigated lowlands	Sweet potato	Spring sowing	15 Feb to 10 Jun
	Five crops in two years	Rice, wheat, legumes	Summer sowing	20-30 May to 10 Jun
	Three crops a year	Sugarcane	Autumn sowing	10 Jul to 10 Aug
	• Hilly dry land			
	Three crops in two years	Maize, vegetables	Winter sowing	1 Nov to 10 Nov
	Two crops a year	Rape seed, etc.		

Main Cultivated Varieties of Groundnut

The groundnut varieties used in China are mainly the intermediate type and the Spanish bunch type. In the northern region, mainly intermediate varieties are cultivated. The Spanish bunch type varieties are secondary, and very few of the Virginia type varieties are grown. Main varieties include Haihua No. 1, Baisha 1016, Xujiu 68-4, Hua 37, Luhua No. 9, Hua 17, Xuxi No. 1, Yuhua No. 2 and No. 3, Luhua No. 10, No. 11, etc. In the southern region mainly the Spanish bunch varieties are cultivated, including Yue you 116, Shan you 27 and Yue you 256. Most of the major cultivated varieties in China were bred by research institutes, colleges, and universities. The varieties released by the State or Provincial Varietal Committee(s) were multiplied, then sold to the seed companies and finally to growers.

The Investment in Groundnut Production

Since the benefit from groundnut is much higher than from other crops the growers are willing to spend more money According to the investigation of 219 groundnut-growing families in 13 provinces, including Shandong, Hebei, Guangdong, Fujian, Hubei, and Shanxi in 1991, the results show that the yield averaged 2012 kg ha^{-1}. The total cost per hectare was 1227.2 Yuan (US$ = 144.4). The net profit per hectare was about 1230.75 Yuan (US$ 144.8).

Mechanization Levels

The level of mechanization in groundnut production in China has made significant progress. Mechanization in plowing, harrowing, ridging, intercultivation, digging and harvesting, plucking, and shelling in groundnut production has been introduced. Experimental programs on sowing, polythene film mulching, pesticide spraying, and mechanical seed processing have been successful.

Distinguishing Features of the Development of Groundnut Production in China

Generally, there have been four distinguishing features.

The Co-existence of Lower and Higher Yields

Although the yield of groundnut in China is generally low, there are still many areas of higher yield. The annual average yield from 1950 to 1993 in China was about 1592 kg ha^{-1}, lower than in the United States of America (USA). But there were some exceptions, for instance, in 1972, the yield in some small areas was up to 6000 kg ha^{-1}, 7500 kg ha^{-1} in 1979, 9840 kg ha^{-1} in 1980, and 10 500 kg ha^{-1} in 1982.

In general, the development of groundnut production in China was slow. The annual increasing rate of yields from 1950 to 1993 was about 0.9%, slower than that of USA. From 1980 to 1993 the annual rate of increase in yield and production were up to 4.4% and 8.3% respectively, which were the highest in the world for this period.

The General Level of Science and Technological Innovation in Groundnut Production in China

The level of application of science and technology in a country or a region can be demonstrated if the production of groundnut in that country or region keeps increasing steadily. At present the overall level of science and technology in groundnut production in China is relatively low. However, since 1970 many advanced scientific techniques have resulted in higher yield, where there has been a drive to tackle key problems of production.

The annual yield and production from 1991 to 1994 in Shandong Province, where the annual cultivated area of groundnut is the largest compared with that of other provinces, were up to 3048 kg ha^{-1} and 2.19 million tons. This was 21.7% and 22.3% higher than in the 1980s. These typical cases of high yield in groundnut production have set a very good example for the rapid and healthy development of groundnut production in China since 1980s, based on scientific and technological inputs.

Change of Crop Management Patterns from Labor Intensive to Technology Intensive

Intensive and meticulous farming is one of the traditional features of Chinese agriculture. In the past, groundnut crop management was mostly by manual labor operations. With the development of technology, especially the extension of mechanization, polythene film mulching, chemical weed control, and growth regulators, the science and technology component in groundnut production has greatly increased. Groundnut production has become technologically intensive instead of labor intensive. The grower's operations in groundnut cultivation have been lightened, and the working efficiency and yield increased.

Change in the Factors which have Increased Production

Increase in production, which formerly depended on the enlargement of cultivated area, now depends much more on the introduction of advanced technology to groundnut production. In contrast with that in 1980s, the increased amount of annual production from 1991-1994 was 2.762 million t, of which 37.6% depended on the enlargement of cultivated area, and 62.4% on the increase in yield.

Major Factors of Development of Groundnut Production

The rapid development of groundnut production in China, especially since the 1980s, might be attributed to the following three major factors:

- The growers all over the country have received many benefits from the reforms of the economic system, such as the output-related system of contracted responsibilities. Their initiative in groundnut cultivation in China keeps increasing gradually.
- The state and provincial governments have formulated and carried out certain policies, such as providing rewards to groundnut growers, promoting the purchasing price, and making the market more open.
- The progress of science and technology has been the key for groundnut production studies and the extension of advanced technology relevant to groundnut production.

At present there are more than 20 provincial and 40 prefectural agricultural colleges and research institutes in China which have been concentrating on the study and extension of some aspects of advanced science and technology relevant to varieties, tillage, cultivation, plant protection, etc. Advanced technologies applied and extended in groundnut production include:

- Development and extension of improved groundnut varieties. Since the foundation of the People's Republic of China, more than 200 good varieties have been bred and widely extended throughout the country From 1982 to the present more than 80 varieties have been introduced and used. These cover more than 90% of the total groundnut area in China.
- Efforts to promote improved cultivation systems. Arable land is limited, and as there is competition for cultivated land the cultivation systems of winter wheat/summer groundnut relay cropping in the northern region and rice/rape seed rotation in the southern region have developed. As a result, the national total multiple-cropping area of cereals with oil crops in 1993 accounted for about 40% of the national groundnut cultivation area. The multiple cropping area of wheat with oil crops in Henan Province (about 80% of its groundnut cultivation area) was the largest in the country.
- The application of polythene film mulching technique. The results show that the polythene film mulching technique was most effective in promoting the increase of groundnut yield. Up to 1993 the national total extension area of the technique was about 2.37 million ha.
- Carrying out fundamental development of cultivated land, improving the soil conditions, implementing crop rotation and crop changes, amending the loose top soil layer, increasing soil nutrition, and management of soil moisture and nutrients have all contributed to high yields.
- The extension of high-yield technologies such as increasing the organic manure application, rational close planting, plowing, etc., has been widespread.

The application and extension of these activities have played a very important role in increasing yield and improving quality of groundnut. In recent years, although the development of groundnut production in China has improved, a lot of problems still exist.

- About 70% of the total groundnut cultivation areas are hilly-mountainous, infertile, dry land, or low-lying sandy and saline-alkali land, all of which have a very low capacity to withstand drought or waterlogging.
- The low inputs for groundnut production. For instance, the amount of applied organic manure is very low, application of N P K fertilizer is empirical, and the scope for enlargement of irrigation areas is limited.
- Poor farming practices such as the degeneration and mixture of varieties, continuous monocropping of groundnut, irrational close sowing, and lack of control of diseases and harmful pests at the appropriate time restrict yields and quality.
- The main use of groundnut seeds is still for oil extraction, which is less profitable than for direct use for eating.

Future Prospects

On the basis of the present situation in China it is predicted that by the year 2000, the goal that the national annual cultivated area under groundnut will reach about 3.2 million ha, the yield about 3000 kg ha^{-1}, and the production about 9 to 10 million t could be realized. Although this will be difficult the potential still remains large and the prospect bright. In order to realize the above goal the following principles should be adhered to: stabilizing the cultivation area, increasing the yield, improving the seed quality, and increasing the economic benefit. In addition, scientists should concentrate on the breeding for quality, multiple resistance, and special-purpose varieties, and on the study of the physiology and models of high yield cultivation, and on processing techniques for groundnut products. They should continue to carry out the extension, purification and rejuvenation of groundnut varieties, and advise on improved cultivation systems. As long as the above strategies are carried out with determination the expected goal in groundnut production in China should be fully accomplished, and the advantage of increased yield in groundnut production in China would be turned into economic advantage.

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The Status of Technologies used to Achieve High Groundnut Yields in India

M S Basu and P K Ghosh[1]

Abstract

Groundnut is the premier oilseed crop of India; it holds a 35% share of the total oilseed area (24 million ha) and contributes nearly 40% of the total oilseeds production (20 million t). The low level of productivity in India is largely because the crop is rainfed, exposed to various biotic and abiotic stresses, and to the socioeconomic factors associated with small and marginal farmers in dryland areas.

Concerted research efforts have been made to alleviate the constraints by emphasizing the development of high-yielding varieties with multiple resistances to foliar diseases and pests, and resistance to drought; breeding for earliness; introducing efficient *Rhizobiwn* strains; and developing economically viable production and protection technologies with an emphasis on IPM. The use of these technologies can result in yield advantages of 50-63%. Present research priorities are confined to the development of a crop production technology for rice-based cropping systems with special reference to acid soils; aflatoxin management; on-farm research; and defined postharvest technologies. The encouragement of groundnut growers' cooperatives in new niches and nontraditional areas will ensure adequate price support and marketing that will contribute to achieving high yields and crop sustainability

花生是印度最主要油料作物，占全部油料作物面积(2400 万公顷）的 35%，而总产约占油料作物总产量(2000 万吨）的 40%。印度花生生产水平较低的主要原因是对雨水浇灌的依赖、各种生物与非生物因子的限制，以及与生活在干旱边远地区农民有关的社会经济因素。

为了克服上述因子对花生生产的制约，重点从以下几个方面进行了研究：培育抗叶部病虫害、抗旱的高产品种；培育早熟品种；引进有效的根瘤菌(*Rhizobium*) 菌株；开发以 IPM 系统为重点的经济可行的生产与植保技术。这些技术的应用可以使花生产量增加 50%－63%。当前的研究重点是：在酸性土壤中推广以水稻做前茬的作物生产技术；黄曲霉毒素的防除；大田研究；及某些收获后技术的研究。鼓励种植者与花生新产区和非传统产区合作能够确保花生有良好的价格和广阔的市场，而这对花生的高产、稳产至关重要。

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Introduction

India is favorably endowed with diverse agroclimates that permit a wide array of crops to be grown. The oilseeds groundnut, rapeseed and mustard, sunflower, sesame, safflower, niger, linseed, castor and soybean are grown in about 24.0 million ha, a total area second only to cereals. Among the oilseed crops, groundnut, and rapeseed and mustard account for 87 % of the total production. Currently groundnut is sown on an area of about 8.4 million ha and production is 7.8 million tonnes, making India the world's largest producer. Unlike rapeseed and mustard, the majority of the groundnut area (7.0 m ha) is rainfed and drought takes a heavy toll. There are also considerable yield losses resulting from a plethora of diseases and pests. Consequently, productivity of groundnut in dryland farming situations is low (927 kg ha^{-1}). In contrast, the productivity of groundnut in postrainy season is almost double (1567 kg ha^{-1}) and the crop is grown under irrigated/assured residual soil moisture conditions with fewer problems from diseases and pests.

About 91% of the total groundnut area and production occur in the states of Andhra Pradesh (2.39 m ha, 2.21 m t), Gujarat (1.91 m ha, 1.24 m t), Karnataka (1.24 m ha, 1.03 m t), Tamil Nadu (1.09 m ha, 1.49 m t), Maharashtra (0.76 m ha, 0.81 m t), and Orissa (0.32 m ha, 0.43 m t). The remaining area is scattered through other states.

In India, groundnut is grown on a variety of soils including red sandy loam, alluvial, mixed red and black, and medium black soils with the most suitable soils being well drained, loose, sandy loam soils well supplied with calcium and moderate amounts of organic matter. The pH in Indian soil ranges from 4.0 to 9.0 but a pH of 6.0-7.5 appears to be ideal when considering nutrient availability.

Eighty-three percent of the total groundnut area throughout the country produces a rainy season crop grown during the south-west monsoon period (Jun-Sep). Groundnut in the postrainy season is cultivated in the remaining 17% of the area utilizing (1) residual moisture (Nov-Mar); (2) spring season irrigation; and (3) summer season irrigation (Feb-May). Groundnut grown under residual moisture conditions is confined to southern and south-eastern regions and is grown mostly in rice fallows during Oct-Mar. Summer and spring season irrigated groundnut grown during Jan-May are confined to the central and northern states, namely Gujarat, Maharashtra, Uttar Pradesh, Madhya Pradesh and Punjab.

Major Constraints Limiting Groundnut Productivity

A number of biotic, and abiotic factors limit the productivity in different production systems. During the rainy season drought stress at various phenophases, the use of low levels of inputs by smallholders and marginal farmers in dryland areas, and the high incidence of foliar fungal diseases (rust and leaf spots), peanut bud necrosis disease, attack by white grub (north India) and insect pests *(Spodoptera, Helicoverpa,* leaf miner) may all restrict productivity.

Postrainy season productivity may be limited by poor plant stands resulting from loss of seed viability, lack of fresh seed dormancy in bunch varieties, lack of early-maturing varieties for the residual moisture situations, poor soil tilth in rice fallows, lack of cold-tolerant varieties, and nutrient deficiencies in acid soils.

The estimated losses of yield resulting from these factors either singly or in combination, have been found to vary from 10-70% depending upon severity.

Concerted efforts were made to evolve superior genotypes with inbuilt resistance/tolerance to biotic and abiotic stresses and to develop economically viable production and protection technologies.

To alleviate the constraints, major emphasis was given to:

- Breeding for resistance to biotic stresses (rust, leaf spots, *Alternaria,* leaf miner, *Helicoverpa, Spodoptera)* and abiotic stresses (drought, cold, acid soils).
- Incorporation of earliness and peg strength in Virginia runner groundnut.
- Development of varieties for rainfed acid soils in general and upland paddy fallows in particular, with special reference to earliness and fresh seed dormancy.
- Development of bold-seeded varieties with less aflatoxin risk.
- Development of efficient *Bradyrhizobium* strains for improving biological nitrogen fixation.
- Integrated pest management (IPM).
- Undertaking 'on-farm' demonstrations of the proven technologies.

Description of Different Production Systems

The contribution of different technologies in increasing groundnut productivity in India are summarized in Table 1 and described below.

Table 1. Contribution of different production technologies developed in India.

Technology	% Yield increase	References
Improved variety	30.0	Reddy and Basu (1989)
Paired-row sowing	28.5	Devidayal and Reddy (1987)
Broadbed-and-furrow	15.3	ICRISAT (1993)
Criss-cross sowing	18.0	Devidayal et al. (1994)
Wheat straw mulch	23.0	Devidayal et al. (1992)
Pre-monsoon sowing	20.0	NRCG (1989-90)
Protective irrigation	33.0-63.0	Basu and Reddy (1989)
Bradyrhizobium	6.0-18.0	Joshi et al. (1989)
Gypsum application	24.0	NRCG (1992-93)
Integrated Pest Management	43.0	NRCG (1991-92)

Improved Variety

Since inception of the All India Coordinated Research Project on Oilseeds in 1967 as many as 90 groundnut varieties have been released in different habit groups for general cultivation. Many of them are season/location-specific varieties released for different agroclimatic zones.

Prior to 1980, breeding efforts were directed mainly towards improving the yield per se. With the identification of resistance sources to major diseases and insect pests, resistance breeding received a strong stimulus resulting in identification of tolerant varieties. Important characteristic features of the recently released improved groundnut varieties in India are given in Table 2.

In traditional groundnut-growing areas farmers with fairly large holdings usually keep their own seed and replace this seed at an interval of 3-4 years. In nontraditional areas where groundnut is grown only during the postrainy season, farmers procure fresh seed every year as storage between seasons causes a rapid loss of seed viability.

In India, groundnut breeders are assigned a target of producing 600 - 700 t of breeder seed of improved varieties annually and those seeds are put into the Foundation and Certified Seed production chain by the seed-producing agencies in both public and private sectors. The certified seeds once produced, are processed and marketed at state level by the respective seed producing agency

Sowing Time

Rainy season crop. The optimum sowing time ranges from the second fortnight of Jun to the first fortnight of Jul, depending upon the onset of monsoon. Pre-monsoon sowing with 1 or 2 irrigation(s) was found to be beneficial and increased pod yield by 16-20%.

Postrainy season. Since low temperature (<18°C) affects the germination process in groundnut, sowing is usually done from the second fortnight of Jan when the temperature starts rising. In residual moisture areas (rice-based/river bed) sowing is done during Sep-Oct, immediately after the harvest of rice/ receding of river water. In northern states, groundnut is usually grown after the harvest of Toria (rape seed - *Brassica campestris* L. var *Sarson)* or potato, and in such cases the crop is sown during March.

Method of Sowing

Groundnut is usually sown in flat beds with spacings of 30 x 10 cm for bunch, 30 x 15 cm for semispreading, and 45 x 15 cm for spreading varieties. Seed rate also varies from 100-120 kg kernel ha^{-1} in case of bunch varieties and 90-100 kg kernel ha^{-1} for spreading/semispreading varieties. Generally, groundnut farmers use country seed-drills for sowing the seed. For large scale sowing, tractor mounted seed drills are used in major groundnut-growing areas. Seeds are usually placed at a depth of 2.5 - 5 cm.

Table 2. Characteristics of recently released groundnut varieties in India.

Name of variety	Habit group	Year of release	Pod yield (kg ha^{-1})	Shelling (%)	Salient features
Somnath	Virginia runner	1990	1900	72.3	High yielding, early maturing, bold seeded, HPS grade for rainy season.
ICGS 1	Spanish bunch	1990	2300	70.0	Variety suitable for both rainy and spring season.
ICG (FDRS) 10	Spanish bunch	1990	2200	67.0	Suitable for rainy season, tolerant to rust, LLS diseases and BND problem.
VRI 3	Spanish bunch	1990	1668	75.0	Pods and seed are small. Pods have slight to moderate constriction with little or no beak. Highly suitable for situation of delayed south-west monsoon.
ICGS 37	Spanish bunch	1990	3000	70.0	Sequential flowering.
RSHY 1	Spanish bunch	1991	2480	73.0	Suitable for post-monsoon residual moisture conditions.
TAG 24	Spanish bunch	1991	1683	70.0	Early, with 2-3 seeded pods, tolerant to BND, leaf spot, jassid, and caterpillar.
Tirupati 2	Spanish bunch	1991	2100(R)[1] 3500(PR)	77.0	Suitable for both seasons, possesses high peg strength and tolerant to Kalahasthi malady.
ICGV 86590	Spanish bunch	1991	1785	62.0	Multiple disease and insect pest resistance.
CSMG 84-1	Virginia runner	1992	2704	64.0	Tolerant to thrips, termites, pod borer, and foliar diseases.

Continued....

Table 2. *Continued....*

Name of variety	Habit group	Year of release	Pod yield (kg ha^{-1})	Shelling (%)	Salient features
ICGS 5	Virginia bunch	1992	2385	68.0	1-2 seeded, tolerant to drought.
BAU 13	Virginia bunch	1993	2191	63.0	Bold seeded HPS for export trade.
TKG 19A	Virginia bunch	1993	2260	63.0	Bold and attractive kernels, seed qualifies for HPS grade.
B95	Virginia bunch	1993	3345	68.0	Suitable for summer cultivation, extra bold seeded, HPS grade.
K 134	Spanish bunch	1993	1677	71.0	Early maturing, high yielding with tolerance to leaf spot and drought.
ICGV 86325	Virginia bunch	1994	2700	70.0	High yielding under rainfed conditions, tolerant to BND.
GG 3	Spanish bunch	1994	1283	68.7	Early maturity, green foliage at harvest stage.
DRG 17	Virginia bunch	1994	2100	68.0	Suitable for rainy season, tolerant to moisture stress.
DRG 12	Spanish bunch	1994	2604	69.0	Suitable for postrainy season, tolerant to foliar disease and BND.
TG 26 (Identified)	Spanish bunch	1995	1596(R) 2425(PR)	65.0	Earliness and fresh seed dormancy.

1. R = Rainy PR = Postrainy.

Paired row sowing. Sowing of groundnut in set-furrow and wider-row spacing (90 cm apart) is a common practice amongst farmers in the Saurashtra region of Gujarat. Set-furrow farmers are now switching over to the paired row method of sowing which increases pod yield by 28%. In this method two pairs of rows are spaced at 45 cm apart. Within the paired row seeds are sown more widely spaced (22.5 cm). This keeps the plant population evenly distributed. Since the same quantity of seed used for one single row spaced 90 cm apart is distributed in a pair of rows, there is no increase in the seed rate. Rather inter-plant competition for light, moisture, and nutrients is reduced to a great extent resulting in higher pod yield.

Criss-cross sowing. Change in direction of sowing has been found to increase yield in groundnut by 18% as compared to normal sowing in the postrainy season. Minimization of inter-plant competition due to uniform distribution of seed in the criss-cross method might be responsible for yield improvement. In the criss-cross method, the first half of the seed is sown in one direction adopting recommended row-to-row spacing, and then the remaining half is sown at 90° to the orignal direction by adopting the same row spacing. This practice is followed in rice-based cropping systems to avoid low plant stands due to poor soil tilth.

Broadbed-and-furrow method. This method of sowing, developed by ICRISAT, has been found more beneficial than traditional flat bed in both rainy and postrainy seasons. On average, 15% higher yield has been recorded for the broadbed method of sowing. The yield increase may be attributed to the reduction in soil compaction around the pod zone, better conservation of moisture, and a uniform plant stand.

Mulching

In the postrainy season, low temperature (<18°C) at the time of sowing affects germination whereas high temperature affects pod development at a later stage. Use of wheat straw at 5 t ha^{-1} applied uniformly on the surface after sowing of groundnut minimized the temperature fluctuation during the crop growth and resulted in higher pod yield. Wheat straw mulch not only raised soil temperature by 2-3°C at emergence and early vegetative stages, but also lowered the soil temperature by 3-5°C during the pod development stage.

Recent study has also revealed that the use of polythene mulch raised soil temperature by 5-6°C resulting in quicker germination (5-6 days after seeding as compared to 10-12 days with wheat straw). In control plots the entire germination process took about 2-3 weeks. This mulch technology is very useful in the north-eastern areas where low temperature during the postrainy season interferes with germination of groundnut seed.

Fertilizer Use

The NPK fertilizer doses recommended for the major groundnut-growing states in India are 15-20 kg N, 17.5-26.2 kg P and 0-37.4 kg K ha^{-1}. However, it differs from region to region and growing situations. Single superphosphate (SSP) and ammonium sulphate are the preferred fertilizers for groundnut crops. Half the nitrogen and a full dose of phosphorus is applied at the time of sowing and the remaining half of N at 25-30 DAS. Since Indian soils are generally rich in K, unless the soil has less than 150 kg ha^{-1} of available K, there is no need to apply K. Gypsum is able to provide Ca and S, and is known to increase pod yield. The response of gypsum and Ca application to groundnut was quadratic. Application of 750 kg gypsum ha^{-1} increased pod yield by 24% over the control. Since there is little residual effect of gypsum it is necessary to repeat the application every season. As Ca and S are relatively immobile in plant tissue, and are not translocated in sufficient quantities from the root to developing pods, application is, therefore, made as close to the pod zone as possible.

A majority of the rice fallows where groundnut is grown are acidic. Application of lime at 1.5-2 t ha^{-1} is beneficial since it improves the base saturation, inactivates Al, Fe and Mn present in excess, and reduces P fixation. In the absence of lime, a mixture of SSP and rock phosphate at 60-80 kg ha^{-1} (1:1) is applied.

Weed Management

During the rainy season groundnut must compete with several weed species since the annual grasses and seasonal broad-leaf weeds grow luxuriantly and dominate during this season as compared to the postrainy season. Spanish bunch types are more affected than Virginia types. The average loss of yield owing to crop-weed competition is about 25-50%. Weed competition in the early stages of groundnut growth is maximum because of slow initial foliage growth. However, competition is relatively low at the end of the expansion phenophase when complete ground cover is attained by the groundnut canopy The critical period for weed competition was found to be 45 DAS. The first hand weeding or harrowing in groundnut is usually done at 25 days and repeated once or twice depending upon the weed vigor. Beyond 45 DAS no weeding is done to avoid damage to the growing pegs and developing pods. The recommended herbicides for groundnut in India are alachlor at 1.0 -1.5 kg a.i. ha^{-1}; butachlor at 0.5 kg a.i. ha^{-1}; pendimethalin at 1.0 kg a.i. ha^{-1}, and fluchloralin at 0.7 kg a.i. ha^{-1}. Since a mechanical or cultural method alone does not ensure weed-free conditions, the use of herbicide in combination with a cultural method is advocated.

Micronutrients

Groundnut is highly susceptible to Fe deficiency. Iron chlorosis in groundnut has been reported from all the major groundnut-growing areas especially in calcareous soil having free carbonate and bicarbonate. Foliar application of 0.5% $FeSO_4$ + 0.1% citric acid has been found to correct the yellowing. Genotypes tolerant to Fe chlorosis have been identified. Among the released varieties, GG 2 is tolerant to iron chlorosis. Zinc deficiency is also widespread in most areas. Application of 15-25 kg $ZnSO_4$ to the soil once in 3 years is a recommended practice to overcome the deficiency. Soils of Tamil Nadu, Maharashtra, and Uttar Pradesh have been found to be deficient in boron. About 5-10 kg borax ha^{-1} is applied to soil at the time of final land preparation to correct the deficiency.

Biofertilizer

The population of native *Bradyrhizobium* in rice-fallows is usually low due to anaerobic conditions created while retaining water in the field during rice cultivation. Two improved strains, namely IGR 6 and IGR 40, developed for rice fallows, increased pod yield of groundnut by 150 - 170 kg ha'[1]. Unlike other strains, IGR 6 and IGR 40 were found tolerant of commonly used seed-treating fungicides like Bavistin® and thiram. These two strains are now available to farmers at nominal cost through a wide manufacturing network.

Groundnut-based Cropping Systems

Sequential crops. This refers to growing more than one crop in succession on the same piece of land in a year. Groundnut is usually rotated with wheat and pulses in northern states, and with sorghum and sunflower in southern states. Groundnut-groundnut rotation is practiced where irrigation facilities are available. In multiple cropping systems, rice-groundnut-green gram, rice-groundnut-rice, rice-groundnut-pearl millet rotations are followed. In groundnut-pearl millet rotations the preceding groundnut crop increased the yield of pearl millet by 22.8%. In central parts of India, groundnut-cotton, groundnut-sorghum and groundnut-pigeonpea sequences are practiced. In the eastern region mustard yield (1.3 t ha^{-1}) was more after groundnut than after rice or maize. In recent years a rice-groundnut sequence has gained momentum in the coastal belt of Andhra Pradesh, Tamil Nadu, Kerala, Orissa, West Bengal, Assam and north-eastern states, and has been found to be more remunerative. Short duration, high-yielding varieties of rice like Banaprava (85 days), Kalinga (85 days), and Ananda (105 days) are being introduced in rice-groundnut rotations to facilitate early sowing of groundnut and optimize soil moisture utilization.

Intercropping. In this system 3-10 lines of groundnut are intercropped with 1-5 lines of companion crops. Results of some promising intercroppings practiced in different parts of the country revealed that the intercropping system was more remunerative than sole crops giving a higher net monetary return. Details of the recommended intercroppings are given in Table 3.

Water Management

A groundnut crop requires on an average 400-500 mm of water. In India, rainy season groundnut is subjected to the vagaries of the monsoon. Water stress at flowering, pegging, and pod development stages diminishes yield drastically.

Table 3. Different intercropping systems in India.

Intercropping	Ratio	Yield advantage (%)	Net return $(Rs.\ ha^{-1})$[1]	LER2
Groundnut+sunflower	6:1 or 2	50-80	10120-12615	1.58-1.85
Groundnut+pigeonpea	6 or 5:1	36-67	14909-22333	1.53
Groundnut+castor	6:1	.3	9671-10141	1.19-1.20
Groundnut+pearl millet	1:1	26	-	1.26
Groundnut+sorghum	8:2	38-57	3221-3200	-
Groundnut+sesame	2:1	72	8391-12292	
Groundnut+rice (upland)	1:2	12	2145	1.38
Groundnut+tapioca	Dibbled in ridges	55	-	-
Sole groundnut		-	8350	-

1. 1 US$ = Rs.30/-
2. LER = Land Equivalent ratio.
3. Data not available.

Provision of protective irrigation during critical stages increases pod yield to the extent of 33-63%.

Whereas, in the postrainy season frequent irrigations (12-20) are required for realizing high pod yield, withholding irrigation after the establishment of seedling to flower initiation (30-50 days) and then releasing water stress through flood irrigation has resulted in synchronous flowering and ultimately higher yields. The best and cheaper method of irrigation is border strip but farmers find check-basin irrigation more convenient to use.

Plant Protection

Insect pests. Groundnut crops are attacked by a number of insect pests from sowing to storage. The economically important groundnut insect pests are leaf miner, jassids, red hairy caterpillar and tobacco caterpillar in southern parts of India, whereas, jassids, aphids, thrips, leaf miner, and tobacco caterpillar are important in central and western India. In sandy soils of northern India white grub is the most important pest. The main emphasis in the past has been on chemical control. Some chemicals like monocrotophos (0.05%) for control of aphids, jassids and thrips, carbaryl (0.2%) for red hairy caterpillar and leaf miner, quinolphos (0.05%) for tobacco caterpillar, are advocated. Efforts have been made to combine cultural practices and host-plant resistance to develop integrated pest management (IPM) systems. Some of the widely used IPM technologies are: shielding the groundnut crop within 1-2 rows of castor and pearl millet; growing 1 row of soybean per 4 rows of groundnut as a trap crop; keeping 10 pheromone traps ha^{-1} for leaf miner and 8 traps for *Spodoptera;* and using three sprays of insecticide mixture (crude neem oil + phosphamidon + endosulfan) at 15-day intervals.

In recent years, genotypes have been screened for resistance to thrips, jassids, leaf miner, *Spodoptera* and aphids. Breeders are incorporating these resistances into high-yielding, commercially-acceptable cultivars.

Diseases. Early leaf spot (ELS), late leaf spot (LLS), alternaria leaf spot, rust, and bud necrosis disease (BND) are the economically important foliar diseases of groundnut in India. Also, seed and soilborne diseases like collar rot, stem rot, and dry root rot are considered to be the major limitations. These diseases are capable of causing cumulative yield losses of up to 70%. Chemicals used for control of foliar diseases are a mixture of Bavistin® (0.05%) + Dithane-M 45® (0.2%) sprayed at 2-3 week intervals. The chemical control of foliar diseases of groundnut is effective but expensive. As an alternative, early sowing and intercropping with pigeonpea and castor is advocated to reduce the severity of LLS and rust. The early and late leaf spots are reduced by 33-63% when groundnut is intercropped with pigeonpea and sprayed twice at 55 and 70 DAS with fungicide mixture (Carbendazim® 0.05% + Mancozeb® 0.2%).

Bud necrosis is a virus disease transmitted by thrips. Chemical control of the vector is not always effective. Cultural methods such as timely sowing, closer spacing, and intercropping with cereals help in reducing the disease incidence in the field.

Breeding for resistance to diseases has received more attention in India. Significant progress has been made in developing cultivars resistant to rust, late leaf spot and bud necrosis diseases. Some of the foliar disease-resistant varieties developed and released are Girnar 1, ICG (FDRS) 10, ICGV 86590, and R 8806.

Harvest, Drying, and Storage

The crop is harvested manually by small and marginal farmers. In the case of large holdings tractor or bullock-drawn diggers are used. At the time of harvesting, groundnut pods usually have a moisture content around 40% at physiological maturity. Therefore, proper drying is necessary to bring the moisture level to <10%. Generally small farmers strip off the pods soon after harvest and carry home the produce for drying. Where holdings are large, plants are kept in the field or in small heaps for sun drying before stripping off pods with mechanical threshers. Farmers usually dispose of their groundnut pods within 3 - 4 weeks after harvest, although rich farmers store the pods for 3 - 4 months in the hope of favorable market prices.

Rapid loss of seed viability is a perpetual problem in postrainy season groundnut. Farmers are not able to carry over seed from one postrainy season to another unless the following low cost technology is implemented.

- Delay harvest as much as possible after giving the last irrigation to bring down the pod moisture to a desirable level.

- Harvest the crop at physiological maturity.
- Allow slow drying of plants in the shade with their pods intact.
- The pod should give a rattling sound at the time of stripping.
- Bring down the pod moisture to the level of 8-9% by regular drying.
- When the pods are thoroughly dried, they may be stored in polythene-lined gunny bags along with calcium chloride at 250 g for a 30 kg bag. The calcium chloride should be placed in a wide-mouthed plastic bottle with pores in its upper portion.

This method keeps up to 80% of seed viable for a period of 8-10 months. This technology has solved the farmers' problem in the areas where groundnut is only grown in rice-fallows during the postrainy season.

Aflatoxin

Aflatoxin production on groundnut caused by the *Aspergillus flavus* group of fungi takes place mainly during post-harvest processing and storage. In India 81% of the kernels are immediately crushed for oil and so aflatoxin is not a problem in the domestic market. However, aflatoxin is a concern in exportable commodities, i.e., kernel, oilseed cake, etc. Recently bold- to medium-bold-seeded genotypes resistant to invasion, colonization and production of aflatoxin by *A. flavus* have been identified for export purposes.

Utilization and Marketing

In India, about 81% of the groundnut produced is used in oil extraction, 12% as seed, 6% for edible use and 1% for export. A well-organized marketing system for groundnut exists in India. Groundnut is marketed mostly as nuts in shell and very little as kernel. The period of marketing is mainly Nov-Dec when about 70-80% of the marketable surplus is sold in the market directly by farmers. The vegetable oil wing of the National Dairy Development Board (NDDB) was authorized by the Government of India to undertake the Market Intervention Operation (MIO) to ensure a fair price to producers and a fair deal to consumers. The MIO brought about price stabilization in edible oils with a reasonable degree of success.

NDDB has also developed processing facilities throughout the country for crushing, solvent extraction, and refining of oil by cooperatives.

Oil Yield and Quality

For better oil yield and quality, the runner varieties should be harvested between 140-145 days, and the Virginia bunch between 130-135 days after sowing.

Machinery

In India, machines available for shelling, threshing, and digging are popular with groundnut farmers. Equipment like planters which can maintain plant-to-plant spacing within a row, wet threshers, and graders are in demand. The groundnut planter developed by Tamil Nadu Agricultural University, Coimbatore, is reported to be ideally suited for sowing groundnut in sandy loam soils and can regulate spacing both between rows and between plants within the row.

Mission Mode Approach

With the launching of the Technology Mission on Oilseeds in 1986 there has been a quantum jump in the production of oilseeds from 13 million t (1985) to 20.4 million t (1993) and consequently it has been possible to make the country self-reliant in edible oil This has resulted from the integrated and mutually synergistic policies and measures initiated by the Mission like (1) declaration of minimum support prices for oilseeds with assured market support and an intervention mechanism; (2) availability of easy credit and other farmers' support services; (3) development of location-specific production/protection technologies and their transfer; (4) building up of buffer stock of oil for effective market intervention to prevent steep price fluctuations.

The challenge, however, is to keep the demand-supply gap at a minimum level considering the present population growth. By the turn of the century, the country is required to produce about 26 million t of oilseeds from almost the same area since the possibilities for area expansion are limited. Thus, there is no option but to work towards increasing the productivity level of the oilseed crops. The National Research Centre for Groundnut, Junagadh and the All India Coordinated Research Project on Groundnut, through its 24 research stations scattered throughout the country, are providing strong research support for developing technologies to make the crop more productive, predictive, and remunerative in harsh environments.

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The Status of Technologies used to Achieve High Groundnut Yields in Indonesia

Nasir Saleh and T Adisarwanto[1]

Abstract

In Indonesia the national production of groundnut is around 652 000 t, produced from approximately 650 000 ha with an average yield of 1.04 t ha^{-1}. Most groundnut (66%) is produced under rainfed conditions with the remainder grown on irrigated wetland. The cropping system varies among locations and sowing seasons. On dryland or on rainfed wetland, groundnut is generally sown in mixed cropping with maize or cassava, while on wetland, during the dry season, it is generally sole cropped. The present groundnut productivity of around 1 t dry pods ha^{-1} is considered low. Using improved technology consisting of good quality seeds, adequate land preparation (plowing followed by harrowing), appropriate fertilizers (50 kg urea + 75 kg triple superphosphate + 50 kg muriate of potash ha^{-1}), two sprays of Topsin-M® at 7 and 9 weeks after sowing, and the insecticide monocrotophos at 65 days, yields of 1.8 t ha^{-1} dry pods can be obtained by farmers in dryland situations. Similar yields also can be obtained from irrigated wetland using improved technology including seed bedding, seed treatment, appropriate fertilizers, and crop protection. The improved technology for each production system has been developed through on-farm research and disseminated among farmers by means of demonstration plots covering large areas. These on-farm research and development activities have involved cooperative efforts of farmers, extension agents, local governments, and scientists.

印度尼西亚全国花生产量约为65.2万吨，面积约为65万公顷．大部分(66%)花生种植在雨养条件下，其余的是可灌溉的水浇地．在干旱和雨养地区，花生通常与玉米、木薯等混播，而在水浇地上旱季一般是单植． 按目前的水平，每公顷1吨的产量是较低的．
但在旱地上采用选用良种、精耕细做、增 施肥料(每公顷施尿素50公斤，过磷酸钙75公斤，氯化钾50公斤)、播后7−9周喷2次 Topsin−M及播后65天施用杀虫剂久效磷等技术可以使花生产量达到1.8吨/公顷．在水 浇条件下运用苗床种植、种子处理、合理施肥和加强植保等措施后也可达到类似的产量水 平．每种生产系统的改良技术都已通过田间研究及大区示范而在农民中推广开来． 种植 者、推广部门、当地政府和科学家们都为这些技术的田间研究和推广应用做出了贡献．

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Saleh, Nasir and Adisarwanto, T. 1996. The status of technologies used to achieve high groundnut yields in Indonesia. (In En. Summary in Ch.) Pages 41-49 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Introduction

Groundnut is the second most important grain legume in Indonesia, used almost entirely for human consumption. As the national production of groundnut has not increased dramatically during the last decade (528 000 t in 1985 to 624 128 t in 1992), Indonesia has to import around 50 000 t groundnut annually to meet increasing demands for confectionery and snack food uses. In spite of the significant economic importance of groundnut to Indonesian farmers, the government has not included this crop in national intensification programs. Therefore, the national average yield of groundnut is still low, around 1000 kg ha^{-1}, although in some areas where improved technology is used farmers can obtain yields of 1500-2000 kg ha^{-1} dry pods.

Groundnut Production Systems in Indonesia

Groundnut is mostly grown in dryland areas (66 %) and only 34% is grown on wetlands under a variety of production systems (Table 1) (Sumarno and Manwan 1990).

Production System on Rainfed Dryland

Tuban and Lamongan districts are representative of dryland groundnut production systems. The dominant soil type is Red Mediterranean (calcareous, red sandy loam) and the annual rainfall 1500-1900 mm. Groundnut is sown as a mixed crop or intercrop with maize or cassava. As the groundnut crop depends entirely on rainfall, low productivity is often the result of drought. On dryland, groundnut is grown during the early rainy season (Nov/Dec or Feb/Mar) or during the late rainy season (Apr/May - Jun/Jul) as shown in Figure 1. Thereafter, rainfall is insufficient and the land normally remains fallow until the rains begin again in October.

The first growing season involves high risk because of the unreliable rainfall and the first season's crop is mainly used for seed production for the Feb/Mar sowing. The second crop of groundnut in the dryland also suffers from drought sometimes. Crop rotation on dryland follows the sequence of:

Groundnut/cassava/maize - maize/cassava
Groundnut/cassava/maize - groundnut/cassava
Upland rice/cassava/maize - groundnut/cassava

Land preparation is usually done during the dry season when there is no crop in the field. For the late rainy-season crop, only minimum tillage is done before sowing. In most cases, land preparation is inadequate to provide the optimal environment for seed germination. Sometimes land cannot be prepared in time due to the presence of cassava intercrop.

Table 1. Main environments and production systems of groundnut in Indonesia.

	Irrigated wetland[1]	Rainfed wetland[2]	Rainfed dryland[3]	Newly-opened land[4]
Percent of total groundnut area	34%	5%	50%	11%
Average yield (t ha^{-1})	1.3	1.2	1.0	0.8
Yield potential (t ha^{-1})	3.0	2.5	3.0	2.5
Crop stand	Monocrop	Monocrop	Sole crop and intercrop	Sole crop and intercrop
Regions	East Java: Kediri, Pasuruan, Blitar Central Java: Jepara Yogyakarta West Java: Subang, Majalengka South Sulawesi: Soppeng, Barru	Tuban, Blitar Wonogiri Sukabumi	Tuban, Bojo- negoro, Blitar Wonogiri Sukoharjo Kebumen Bantul Garut, Serang	N.Lampung S.Sumatra Jambi
Cropping patterns	R-R-G R-G-M or F SU-G	G-R	G-M or S UR-G G-G	G-M UR- G,M,C

1. Two seasons: early dry season, April to June; late dry season, July to October.
2. One season: early rainy season, November to January.
3. Two Seasons: early rainy season, November to January; late rainy season, February to May.
4. Transmigration areas.
R-Rice, G-Groundnut, M-Maize, F-Fallow, C-Cassava, SU-Sugarcane, UR = Upland rice, S-Soybean.

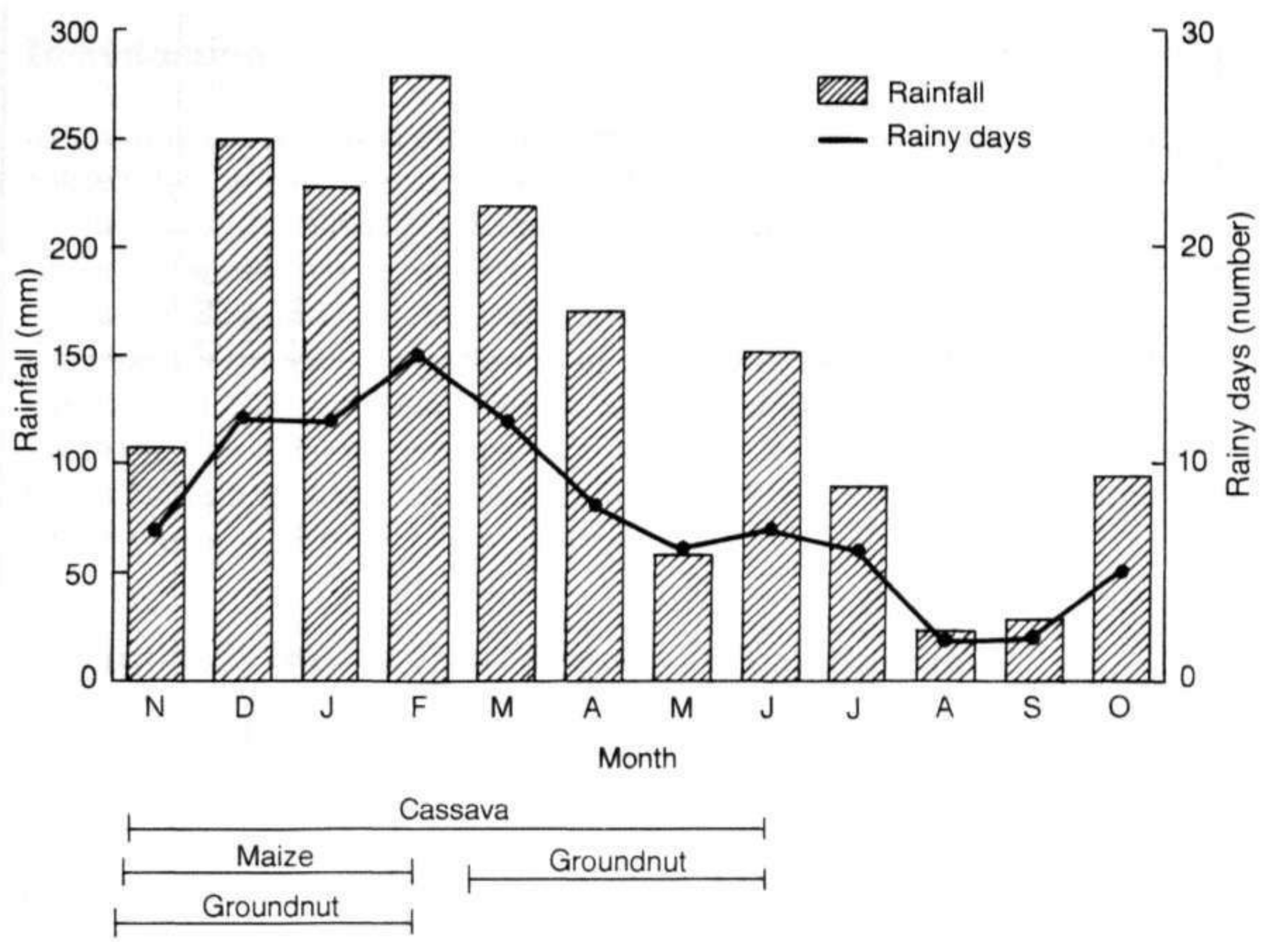

Figure 1. Rainfall, rainy days, and groundnut cropping system on dryland of Tuban, East Java, Indonesia.

Land preparation is carried out using an animal-drawn plow followed by harrowing to obtain a loose tilth suitable for sowing. Soil tillage is usually shallow, <15 cm deep, resulting in serious soil compaction. Groundnut seed is dropped behind the plow and then covered with soil. This method is faster than hand sowing but the position of the seeds in the rows is irregular, and some seeds are buried too deep or are stepped on by the draught animal. This method requires a rate of around 100-120 kg seed ha^{1} of small-seeded varieties. In most cases poor soil physical characteristics and low fertility contribute to low groundnut yields.

Farmers mostly use small-seeded and early-maturing local varieties as they are easy to sell. They can be harvested after 85 - 90 days. Farmers either produce their own seeds or buy them from the local market, or from other farmers. Occasionally seed merchants provide seed, but at present, there are no commercial seed growers. Therefore, seed supply relies on farmer-to-farmer transfer/exchange systems.

The main factors constraining higher productivity are nutrient deficiencies, drought during the reproductive stage, leaf spot and rust diseases, and jassids, thrips and aphids infestations (Saleh et al. 1993a, Harsono et al. 1994).

Use of improved technology can result in yields of 1.5 - 2.0 t ha^{-1} dry pods on farmers' fields in Tuban and Lamongan districts (Table 2). The technology was

Table 2. Improved groundnut technology for rainfed dryland.

Component		Tuban and Lamongan districts
Variety	-	Local Tuban/local Lamongan
Seed	-	Good quality (over 90 % seed germination rate)
Land preparation	-	Plowing followed by harrowing
Seeding rate	-	80 kg seed ha^{-1}
Fertilizers[1]	-	50 kg urea + 75 kg TSP + 50 kg KCl ha^{-1} (Tuban), 25 kg urea + 25 kg TSP + 25 kg KC1 ha^{-1} (Lamongan)
Planting	-	Seed dropped behind the plow track
Cultivation	-	Hand hoe weeding and hilling up at 3 and 6 weeks
Protection	-	Fungicide Topsin-M® at 7 and 9 weeks after sowing Insecticide Furadan® 10 kg ha^{-1} prior to sowing Insecticide monocrotophos at 8 and 10 weeks after sowing
Harvest	-	Hand digging and pulling at 105 days after sowing

1. TSP = triple super phosphate, KC1 = potassium chloride.

developed through on-farm research consisting of component and package technology testing of the AGLOR.

On flat land, drainage canals every 3 - 4 m are recommended. For the second groundnut crop, it is sometimes necessary to use the insecticide Furadan®, at the rate of 10 kg ha^{-1}, prior to sowing to control termites. It is also recommended that maize stubble be removed from fields as this promotes termite infestation.

Fertilizers are broadcast evenly prior to sowing. Hand hoe weeding and hilling are done at 3 and 6 weeks after sowing. The fungicide Topsin-M®, at the rate of 0.5 kg ha^{-1}, is applied 7 - 9 weeks after sowing to control groundnut leaf spots and rust diseases. The insecticide monocrotophos, at 2 L ha^{-1}, is used to control jassids, thrips and leaf-feeding insects.

Pods are removed from plants after harvest and sun dried. Drying of fresh pods takes approximately six to seven days to reach a moisture level of around 20 - 25%. Due to soil compaction some pods are left in the soil.

Production System on Rainfed Wetland

Groundnut is rarely sown on rainfed wetland due to shortness of the growing season prior to sowing of the main crop, rice. Furthermore, the sowing season on rainfed wetland coincides with the sowing season on rainfed dryland, where most of the groundnut is produced. This often creates a shortage of seed for sowing groundnut on rainfed wetland. Blitar represents a groundnut production system on rainfed wetland.

Production System on Irrigated Wetland

Groundnut is sown on wetland after the first or second rice crop, or after sugarcane during the early or late dry season. Crop rotations involving groundnut in wetland follow the sequence of:

rice - rice - groundnut

rice - groundnut - maize or fallow

sugarcane - groundnut

Subang district (West Java) and West Lombok represent the groundnut production system on irrigated wetland. At Subang, average rainfall for the district is 2700 mm, with most rain falling during Nov - Apr. Most of the food crops are cultivated with reliable irrigation through a canal system from Jatiluhur dam. Groundnut on wetland is grown on light-structured soil such as alluvial, Regosol, Andosol and red Latosol (Arsyad et al. 1995). In West Lombok, the dominant soil type is Regosol. The average rainfall is around 2500 mm, also distributed from Nov until Apr and about 60% of the agriculture area is well irrigated.

Both in Subang and West Lombok, the first rice crop is grown during Nov/Dec to Feb/Mar, and the second rice crop from Mar/Apr to Jun/Jul. Secondary crops, mainly groundnut, are grown from July to Sep/Oct (Figure 2).

The main constraints to production include poor drainage and soil compaction, drought stress for crops sown in the late dry season, and diseases (leaf spots, rust, and peanut stripe virus).

Table 3 lists the improved technology introduced at Subang (West Java) and West Lombok.

Most of the farmers at Subang and West Lombok use a local variety because of the unavailability of improved varieties. The local variety in these areas is very similar to Gajah or Schwarz-21, an improved variety released in the 1950s, which can be harvested in 90 - 100 days. Farmers in West Lombok obtain groundnut seeds from other farmers who specialize in seed production.

In Subang land preparation is usually carried out using an animal-drawn plow. However, in light-structured soil, West Lombok farmers often plant groundnut on unfilled wetland. They just cut the rice straw and groundnut is planted using a dibbling stick. In West Lombok, seed is dibbled by using a dibbling stick, covered by soil and rice straw (51 ha^{-1}) and then the rice straw burned. Both at Subang and West Lombok, plant spacing is 40 cm x 10 cm, with 1 plant $hill^{-1}$. Groundnut on wetland during the dry season requires four to six irrigations to obtain sufficient vegetative growth and to produce high yield. Irrigation is sometimes needed prior to harvesting to ease pulling of the plants and to minimize pod retention in soil.

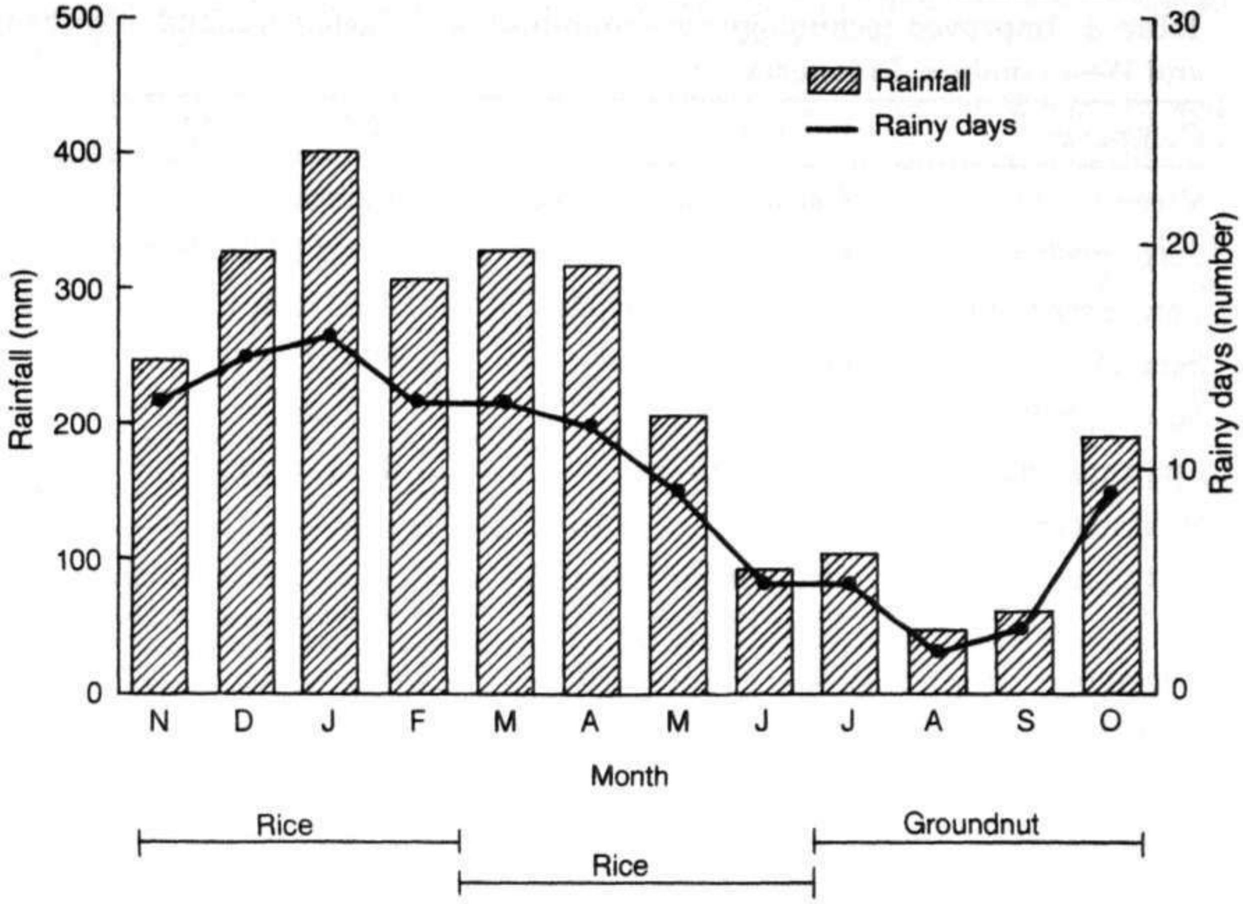

Figure 2. Rainfall, rainy days, and groundnut cropping system on irrigated wetland of Subang, East Java, Indonesia.

Production System on Newly-opened Land

In transmigration areas in North Lampung, South Sumatra, and Jambi, groundnut seems more tolerant of acid soil than soybean, although its yield is relatively low. Main constraints to productivity on these newly-opened areas are low soil fertility, low soil pH, poor organic matter content and disease infestation. Yields are usually low, varying from 0.6 - 1.0 t ha^{-1}

Marketing System

Groundnut is a cash crop in Tuban and Lamongan districts. Usually all the groundnut produced is sold at harvest or within one month after harvest (20%). Sometimes, due to the pressing need for cash, some farmers sell their standing crops (25%). Basically, there are three nodes for groundnut marketing; namely, farmer (producer), collector buyer, and district collector/processor. Although farmers seem to have access to direct marketing, the price is entirely dictated by collectors. The system is worsened by the practice of traders giving advance payment to farmers when the crop is sown. Village cooperatives have not been functioning in providing credit or in assisting farmers with groundnut marketing.

Table 3. Improved technology for groundnut on irrigated wetland at Subang and West Lombok, Indonesia.

Component	Subang[1]	West Lombok[2]
Variety	Gajah, Kelinci or local	Kelinci or local
Seed quality	Good	Good (>90% germination)
Land preparation	Plowing, harrowing	Zero tillage
Seed rate	80 kg ha^{-1}	80 kg ha^{-1}
Sowing method	Dibbling	Dibbling
Plant spacing	40 cm x 10 cm	40 cm x 10 cm
Seed treatment	Captan	None
Fertilizers	25 kg urea + 50 kg TSP 50 kg KC1 ha^{-1}	25 kg urea + 25 kg TSP + 25 kg KC1 ha^{-1}
Mulching	None	5 t ha^{-1}
Hand weeding	Twice	Twice
Irrigation	6 times	3-4 times
Crop protection	Fungicide 2 sprays Insecticide as needed	Fungicide 2 sprays Insecticide as needed
Pod yield	Gajah 2.2 t ha^{-1} Kelinci 2.75 t ha^{-1} Local 1.9 t ha^{-1}	Kelinci 2.5 t ha^{-1} Local 1.8 t ha^{-1}

1. Arsyad et al. 1995.
2. Saleh et al. 1993b.

Dissemination of Technology

Dissemination of improved technology was conducted through developmental research which evaluates the performance of innovations in large areas on an economic scale and involves farmers, extension agents, and local government. By communicating with the traders and cooperatives, it aims to verify the economic feasibility of the technology adoption by farmers. Developmental research is designed as a bridge between research and development, and accommodates linkages between researchers, agricultural services/extension, local government and farmers. It functions as a pilot project for technology recommendations.

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The Status of Technologies Used to Achieve High Groundnut Yields in Korea

Chang Hwan Park[1]

Abstract

Groundnut is both a useful food legume and an oilseed crop. It has been cultivated in Korea since before 1845. Groundnut cultivated area was 10 200 hectares and production in Korea was about 17 000 t in 1993.

The newly-developed varieties and improved cultural practices have increased kernel yields fourfold in the 30 years since scientific research programs began in Korea. Groundnut cultivation area showed a continuous increase from about 2000 ha in the 1960s to 10 200 ha in 1993.

Groundnut is mainly eaten in Korea as roasted preparations (54%) and components of bread and confectionery (40%). The annual per capita consumption has shown a continuously increasing trend from 0.36 kg in 1981 to 0.85 kg in 1994.

A groundnut breeding program was initiated at the Crop Experiment Station in the 1960s, and a hybridization breeding program began in 1969. This resulted in release of Seoduntangkong in 1978. A new 'Shinpung' plant type variety developed from the cross between Virginia and Spanish types in 1982 has few branches and bears flowers and fruits mainly on the first branch. It has high yield potential, and is an ideal erect plant type.

A polythene (PE) film mulching technique was developed in the 1970s to accelerate initial growth, flowering, and fruit setting, and to extend the growing period. The technique resulted in a 'White Revolution' in groundnut production, when grain yield in Korea quadrupled. For the national average productivity, the grain yield was only 410 kg ha^{-1} in 1960s, but is now 1900 kg ha^{-1}, and the best groundnut growers produced 4000 kg ha^{-1} in 1991 by using polythene film mulching, and sowing high-yielding cultivars.

花生既是一种豆科粮食作物又是一种油料作物，在韩国的栽培历史可追朔到 1845 年之前。1993 年韩国的花生种植面积为 10200 公顷，产量 17000 吨。

实施科学研究计划 30 年来培育了新的品种、改进了栽培技术，使韩国的花生产量提高了 3 倍。60 年代到 1993 年间花生面积持续增加，由 2000 公顷增加到 10200 公顷。

在韩国，花生主要用于烤制食品(54%) 和作面包、糖果的原料(40%)。1981－1994 年，

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More than 50% of the groundnuts produced in Korea are eaten as roasted nuts, and about 40% used in baking such confections as sweets, snack crackers, and cookies. Large-seeded groundnuts are preferred for roasting, and they fetch a higher market price than small-seeded groundnuts.

In Korea, groundnut is usually cultivated in the sandy soil on river banks that suffer flooding during the monsoon season, and also from drought. Irrigation is not available for upland crops, with the exception of some high-income cash crops. In recent years, the groundnut area has increased in newly opened upland fields in the hilly areas of the southern region. Because of its long growth duration groundnut is intercropped and/or mixed cropped.

Continuous cropping of groundnut reduces pod yield. Other limiting factors to groundnut cultivation are low temperatures during the sowing (Lee et al. 1984c) and maturing stages, and heavy rainfall at the pegging stage. Thus, in Korea the polythene film mulching technique has been widely used to overcome low temperatures, water deficit, and weeds.

Groundnut Breeding in Korea

Breeding Goals

Major emphasis has been placed on the development of cultivars that yield well, are adapted to mechanized cultivation, and have good flavor and desirable characteristics for roasting and confectionery. Breeding for tolerance of, and resistance to, abiotic and biotic stresses has also received attention. The incorporation of early and late leaf spot and web blotch resistance into adapted cultivars has become a goal of the Korean groundnut breeding program.

Groundnut Cultivars Developed in Korea

Groundnut hybridization was started in the 1960s at the Crop Experiment Station. The breeding goal at that time was to select high-yielding pure lines with large seeds for the roasted groundnut trade. From 1969 to date, 14 varieties have been developed from the hybridization program, of which eight are of the Virginia type with large or extra-large seeds. The rest are small-seeded. The first large-seeded varieties, Seoduntangkong and Yeonghotangkong, developed by hybridization are used for roasting, and are adapted to the southern region.

The first small-seeded variety, Oltangkong, was developed for confectionery use. In attempts to develop an ideal erect plant type with few secondary branches that is adapted to the climate of Korea, Shinpungtangkong (Lee et al. 1983b), Seadltangkong, and Daekwangtangkong were developed from crosses between Virginia and Spanish types in the early 1980s. These varieties are of a promising plant type, they produce large seeds, and are early-maturing with wide adaptability (Ree 1974) (Table 2).

Table 3. Agronomic characteristics of Shinpung, Spanish, and Virginia type groundnuts.

Characters	Shinpung	Spanish	Virginia
Plant growth habit	Bunch	Bunch	Runner/Bunch
Flowering time	Early	Early	Late
Branches	Few	Few	Many
Branching pattern	n+l/n+2	n+l/n+2	n+l/n+2/n+3
Flowering habit	Irregular	Sequential	Alternate
Maturity	Early	Early	Late
Kernel size	Large	Small	Small to Large

Development of Shinpung Plant Type

To overcome the unfavorable climate and cultural environments for groundnut in Korea, a new plant type was developed from a cross between Ped 393-6-3-2-2-3-1-2 introduced from USA and Florigiant x Chibahandachi in 1982 (Park et al. 1991). This new Shinpung plant type has very desirable agronomic characteristics similar to those of Spanish types as shown in Table 3. Shinpung flowers earlier than Virginia types, and its reproductive nodes are borne successively on the first branches, resulting in very few secondary branches. It has larger kernels than Spanish varieties. Maturity is similar to that of Spanish, but earlier than Virginia types. Shinpung differs from other plant types not only in the number of days it takes to flower but also in flowering pattern and number. The maximum flowering occurs in mid-July, and is more effective than that of Spanish and Valencia types. Therefore, there is little late flowering and flowering ends much sooner than in Spanish and Valencia types. Shinpung matures very early and produces more pods than any other type. On Shinpung plants 43% of the pods were mature by 18 August while only 14 to 38% of the pods were mature on other types by that time.

Development of Propagation Technique

The vegetative cutting system for groundnut seed propagation developed at the National Crop Experiment Station is a highly efficient way of accelerating seed propagation at low cost. The method can also be used for groundnut breeding and seed multiplication (Lee et al. 1983a). This method involves treatment with naphthalene acetic acid (NAA) which is more effective than indole acetic acid (IAA) for rooting cuttings (Table 4). Soaking cuttings in 100-200 $\mu g\ g^{-1}$ NAA solution effectively induced rooting. Stem cuttings taken from the upper part of the plant were better than those from the lower part which is too hard to cut

Table 4. Effect of NAA concentration on rooting and root dry mass of groundnut cuttings.

		NAA concentration (μg g^{-1})				
	Control	50[1]	100[1]	200[1]	400[1]	1000[2]
Rooting ratio (%)[3]	34	98	100	100	98	87
Root dry mass (mg $plant^{-1}$)	19.0	26.4	31.5	27.2	25.9	21.5

1. Soaking for 24 h in NAA solution. 2- Dipping for 5 seconds. 3. More than 6 roots.

easily. Cuttings from young plants were more healthy than those from old plants, and rooted effectively and rapidly. Yeonghotangkong, a Virginia type with many branches, produced more cuttings than Shinpungtangkong that has fewer branches (Park et al. 1986a). In total 698 seeds were harvested from all the cuttings and the stock plant, 22 times more seeds than were produced by direct seeding.

Production Approaches, Cultural Practices, and Plant Protection

Polythene (PE) Film Mulching Technique

To increase productivity, seeds must be sown as early as possible in order to accelerate growth and maturity in the warm temperatures of Korean summers. Varieties also need to germinate well, and to have assimilative ability with vigorous seedling growth and flowering. Small-seeded Spanish or Valencia varieties could be useful in developing varieties that germinate well under low temperatures. PE film mulching results in consistently higher yields because under it crops grow fast and vigorously in the short frost-free growth period on the Korean peninsula (Lee et al. 1979, Kang et al. 1982).

Emergence in mulched plots was 11-15 days earlier than in nonmulched plots, when sown on 10 April, and 4-5 days earlier when sown on 1 May Young seedling growth was accelerated by a factor of two to six, and flowering was 17-18 days earlier in mulched plots sown on 10 April than in those sown on 1 May (Lee et al. 1984a). There were almost twice as many pods per plant in the mulched plots as in the nonmulched plots. Shelling percentage was 3-4% higher, and kernel mass was 4-5 g heavier in the mulched plots. Mulching increased the kernel yields dramatically because it increased soil temperature, and prevented soil moisture evaporation (Table 5).

The national average groundnut yields increased dramatically as the mulched area increased/The technique has been adopted by farmers in the northern part of Korea so that they can sow earlier than before, and can improve the temperature, moisture, nutrition, and physical conditions of their soils.

Mechanization

While mulching increased groundnut productivity, it increased the labor requirement needed to spread the mulch and remove it at harvest time. Cutting production costs by using labor-saving mechanization, and new higher-yielding varieties and cultural methods adapted to mechanization are major goals in growing groundnuts in Korea. The most labor-intensive practices are sowing and harvesting. Agronomists and engineers are working together on these problems. A four-row 'groundnut seeder' powered by tractor has been devised and tested in nonmulched conditions. Mechanical groundnut harvesters are being developed.

Fertilizer Application

Standard fertilizer application levels for nonmulched crops were 30 kg N ha^{-1}, 30.6 kg P ha^{-1}, and 83 kg K ha^{-1} with 50% of the nitrogen and potassium fertilizers applied as top dressing. However, 30 N, 61.2 P and 83 K kg ha^{-1} as basal application is reasonable when mulch is used (Shin et al. 1985). The increased application of phosphate to mulched crops resulted in vigorous plants with more pods. A compound fertilizer was developed not only for the farmer's convenience in applying fertilizers but also to add 3% of Mg, and 0.5% of B_2O_3 to the fertilizer, once the positive effects of these minor elements on higher-quality groundnuts were recognized in Korea. The effects of calcium applied as lime not only neutralized soil acidity, but also was essential for shell and kernel formation, and growth (Son et al. 1972). Empty pods, abnormal kernel growth, and poor germination rates occurred when the soil was deficient in calcium.

Weed Control

Troublesome weeds in groundnut cultivation were almost similar to those that affect other upland crops (Ryang et al. 1984). The most efficient preemergence herbicide used in Korea on groundnuts was Alachlor® 43.7% EC (3 L ha^{-1}) that caused little injury to groundnut plant growth, and gave excellent weed control. The preemergence herbicides, Pendimethalin® and Ethalfluralin® and postemergence compound herbicide Fluazifopbutyl® were also selected as effective chemicals for weed control in groundnut. Suitable dosage rates were 20 kg ha^{-1} of Pendimethalin® 5% granules, 3 L ha^{-1} Ethalfluralin® 35% EC, and 1 L ha^{-1} of Fluazifopbutyl® 35% EC.

Pest and Disease Control

Diseases and pests of groundnuts are generally considered of local importance in Korea. Major pests and diseases include white grubs and such foliar diseases as early leaf spot *(Cercospora arachidicola),* late leaf spot *(Phaeoisariopsis personata)* and web blotch *(Didymella arachidicola).* Early leaf spot appears from early to mid-July and spreads rather more slowly than other diseases, but web blotch and late leaf spot occurring from mid-July to early August spread rapidly and seriously

Table 5. Acceleration of initial growth of groundnut plants by film mulching.

Sowing date	Cultural technique	13 June			20 August			
		Fresh wt. (F) (g pl^{-1})	Dry wt. (D) (g pl^{-1})	(D/F) (%)	Stem length (cm)	Fresh wt. (F) (g pl^{-1})	Dry wt. (D) (g pl^{-1})	(D/F) (%)
April 10	Mulch	63.8	12.9	20.2	33	442	99	22.4
	Nonmulch	33.4	6.5	19.5	24	299	66	22.1
May 1	Mulch	14.5	2.9	20.0	35	405	91	22.5
	Nonmulch	12.5	2.3	18.4	27	256	55	21.4

Table 6. Effects of soil conditioners on agronomic characters and yield of groundnuts in continuously cropped fields.

Soil conditioner	Stem length (cm)	Branches $hill^{-1}$	Pods $hill^{-1}$	Shelling percentage (%)	100 kernel mass (g)	Leaf spot (%)	Kernel yield (kg ha^{-1})
Control	68.5	20.5	21.9	70.7	74.0	3.8	2200
Deep tillage (De)	72.0	21.9	22.7	71.7	75.5	3.1	2270
Compost (Co)	71.2	21.0	22.9	68.3	74.4	3.5	2220
Magnesium lime (Mg)	75.0	23.8	24.9	70.5	77.6	2.8	2430
Gypsum	72.4	24.9	24.3	68.1	74.8	2.8	2230
Silicate	74.6	25.3	22.9	68.1	78.2	3.0	2280
(De)+(Co)+(Mg)	75.6	26.3	25.4	73.6	79.8	1.7	2550

damage groundnut plants, causing defoliation (Park 1988). The spread of web blotch disease increased as cultivated area shinpung types expanded. Effective chemicals for controlling these diseases are Thiopanatemethyl® 70% WP 1000X, Benomyl® 50% WP 1000X, Chlorothalonil® 75% WP 600X, and the time to spray is two or three times in the early stages of growth, or just before disease symptoms are seen in the field. The white grubs that attack groundnut are Coleopteran larvae, nine species of which are known to damage groundnut pods and roots. *Anomala corpulenta, Holotrichia morosa,* and *A. rufocuprea* appear from early June to mid September and attack mainly from late June to late July. *H. diomphalia* occurs in late April and attacks from mid-May to late June. Effective insecticides for white grub control are Terbo® 3% G., Dyfonate® 5% G., Ethop® 5% G., optimally applied at 60 kg ha^{-1}, during the flowering and fruiting stages.

Cropping System

Continuous cropping of groundnuts has been practiced because of the small and restricted favorable growing area for groundnut. This intensive cultivation results in serious damage to groundnut production due to adverse changes in soil properties and environmental conditions accompanied by abiotic and biotic stresses. To improve soil characteristics and fertility, deep tillage with the application of magnesium, lime, and silicate are advocated (Table 6). Sulfur application is. also helpful in preventing yield reduction in groundnuts grown on the sandy soils of river banks.

Cultivation on Reclaimed Land

Groundnuts are well adapted to loam and sandy loam soils - the main groundnut producing regions are along the banks of four big rivers in South Korea (Chung et al. 1989, Kang et al. 1991). These areas have been continuously cropped for over 10 years, and yields are falling because of diseases and microbiological changes in the soil (Choi et al. 1988). To overcome this situation, newly reclaimed land has been used to grow groundnuts. The crops grew well and produced better yields than those on continuously cropped land, when fertilizers were applied at the optimum rates shown in Table 7. Higher rates of phosphorus, potassium, and nitrogen are needed on reclaimed land than on traditionally cultivated land.

Korean Groundnut Research Strategy

Varietal Improvement

Major breeding goals for groundnuts in Korea are for high stable yields, adaptability to mechanized cultivation, and high seed quality For stable yields, early maturity, tolerance to lodging, and disease resistance are important agronomic characteristics. Plant that grow erect are preferable for mechanized cultivation because their podding zone is narrower than that of runner or

Table 7. Fertilizer application levels suitable for groundnuts grown on newly reclaimed land.

N-P-K (kg ha^{-1})	Pods per plant	Matured pods (%)	Shelling pods (%)	Kernel yield (kg ha^{-1})
30-30.6-83	48	85.6	70.7	1950
40-131-160	53	88.1	74.1	2460

semirunner types. High grade, uniform seeds are important in marketing, shelling, and food-processing systems (Lee et al. 1989).

Shinpung types could be used in breeding for yield improvement. This plant type is suited to monsoon-type temperate zones like Korea, and its large seed and uniformity are preferred by consumers.

Shinpung's high yield potential, disease resistance, and yield stability across adverse environments will be accelerated by incorporating genes for resistance to foliar diseases, tolerance to lodging, and short strong stems. At present Shinpung cultivars do not have resistance to the main diseases that occur in Korea. Some of the wild *Arachis* species are resistant to foliar diseases and to insects, and possess other useful genes. The technique of introducing genes from wild species into cultivated varieties has been adopted in Korea. Lodging tolerance could be improved by introducing genes for hard stem from Valencia types, together with dwarf genes, because Valencia types generally have tall stems.

It is difficult to develop early-maturing cultivars with large seeds because the characters are negatively correlated. Subspecies hybrids between early-maturing Spanish, and large-seeded Virginia types have been attempted in order to develop lines with 150-day growth duration. Extra-early-maturing groundnuts tend to be small-seeded, less vigorous in top growth, and low in yield potential due to their short vegetative growth duration. Genotypes adapted to dense sowing could produce higher yields from this type of groundnut.

Extra-large-seeded groundnuts are preferred for roasted salted groundnuts. The genetic sources of extra-large seed are found in Virginia types that produce vigorous vegetative growth and lodge. Extra-large-seeded Virginia types of late-maturing varieties have been developed, and early-maturing extra-large-seeded Shinpung lines have been selected from crosses between them and Shinpung types.

To improve seed quality, the breeding target was to improve the fatty and amino acid composition of seed. Variations in oil and protein contents in desirable breeding materials were evaluated and selections made for quality. Seed size was negatively correlated with oil content, but positively correlated with protein content. The major unsaturated oleic and linoleic fatty acids, that significantly affect nutritional value and oil quality, are negatively correlated.

Germplasm

About 2100 germplasm lines have been collected and stored in the gene bank of the Rural Development Administration. Most of this germplasm has been evaluated for agronomic traits, and some of it for chemical properties. Germplasm collection (including wild *Arachis* species) and evaluation for breeding is carried out in collaboration with breeders and gene bank botanists.

Improvement of Cultural Practices for Mechanization

Film-mulching cultivation techniques are intensively practiced and have dramatically increased yields. However, mulching hinders mechanized sowing and harvesting, and results in high labor input and costs. It is important to develop production techniques that save labor and time in groundnut. The development of suitable machines for groundnut cultivation that do not reduce yields is the most urgent task to be solved in Korea.

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Groundnut Production Technologies in Myanmar

Hla Shwe[1]

Abstract

The total area of groundnut in Myanmar in 1993/94 was 467 449 ha. Total production was 432 261 t and the national average yield was 886 kg ha^{-1}. Groundnut is mostly grown in the dry zone where annual rainfall ranges from 500 mm to 1270 mm. In the rainy season farmyard manure of 4 t ha^{-1} is applied together with fertilizers at rates of 12 kg N ha^{-1} and 19.7 kg P ha^{-1}. Gypsum is also applied at 350 kg ha^{-1}. Spanish type monsoon groundnut fresh seeds yielded 1850 kg ha^{-1}. Winter groundnut after rice gave a yield of 1403 kg ha^{-1} and irrigated groundnut yielded 3800 kg ha^{-1}.

1993－1994年度缅甸的花生总面积为467449公顷，总产量为432261吨，全国平均单产886公斤/公顷。缅甸的花生主要种植在年降雨量在500－1270mm的旱带地位。在雨季每公顷土地施4吨农家肥及12公斤氮肥、19.7公斤磷肥和350公斤石膏。季风季节西班型花生鲜籽仁产量为1850公斤/公顷，稻茬冬花生的产量为1403公斤/公顷，灌溉田的花生产量为3800公斤/公顷。

Introduction

The total harvested area of groundnut in Myanmar in 1993/94 was 466 472 ha with an annual average production of 431280 t and national average yield of 924.6 kg ha^{-1} (Table 1). The main area of groundnut cultivation is the central dry zone where annual rainfall ranges from 500 mm -1270 mm. Irrigation is used near river banks and irrigation dams and underground water from tube wells is an additional but limited irrigation source.

Groundnut is cultivated on various types of soil and in different growing seasons. Those soils along the riverbanks are loamy, while some upland soils are sandy, and others loamy. The soils where groundnut is sown following rice are light loams. The lengths of growing seasons vary according to the type of groundnut and the time of sowing. The rainy season Virginia type is sown in May

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Table 1. Yearwise production, area, and dry pod yields of groundnut in Myanmar[1].

Year	Production ('000 t)	Area harvested ('000 ha)	Yield (t ha^{-1})
1975-76	411.4	661.4	0.62
1976-77	423.6	570.9	0.74
1977-78	464.8	563.5	0.82
1978-79	390.9	522.6	0.75
1979-80	342.8	455.9	0.75
1980-81	482.5	489.8	0.89
1981-82	573.9	555.5	1.03
1982-83	551.1	540.4	1.02
1983-84	532.3	522.9	1.01
1984-85	667.4	620.3	1.07
1985-86	561.0	548.9	1.02
1986-87	544.7	522.7	1.04
1987-88	520.5	505.4	1.03
1988-89	438.9	515.2	0.85
1989-90	459.0	524.0	0.87
1990-91	472.7	529.4	0.89
1991-92	370.9	468.4	0.79
1992-93	433.3	484.7	0.89
1993-94	431.3	466.4	0.92

1. Myanmar Agriculture Statistics of Myanmar Agriculture Service for 1993-94.

and June and harvested in November and December. The early rainy season Spanish type is sown in May and June and harvested in September and October. The winter Spanish type groundnut is sown in November and December and harvested in March and April.

The cropping pattern normally practiced is early rainy season Spanish groundnut followed by late sesame or pulses. Near the riverbanks, premonsoon irrigated sesame is followed by winter Spanish groundnut. Normally most of the riverbank areas are flooded for a few months during the rainy season. The usual rotation practice is to sow Virginia groundnuts in the first year and early sesame followed by pulses or sorghum in the second year. Winter groundnut and maize are grown mixed on some riverbanks.

Rainfed Groundnut Production Technologies

Rainfed groundnut is of two types, Spanish and Virginia. Some Spanish improved varieties are Sp. 121-070, Magwe-10, Magwe-11, Magwe-12, Magwe-15, Sinpadetha-2, and Sinpadetha-5. Their duration is about 110420 days. An improved Virginia variety is Kyaunggon. Sp. 121-070 is a selection from a Spanish variety. Magwe-10 is a cross between Sp. 121-070 and S.S. 50/05 possessing a high shelling percentage of about 76%. Magwe-11 and Magwe-12 are selections from exotic varieties. Magwe-15 is also a cross between Spanish and Virginia types that has partial seed dormancy (14 days) at harvest time. Important characteristics of the varieties are shown in Table 2.

Seed Production

Breeder seed is produced at the Central Agricultural Research Institute and foundation and registered seeds are produced on Central Seed Farms. Certified seeds are produced in registered growers' fields.

Farmers prefer to use fresh seed so, for rainy season sowing, farmers like seed harvested in March to plant in April. Upland rainfed Spanish crop growers directly exchange their seed with that of riverbank growers of the same region. Therefore, there are no seed storage problems. Seed is distributed by extension workers of the Myanmar Agriculture Service to farmers who need it. As the seed-to-seed ratio is very narrow in groundnut, seed multiplication and distribution rates are very low.

Farmyard manure at the rate of 4 t ha^{-1} is applied at the time of land preparation in March and April. Plowing is usually with a 3-disc plow and harrowing with a 16-disc harrow. During the last week of April triple superphosphate at the rate of 19.7 kg P ha^{-1} is applied and incorporated into the soil. Urea fertilizer at the rate of 12 kg N ha^{-1} is applied only at the time of sowing i.e., in May and June, if there is enough monsoon rain. Three hundred and fifty kg ha^{-1} of gypsum is applied at sowing time. Although it is recommended to apply gypsum 30 days after sowing, farmers have difficulty in applying gypsum in between rows and therefore it is applied at sowing time.

To achieve high yields early sowing is essential so land preparation must be finished before the onset of the monsoon. Sowing in the first week of May gave yields of 1850 kg ha^{-1} using fresh seed (from winter riverbank groundnut) whereas old seed (seed from the previous year's rainy season crop) sown at the same time gave yields of 1700 kg ha^{-1}. Sowing in the second week of May using fresh seed yielded 1600 kg ha^{-1} and old seed sown in the same period yielded 1385 kg ha^{-1}. Sowing in the first week of June using fresh seed resulted in yields of 750 kg ha^{-1}, whereas sowing at the same time using old seed resulted in yields of 650 kg ha^{-1}.

Even on the same day, the yield from seed sown in the morning was higher than from that sown in the afternoon i.e., morning sowing produced a yield of

Table 2. Varietal characteristics of groundnut cultivars of Myanmar.

Cultivar Characters	Sinpadetha -2	Sinpadetha -3	Sinpadetha -4	Magwe -9	Magwe -10	Magwe -11	Magwe -12	Magwe -15
Original variety	J L 24	Robut 33-1	F 3241	Sp. 121-070	Sp. 121-070 × S.S. 50/05	Schwartz	Taiwan 9	UPL-PN-2 × Kyaunggon
Type	spanish	spanish	spanish	spanish	spanish	spanish	spanish	spanish
Duration period (days)	100-110	120-130	100-110	115-120	100-110	100-110	110-120	110-120
Seed color	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink
1000 seed weight (gm)	350	330	315	300	338	350	350	380
Oil content (%)	53	53	51	50	51	51	52	54
Shelling (%)	71	72	73	73	76	75	74	75

1150 kg ha^{-1} whereas a yield of 800 kg ha^{-1} was obtained from sowing in the afternoon, probably because soil temperatures are lower in the morning giving a higher germination rate. Plant spacing recommended by the Myanmar Agriculture Service for Spanish types of monsoon groundnut is 38 cm x 10 cm and for Virginia varieties recommended spacing is 45 cm x 15 cm. Seed rate recommended for Spanish types is 120 kg ha^{-1} and that for Virginia types is 100 kg ha^{-1}.

Seeds are treated with both insecticide and fungicide at the time of sowing. Rhizobial inoculum is also used, especially in locations where inoculum storage facilities are available.

The Agriculture Mechanization Department is mainly responsible for mechanized farming. Privately-owned tractors are also used for land preparation in some areas.

Intercultivation

The first cultivation is carried out 5 days after sowing so that early weeds are suppressed, and the soil becomes loose to facilitate seedling emergence. Second and third intercultivations are done 15 and 25 days after sowing. Fields of Spanish groundnut are handweeded 30 days after sowing, and Virginia are weeded 45 days after sowing.

Irrigated Groundnut

Winter-irrigated groundnut is grown on riverbanks irrigated using high lift pumps. In these areas the yields can reach 3800 kg ha^{-1}.

Seed Storage

For groundnuts grown after rice in lower Myanmar fresh seeds from both the central part of Myanmar and Shan State are used. Owing to the high transport charges incurred, formerly the extent of the area sown to groundnut after rice was limited. This problem has been resolved by storing groundnut seeds in sealed tin containers to be grown in the following year's winter season. Storing the pods either in bamboo bins or in plastic bags gives poor germination rates. However storing in plastic bags is better than storing in bamboo bins. Winter groundnut after rice yields about 1400 kg ha^{-1}.

Insect Pests and Diseases

Leaf miner *(Approaerema modicella)* is a serious pest occurring in both the rainy season and in winter. In the sandy soils area groundnut white chafer grub *(Eulepida mas hona)* is also serious in some years. Collar rot *(Aspergillus niger)* and early leaf spot *(Cercospora arachidicola)* and late leaf spot *(Mycosphaerella berkeleyi)* are major diseases that reduce yields. Precautions are taken by treating seed with suitable chemicals.

Conclusion

Myanmar people consume groundnut and sesame oil in large amounts and at present oilseeds production is insufficient to meet the demand. Groundnut plays a very important role in contributing to local needs as the harvested area is greater than that of other oilseeds.

Therefore, application of high technologies for groundnut production is essential in the oilseeds industry and Myanmar Agriculture Service personnel, in cooperation with other agencies, are trying to meet the demand for self-sufficiency

The Status of Technologies to Achieve High Groundnut Yield in The Philippines

V C Perdido[1], and E L Lopez[2]

Abstract

Groundnut is an important commercial crop because of its varied uses and The Philippines has economic advantages over some other countries producing the crop.

Hectarage of groundnut in 1993 was only 44 909 ha, a decline from 1989, when the area was 50 416 ha. Despite fluctuations in the area planted, because of unstable prices and shortage of seeds, the national average yield has remained at 720 kg ha^{-1} for five years. Almost 50% of the groundnut in the country is grown in the northern Philippines (Cagayan Valley region). Groundnut could be grown over a greater area but farmers have shifted to other commodities due to problems related to production and marketing. Although the crop could be grown throughout the year the yield during the wet season is very low.

During the last decade, in the key production area (KPA) for groundnut, yield has reached more than 2500 kg ha^{-1}. This increase has been attributed to the improved varieties grown, the use of appropriate rhizobial inoculant and high plant population ha^{-1}, resulting from the use of sowing drills.

Improved varieties are developed or introduced and evaluated under various growing conditions by breeding institutions in the country The seeds of the superior varieties initially are increased by the breeding institution and then mass produced by the seed stations of the Department of Agriculture and agricultural colleges.

Inoculants and improved sowing methods have been introduced to farmers by technology verification trials and pilot and commercialization programs involving many farmer-cooperators over large areas.

由于花生的用途广泛和在菲律宾具有其有利的生长条件使它成为该国的一种重要经济作物.

菲律宾的花生种植面积从1989年的50416公顷下降到1993年的44909公顷. 尽管由于价格不稳,种子不足等原因致使播种面积有所变化,但5年中全国平均单产一致保持在720公斤/公

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顷．菲律宾差不多 50% 的花生种植在北部地区(Cagayan 山谷地区）. 花生本来可以在更广泛的地区种植，但由于某些生产及市场问题使得许多农民转而种植其它作物．花生在菲律宾可以周年生长，但雨季的产量很低．

过去的十年中，年花生主产区的产量已超过 2500 公斤/公顷，这主要应归功于：品种的改良，接种根瘤菌以及采用打孔播种方法提高了单位面积上的群体密度．

该国的育种机构培育或引进优良品种，并在各种生长条件下对其进行评价．优良品种首先由育种单位繁殖，然后由农业部的种子站和农业院校大量繁殖推广．

通过试验示范把根瘤菌接种和良法种植技术介绍给农民，而且有关技术的大面积商业化推广也离不开农民协作者的作用．

Introduction

Groundnut, popularly known as peanut in The Philippines, is an important commercial cash crop for Filipino farmers. It is used for local consumption in various forms, prepared into delicacies such as peanut brittle, or processed into other food products (Garcia et al. 1990).

Hectarage grown to groundnut has fluctuated, mainly due to unstable prices of the product and lack of seed availability at planting time. In 1989, area sown to groundnut was 50 416 ha and it gradually reduced to 44 909 ha in 1993 as farmers changed to more remunerative crops (BAS 1993, 1994). However, the national average yield has remained at 720 kg ha^{-1} for the last 5 years. Almost 50% of the

Table 1. Groundnut production in The Philippines, 1992 and 1993.

	Area (ha)		Production (t)		Yield (t ha^{-1})	
Region	1992	1993	1992	1993	1992	1993
Philippines	44563	44909	33993	34028	0.72	0.72
Cordillera Adm. Region	312	313	133	134	0.43	0.43
Ilocos Region	6999	7409	8396	8861	1.20	1.20
Cagayan Valley	21751	21278	14998	14244	0.69	0.69
Central Luzon	1065	1111	1065	1118	1.00	1.01
Southern Tagalog	2922	2886	2053	2059	0.70	0.71
Bicol Region	1410	1406	1155	1147	0.82	0.82
Western Visayas	2244	2251	1045	1047	0.47	0.46
Central Visayas	2790	3133	1841	2068	0.66	0.66
Eastern Visayas	922	921	493	491	0.53	0.53
Western Mindanao	1162	1163	487	486	0.46	0.42
Northern Mindanao	808	814	749	757	0.93	0.93
Southern Mindanao	760	794	460	486	0.61	0.61
Central Minadanao	638	642	541	549	0.83	0.86
ARRM	780	788	575	581	0.74	0.74

Source: Bureau of Agricultural Statistics; 1993, 1994. Department of Agriculture, Quezon City, The Philippines.

groundnut grown in The Philippines is found in the Cagayan Valley region. In 1993 alone, the area planted to the crop in this region was 21 278 ha, though the average productivity was one of the lowest in the country (670 kg ha^{-1}).

The area of highest productivity is the Ilocos region with 1200 kg ha^{-1} (Table 1). While the average production in the country is low, the potential of some varieties in the Key Production Areas (KPA) for groundnut could reach more than 2500 kg ha^{-1}, similar to that obtained on government seed farms.

Traditionally groundnut is a dry season crop sown after the wet season maize or rice, and grown during the tail-end of the rainy season (Oct to Dec). Groundnut grown during the wet season (May sowing) is for seed purposes and farmers follow the garden-type production where the area sown by each individual farmer is just enough to produce seed for the dry season cropping. Yield of the crop during the wet season is very low, ranging from 400 to 600 kg ha^{-1}.

Production Systems for Groundnut in The Philippines

Soils and Sowing Times for Groundnut Production

Major groundnut production areas in the country are on the river flood plains where soils are described as well drained, light textured, slightly acidic (pH 5.5 - 6.5), and relatively fertile with high organic matter.

Groundnut is a relatively short-duration crop, maturing in less than 120 days. The cropping season is from May to Oct for the wet season and Nov to Apr for the dry season. During the wet season (May sowing), the crop is grown on the hillsides.

Varieties Commonly Grown in The Philippines

Varieties commonly used by growers are shown in Table 2. There are other varieties but they are not acceptable to growers. The most preferred varieties are large seeded, with two seeds pod^{-1} and a pink colored seed coat. In the Ilocos region, a red seeded traditional variety is still popular and this is used mainly for local consumption. The general performance of this variety in the farmers' field trials at Isabela was inferior to the other recommended varieties but superior to the farmers' traditional variety (Table 3). Farmers also use improved varieties that are not certified but have been grown for generations or bought from seed dealers from other regions. Generally, farmers produce their own seeds.

Initial seed stocks of improved certified varieties are multiplied by breeding institutions and then multiplied on government seed farms. There are no registered seed growers venturing into groundnut seed production except for trained cooperative members. For the last three seasons, seeds of improved varieties have been increased by a Farmers' Cooperative in Isabela and are now widely used by its members.

The introduction of the barangay[1] based garden-type seed production program has helped farmer-members of cooperatives to ensure the availability of quality

Table 2. Yield and agronomic performance of recommended groundnut varieties commonly grown in The Philippines.

Variety	Pod Yield (kg ha^{-1})	Days to Maturity	Seed Quality		Reaction to Disease	
			Color	Size	CLS[1]	Rust
BPI Pn 9	1550	114	Pinkish	Large	MS	MS
BPI Pn 2	1889	101	Pinkish	Large	MR	MR
UPL Pn 2	1950	110	Pinkish	Large	MR	MR
UPL Pn 8	2170	110	Pinkish	Large	MR	R
UPL Pn 10	1750	100	Light pink	Large	S	MR

1. CLS = Cercospora Leaf Spot
Rating Scales: R = Resistant, MR = Moderately Resistant, MS = Moderately Susceptible, S = Susceptible

Source: Philippine Seed Board, 1993.

Table 3. Mean pod yield of groundnut varieties obtained in on-farm trials, Isabela, The Philippines.

Variety	1992-93 DS[1]	1993 WS[2]	1993-94 DS	1994 WS	1994-95 DS
BPI Pn 2	3648 bc	1394 c	4240 ab	2082 c	3090 b
UPL Pn 8	3875 ab	2092 b	3687 b	2329 bc	2900 b
BPI Pn 9	4410 a	2666 a	4589 a	3227 a	2947 b
UPL Pn 10	3970 ab	1592 b	4608 b	2707 ab	3400 a
Ilocos Red	3291 bc	1463 c	3823 c	936 d	3016 b
Local variety	3168 c	1377 c	2005 c	1081 d	1800 c

1. DS - Dry season; 2. WS - Wet season
In the column, means having the same letter are not statistically different at 5% level, by DMRT.

seeds during the regular season (Perdido et al. 1994). Besides, it makes the marginal sloppy areas productive during the wet season. Seeds produced during the regular dry season are shared with farmers in other areas through the intervention of the government agriculture sector. A government seed assistance program by seed exchange (exchanging the seed of the farmer with the improved variety) or through seed loans payable in kind after harvest has been introduced.

Production Inputs

Groundnut culture requires minimum inputs. The production areas are rainfed with no supplemental irrigation. As groundnut is a relatively drought-tolerant crop, it produces acceptable yields during the normal cropping season without irrigation.

Fertilizer application in less fertile soils involves the application of 100 kg ha^{-1} of complete fertilizers (14-14-14), applied as basal before planting. In most areas, the native *Rhizobium* population is sufficient.

Chemicals are used only in the control of insect pests.

Availability of Credit

Farmers' organizations like cooperatives are encouraged. Government lending institutions such as the Land Bank of The Philippines (LBP) and Rural Banks (RB) extend assistance only to organized groups who are producing high-value commercial crops.

Private lenders still dominate despite higher interest rates since it is easy to borrow from them. They impose the condition that farmers must sell their harvest to them with the result that farmers cannot bargain for a better price because of their standing accounts (Huelgas 1990).

Farm Mechanization

The use of machines in groundnut production is common only for land preparation, when hired tractors are available in the locality. However, small farm machines have been developed to reduce the cost of groundnut production and improve the quality of the products. These machines include the following:

Animal-drawn multicrop seeder-fertilizer applicator. The implement opens furrows, and drops and covers seeds and fertilizer simultaneously in one operation. It can cover 0.65 ha day^{-1}. This implement can save around 60% of the total human-animal labor required ha^{-1} and consequently the total cost of production. It saves time especially when hired laborers are not available.

Animal drawn inter-row weeder-cultivator for dryland farming. One advantage of the implement is that it can save 66% of human-animal days over the conventional row-weeding, and 53% person-days ha^{-1} for within-the-row handweeding.

Multi-crop stripper/thresher. A hold-on type of multi-crop stripper/thresher has been designed for groundnut. Stripping capacity ranges from 50 to 70 kg h^{-1} with zero pod damage and pod loss, and it can save 72% labor in stripping either newly uprooted or partially dried groundnut compared to manual hand-picking of pods.

Groundnut sheller. This machine can be pedal operated or powered mechanically by a 5 hp gasoline engine to suit high volumes of production. Output capacity ranges from 30 to 60 kg h^{-1} for pedal operation and 50 to 100 kg h^{-1} when using engine. Shelling efficiency ratings are 80-98% for pedal and 85-99% for engine drive with only 4.5% broken seeds. With the machine, a farmer can save 94% of the person-days required to handshell groundnut.

Crop Rotations and Cropping Patterns

Groundnut is planted as monoculture after rice and maize, or in combination (strip- and intercropped) with other crops like maize, beans, mung bean, and string beans ('sitao')/ and as an alternate crop for sweet potato. Maize (white flint or glutinous) as an intercrop is dominant.

The ratio of groundnut with other crops is 5:1, or 5:2 for maize (maize is planted in double row with spacing of 30 cm x 25 cm), and 5:1 with other legumes like mung bean, sitao, and beans.

Cultural Practices in Groundnut Production

Land preparation. Groundnut fields are prepared following the conventional method of land preparation in upland areas (well prepared seedbed) using either animal-drawn implements or farm tractors. After the last harrowing, furrows are set 50 cm apart.

Sowing. Seeds are drilled along furrows at the rate of 10-12 seeds m^{-1}. Some farmers sow by dropping 2-3 seeds per hill spaced 15-20 cm apart within the row. Seeding rate is 160 kg ha^{-1} (unshelled) or 100-110 kg ha^{-1} of shelled groundnut giving a population of 200 000 plants ha^{-1}.

Cultivation. A small spiketooth harrow is passed between furrows to destroy germinating weeds 10 days after seedling emergence. Hilling-up is done 25-30 days after emergence or before the pegging stage.

Fertilizer application. Groundnut is usually not fertilized with granular fertilizers. Following a heavily fertilized wet season maize or rice, the groundnut may depend on the residual fertilizer applied during the previous season. In less fertile soils, 100 kg ha^{-1} of complete fertilizer (14-14-14) may be applied as a basal application.

Rhizobial inoculation may also be practical in some groundnut production areas. The *Rhizobium* culture can be obtained from the regional offices of the Department of Agriculture, the Bureau of Soils and Water Management at Quezon City, and the Institute of Biotechnology at The University of The Philippines, Los Banos.

Water Management. Groundnut is grown under rainfed conditions generally without irrigation. If irrigation is ever applied, it is done during the critical stages of the crop such as germination, flowering, pod development, and pod filling.

Weeds, pest, and diseases control. Cultivation and handweeding are the most common means of eliminating weeds and these are done in the first 4-6 weeks of crop growth. Pesticides are very seldom applied except in the control of insect pests. Diseases are not controlled.

Harvesting. Groundnut is harvested by uprooting or pulling the plant after passing an animal-driven plow on both sides of the row to loosen the soil. The uprooted plants, with pods, are left in windrows for drying after which pods are hand-picked or threshed by the groundnut stripper.

Postharvest practices. The harvested pods are sun dried 2-3 days until the seeds become loose within the pods. Farmers traditionally store unshelled groundnut for seed purposes or while waiting for a higher price.

Groundnut pods are stored in airtight containers (after drying) if they are intended for seed purposes. This includes the use of drums covered with plastic sheets.

Groundnut shelters are available but due to limited quantity, handshelling still dominates.

Constraints on Groundnut Production

Several constraints on groundnut production have been identified in the key production areas (Perdido, 1994).

Inadequate seed production. Private seed growers concentrate on seed production of rice and maize, and not on groundnut seed. Groundnut seed farms are the only sources.

Insufficient seed supply of improved varieties. If good quality seeds are unavailable, farmers have to be content to use whatever seeds they have at sowing time.

Prevalent pests and diseases of groundnut that reduce plant population at harvest time. There are many pests and diseases of groundnut but farmers rarely apply control measures.

Occurrence of drought. Groundnut grows well under rainfed conditions, but yields are reduced under severe moisture deficiency. Most upland farmers do not possess the necessary means of irrigating their crop in cases of drought.

Limited technical knowhow in groundnut production. Most government technicians are located in the rice and maize areas and farmers growing legumes are sometimes neglected.

Lack of capital. Government lending institutions extend credit assistance only to registered cooperatives. Upland farmers are not yet organized or sufficiently credible to transact loans with lending institutions.

Lack of market and price incentives. Prices of groundnut are dictated by traders, and government marketing organizations prefer to purchase rice and maize, and not legumes.

Marketing of Groundnut

The farmers sell their produce to traders, assemblers, wholesalers or wholesaler-retailers. Traders usually function as middlemen who visit the field during harvesting, and both the trader and the farmer agree on a price. With the advent of the KPA approach to crop production, where groundnut is considered as one of the key commercial crops, marketing assistance will be extended to growers' cooperatives through scouting of markets so that intervention of middlemen is avoided.

Technologies Used to Improve Productivity

Technology development on groundnut is mainly the concern of the national research agencies and regional R and D institutions where groundnut is one of their major commodity responsibilities. Crop improvement has been concentrated mainly at the national crops research centers because of their expertise, linkages, and access to germplasm from international institutions. Regional research centers also have access to international germplasm but the acquired materials are limited to field testing.

Technologies developed by national research centers are made available to other agencies after the research and development reviews conducted by the Philippines Council for Agriculture, Forestry, and Natural Resources Research and Development. These technologies are tested in various locations in the regions by research agencies mandated to conduct technology adaptation, and verification to evaluate location specificity and appropriateness of the technology.

In the piloting and technology commercialization stages (pre-production phase), the technology components which have the highest impact on production are assembled into a package of technology (POT). This POT is tested against the farmers' practice and it is also at this stage where support services (including a seed support system, other technology inputs, extension, credit, market, post harvest facilities, and machinery support) are assessed as to their contribution to the adoption of the technology. During the commercialization phase, a monitoring and evaluation scheme is set up to determine the impact of the technology on farmers, and the extent of adoption and sustainability of the production and support systems.

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Barangay = local government district similar to a Shire.

The Status of Technologies Used to Achieve High Groundnut Yield in Thailand

Sanun Jogloy[1] and Tugsina Sansayawichai[2]

Abstract

Groundnut *(Arachis hypogaea* L.) is the major food legume and oil crop of Thailand. Over 100 000 hectares are planted to groundnut annually Total annual production is approximately 140 000 t, and 1.4 t ha^{-1} is estimated as the national average yield. The groundnut crop is generally grown in upland areas in the rainy season by monocropping and double cropping. The crop is also sown following rice *(Oryza sativa* L.) in the dry season when irrigation is available.

Technologies used to achieve high groundnut yield are improvement of cultivars, and crop management practices. At present, six groundnut cultivars have been released. Two of them are Spanish with medium seed size, namely Tainan 9 and Khon Kaen 60-1. Four cultivars are boiling type groundnut, S K 38, Lampang, Khon Kaen 60-2, and Khon Kaen 4. A large-seeded Virginia type cultivar, Khon Kaen 60-3, has been introduced for farmers. Several cultural practices have been recommended. The three sowing times are early rainy season (mid Apr-May), late rainy season (Jul-Aug) and dry season (Dec-Jan). Land should be tilled 2-3 times up to 20 cm depth. Plant spacing of 30-60 cm x 10-20 cm is recommended depending on time of sowing, location, and cultivar. Hand weeding at 15 and 30 days after sowing is recommended. Application of alachlor herbicide is also recommended for preemergence treatment. Fertilizer (18 kg of N, 24.5 kg of P and 30.7 kg of K ha^{-1}) is applied prior to sowing. Hilling up is done at 10 days after flowering. Gypsum as a source of Ca is also applied just before hilling up. Pesticides are also suggested for control of insect pests. Proper pod drying is also recommended after harvesting to reduce mycotoxin contamination. Small machines have been developed for stripping, and shelling.

花生(*Arachis hypogaea* L.)是泰国的主要食用豆科作物和油料作物，每年的种植面积超过 10 万公顷总产达 14 万吨，全国平均单产 1.4 吨/公顷．花生一般在雨季以单作或间作方式种植于高地势地区，有水浇条件的也可以在旱季作为水稻的下茬作物种植．

品种改良和加强管理等技术能提高花生的产量．目前，已推广了 6 个花生品种，其中 Tainan－9 和 Khon Kaen60－1 是 2 个籽仁中等大小的西班牙型品种，SK38、Lampang、Khon

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Jogloy Sanun and Sansayawichai Tugsina. 1996, The status of technologies used to achieve high groundnut yields in Thailand. (In En. Summary in Ch.) Pages 81-88 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Kaen 60－2 和 Khon Kaen4 是 4 个蓬松型品种。另外，一个弗吉尼亚型大籽品种 Khon Kaen60－3 也已介绍给了农民。若干栽培措施也已向农民做了推荐，包括播种时季分为早雨季(4 月中－5 月)、晚雨季(7－8 月)和旱季(12－1 月)；土地要深耕 20cm 2－3 次；根据不同的季节、地区和品种进行合理密集，行株距为 30－60cm× 10－20cm；播后 15－30 天人工除草；芽前喷施除草剂甲草胺；播前施肥(每公顷施 18kg N 肥，24.5kg P 肥和 30.7kg K 肥)；开花后 10 天扶垄；扶垄前施石膏；施用农药防治害虫；收获后果实用正确方法干燥减少真菌毒素污染；采用小型机械脱壳去皮。

Introduction

Groundnut *(Arachis hypogea* L.) is the major food legume and oil crop of Thailand. The crop, over 100 000 ha sown annually, is grown by small farmers in all parts of the country with the major growing areas in the North and Northeast regions. Total annual production is approximately 140 000 tons, and the estimated national average yield is 1400 kg ha^{-1}. The crop is generally grown in upland areas in the rainy season as a monocrop and intercrop.

This paper reports recommended groundnut varieties and their durations, inputs, availability of credit, extent of mechanization, cropping patterns, cultural practices, production constraints, marketing, and technologies used to improve productivity of groundnut in Thailand.

Varieties and Seeds

At present, seven groundnut cultivars have been released. Two of them are Spanish types with medium-size seed, namely, Tainan 9 and Khon Kaen 60-1. Four cultivars have been released as a boiling-type groundnut: SK 38, Lampang, Khon Kaen 60-2, and Khon Kaen 4. They are Valencia types with long pods, 3-4 seeds per pod and excellent pod appearance. One cultivar, Khon Kaen 60-3, was released as a large-seeded Virginia type groundnut and has seeds about twice as big as the other released cultivars. However, the crop duration of this cultivar is longer than those of Spanish and Valencia types. The crop duration of Khon Kaen 60-3 is 115-120 days while the crop duration of the other varieties is approximately 95-100 days. Groundnut seed production is done by government agencies (Seed Multiplication Centers). Usually farmers get groundnut seed from shelling factories. In some cases, seeds are exchanged between rainy season growers and dry season growers.

Breeder's seed is produced by the Department of Agriculture while certified seed is produced by Seed Multiplication Centers of the Department of Agricultural Extension and distributed to farmers. A seed production plan is followed to ensure high quality seeds, and genetic purity is maintained by field inspection to remove off-type plants. Healthy bold pods are hand-picked from the harvested plants for seed purposes. The seed-pods are thoroughly dried for 7-10 days by spreading in a thin layer on nylon net until a seed moisture content of 4-5% is reached. Inert matter, seeds of other crops, and weed seeds are discarded. After drying and cleaning, the pods then are stored in gunny bags under ambient conditions by farmers or in a cold room (15-20°C, 50-60% RH) at the Seed Multiplication Center. The seed-pods have been found to have a good germination percentage (70%) even after 4 months under ambient conditions or after 18 months in cold room conditions. Farmers shell the seed-pods by hand or by hand-operated sheller 2-3 days before sowing. Seed treatment with Vitavax® at 3 g kg^{-1} seed is recommended to control seedling blight (=collar rot) diseases caused by *Aspergillus niger.*

Inputs

Lime and Fertilizers

Generally, lime at the rate of 625-1875 kg ha^{-1} is recommended for pre-planting application in soils with low pH (pH < 5.5). Normally the optimum soil pH for groundnut ranges from 5.5-6.5 (Keerati-Kasikorn and Ratanarat 1993). Under optimal pH conditions, nutrients are available for the crop. For a soil which has P <8 mg kg^{-1} and K <30 kg ha^{-1}, application of 18 kg N ha^{-1}, 24.5 kg P ha^{-1} and 30.7 kg ha^{-1} of K is recommended prior to planting (Keerati-Kasikorn and Ratanarat 1993).

Ca is also needed for pod development. Lack of Ca causes empty pods (pops) and shrivelled seeds. So, lime (625-1875 kg ha^{-1}) or gypsum (300-600 kg ha^{-1}) as a source of Ca is incorporated at the pegging stage. In soils with boron deficiency (< 0.12 mg kg^{-1}) the inner faces of the cotyledons are depressed and discolored. This is classified as a form of internal damage called 'hollow heart' (Cox et al. 1982). Application of B at the rate of 0.25-0.5 kg ha^{-1} is recommended for soils with B deficiency and is best applied at the flowering/pegging stage, mixed with gypsum.

Insecticides

Insects of economic importance in groundnut are leaf miner *(Aproaerema modicella=Biloba subsecivella),* aphid *(Aphis craccivora),* thrips *(Frankliniella spp.),* bollworm *(Helicoverpa armigera)* and subterranean ant *(Dorylus orientalis).* Leaf miner, aphid, and thrips damage the groundnut crop from the seedling stage to 30 days after sowing. Carbofuran 3% G (Furadan®) at the rate of 18-31 kg ha^{-1}, is applied prior to sowing, or monocrotophos (Nuvacron®) is sprayed to control these insects. Bollworm damages the leaves from flowering to the pod development stage. Systemic insecticides, such as monocrotophos (Nuvacron®), are effective to control bollworm (Keerati-Kasikorn 1985). Subterranean ants damage young seeds and pods. Carbofuran 3% G, at the rate of 18-31 kg ha^{-1}, is recommended for controlling ants at the pegging stage.

Fungicides

The important diseases of groundnut in Thailand are rust *(Puccinia arachidis),* late leaf spot *(Phaeoisariopsis personata),* early leaf spot *(Cercospora arachidicola),* and seedling blight *(Aspergillus niger).* Yield losses caused by rust and leaf spots range from 20-80% (Wongkaew 1985). Benomyl (Benlate®) and chlorothalonil (Daconil®) at every 7-14 days from flowering to the pod development stage are recommended to control foliar diseases. Seedling blight causes yield losses of up to 50%. Seed treatment with tetramethyl thiuram disulfide (Thiram®) is recommended to control this disease.

Herbicides

Yield losses due to weeds range from 30-70% (Rakkla 1993). Weeding is usually done twice, first at 15 days and second at 30-35 days after sowing. Where labor is scarce and expensive, use of herbicides is effective to control weeds. Lachlor (Lasso®) 3-4 L a.i. ha^{-1} is sprayed immediately after sowing. Fomesafan (Flex®), for broad-leafed weeds, and haloxefop-ethoxyethyl (Gallant®), for grasses are recommended as postemergence treatments.

Irrigation

Most farmers grow groundnut under rainfed conditions in upland areas. The yield and quality of groundnut are dependant on the amount and distribution of rain. Irrigation is needed if the crop is hit by drought within 30-60 days from sowing (Sansayawichai 1993). In the paddy fields, when groundnut is grown following rice, irrigation is needed every 7-14 days throughout crop duration to get high yields.

Availability of Credit

Usually, to avoid risks, groundnut farmers are reluctant to invest in inputs for production because of price fluctuations and low prices. Only small amounts are spent on inputs and the major sources of farmers' finance are the village merchants and owners of shelling factories. The Bank of Agriculture and Cooperatives also gives credit directly to farmers.

Extent of Mechanization

Groundnut production is labor intensive. As each family grows groundnut on less than a half hectare, small machines are needed for production. A manually operated shelter, with a capacity of 60-80 kg h^{-1}, effectively shells pods to provide seed for planting, and a simple pedal operated groundnut stripper, with a capacity to strip pods of 18-24 kg h^{-1}, is recommended for small holdings. Other tasks are done manually or with animals.

Cropping Patterns

Upland Areas

Sixty percent of groundnut is sown in upland areas (Table 1). The production is divided into three cropping patterns: monocropping, double cropping, and intercropping. In monocropping, farmers usually grow groundnut in the early rainy season (May-Aug), and for double cropping, it is grown as the first crop in the early rainy season (May-Aug) or as the second crop following maize *(Zea mays)* in the late rainy season (Aug-Nov). In a few uplands areas, groundnut is intercropped with young rubber trees *(Hevea brasiliensis).*

Table 1. Groundnut growing area in various cropping systems in Thailand.

Area	Cropping system	Production area (ha)	% of total area
Upland		52603	60.3
	Monocropping	23220	26.6
	Double cropping	27984	32.1
	First crop	14190	16.3
	Second crop	13794	15.8
	Intercropping	1399	1.6
Paddy fallows		32921	37.8
	Under irrigation	30318	34.7
	Without irrigation	2603	3.1
Riverbanks		1680	1.9
Total		87204[1]	100

1. Data are from major groundnut production areas only.

Paddy Fields

About 38% of groundnut is grown in the paddy fallows (Table 1). The crop is generally sown in the dry season (Jan-Apr) with irrigation (35%), but a small proportion is grown without irrigation by utilizing residual soil moisture following the rice *(Orzya sativa)* harvest (3%).

Riverbanks

Only 2% of groundnut is grown in the areas along the river banks, after flood water recedes (Table 1). It is sown in the postrainy season (Nov-Mar).

Cultural practices

Three recommended sowing times are early rainy season (mid Apr-May), late rainy season (Jul) and dry season (Dec-Jan). Land should be tilled 2-3 times up to 10-20 cm depth. In uplands, flat planting is usual (rainy season), however, raised seed-beds are used in paddy fallows with irrigation during the dry season (Sansayawichai 1993). Either whole pods or seeds are used for sowing. Sowing with different seed sizes does not affect germination, growth and yields. The seed is spaced 30-60 cm between rows and 10-20 cm between plants within a row, and 1-2 plants per hill. Generally a population ranging from 150 000-250 000 plants ha^{-1} is recommended, depending on time of sowing, location, and cultivar. Seeds are sown to a depth of 5-7 cm and the seed rate is 125-150 kg ha^{-1}, depending on plant spacing and size of seed. Hilling up is done 10 days after flowering. Other necessary practices including irrigation, and application of fertilizers, herbicides, insecticides, and fungicides have been discussed under 'Inputs'.

The proper stage of harvesting is determined by pulling out a few plants at random and examining the maturity of the pods (70% pods are mature). The plants are lifted from soil and then the pods are stripped by hand or pedal-operated stripper. Pods are cleaned and dried to bring the moisture content to 9%. Usually, farmers sell their groundnut pods within 3-4 weeks of harvesting. Unshelled pods are stored in gunny bags. Pods are shelled only a week or two before seeds are required for various uses.

Constraints

The average groundnut yield obtained in Thailand is relatively low compared with those reported from the USA and the People's Republic of China. The main constraints on yield of groundnut in Thailand are presented in Table 2. They include abiotic factors such as drought, low soil fertility, and low cost of product. Several biotic factors such as insects, disease, and weeds also contribute to low yield.

Marketing

Groundnut is sold by farmers as pods, and a small percentage as kernels. Usually the product is sold by farmers to local assemblers, regional assemblers or shelling factories. Split, broken, and diseased kernels are separated after shelling. The shellers also grade the kernels and sell to oil factories, wholesale merchants, and a small amount to exporters. The wholesale merchants sell kernels to retail merchants and the retail merchants sell kernels to consumers. The marketing of the rainy season crop is generally during Sep-Jan while that of the dry season crop is Mar-Jun. The price of the rainy season crop is lower than that of the dry season crop because the quality of rainy season crop is lower than that of the dry season crop. In the peak period of marketing (Sep-Oct) the price is much lower than that of any other period.

Table 2. Constraints to groundnut production in Thailand.

Constraints	Yield losses (%)
Drought	*
Low soil fertility	*
Insects	
Leaf miner	Up to 50
Aphid	*
Thrips	*
Bollworm	*
Subterranean ant	Up to 32
Diseases	
Leaf spots	20-80
Rust	*
Seedling blight	Up to 50
Weeds	30-70

* Data not available

Technologies Used to Improve Productivities

Cultivar improvement and proper crop management are keys to improved productivity. The National Groundnut Improvement Program was set up in 1983 and a coordinated program between the Department of Agriculture and the Agricultural Universities was formulated with the aim of combining efforts and effectively utilizing the strengths of the institutes. Several improved cultivars have been developed and released to farmers for cultivation by the Department of Agriculture.

Promising lines were selected and tested in the standard yield evaluation scheme in diverse growing environments. The better-performing cultivars across the environments were selected and tested in farmers' fields and the best cultivars released. Tainan 9, SK 38, and Lampang have been well adopted by the farmers. Tainan 9 is shelled for kernels while SK 38 and Lampang are used as fresh pods for boiling. Newly released cultivars, Khon Kaen 60-1, Khon Kaen 60-2, Khon Kaen 60-3, and Khon Kaen 4, are currently being grown only in small areas because of lack of seed for the farmers, and their specific adaptability.

Improvement in productivity can also be achieved by improved crop management. Technologies and inputs have been suggested to growers. However, adoption of new technologies is not extensive. As the price of groundnut fluctuates widely farmers prefer to avoid risks and are reluctant to invest in inputs for production. Also, groundnut is considered by the growers as a minor crop. Similarly, although technologies for control of weeds, diseases and insects are recommended to farmers the adoption of these technologies has been slow.

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The Status of Technologies Used to Achieve High Groundnut Yields in Vietnam

Ngo The Dan[1], Nguyen Thi Chinh[2], Tran Nghia[2], Phan Lieu[3], Tran Van Lai[2], Nguyen Xuan Hong[2]

Abstract

The area under groundnut in Vietnam is 234 000 ha, production is 259 000 t, and the average yield is 1.08 t ha^{-1}.

In North Vietnam, groundnut is grown mostly in spring from Feb to Jun. In upland areas it is also cultivated in autumn (Jul-Nov), mainly to produce seed for the spring-season crop. In South Vietnam, groundnut is grown mainly in the dry season (Nov-Mar) after rice, or in the rainy season (Jun-Sep) intercropped with maize, mung bean, or cassava.

In North Vietnam, technologies used by farmers include: fertilizer application (30 kg N ha^{-1}, 39.3 kg P ha^{-1}, 49.8 kg K ha^{-1}) lime application (200 kg ha^{-1} as basal application, and 200 kg ha^{-1} at the flowering stage); pest management; and irrigation. Farmers consider such other technologies as rhizobial inoculation, and chemical seed treatment too complicated to use, but efforts are continuing to popularize these inexpensive practices.

In South Vietnam, technologies used by farmers include: using Rovral® to treat seed before sowing; spraying growth-stimulator (3-N=GH); applying suitable fertilizers (30N : 66.4 K : 39.3 P); spraying Anvil® to control foliar diseases; and split doses of both lime (400 kg ha^{-1}) and nitrogen fertilizers.

越南的花生种植面积为 23.4 万公顷，总产量 25.9 万吨，平均单产 1.08 吨/公顷。

越南北部，花生主要在 2－6 月间种植，高原地区在秋季(7－11 月）亦有种植，但主要是为来年春季生产种子．在南部，花生主要在水稻收获后的旱季(11－3 月）种植，或者是在雨季与玉米、绿豆、木薯等间作．

北越农民应用的技术包括：施肥(每公顷施 N 肥 30 公斤，P 肥 39.3 公斤，K 肥 49.8 公斤)；施石灰(每公顷施 200 公斤作基肥，开花期再追施 200 公斤)；有害生物防治；灌溉．农民认为诸如根瘤菌接种、化学物质处理种子等技术太复杂，不够实用，但有关部门仍在继续努力普及这些成本不高的技术．

越南南部农民应用的技术有：播种前用 Rovral 处理种子；喷施生长调节剂(3－N＝GH)；合理施肥(30N:66.4K:39.3P)；喷施 Anvil 控制叶部病害；分批施用石灰(400 公斤/公顷）和氮肥．

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Introduction

Groundnut is the most important legume crop in Vietnam. At present, groundnut is widely used in various ways as both food and feed. It also plays an important role as one of the major export commodities of Vietnam. Groundnut is a crop with high economic efficiency on degraded soils, and under rainfed conditions. It contributes to diversity in production systems, enhancement of employment and income-earning opportunities for farmers. However, groundnut production in Vietnam receives no investment in intensive cultivation, and groundnut yield remains low at around 1-1.1 t ha^{-1}.

To improve groundnut production and increase annual income per unit area, it is necessary to identify appropriate production systems, promising technologies, and new varieties.

This report describes the main production systems, and technologies used to achieve high yields in the four largest groundnut-growing provinces in the country

Background Information

According to the General Statistical Office (1994), the area under groundnut was 234 000 ha, production was 259 000 t and average yield was 1.08 t ha^{-1} for the country (Table 1).

Table 1. Area, production, and average yield of groundnut in Vietnam, (1990-1994).

Year	Area ('000 ha)	Production ('000 t)	Mean yield (t ha^{-1})
1990	201.4	213.5	1.06
1991	210.9	231.1	1.11
1992	217.3	226.0	1.04
1993	224.0	239.7	1.07
1994	234.0	259.0	1.08

Source: General Statistical Office, 1994.

Groundnut production is distributed among 8 agroecological regions of Vietnam. Of these, the midlands, north-central coast, and southeast highlands are important at the national level. Ten key groundnut-growing provinces occupy 58.46% of the area and 62.64% of the total production of the country. Details of the main characteristics of the major groundnut-growing provinces of Vietnam are given in Table 2.

Table 2. Main characteristics of the major groundnut-growing provinces of Vietnam.

Province	Major soil type	Mean annual rainfall (mm)	Monthly temperature range (°C)	Cultivated area of groundnut (t ha^{-1})	Average yield (t ha^{-1})	Main cropping season of groundnut
Nghe An	sandy, sandy loam	2060	17.3-29.5	20000	1.06	Feb-Jun
Ha Bac	Alluvial red soil, degraded soil	1750	13.0-29.0	8900	0.97	Feb-Jun
Tay Ninh	Alluvial gray soil, sandy, sandy loam	1910	24.9-28.8	23800	1.55	Nov-Mar
Long An	Acid sulphate soil	1520	26.0-29.5	10700	1.67	Nov-Mar

Ha Bac Province is located in northern Vietnam (21-22°N). It belongs to the midland region. Nghe An Province is located in the north-central part of Vietnam (18-20°N). In both Ha Bac and Nghe An Provinces, groundnut is grown mostly in spring (Feb-Jun). In high elevation areas (midlands and sloping areas), it is also cultivated in autumn (Jul-Nov) mainly for seed production for the spring season crop. In Ha Bac Province, after harvesting groundnut, autumn rice or soybean are grown and after that sweet potato or maize are grown. On the degraded soils of Ha Bac Province, groundnut is the crop with the highest economic efficiency. In Nghe An Province after harvesting groundnut, sesame or upland rice or sweet potato are grown (Jul-Sep), and after that sweet potato or maize are grown (Oct-Dec).

Tay Ninh Province is located in the southeast highlands of Vietnam (11-12°N) and Long An Province is located in the Mekong River Delta(10-11°N). Both Tay Ninh and Long An have a tropical monsoon climate where the rainy season is from May to Oct and the dry season from Nov to Apr. Groundnut is grown mainly in the winter-spring season (Nov-Mar) with irrigation, but it could also be grown in summer (Jun-Oct).

The groundnut crop grown in the dry season is irrigated, and in general subject to high input and intensive farming, so that high pod yields (2-3 t ha^{-1}) are obtained. Conversely, the groundnut crop grown in the rainy season is considered low input, extensive farming, and usually gives a low pod yield (0.7-0.9 t ha^{-1}). In Tay Ninh Province groundnut is grown mostly in sandy, sandy loam, and alluvial grey soils, where the main rotational system is groundnut-rice in lowlands, or intercropping with maize, mung bean, cassava or perennial industrial crops such as coffee, or rubber in uplands. In Long An Province groundnut is grown mostly in acid sulphate soils in a rotational system with rice. The groundnut pod yield of Long An Province is the highest of all groundnut-growing provinces in the country.

Details of the cropping patterns of the four largest groundnut-growing provinces are given in Figure 1.

Technologies Used to Achieve High Groundnut Yield in Northern and Southern Vietnam

Northern Vietnam

Ha Bac and Nghe An are the two largest groundnut-growing provinces of northern Vietnam. However, until recently, the majority of farmers of Ha Bac and Nghe An Provinces showed little interest in investing in intensive cultivation and promising technologies. In the past, farmers used widely available groundnut varieties like Do Bac Giang, Su Tuyen and Sen Nghe An. However, since 1990, some new varieties giving a 10-20% increase in yield have become available. In Ha Bac Province V79 variety with a 120-125 day growing period has been adopted

Region	Cropping patterns	J	F	M	A	M	J	J	A	S	O	N	D
		Months											
I	CP1		●	●	●	●	●	*	*	*	▲	▲	▲
	CP2		●	●	●	●	●	*	*	*	□	□	□
	CP3		●	●	●	●	●	○	○	*	*	*	
	CP4	*	*	*	*	*	○	○	*	*	*	*	
II	CP1	●	●	●	●	●	■	■	■	▲	▲	▲	▲
	CP2	●	●	●	●	●	■	■	■	□	□	□	□
	CP3	●	●	●	●	●	*	*	*	*	*		
	CP4	●	●	●	●	●	▲	▲	▲	▲	▲	▲	▲
III	CP1	●	●	●	●	●	●	●	*	*	*		●
	CP2	●	●	●	*	*	*	*	*	*	*		●
	CP3	●	●	●		*	*	*	*				●
	CP4	●	●	●				*	*	*	*		●
IV	CP1	●	●	●	*	*	*	*	*	*	*	*	●
	CP2	●	●	●				*	*	*	*	*	●
	CP3	●	●	●	●	●	●	●	*	*	*	*	●
	CP4				●	●	●	●	*	*	*	*	
	CP5	●	●	●	●	*	*	*	*	*	*	●	●

●	Groundnut
■	Sesame
▲	Sweet potato
□	Maize
*	Rice
○	Soybean
	Fallow

Region I = Tanyen, Habac Province

Region II = Dien Chau, Nghe An Province

Region III = Tay Ninh Province

Region IV = Long An Province

Figure 1. Cropping patterns of the major groundnut-growing provinces of Vietnam.

Table 3. Technologies used for producing groundnut at Ha Bac and Nghe An, northern Vietnam.

	Ha Bac Province		Nghe An Province	
Technology	Traditional practices	Improved practices	Traditional practices	Improved practices
Variety	Do Bac Giang, Su Tuyen	V79	Sen Nghe An	Sen Lai
Growth-duration (days)	120-125	120-125	115-120	125-130
Fertilizers				
Farmyard manure ($t\ ha^{-1}$)	4	8	4	10
Urea ($kg\ ha^{-1}$)	40	65	30	65
Potassium chloride ($kg\ ha^{-1}$)	none	105	none	200
Superphosphate ($kg\ ha^{-1}$)	150	300	150	400
Dry pond mud ($kg\ ha^{-1}$)	8000	none	none	none
Lime ($kg\ ha^{-1}$)	150	400	200	400
Pesticides (No. of sprays)	2	3	2-3	3
Fungicides (No. of sprays)	none	none	none	2
Irrigation	rainfed	rainfed	rainfed	rainfed
Pod yield ($kg\ ha^{-1}$)	970	1610	1210	2050

and in Nghe An Province farmers are growing Sen Lai variety which has a duration of 130-135 days.

Most farmers use seed from their spring crop for the next spring crop but some farmers use autumn season groundnut seed for the following spring crop as the seed has high viability. Seed is stored in ceramic pots.

Before sowing farmers apply farmyard manure mixed with dry pond mud to soil. Inorganic fertilizers were rarely used by farmers in the past. However, in recent years inorganic fertilizers (30N:35P:75K) have been used by one third of the farmers in Ha Bac. lime application of 400 $kg\ ha^{-1}$ has been adopted by farmers as it is an economically efficient technology.

The farmers use insecticides up to three times (usually 1-2 times) to control insect pests but control of diseases is not undertaken.

Groundnut is grown mainly under rainfed conditions. However, irrigation can increase yield by 30-40%. In Dien Chau district, Nghe An Province, the Sen Lai variety produced a pod yield of 4 t ha^{-1} in an area of 2000 ha.

In both Ha Bac and Nghe An Provinces, technologies adopted by farmers are: lime application, a balanced ratio of NPK, spraying of insecticides, and irrigation. Other technologies such as rhizobial inoculation and seed treatment with chemicals are not followed by farmers because they consider them too complicated. Details of the traditional and improved practices followed by farmers of Ha Bac and Nghe An Provinces are given in Table 3.

Southern Vietnam

Technologies used in both Tay Ninh and Long An Provinces are presented in Table 4.

Varieties Ly, Giay, and Moket, with 85-90 days growth-duration, are used by a majority of the farmers to sow in the dry season.

Farmers use seed from groundnut pods grown for seeds in the previous rainy season and stored in nylon sacks. Seeds bought from the market are also used.

Most farmers apply coconut ash up to about 1500 kg ha^{-1} and various amounts of manure, inorganic fertilizers and lime. The quantities applied depend on

Table 4. Technologies used for producing groundnut in Tay Ninh Province of southern Vietnam, in the spring season.

Technology component	Traditional practices	Improved practices
Varieties	Ly, Giay, Moket	Ly,Giay, Moket
Growth duration (days)	85-90	85-90
Fertilizers (kg ha^{-1})		
Coco-ash	1000	1500
Urea	54	65
Superphosphate	-	450
Potassium chloride	100	160
Composite fertilizers NPK (16:16:8)	-	100
Lime	500	500
Growth-stimulator (sprays)	-	2
Fungicides		
Seed treatment with Rovral® 3g kg^{-1} seed	-	+
Anvil® to control foliar disease (sprays)	-	+
Insecticides		
Sherpa®, Shergeon®, Methyl parathion (sprays)	4	4

Note: - = not used, + = used.

Table 5. Cultural practices for groundnut in north Vietnam in the spring season.

1. Land preparation
   - Plow — l-2times
   - Harrow — 2-6times
2. Emergence — 85-100%
3. Seedbed
   - Raised beds 1.5-10 m wide for Nghe An Province
   - Raised beds 0.8-1.0 m wide for Ha Bac Province
4. Seed/hill:
   - In Nghe An most farmers use sprouted seeds for sowing (1 seedling/hill)
   - In Ha Bac (1 seed/hill)
5. Seedlings or seed are sown by hand
6. Spacing: 20-30 x 10-15 cm
7. Seed treatment: none
8. Fertilizers kg ha^{-1}:
   - Basal application of 8-10 t of manure + 35 kg P + 200 kg of lime ha^{-1}
   - Top dressing of 30 kg N + 27 kg P ha^{-1} at 2-3 leaf stage
   - 200 kg ha^{-1} of lime at flowering stage
9. Weeding (manual):
   The first at 3-4 leaves/main stem
   The second at 6-7 leaves/main stem
   The third at 10-15 leaves/main stem
10. Hilling up: after peak flowering
11. Irrigation: by furrow method at flowering and pod-filling stage
12. Insecticides: Monitor or methyl parathion 0.2%, when necessary to control insect pests
13. Harvesting: manual
14. Storage: in ceramic pots after air drying
15. Variety: Sen Lai, V79, Sen Nghe An, Bac Giang

the farmers's capacity to invest. Other inputs, such as insecticides, are used singly or in a mixture to control defoliating insect pests and most farmers use fungicides e.g., Rovral® to control damping-off disease, although no disease control was undertaken in the past.

Growth-stimulator is applied by farmers and it increases pod groundnut yield by 13-17%, and weeds are controlled by Ronstra®.

The groundnut crop in the dry seasons (winter and summer) is irrigated from canals or shallow wells by the furrow method (and splashing water on to beds) or by spraying (in case of pumps) using a hose pipe. Details of cultural practices are shown in Tables 5 and 6.

Table 6. Cultural practices for groundnut in South Vietnam in the dry season.

1. Land preparation	
-Plow	1-3 times
-Harrow	2-3 times
2. Emergence	70 - 100%
3. Seed bed: Raised beds	1.0 - 3.0 m wide
4. Spacing:	15-20 x 15-20 cm
5. Plant population: 2-3 seeds/hill = 50 plant/m^2	
6. Fertilizers (kg ha^1)	
- Coco-ash	1500 - 3000 kg
- Composite fertilizers NPK (16:16:8):	100 kg
- Potassium chloride	160-200 kg
- Superphosphate	400-450 kg
- Urea	30-65 kg
- Lime	500 kg
All basal application, except 50% of urea top dressed at 4-5 leaves/main stem and 50% of lime topdressed at flowering	
7. Weeding: (2-3 times by hand)	
1:15-30 DAS	
II: 20-50 DAS	
III: 40-60 DAS	
8. Irrigation is by furrow method (and splashing water on to beds) or by spraying (in case of pumps) using a hose pipe (10-15 days interval)	
9. Insecticides (sprays): Methyl parathion, Sherpa®, Shergeon® to control insect pests. Insecticides are sprayed in the evening or night. The first spray is done at 20 DAS.	
10. Seed treatment: Rovral® 3 g kg^{-1} seed to control damping-off	
11. Herbicides: Ronstra® 1 L ha^{-1} spray one day after sowing	
12. Growth-stimulator: Bayfoland® 0.2%	
- first spray at 20 DAS	
- second spray at 40 DAS	
13. Fungicides: Anvil® (0.4%) to control foliar diseases	
- first spray at 40 DAS	
- second spray at 50-55 DAS	
14. Harvesting by hand, crop is windrowed 0-7 days before stripping	
15. Variety: Ly, Giay, Moket.	

Constraints to Groundnut Production of Vietnam

Details of constraints to groundnut production of Vietnam are given in Table 7. Recently, to alleviate some of these constraints to production, the Vietnam

Table 7. Constraints to groundnut production in the major groundnut-growing provinces of Vietnam.

Constraints	Priority ranking[1]			
	Nghe An	Ha Bac	Tay Ninh	Long An
Socioeconomic				
Lack of cash for input	1	1	1	1
Unstable/low price for crop	2	1	-	3
Lack of drainage system	2	3	-	-
Lack of irrigation water	2	2	3	2
Abiotic				
Poor soil fertility	-	2	-	-
Drought	3	2	-	-
Biotic				
Lack of high-yielding varieties	2	1	1	1
Leaf eaters/other insect pests	2	2	1	1
Soil borne diseases	2	3	2	2
Foliar diseases	3	2	2	2
Yellow leaf diseases	3	-	3	3
Weeds	-	-	2	2

1.1 = high, 2 = intermediate, and 3 = low priority, - = Constraint not identified.

Government has been encouraging groundnut growers to invest in intensive farming by advancing funds to buy fertilizers, insecticides, and fungicides.

Marketing

In Vietnam, groundnut is grown mostly for export (70% of total production) to Singapore, Indonesia, The Philippines, and Malaysia. The Vietnam Government encourages farmers to produce groundnut and sell in the free market. The production is sold to private traders at 65-70% of the consumer's price.

Farmers' Reaction to the Improved Technologies

In the framework of UNDP/FAO RAS/89/040 and ICRISAT/MAFI collaboration, the Asia Grain Legumes On-farm Research (AGLOR) project has been implemented from early 1991 to help Vietnam tackle key constraints to groundnut production in the country. After three years (1991-1993) of on-farm research, new technologies in groundnut production are being applied by farmers and they regularly obtain high yields. This is occurring not only at the project locations but also in neighboring provinces such as Thanh Hoa and Thai Birth, in North Vietnam, where the technologies are being implemented on a large scale over hundreds of hectares.

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The Status of Technologies Used to Achieve High Groundnut Yields in Zimbabwe

G L Hildebrand[1]

Abstract

About 160 000 ha of groundnut is grown in Zimbabwe, mostly by smallholder farmers, and mainly for home consumption. Pod yields are very low, around 0.5 t ha^{-1}. A small area, about 3000 ha, is grown on large commercial farms where high-input technologies have increased average pod yield to 3-4 t ha^{-1}. Established growers achieve yields of 4-6 t ha^{-1}, and a record yield of 9.6 t ha^{-1} was achieved in the early 1970s.

The two production systems are very different. The smallholder crop is grown with low or zero inputs on poor soils in the drier areas of the country, and consists almost entirely of Spanish cultivars. The commercial crop is almost entirely of long-duration Virginia cultivars which are sown with irrigation before the onset of the rains. Early sowing has increased yields considerably, justifying higher input levels. The recent liberalization of the Zimbabwe economy has allowed the development of a market-driven economy which should improve profitability.

The Ministry of Agriculture's Department of Research and Specialist Services was responsible for the development of most of the currently recommended production technology, and technology transfer was done mainly by the Department of Agricultural, Technical and Extension Services.

津巴布韦的花生种植面积约为160000公顷,其中大部分由农民零散种植,而且产品主要用于家庭消费,荚果产量亦很低,仅有0.5吨/公顷. 有小部分面积,约为3000公顷,是由大农场采用高投入技术进行大规模商业化种植,平均荚果产量已达3-4吨/公顷,有的产量已高达4-6吨/公顷,甚至70年代早期曾有过9.6吨/公顷的记录.

两种生产系统差异明显. 零散种植分布于该国的干旱地区,地力差,而且投入很少或根本不投入,所栽种的也几乎都是西班牙型品种. 而商品化种植的几乎都是生育期长的弗吉尼亚型品种,在雨季到来之前灌溉后播种,早播能显著提高荚果产量,也才能使高投入得到回报. 最近,津巴布韦的经济解放,已允许市场经济的发展,这将会提高花生的种植效益.

农业部的专家服务部负责目前多数推荐技术的研究开发,而技术推广主要由农业技术及推广服务部承担.

1. Seed Co-op Company of Zimbabwe, Rattray Arnold Research Station, P O Box CH 142, Chisipite, Harare, Zimbabwe

Hildebrand, G.L. 1996. The status of technologies used to achieve high groundnut yields in Zimbabwe. (In En. Summary in Ch.) Pages 101-114 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C, Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Introduction

Zimbabwe varies in altitude from 400 m to 2000 m above sea-level, and annual rainfall, most of which falls during the summer (Nov to Mar), varies from 300 mm to over 1800 mm. In the main cropping area, from 600-1500 m altitude, rainfall varies from 600-1200 mm, but the rainy season seldom exceeds 130 days. In many areas it is considerably shorter

The total area sown to groundnut in Zimbabwe is of the order of 163 000 ha. There are two main production systems that are very different. A small area (about 3000 ha) is grown with high levels of inputs on farms in the Large Scale Commercial (LSC) farming areas. An important feature of this system is the use of supplementary irrigation to allow long-duration Virginia cultivars to be sown before the onset of the rains.

The remainder of the crop is grown without irrigation, and therefore is restricted to short-duration Spanish and Valencia cultivars. Much of this (about 140 000 ha) is grown as a subsistence crop, by peasant farmers on communally-owned land known as the Communal Farming Areas (CFA), and is grown with little or no inputs. Yields are low and the majority (75%) of the crop is retained for local consumption.

About 20 000 ha is grown on land where farmers have tenure in the Small Scale Commercial (SSC) farming sector, and in Resettlement Areas, where communal area farmers have been allocated land in former LSC areas. In these areas, some inputs are applied and yields are slightly higher. About 30% of production is traded. Area, production, and yield data for the different areas are shown in Tables 1 and 2.

Groundnuts can be grown successfully on a wide range of soil types, but light sandy soils are favored for ease of harvesting. The rainfed crop is grown mainly in the drier areas from 500-900 m altitude, where annual rainfall varies from 300-600 mm. The irrigated crop is grown mainly in the higher altitude (900-1500 m) areas, where the rainfall is higher (600-1200 mm).

Communal area groundnut crops are grown mainly to supplement the staple food, maize, for household food security. No definite rotation patterns are followed, mainly because of farm size, and groundnut sowing usually follows that of maize and any other cash crops that may be grown. In the commercial sector, groundnuts are grown in rotation with maize and tobacco, mainly on the lighter sandy soils. The total crop is marketed through the formal sector, and some is exported to Europe for confectionery purposes.

Table 1. Groundnut production (commercial), in Zimbabwe 1969-1995.

Year	Production (t)	Area (ha)	Yield (t ha^{-1})
1969/70	6520	21420	0.30
1970/71	12590	18190	0.69
1971/72	18160	19240	0.94
1972/73	10180	21150	0.48
1973/74	18150	19820	0.92
1974/75	17350	20570	0.84
1975/76	19520	17760	1.10
1976/77	11230	15280	0.74[2]
1977/78	12740	13400	0.95
1978/79	7540	3240	2.33
1979/80	10680	3840	2.78
1980/81	18800	12910	1.46
1981/82	16380	11920	1.37
1982/83	9150	10710	0.85
1983/84	5000	3000	1.67
1984/85	3200	1500	2.13
1985/86	6600	2200	3.00
1986/87	16350	5100	3.20
1987/88	17750	5500	3.23
1988/89	17250	6000	2.88
1989/90	10120	3250	3.12
1990/91	11200	3500	3.20
1991/92	3000	1500	2.00
1992/93	2200	700	3.14
1993/94	8400	3000	2.80
1994/95[1]	9000	3000	3.00

1. Estimate
2. Irrigated area began increasing about this time.

Production Systems

Supplementary Irrigated Groundnut Production System

In the main cropping area of Zimbabwe, the season length of Virginia groundnuts varies from 150 to 190 days depending on altitude. This precludes the growing of these cultivars under rainfed conditions. However, there is a demand, both overseas and locally, for Virginia groundnuts for confectionery use, as they produce large seed of satisfactory quality.

Early research in Zimbabwe (Metelerkamp 1967) showed that extending the growing season by using irrigation to allow sowing before the onset of the rainy

Table 2. Groundnut production (communal areas), in Zimbabwe, 1969-1995.

Year	Production (t)	Area (ha)	Yield (t ha^{-1})
1969/70	29950	244800	0.12
1970/71	16200	216000	0.08
1971/72	16540	220500	0.08
1972/73	10200	200000	0.05
1973/74	187317	290000	0.65
1974/75	110000	310000	0.35
1975/76	172900	325000	0.53
1976/77	129680	275000	0.47
1977/78	100860	200000	0.50
1978/79	100000	240000	0.33
1979/80	67000	175000	0.38
1980/81	100000	300000	0.33
1981/82	95000	240000	0.40
1982/83	22500	180000	0.12
1983/84	20000	140000	0.14
1984/85	66500	131000	0.51
1985/86	54100	135500	0.40
1986/87	62700	197200	0.32
1987/88	117500	219300	0.54
1988/89	83600	184500	0.45
1989/90	108690	207900	0.52
1990/91	95140	214800	0.44
1991/92	31030	167600	0.18
1992/93	53350	113000	0.47
1993/94	58700	131700	0.45
1994/951	43300	151500	0.29

1. Estimate.
Source: Ministry of Agriculture, Crop Forecast Committee.

season, and supplementing rainfall thereafter, resulted in high yields and enhanced confectionery quality The high levels of radiation and temperature during October and November are believed to contribute markedly to the high yields obtained (Williams et al. 1978). The yields obtained showed potential for greatly improved profitability and the desirability of raising the level of input use.

This technology was evaluated on-farm in the 1971/72 growing season, and, with further refinement, was adopted by a number of farmers in the 1972/73 growing season. In 1973/74 and 1974/75 pod yields of 9600 kg ha^{-1} were achieved by a farmer growing the cultivar Makulu Red (Smartt 1994). These were exceptional yields, however, and have not been achieved since.

State-controlled groundnut prices have increased, since 1980, from Z$420 to 2500, but with high inflation rates and devaluation, this equates, in US$ terms, to a decline from $490 to $300. Total variable cost of production meanwhile, has increased from Z$800 ha^{-1} (US$860) to Z$6300 (US$750), but has remained relatively static in US$ terms. As a result, commercial sowings have remained at a low level Recent liberalization of the economy of Zimbabwe has led to the de-control of a number of agricultural commodities, and a renewed interest in groundnut production, mainly for the export confectionery market.

Varieties

Long-duration cultivars have been grown in Zimbabwe since the 1950s, but yields were generally low. Only with the advent of irrigation did the growing of long-duration cultivars become feasible.

Makulu Red, developed in Zambia (Smartt 1978), was first grown in Zimbabwe in 1960 and replaced Virginia Bunch. Although still grown in small quantity, Makulu Red was superseded by the release of Egret in 1974 (Hildebrand 1975), and Flamingo, a red-seeded cultivar with improved confectionery quality, in 1982 (Hildebrand 1983a). Flamingo is the main cultivar grown since Heron, released in 1992 (Z. A. Chiteka, University of Zimbabwe, Harare. Personal communication), has not proved very popular with European buyers and processors.

The Seed Co-op Company of Zimbabwe has a bipartite agreement with the Government of Zimbabwe to multiply and commercialize groundnut cultivars developed by the National Agricultural Research System (NARS). Flamingo, developed by the NARS breeding program, is currently included in the Seed Co-op certified seed scheme and Foundation A, Foundation B, and Certified seed is grown on contract by commercial farmers. Seed is available from the Seed Co-op or its appointed agents.

Inputs

Fertilizers. Groundnuts usually respond better to residual soil fertility following a well fertilized crop than to directly applied fertilizer. On commercial farms groundnuts are usually rotated with well fertilized crops such as maize and tobacco and therefore, only a basal dressing of fertilizer is recommended. Gypsum is recommended in two applications of 200 kg ha^{-1} each, applied at 8 and 12 weeks after sowing.

Although past research has shown small and inconsistent responses to the use of *Bradyrhizobium* inoculant, it is manufactured locally and supplied at low cost, and therefore is recommended as an inexpensive insurance.

Herbicides. Use of pre- and postemergence herbicides, to control grass and broadleaf weeds, is common practice.

Pesticides. The two most important foliar diseases of irrigated crops, early leaf spot *(Cercospora arachidicola)* and web blotch *(Phoma arachidicola),* are responsible for yield losses of 30-50%. Current recommendations are to apply chlorothalonil

(6-7 applications at 7-14 day intervals of Bravo 500®, at 2.0-2.5 L ha^{-1} in 300 L ha^{-1} of water), or tebuconazole (3-5 applications at 10-14 day intervals of Folicur® 250 EC, at 500 ml ha^{-1} in 300-500 L ha^{-1} of water).

Recent research has confirmed results obtained in Malawi and Zambia, that fewer strategically timed applications are economically feasible. Cole (1994) showed that a reduction in the number of fungicide applications, from the previously recommended 6, to 3 resulted in relatively small reductions in yield, but reduced input costs considerably Occasionally, grey mold *(Botrytis cinerea)* may occur, particularly in wet seasons, and this may be controlled with tebuconazole or by spot sprays of benomyl (Benlate® 50WP, at 10 g L^{-1}).

Insects are of relatively minor importance, but aphids and the sap-sucking groundnut hopper, Hilda *(Hilda patruelis),* are the most common. Early sowing and use of optimum plant density have resulted in very infrequent appearance of rosette virus in commercial crops. *Hilda patruelis* is more common, particularly in dry seasons, and causes considerable damage to crops, particularly on the edges of fields. Hilda is very difficult to control, but band-spraying a mixture of contact (carbaryl) and systemic (monocrotophos) insecticides may assist in preventing invasion.

Availability of credit Credit is available to commercial farmers, but mainly from commercial banks, where current lending rates are in excess of 30%, and the Agricultural Finance Corporation (AFC), which charges lower interest rates. More recently, commercial banks and commodity organizations, principally those commodities that have export potential, have attracted off-shore finance, in the form of pre-shipment payments, at much lower rates of interest.

Mechanization. Typically, commercial groundnut farms are 10-50 ha in size, and the larger farms are mechanized. However, because of high unemployment, and relatively cheap labor, a combination of hand and mechanized harvesting is practiced in many cases. Artificial drying of groundnuts is widely practiced.

Rotations and cropping patterns

Groundnuts are grown in rotation with maize and tobacco, mainly on the lighter sandy soils which are preferable for tobacco and are favored for groundnuts for ease of harvesting. Groundnut is an important rotation crop as it is one of the few legumes suitable for sandy soils. Tolerance to damage by nematodes, mainly *Meloidogyne javanica,* is an important factor in the tobacco rotation.

Management practices

Recommended cultural practices, some of which were established prior to the adoption of irrigated production, include the following (COPA 1988):

Land preparation. Standard land preparation measures are carried out but there is a growing tendency among commercial farmers to practice minimum tillage, particularly where winter wheat is grown in rotation with summer maize and soybean crops. Basal dressings of compound fertilizers are applied at land preparation.

Sowing date. Recommended sowing dates are:

Altitude (m)	Below 900	900-1200	1200-1500	Above 1500
Sowing date	8-23 Oct	1-15 Oct	23 Sep-7 Oct	15-30 Sep

Seeding rates. Early research showed optimum plant density for long-duration groundnuts to be 125 000-150 000 plants ha"[1], and recommended row spacings are 35-45 cm, with in-row spacing of 10-15 cm. Sowing is usually done by machine on a bed or 'tramline' system to allow for tractor access for chemical application and for harvesting. Beds are sown with 3 rows spaced 45 cm, or 4 rows spaced 35 cm apart between the tractor wheeltracks. A seeding rate of 100 kg ha^{-1} is required for currently available cultivars. Seed dressing with a fungicide is strongly recommended, and is supplied with purchased seed.

Weed control. Most crops are treated with herbicide, but occasionally, mechanical or hand weeding is practiced before pegging. Thereafter hand-pulling is recommended to minimize damage to pegs and to allow undisturbed peg penetration.

Harvesting. Depending on size, commercial crops may be harvested completely mechanically using lifters and combines, or by using a combination of mechanical lifting with stationary machine pickers or hand picking. After lifting, the plants are allowed to wilt in windrows for 2 to 3 days before picking. In relatively few cases the plants are heaped for 2-3 weeks before picking, but most crops are picked after wilting and dried mechanically by passing heated air through bin dryers or through tunnels constructed of bags.

Groundnuts are transported to market soon after drying, and except for seed requirements which may be retained for the following crop, little storage is necessary on the farm. Shelling and processing are carried out at centralized depots and not on farms.

Constraints

The most important constraints include:

- cost of credit,
- cost of inputs such as seed, fertilizer, and pesticides,
- unattractive producer prices, and
- shortage of irrigation water.

Marketing

Until the 1992 marketing year, groundnut and a number of other commodities were designated controlled products. Commercial growers were required by law to sell their groundnut crop to the parastatal Grain Marketing Board (GMB) and were paid state-controlled prices. Imbalances between the prices paid for different crops frequently resulted in swings from one crop to another as a result of prices not keeping abreast of market trends. Groundnut prices lagged far behind, and for many years groundnuts were considered unprofitable to grow.

With economic liberalization resulting from structural adjustment programs and the need to reduce food subsidies, the State de-controlled groundnuts and other crops, allowing them to be marketed freely. This market-driven economy has resulted in groundnut prices increasing, mainly as a result of better export prices arising from independent marketing, and groundnuts are now considered to be a more profitable crop.

In 1994, a co-operative of commercial groundnut producers, the Zimbabwe Peanut Growers Go-operative, entered into a joint venture with the Seed Co-op Company of Zimbabwe to establish Reapers (Pvt) Ltd. Reapers has installed a shelling plant and is contracting growers to supply groundnuts which are shelled and sorted, and those meeting export standards are exported to the United Kingdom for confectionery use. The remainder are exported or sold locally for edible, crushing, or seed purposes. Prices paid to the farmer, established each year, are based on a projection of possible earnings from the sale of the various grades.

Rainfed groundnut production system

The majority of groundnut production is in the CFA, on state land which is allocated to farmers by District Councils. In these areas farmers do not have land tenure. In the SSC areas farmers do have tenure in the form of long-term leases which are controlled by the Rural State Land Office. Farmers allocated land in the resettlement areas are also issued long-term leases by the Department of Rural Development who are responsible for ensuring that land is properly used. Any holder not meeting a minimum standard of land use and conservation risks cancellation of this lease.

Spanish groundnut cultivars which have a duration of 100-130 days depending on altitude, are grown on a large part of the rainfed groundnut area. Some Valencia cultivars are grown in the cooler, wetter areas. Only about 25% of the production from this sector is traded. The remainder is retained for local consumption.

Varieties

Short-duration cultivars have been grown in Zimbabwe for many years, and a range of local landraces are still grown. However, a number of released cultivars have been grown over the past 40 years. Natal Common, a cultivar grown widely in South Africa, has been grown in Zimbabwe for many years (Meikle 1965). A number of Spanish cultivars have been released over the past 20 years but few have reached the farmer because of difficulties in seed multiplication. Plover was released in 1982 (Hildebrand 1983b), and Falcon in 1990 (Z. A. Chiteka, University of Zimbabwe, Harare. Personal communication). Neither is yet available in sufficient quantity, but the Seed Co-op is multiplying both. Some Falcon seed is likely to be available for supply to the government for its drought relief seed pack program in 1995/96.

Inputs

Low and erratic rainfall in this production system results in low yields and poor viability, and farmers often cannot afford to apply inputs (Mudimu 1985). Cost of production is also increased considerably by cost of transport. For example, transport charges on a 50 kg bag of gypsum may double its price to some farmers. Seed is also a major cost in groundnut production.

Fertilizer. Use is minimal and is restricted almost exclusively to the SSC farmers. Gypsum is sometimes applied, but *Bradyhizobium* inoculant is seldom used.

Herbicides, These are seldom used. Weeding is done almost exclusively by hand.

Pesticides. Aphids and termites do cause damage in the rainfed crop, particularly in dry seasons, but insecticides are seldom used except for occasional aphid control.

Early leaf spot is a major constraint in these areas, but web blotch is not serious. Earlier research showed that chemical disease control was not viable at yield levels achieved under rainfed conditions. However, yields achieved with reduced fungicide application (Cole 1994) may improve the feasibility of fungicide use under these conditions.

Availability of credit

Credit is very difficult for CFA farmers to obtain because of the absence of collateral through lack of land tenure. However the AFC does provide some short-term loans. In certain circumstances, the AFC has experienced great difficulty in ensuring repayment of loans, and has recently favored group loans, where peer pressure within farmer groups has ensured greater loan recovery. Medium-term loans are also available to individual farmers in this sector based on the normal conditions of collateral security.

SSC and resettlement area farmers have greater access to credit by virtue of land tenure, and individuals and groups make use of AFC, and even commercial bank loans. More recently, commodity loan schemes have been introduced where individuals may apply for loans for specific commodities. At present, the tobacco and cotton commodities make facilities available for growers, and it is likely that schemes may become operational for fertilizer and seed. These loans are usually guaranteed by the Zimbabwe Farmers Union (ZFU), which represents the interests of all noncommercial farmers.

Mechanization

Average farm size in the SSC areas is 1.3 ha, and land preparation is usually by tractor or ox-drawn implements. Some tractors are owned by farmers, and some offer contract tillage. SSC farmers close to LSC areas often benefit from assistance from their LSC counterparts.

In the CFA and resettlement areas, where farm size is usually smaller, land preparation is done largely by oxen or donkeys (it is estimated that 60% of households in this sector own draught animals), or by contract tractor plowing. Soon after independence, State-run contract plowing schemes were instituted, but since revenues are returned to Treasury, lack of finance for renewal, spares, and maintenance of equipment, has affected efficiency. It is hoped that donor finance may be attracted to provide for a revolving fund to alleviate this constraint. Contract plowing co-operatives are also being formed, and these supplement state efforts.

Harvesting is done by hand, and after initial wilting, groundnuts are cured in heaps or on racks for 3-5 weeks or more before hand picking.

Rotations and cropping patterns

No definite rotation patterns are followed, mainly because of size of holdings, and groundnuts are often sown on the same land for a number of years.

Management practices

Recommended cultural practices generally follow those for the commercial crop, but differ in the following respects:

Sowing date. It is recommended that sowing is done as soon as possible after the first planting rains, but lack of labor, and crop sowing sequence and preference, often result in groundnuts being sown about three weeks after the onset of the rains.

Seeding rates. Optimum plant density for short-duration groundnuts is double that of long-duration cultivars, and 250 000-300 000 plants ha^{-1} are recommended. However, plant densities achieved are often considerably below these optima and may contribute to reduced yields and increased risk of rosette virus incidence. Seed is usually retained from the previous season and may have poor viability Very often it is not dressed with a seed protectant.

Constraints

Among the numerous constraints (Shumba 1983, Mudimu 1985), the more important are:

- unattractive producer price,
- lack of credit,
- non-availability of seed,
- shortage of land,

- low soil fertility,
- shortage of labor and draught power,
- lack of transport,
- cost of inputs, and
- low and unreliable rainfall

Marketing

CFA farmers were previously not subjected to the same marketing restrictions as LSC farmers. Informal trading within and between CFAs was permitted, but deliveries were also made to the GMB through numerous traders who were appointed agents. However, prices offered by traders were not always fair, and farmers were reluctant to market in the formal sector. The recent de-control of groundnut trading is likely to have a beneficial effect on smallholder production as well.

Technology development

Research and development activities in Zimbabwe have been limited, but a number of agencies have played an important role over the past thirty years.

Research

Governmental Organizations

- The Ministry of Agriculture's Department of Research and Specialist Services has, since the early 1960s, conducted research in germplasm enhancement, physiology, agronomy, plant protection, soil fertility, and aflatoxin, and the Agricultural Engineering Institute conducted research on mechanization of harvesting and drying (Hildebrand 1980).

Nongovernmental Organizations

In recent years other organizations have played a role.

- The Crop Science Department of the University of Zimbabwe has, over a number of years, conducted research on groundnut disease control, leading to the refinement of current disease control recommendations.
- The Agricultural Research Trust, supported by the Commercial Farmers Union (CFU), has conducted research on irrigation water use efficiency and crop drying, and provides testing facilities for governmental and other organizations.
- The Seed Co-op Company of Zimbabwe, in addition to being the main supplier of groundnut seed, has recently initiated a groundnut breeding program.
- Commercial chemical and fertilizer companies have conducted research on fertilizer, pesticide, and herbicide use, and have evaluated pesticides for registration.

International Agricultural Research Centers (IARCs)

ICRISAT activities in the region, since the establishment of the SADC/ICRISAT Groundnut Project in Malawi in 1982, have benefitted Zimbabwe greatly in terms of:

- increased availability of germplasm. No ICRISAT germplasm has yet been released in Zimbabwe, but current activities show potential for confectionery quality, disease resistance, and drought tolerance/avoidance.
- Dissemination of information through workshops, monitoring tours, and publications.
- Inter-NARS interaction and collaboration.

Technology Transfer

Governmental Organizations

- The Ministry of Agriculture's Department of Agricultural Technical and Extension Services has played an important part in technology transfer, particularly in the smallholder sector in recent years.

Nongovernmental Organizations

- The Commercial Oilseeds Producers' Association (COPA), part of the Commercial Farmers Union, represents the interests of all LSC soybean, groundnut, and sunflower growers, and provides an advisory service to their members. This includes representation in policy matters as well as organizing field days and demonstrations, and publication of the Oilseeds Handbook.
- Fertilizer and chemical companies provide an advisory service to users of their products.
- Banks and other financial institutions have developed agri-business departments which advise clients on credit, economic, and financial matters.

Research Evaluation and Impact Assessment

Very little evaluation of technology adoption has been conducted by governmental or nongovernmental organizations, but IARCs, notably ICRISAT, have recently put greater emphasis on research evaluation in collaboration with NARS in the region. However, it is relatively easy to monitor yield trends in small farms such as the LSC groundnut crop, and production statistics have substantiated yield increases.

Publications

A number of popular and technical publications, handbooks, newsletters, and advisory leaflets that cover aspects of groundnut production are available. These include:

- The Zimbabwe Agricultural Journal (ISSN 0035-4686), a technical journal published six times each year by the Ministry of Agriculture.
- The Zimbabwe Journal of Agricultural Research (ISSN 00354813)/ the designated journal of the Southern African Centre for Cooperation in Agricultural Research and Training (SACCAR), published twice yearly by the Ministry of Agriculture in cooperation with SACCAR.
- The Farmer, a farming news magazine, published weekly by Modern Farming Publications' Trust in conjunction with the CFU. It is directed mainly at LSC farmers, and is distributed to all registered members of the CFU. It is also available at newsagents.
- The Zimbabwean Farmer (Murimi/Umlimi), published monthly by the Zimbabwe Farmers Union is a farming news magazine for the smallholder farming sector.
- The Oilseeds Handbook, an advisory handbook covering soybean, groundnut, and sunflower, published by COPA primarily for LSC oilseeds growers, but available to any interested persons at nominal cost.
- The Oilseeds Newsletter published by COPA is distributed to all COPA members and other persons interested in oilseed development in Zimbabwe, and contains topical information and news on oilseed cultivation, marketing, utilization, and relevant Association matters.

Future Technology Needs

An important feature of Zimbabwean agriculture during the last decade has been the frequent occurrence of subnormal rainy seasons. The 1994/95 growing season was one of the driest of 8 subnormal seasons since 1982/83, and lack of stored irrigation water has serious implications for winter wheat production, and for irrigated crops in 1995/96. Production in the rainfed production system has also suffered as a result of these subnormal seasons.

If such a trend persists, it will be imperative to develop technologies for more efficient use of irrigation water in the irrigation production system, and for drought tolerance or avoidance in the rainfed production system. In addition, as a result of declining productivity and escalating costs, technologies are required to facilitate more efficient use of inputs.

High-yielding ICRISAT confectionery genotypes, currently being evaluated, show potential for improved profitability of the irrigated crop, while short-duration and drought-tolerant ICRISAT genotypes give hope for improved productivity and sustainability in the rainfed production system.

Areas requiring more research effort, in particular, are the efficient use of irrigation water and the reduced use of crop protection chemicals, not only to reduce costs, but also to reduce detrimental impacts on the environment.

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Thematic Papers

Maximizing Groundnut Yields

C Johansen and R C Nageswara Rao[1]

Abstract

The global mean dry pod yield of groundnut is around 1 t ha^{-1} but yields of up to 9 t ha^{-1} have been reported. Thus, globally there is a substantial yield gap between yields realized on farmer's fields and potential yield. It is therefore recommended that the bulk of research efforts concentrate on closing this gap, through the various genetic and management options actually or potentially available. Research aimed at breaking already high yield-ceilings would seem less urgent. Such research would comprise genetic alteration of the crop canopy and physiological processes to make better use of prevailing radiation, temperature, and CO_2 levels. However, current knowledge is sufficient to consider these factors also as 'constraints' (to higher yields). This particularly applies to temperature for which there are both genetic (e.g., tolerance to extreme temperatures) and management (e.g., polythene mulching for low temperature) options that can increase crop adaptation. For systematic tackling of the yield gap, and probing of yield ceilings, it is suggested that an ideotype approach be followed for groundnut whereby desirable putative traits are designed, searched for in the germplasm, and genetically incorporated. Possibilities for using this approach have recently been enhanced by advances in plant and crop modeling techniques, and the ability to transfer genes between species.

虽然已有报道指出，花生荚果公顷产量可高达9吨，从全球情况看，平均只有1吨左右。这表明在农田中的现实产量与产量潜力间的差距是相当大的。所以应致力于利用现有和潜在的各种遗传和管理手段来减少这一差距。创高产记录研究似乎不那么迫切了。这种研究应包括对作物冠层及生理过程进行遗传改造以充分利用现有光、温及CO_2资源。然而现有知识足以认定这些因子同时也是产量的制约因素。就温度而言，尤其如此。遗传的（如对极限温度耐受性）和管理的（如低温下覆膜栽培）手段均可用以提高作物的适应性。为系统地减少产量差距，探查产量高限，建议花生上应用理想株型的方法设计出良好的推断性状，就此发掘种质资源并最终实现遗传渗入。近年植物和作物模型技术和物种间基因转移技术的研究进展使这一方法应用的可能性大大提高了。

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Introduction

Recent economic assessments of global groundnut production and trade (Fletcher et al. 1992, Florkowski 1994) indicate generally upward trends. This is despite significant declines in production and vegetable oil exports from Africa over the previous two decades, and a gradual substitution of groundnut by such vegetable oils as rape seed and sunflower which are considered to have better properties with respect to human health. However, throughout the world there have been significant increases in consumption of groundnut as a food (Fletcher et al. 1992).

Options for meeting this increasing demand for groundnut differ between regions. In Africa, there is considerable scope for area expansion if only to recover areas lost over recent decades. In Asia, however, as scope for area expansion of arable land in general is limited (Penning de Vries et al. 1995), increasing yields in traditional groundnut-growing areas appears to be the only viable option. Of course, where there is scope for area expansion, a stimulus to groundnut farmers over a wider area would be some assurance that they can achieve higher and more stable yields than previously obtained.

This paper discusses a conceptual framework for increasing groundnut yields in a particular region. Approaches to closing the yield gap between realized and potential yields, and breaching yield ceilings are examined, particularly in the light of recent advances in crop modeling and molecular biology. However, in addition to achieving high pod yields, the long-term sustainability of cropping systems in which groundnut is a component needs to be considered. Thus maximization of N_2-fixation also assumes increasing importance.

The Yield Gap

In the major groundnut-producing countries average yields for the 1980s ranged from 0.7 to 2.8 t ha^{-1} with a world average of around 1 t ha^{-1} (Table 1). However, in Shandong Province of China, dry pod yields of 11.2 t ha^{-1} in 0.1 ha plots and 9.6 t ha^{-1} in 14 ha plots have been reported (Sun Yanhao and Wang Caibin 1990). In Zimbabwe, Hildebrand (1980) also reported a yield of 9.6 t ha^{-1}. At ICRISAT Asia Center in peninsular India, yields of up to 7 t ha^{-1} have been obtained in small plots and up to 5 t ha^{-1} on large plots (ICRISAT 1991). Such values can be considered as representative of the yield potential of groundnut for defined agroecological zones.

Yield potential may be defined as the *maximum yield obtainable by the best genotypes available in a specified agroclimatic environment when the known biotic and abiotic constraints are overcome.* The agroclimatic environment is specified by the ambient radiation, temperature, and carbon dioxide (CO_2) regimes. In the case of groundnut, however, where pod formation occurs underground, soil physical characteristics should also be considered as a limit to yield potential (Wright 1989,

Table 1. Average annual production, area, and dry pod yields of groundnut in the major producing countries during the 1980s.

Country/Region	Production ('000 t)	Area harvested ('000 ha)	Yield (t ha^{-1})
India	6432.7	7362.8	0.87
China	4918.7	2731.2	1.78
USA	1672.6	602.2	2.78
Indonesia	780.2	528.3	1.48
Senegal	740.0	903.0	0.83
Myanmar	549.8	577.2	0.95
Sudan	468.7	689.0	0.69
Nigeria	442.0	625.9	0.72
Zaire	366.1	517.2	0.71
Argentina	338.2	168.0	2.01
Others	3180.8	3628.2	0.85
World	-	-	1.08

1. Source: Fletcher et al. 1992.

Nageswara Rao et al. 1992). Abiotic factors such as soil moisture and nutrient availability are considered as known constraints which can be alleviated, and thus are not included as limits to yield potential but rather as factors affecting the yield gap.

From Figure 1, it is apparent that the yield gap, the difference between yields realized by farmers and potential yield, is large, usually greater than 5 t ha^{-1}, for the major producing countries or regions. This implies considerable scope for increasing yields by identifying and addressing the biotic and abiotic stress factors responsible for this gap.

Alleviating Constraints

In developing and implementing the groundnut research agenda for the ICRISAT Medium-Term Plan, 1994-98, ICRISAT groundnut scientists undertook a global constraint analysis for this crop (ICRISAT 1992). This exercise included:

- estimation of average annual yield losses caused by the major stresses across groundnut growing regions;
- estimation of to what extent a focused and intensive research effort could alleviate a given constraint, giving due consideration to expected research lags and the probability of success of a research endeavor;
- calculation of benefit:cost ratios for returns on research investment for each identified constraint, based on estimates of potential adoption of the technology; and

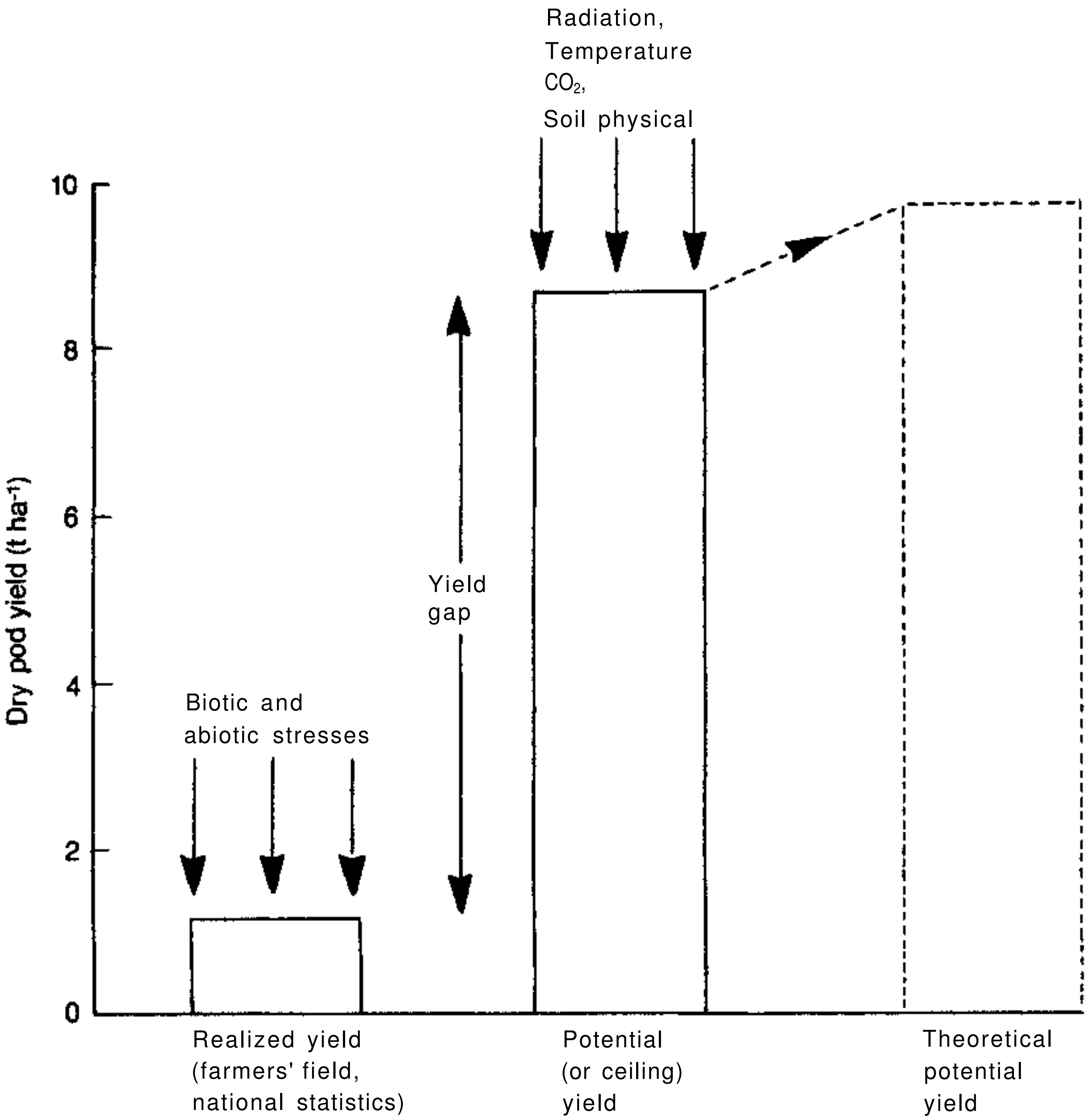

Figure 1. Representation of realized and potential yields and their relationships.

- weighing such ratios with indices accounting for relative poverty of target regions, equity, spillover effects of research (internationality), and considerations of sustainability of production systems.

As the ICRISAT geographic mandate is the semi-arid tropics (SAT), this analysis was primarily directed towards Africa and South and Southeast Asia. Table 2 indicates the ranking of the groundnut constraint themes, with their benefit:cost ratio, among the 92 research themes chosen for the 1994-98 ICRISAT global research portfolio.

It is suggested that this approach would be useful when applied on a more focused scale (e.g., at the level of a country, or a region within a country) to prioritize research endeavors that would best address the existing yield gap. A

Table 2. Ranking of groundnut research themes in the ICRISAT Medium Term Plan, 1994-8.

Theme	Rank[1]	Benefit:cost ratio for projected research
Rust disease	6	47.9
Aflatoxin - genetic improvement options	7	23.1
Late leaf spot disease	8	12.4
Aflatoxin - management options	9	6.4
Early leaf spot disease	15	4.4
Raising yield potential	17	12.3
Enhancing drought resistance	19	5.2
Bud necrosis virus	21	1.2
Leaf miner - genetic improvement	26	6.0
Leaf miner - management options	28	4.5
Spodoptera	30	0.9
Peanut clump virus	31	4.9
Rosette virus	32	8.6
Millipedes	36	8.0
Nematodes (also for chickpea and pigeonpea)	41	5.9
Termites	42	2.4
White grubs	45	1.6
Peanut mottle virus	57	3.5
Adaptation in southern Africa	60	33.9
Peanut stripe virus	62	4.3

1. Ranking of a particular groundnut research theme among a total of 92 themes within the ICRISAT mandate (commodity mandate for groundnut, sorghum, pearl millet, finger millet, chickpea, and pigeonpea and geographical mandate for the semi-arid tropics).
Source: ICRISAT (1992).

necessary prerequisite to attempting this is a comprehensive survey for constraint diagnosis and yield loss assessment. Use of geographic information systems (GIS) technology to map constraints and yield losses of target regions considerably aids this research prioritization process.

Another important consideration in this analysis is deciding the appropriate methodology to follow in tackling identified constraints, as this will decide research lags, probability of success, and research investment costs. A primary consideration is whether the constraint can best be tackled by genetic means such as increasing host-plant resistance to a stress, or by management means, such as application of agricultural chemicals. As indicated in Table 2, prospects for tackling the major constraints contributing to the yield gap in groundnut for Africa and South and Southeast Asia appear promising, at least in terms of return on research investment.

Breaching Yield Ceilings

As defined earlier, yield ceilings are set by generally unspecified environmental factors, such as temperature and radiation regimes (Fig. 1). However, it is possible to identify the factor or factors most likely to be constraining yield below a certain upper limit (yield potential). Therefore, such factors can also be considered as constraints, and addressed in the same way as constraints contributing to the yield gap. To breach yield ceilings then, the challenge is to identify the major constraining factor, or factors, and devise ways of circumventing that limitation. This can be achieved by either of two pathways. One is favorable modification of the limiting factor by management means. Examples include alleviation of low temperature stress by polythene mulching or adjustment of planting date to better utilize ambient temperature and radiation. Another pathway is genetic alteration of the plant to make better use of ambient environmental conditions. Identification of genotypes more tolerant to low temperature and alteration of crop canopy characteristics to improve light use efficiency are examples.

Despite a large yield gap, and possible stress alleviation measures that can be taken to close it, it has been argued that a focus on breaching yield ceilings is also relevant in situations where biotic and abiotic stresses limit yield to, say, around the 1 t ha^{-1} level. The argument is that an increase in yield potential in a 'non-limiting' environment (the 'theoretical potential yield' of Fig. 1) will reflect in a proportional yield increase in an environment constrained by recognized biotic or abiotic stresses. This is represented in Figure 2 by the 'high-yielding, stress-resistant' response compared with the response of the 'standard cultivar'. However, it has been the experience in most crops that crossover effects occur, i.e., a change in genotypic ranking at different levels of stress (Rosielle and Hamblin 1981). This effect is also depicted in Figure 2, where a relatively stress-resistant genotype does not fare well in favorable environments and a genotype with high-yield potential under favorable environmental conditions fares poorly in stress environments. The relationship between yield potential and genotypic resistance to drought stress in groundnut is generally negative, but the degree of relationship varies depending on the timing, intensity, and duration of the stress (Nageswara Rao et al. 1989). Strong negative relationships between yield potential and genotypic resistance to stress mean that drought resistance traits and yield potential are difficult to combine in a breeding program. Where this relationship is weak, such as the case of recovery from early and mid-season drought in groundnut, there is greater scope for combining drought resistance with yield potential.

In genotypic comparisons at different stress levels, the ideal response, as indicated in the upper response line of Figure 2, is rarely found. This may be attributed to a need of stress-resistant genotypes to divert energy to overcome a stress, to the detriment of yield potential in the absence of stress. An example

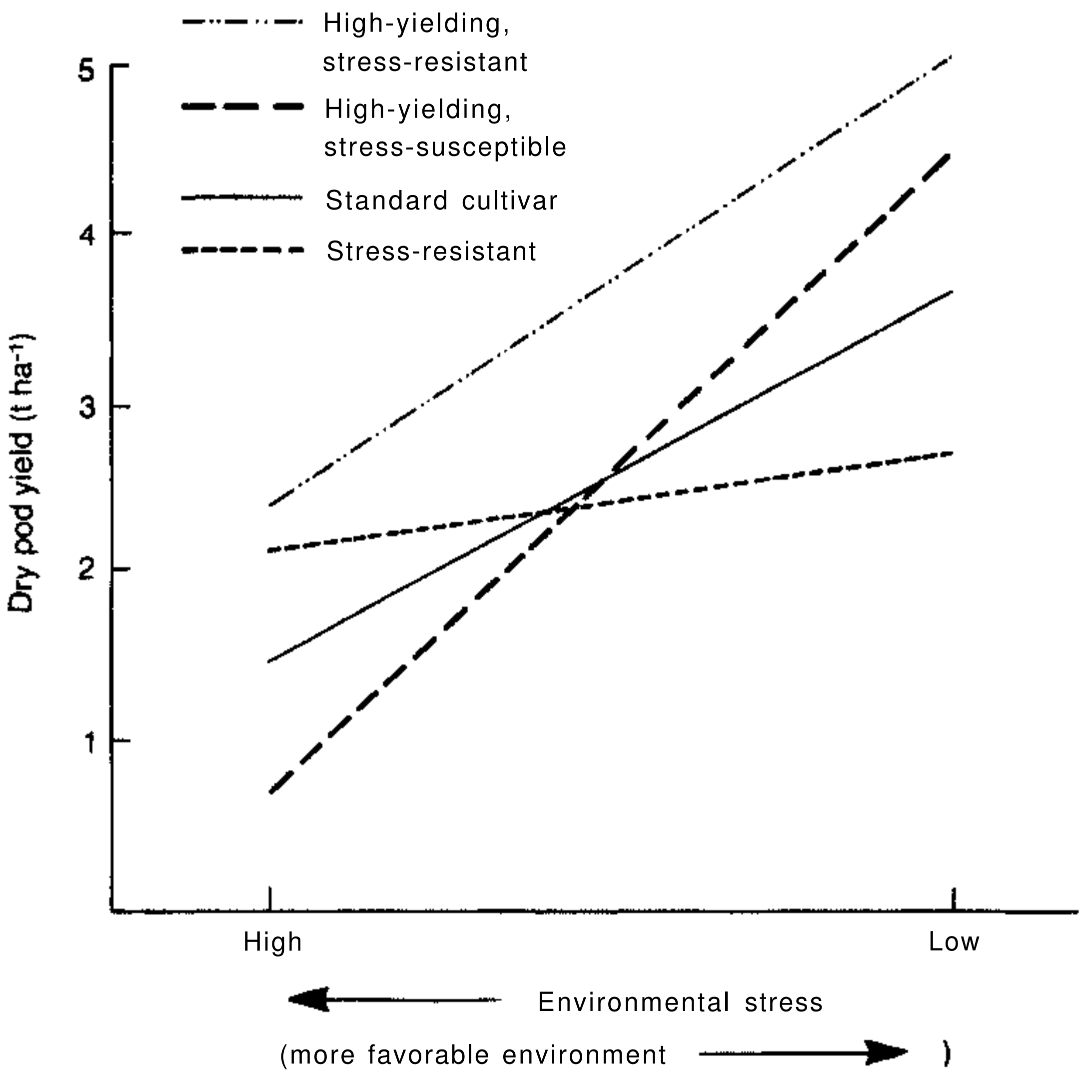

Figure 2. Representation of contrasting genotypic responses to environmental stress.

would be inherently greater partitioning of photosynthates to roots, rather than shoots, which would confer yield advantages to such genotypes in water- or nutrient-limited environments; but greater partitioning to roots would be a disadvantage in environments where water and/or nutrients are not limiting. However, there are exceptions to this apparent nexus, to which physiological reasons can be attributed. One such example is the case of hybrid pigeonpea, which yields relatively better than pigeonpea varieties in both drought-stressed and well-watered environments (Saxena et al. 1992). In this case hybrid vigor allows earlier formation of a larger root system with which to capture scarce available soil water (ASW) in a drought environment as well as faster above-ground growth, with more efficient use of light, when ASW is not limiting.

The yield potential theme mentioned in Table 2 includes possibilities of improving yield in stress environments by making better use of environmental factors likely to be constraining yield potential (see Fig. 1). It also accounts for yield advances that can be made by the synergistic effects of combining, by plant breeding, resistances to stresses that can contribute to reducing the yield gap.

A Systematic Approach

Whether aiming to close the yield gap or to breach yield ceilings we recommend that an ideotype approach be followed. Originally, the ideotype concept was restricted to essentially morphological ideotypes, such as a modified crop canopy structure to increase radiation use efficiency, following the pioneering work of Donald (1968). However, practical implementation of this more directed breeding approach has been difficult for a number of reasons, such as interrelationships among traits (compensation, pleiotropy, etc.), lack of the desired genetic variants, and problems of breeding for multiple traits (Rasmusson 1991, Marshall 1991).

However, we prefer a broader definition of the ideotype concept in the form of 'functional ideotypes'. This can include specification of the major morphological, phenological, physiological, and biochemical traits likely to improve yield and quality in a specified target environment (Saxena and Johansen 1990). Our approach to increasing yield potential, assuming radiation is the prime limiting factor, is based on use of simple physiological models. Pod yield under non-limiting conditions (Y_p) can be defined as a function of radiation (R), radiation use efficiency (RUE) and harvest index (HI), that is:

$$Y_p = R \times RUE \times HI$$

Genotypic improvement is then focused on modifying model parameters favorably, through a functional ideotype approach. For example, selection for narrow leaves could enhance yield by increasing R, by allowing more light into the canopy to permit greater canopy photosynthesis (Nageswara Rao et al. 1994). Selection for RUE is complex, but recent studies have indicated that RUE under non-limiting conditions is strongly correlated with specific leaf area (leaf area per unit dry weight of leaf). Thus selecting for specific traits that enhance model parameters, and combining them, should lead to greater Y_P .

Despite further complicating the genetic enhancement process by attempting to assemble an even wider range of traits, such an approach is becoming increasingly viable for three main reasons. Firstly, knowledge of the physiology of component processes and their interactions is increasing rapidly. Secondly, the recent advances in molecular biology have made it possible to identify genes associated with particular agronomically useful traits. Further, there is a rapidly evolving ability to isolate and transfer these genes from secondary gene pools. Thirdly, our ability to model crops, plants and processes mathematically has expanded recently This ranges from the relatively complex crop simulation models, such as PNUTGRO (Boote et al 1992) to simpler analytical models designed to improve the efficiency of breeding efforts (Williams 1992). Such models permit better a priori analysis of effects of incorporating a trait, taking into consideration the various compensatory and interactive effects that could dilute the originally purported ultimate benefit of the trait. This saves resources in experimentation aimed at confirming a trait's value and guides its most efficient incorporation, if it is concluded that it is worthwhile to do so.

It needs to be emphasized, however, that such functional ideotypes should be tailored for a predefined target environment. As an example, traits applicable to a groundnut ideotype targeted to a rainfed, relatively short-season, long-day environment prone to intermittent drought stress would include: rapid rate of emergence, early growth vigor (shoots and roots), earliness (of flowering), insensitivity to photoperiod, high RUE (narrow leaves), high water-use-efficiency (thick leaves), rapid rate of dry matter partitioning to pods, and minimal thermal time to physiological maturity In this way we would expect to develop quite different ideotypes for contrasting environments.

Groundnut as a Component of Sustainable Cropping Systems

Maximization of yield of groundnut should not be considered in isolation from the long-term sustainability of the cropping system in which it is grown. Rather, the aim should be to optimize yield of the entire cropping system in a sustainable manner. As a legume, there is scope to improve the nitrogen-fixation capacity of groundnut so that the crop not only meets its own N requirements through N_2-fixation but also contributes positively to the N balance of the entire cropping system. However, the latter goal is more difficult to achieve in groundnut than in other grain legumes as the crop must be uprooted, with haulms, pods, and upper root fractions usually removed from the field.

Protocols have been developed for identifying legume genotypes with genetically greater N_2-fixation capacity, even from within existing cultivars (e.g., Rupela 1994). Further, as the presence of even moderate levels of soil mineral N inhibits nodulation and N_2 fixation in legumes including groundnut, N_2-fixation symbioses tolerant of moderate mineral N levels are being sought (Rupela and Johansen 1995).

Conclusion

The above analysis suggests that our main research emphasis should be focused on bridging identified yield gaps, rather than trying to increase yield potential in favorable environments even further. It is proposed that a functional ideotype approach will facilitate genetic improvement attempts in this regard. However, due emphasis should be given to the total cropping system in which groundnut is grown, by considering ways of enhancing the N_2-fixation capacity of groundnut.

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Theoretical Foundations for High Yield of Groundnut in China

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Abstract

In China, groundnut yields of 6.0-7.5 t pods ha^{-1} over a large area, and 10.5 t pods ha^{-1} over a small area were obtained under intensive cultivation. Groundnut is considered a very photosynthetically efficient crop, and in theory its potential yield can reach as high as 17.3 t ha^{-1}. For high yields it is necessary to increase the total biomass, and to improve the harvest index. Emphasis should be placed on adopting varieties with high-yielding plant-types, increasing plant stand per unit area, raising the total pod number, and stabilizing the pod number kg^{-1} pods. Suggestions for high-yielding groundnut cultivation include methods used to create a suitable soil structure; balanced fertilizer application, based on the amount absorbed by the plant; emphasis on applying fertilizer to preceding crops; building up a rational plant population structure with healthy and vigorous seedlings; strengthening field management; and using sustainable methods to create ecological conditions that ensure high and stable yields.

中国花生在较大面积上能实现6．0－7．5吨/公顷，小面积突破10．5吨/公顷，因此认为花生是高光合效能作物，理论上其产量潜力可达17．3吨/公顷．为获得高产，应增加总生物产量并提高经济系数．选用高产株型品种，加大群体株数、提高群体总果数、稳定公斤果数是生产的主攻方向．在栽培上，要创造适宜的土体，根据植株对养分的吸收量平衡施肥，重视前茬作物施肥；建立苗株健壮的合理群体结构；加强田间管理，利用可持续方法创造适宜的生态条件，确保高产稳产．

Introduction

In China, traditional cultivation practices resulted in low groundnut production with yields from small areas being below 4.5 t ha^{-1}. Consequently, groundnut was regarded as a low-yielding crop until the 1970s, when studies aimed at improving cultivation and increasing yields made a breakthrough. In 1993, the total area sown in China was 3.38 million ha with an average yield of 2.5 t. Shandong Province groundnut area was 0.8 million ha, yielding 3.5 t ha^{-1}. This province

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shattered the high-yield record for a small area, as the yield improved from 6-7.5 t ha^{-1} in the 1970s (Panquiao 1979, Liu Jinliang et al. 1980, Sun Yanhao 1982) to 9.4-10.5 t ha^{-1} in the 1980s (Sun Yanhao et al. 1984), showing that groundnut was a high-yielding crop. This paper discusses the new cultural practices resulting in these improved yields.

The Theoretical Foundation of High Yields for Groundnut

Photosynthetic Efficiency

Groundnut has high photosynthetic efficiency although it is a C_3 plant. Sun Yanhao et al. (1984), showed that groundnut needed strong light. The light saturation point of a groundnut population was not obvious even when the light intensity was about 11 million lux (full daylight), while the light compensation point occurred when the light intensity was reduced to 800 lux. The net assimilation rate (NAR) of 8-week old Haihua 1 genotype was (50 mg CO_2 dm^{-2}) d^{-1} in a crop canopy and (34 mg CO_2 dm^{-2}) h^{-1} for a single leaf. The rate of photosynthetic change of the population per day was a unimodal peak curve, but of a single leaf was a double-peaked curve, in which the higher peak was at 1100 h, the trough at 1500 h, and the lower peak at 1600 h. It was reported (SPRI Cultivation Department 1973) that the NAR of a single leaf of 4-week old NCA4 was (51 mg CO_2 dm^{-1}) h^{-1}, which was higher than some other C3 crops. The photosynthetic efficiency of groundnut was higher than that of soybean and maize under weak light and it would reach (40 mg CO_2 dm^{-2}) h^{-1} under 4 million lux, which was double that of soybean. Therefore groundnut could be considered a crop of higher, rather than lower photosynthetic efficiency.

Yield Potential

The yield potential estimated by radiation use efficiency. The yield of the short-duration, medium-bold-podded Spanish cultivars was 11.9 t ha^{-1}, based on the maximum leaf area index (LAI) and NAR (Sun Yanhao 1982) over 60 days (from the flowering and pegging phase to pod-maturing phase) in Guangdong Province, southern China; and the highest pod yield of medium-duration groundnut was 17.3 t ha^{-1} determined by radiation use efficiency, which was 5.4% over 80 days (the phase from pod setting to pod maturity) in Shandong Province, northern China (Sim Yanhao et al. 1982).

The potential estimated from yield structure factors. The key to resolving the problem of the limits set by incident radiation is to get more mature pods. Under the present cultivation system, the plant population is short of light, which is the limiting factor to production of individual plants.

It was estimated that pod yield could reach 14 t ha^{-1} in high-yielding areas. Therefore, it may be deduced from the above analysis that some key cultural measures are required: creating a rational population structure, emphasizing the management, improving the numbers of 2-seeded mature pods, increasing the total pod number, and stabilizing the pod numbers kg^{-1}.

Accumulation and Distribution of Total Biomass

Leaf area index (LAI) and net assimilation rate (NAR). In a high-yielding groundnut population the yield is based on the total biomass which is dependent, in turn, on the leaf area of a large population and a high photosynthetic rate. In such a population the most productive LAI is from the flower-pegging phase to the pod-setting phase, a period of about 60 days, during which the LAI increases gradually from 3.0-3.7 to a sharp peak of 5.0-5.5 and then declines slowly to 3.5-3.0. At the same time the NAR follows a sigmoid curve, declining from 9.5-7.6 g m^{-2} d^{2} to 4-2 g m^{-2} d^{-1}. During this approximately 60 day period the photosynthetic mass is 68-70% of the total biomass (Fig. 1).

The distribution rate of the total biomass. An increase in total biomass is positively correlated with economic yield over a limited range (R=0.914), while it is negatively correlated with the V/R (the ratio of vegetative organs to reproductive organs), (R=-0.636) (Fig. 2). An increase in total biomass results in higher yields. This can be achieved by a rational distribution of dry matter, by improving the transfer of photosynthates from the vegetative structures to the reproductive organs, and decreasing the V/R ratio and increasing the economic index (pod mass / total biomass).

The Structure and Appearance of High-yielding Groundnut Plants

A suitable groundnut variety is the basis of high yield and the following characteristics would be desirable.

- **Green leaves inclined upwards**
  Groundnut could have higher photosynthetic efficiency if the leaves were dark green and inclined at an angle of 45° to the main stem.
- **Alternate branching types**
  The total number of branches of these cultivars is about 9 in an average population, and the effective branches are 90% or more of the total branches. The fruiting branches are healthy and strong but few in number so that passage of light and air is maximized. For high branching types, however, there are more than 15 branches, and fewer than 40% of branches are effective. Many ineffective branches cause poor ventilation and passage of light

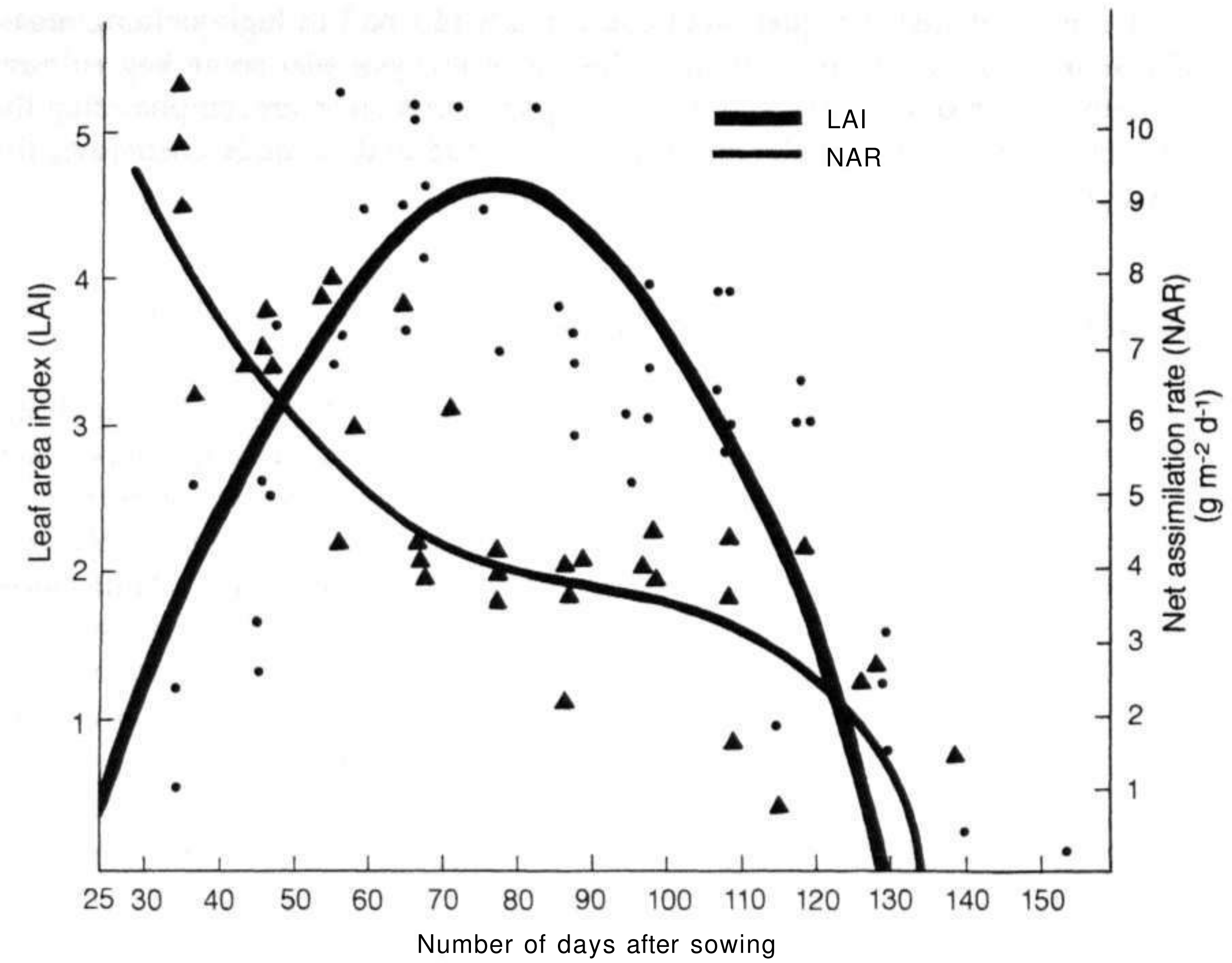

Figure 1. The dynamics of leaf area index (LAI) and net assimilation rate (NAR) of groundnut variety Xuzhou 68-4, Shandong Peanut Research Institute, China.

- **Sequential branching types**
  The indeterminate growth habit of sequential branching types means there is less synchrony of pod maturity than for alternate branching types. However, the fruit-bearing index and pod-maturity index are higher than those of the alternate branching type.
- **Short pegged, and large-podded types**
  The pegs of short-statured varieties that enter the soil and bear fruits are earlier and neater than those of tall varieties. At the same degree of maturity and planting density the individual fruit bearing is not markedly different.
- Short plants are less prone to lodging.

Factors Influencing Improved Yields

Factors. Total groundnut yield is determined by the number of plants in a unit area, and productivity of single plants, and the productivity of a single plant is determined by the number of pods. Therefore yield = plant population in a unit area x per plant pod numbers x unit pod mass. Of the three factors, the plant population is dominant, while per plant pod numbers and the unit pod mass are

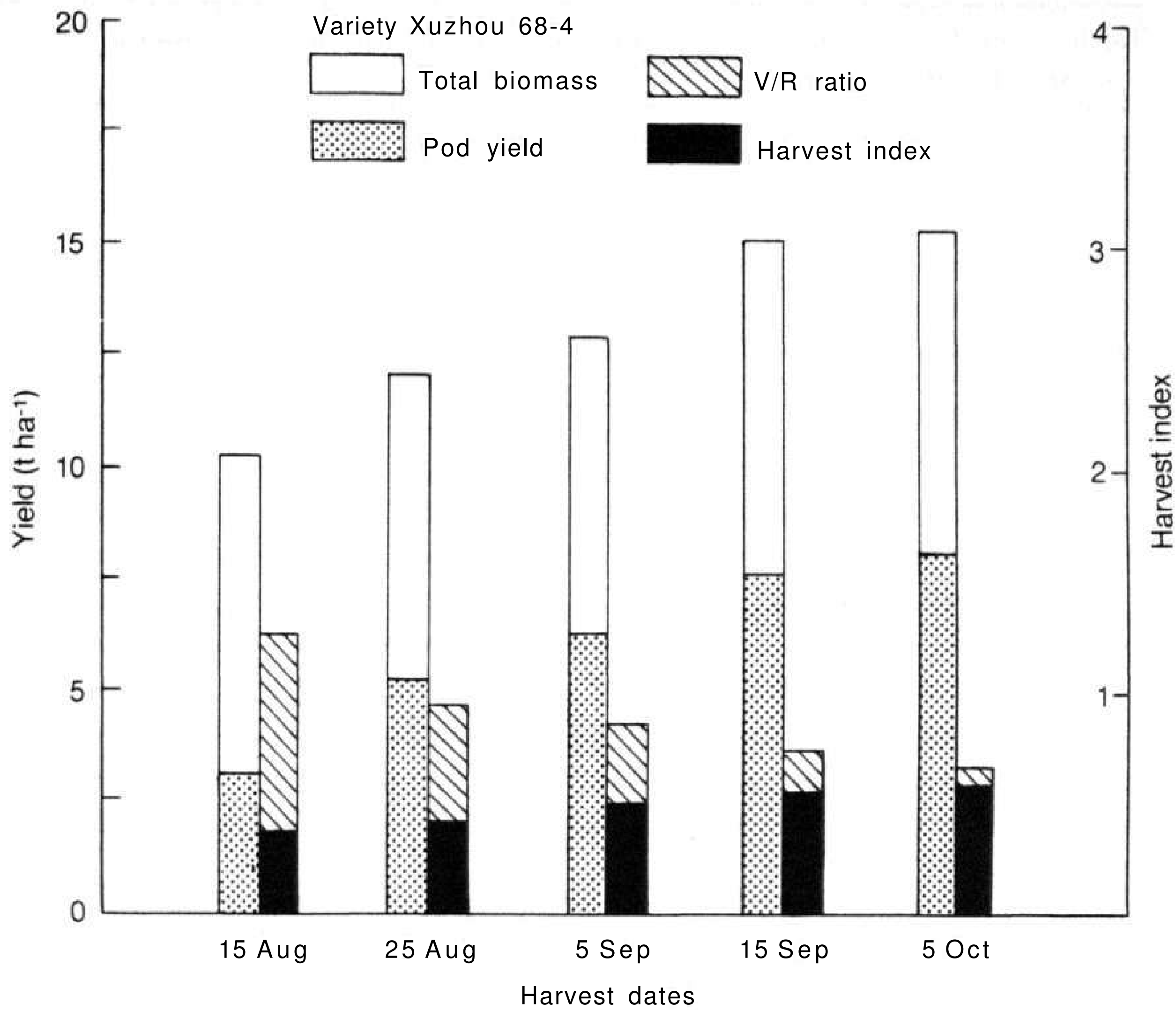

Figure 2. Dynamics of economic yield for a high-yielding groundnut variety (Xuzhou 68-4), Shandong Peanut Research Institute, China, 1979.

dependent on the plant population in a unit area, and hence different yields can be attained.

Structure. The indexes of high yield structure are: the harvested plant numbers in a unit area are 195000-236000 plants ha^{-1}, per plant pod numbers are 17.1-20.0, the total pod number ha^{-1} is more than 4.5 million ha^{-1}, pod numbers per kg are 450 or less, and the theoretical yield is 8.2-8.7 t ha^{-1}, while the harvested yield is 8.0-8.3 t ha^{-1} (Table 1), during 1979-83. Yields obtained during 1989-91 were much higher.

Cultural Practices to Attain a High Yield of Groundnut

Create a deep, loose, and fertile soil structure. The whole horizon should be more than 50 cm deep, the plow layer about 0-30 cm, the fruit-bearing layer (loamy sand) 0-10 cm deep. Table 2 summarizes optimal characteristics of soil structure contributing to high yields. The plow layer (0-30 cm) should have

Table 1. Factors determining high yield in groundnut, Shandong Peanut Research Institute, China.

Years	Variety	Pod yield (t ha^{-1})	Harvested plant number (thousand plants ha^{-1})	Pod number (plants ha^{-1})	Total pod number (million kg^{-1})	Pod number (ha^{-1})
1979-83	Haihua 1	7.85- 9.58	225-236	17.0-19.9	2.43-4.01	468-410
	Xuzhou 68-4	7.69- 8.22	195-213	18.6-20.0	3.9 -4.0	490-462
	Hua 37	7.76- 8.14	201-231	17.9-19.6	3.9 -4.1	500-430
	Hua 17	7.99- 8.28	210-236	18.5-19.9	4.2 -4.4	512-500
1989-91	Haihua 1	10.87-11.14	243-257	20.5-22.5	5.5 -5.3	432-434

organic matter content of 0.654.10%, total N 0.06-0.09%, available P 11-22 mg kg^{-1}, available K 50-80 mg kg^{-1}, and Ca 0.11-0.18%. Therefore, water, fertility, aeration, and temperature all affect groundnut growth. The proper management of tillage is as follows:

- Soils with shallow, thin horizons should be deep-plowed, and prepared before winter in order to deepen the cultivation layer. Soils with a deep, thick horizon that is shallowly plowed year after year should be deep-plowed late in the year to break the plow pan. Soil that has been properly tilled for many years, which has a loose upper layer, and firm lower layer, should be tilled to different depths each season in order to prevent pan formation.
- In order to improve the fruit-bearing layer, the soil horizon should be ameliorated by adding sand to clay soil, and by improving sandy soil.
- Improve soil fertility by growing such crops as cereal, cotton, yam, and vegetables in a 3-4 year rotation.

Table 2. Soil structure suitable for groundnut cultivation in China.

Depth (cm)	Bulk density (g cm^{-3})	Capillary porosity (%)	Non-capillary porosity (%)	Soil texture
0-10	1.22-1.32	35.0-38.0	14.0-16.0	Loamy fine sand to Loamy coarse sandy grain
10-30	1.41-1.45	36.0-38.2	9.1-10.0	Loamy fine sand to Sandy clay loam
30-50	1.43-1.49	37.2-40.1	5.9- 6.6	Sandy clay loam

Balanced nourishment. The requirement to balance nourishment to groundnut increases as soil fertility and pod yield increase. The amount of nitrogen obtained from rhizobia is reduced as soil fertility and pod yields increase. Under low-yield conditions the crop needs 5 kg N, 0.44 kg P and 1.66 kg K to produce 100 kg pods. During the growing stage, the amount of N from rhizobia is 79.0-87.5% of the total N required by plants (Zhang Sisu et al. 1989). Under high-yield conditions, the crop needs 5.5 kg N, 1.1 kg P and 3.3 kg K, and the amount of N obtained from rhizobia is 35.6-52.7% of the total N required. All these nutrients, with the exception of fertilizer N, are mainly from soil, while the fertilizer applied to current crops is not absorbed to any great extent.

Groundnut crops during pod-setting need 55.65% N, 50.66% P, and 32.21% K of total nutrients absorbed during the entire growing season. At flowering and pegging the plant needs 27.5% N, 34.8% P, and 47.25% K of the total absorbed nutrients. Groundnuts have the capacity to absorb fertilizer not only directly through their roots, but also through their leaves, pegs, and developing pods.

To achieve adequate plant nourishment:

- Fertilize the preceding crop, and complement the soil for the current crop.
- Basal fertilizer is the major requirement, and topdressed fertilizer is supplementary
- Balance the rate of fertilizer application based on the amount absorbed by groundnuts in low-yielding fields. In high-yielding fields, apply half the N, twice the P and all the K as a basal application, and at levels that can adjust the amount of N, P and K in the soil, while maintaining the level of N derived from rhizobia to improve yields.

Create a plant population structure with more and healthy plants. To create an appropriate population it is most important to determine the planting density. It is reported (Sun Yanhao et al. 1984) that high-yielding population density is closely correlated with plant height. The length of lateral branches can be an important basis by which to calculate planting density since this is proportionally related to inter-row distance and hill spacing.

The empirical indexes used to determine plant density are:

• Bunch types	:	inter-row distance = lateral branch length x 0.95 hill spacing = lateral branch length x 0.38
• Thick branching types	:	inter-row distance = lateral branch length hill spacing = lateral branch length x 0.44

Row, hill spacing, and plant densities of popular cultivars are given in Table 3.

An established high-yielding population of healthy young seedlings is the foundation of a good groundnut crop. Seedlings with a germination rate of 95-99% are required. It is important to ensure early emergence, rapid

Table 3. Appropriate population densities for groundnut varieties, Shandong Peanut Research Institute, 1985.

Varieties	Lateral branch length (cm)	Interrow distance (cm)	Hill spacing (cm)	Hill number (thousand ha^{-1})	Seed $hill^{-1}$
Haihua 1 (Bunch type, short statured, medium-maturing)	45-48	43.0-44.6	17.0-18.0	124-137	2
Xuzhou 68-4 (Bunch type, tall, medium-maturing)	50-55	47.5-53.0	19.0-20.1	94-111	2
Luhua 9 (Bunch type, tall, early-maturing)	46-50	43.7-47.6	17.5-19.0	111-130	2
Hua 17 (Thick bunch type, short statured, medium-maturing)	42-46	42.0-46.0	18.5-20.0	109-129	2

development abundant flowering, good capacity for absorbing water and nutrients, and a high photosynthetic rate.

Seedling management.

- Choose first grade seed with a high germination percentage, and facilitate germination by treating the seeds with pesticides, micro-nutrients, and rhizobial inoculant.
- Sow at the appropriate time, when the average soil temperature at 5-cm depth is more than 15°C. The soil temperature 5 cm below polythene film mulch is 2.5-4.0°C higher than that of soil in the open air. Sowing, therefore, can be advanced 7-10 days by the use of polythene film mulch.
- The best sowing depth is 3 cm under polythene film mulch and 1 cm for nonmulched fields. Sow two seeds per hill and apply pesticides.

Maintain steady growth and healthy plants. The seedling phase is from 50% emergence to when 10% plants are flowering. This phase is 20-25 days for early maturing varieties, and 25-30 days for the medium-maturing varieties. This is the vegetative growth phase, and is characterized by a main stem about 6-7cm high, lateral branches 7.5-8.8 cm long, plant feature index (the ratio of lateral branches to main stem) more than 1, compound leaves on the main stem 7-8, and the main root about 60 cm long. The first flower buds on lateral branches differentiate between nodes 5-7. Flowers emerge on the basal nodes, and the third lateral branches differentiate from the first emerged branches. At this stage total plant dry mass is 7.5-8.9% of the total biomass of the mature plant. Management for this stage includes interculture, water, and nutrient management.

The flowering and pegging phase is the time from flowering to when 10% of the plants have formed pods (with kernel visible and edible). In early-maturing varieties it is 20-25 days after the seedling phase, and 25-30 days in medium-maturing varieties. At this stage, the main stem is 20.8-27.0 cm high, with 14-16 compound leaves, the lateral branches are 26.3-32.5 cm long, plant feature index is 1.20-1.26, and the main root is about 80 cm long. In a single plant 50% of early flowers become pegs, 20% of which enter the soil and form young pods. The total dry matter mass is 25.0-27.0% of the whole life dry matter mass. Management of this phase includes water and nutrient management, and control of insect pests and diseases.

The pod-forming phase is the time from pod formation to when 10% of the plants have mature pods. This takes 35-40 days in early-maturing varieties, and 45-50 days in medium-maturing varieties. In this phase, the main stem is 38.0-47 cm high, with 18-20 compound leaves, the first lateral branches are 44.0-54.0 cm long, the main root is about 100 cm long, plant feature index is about 1.2. At this stage, 60-70% of the pods are formed, and plant dry matter mass is 65.2%-66.5% of the whole life dry matter mass. Management for this phase includes control of diseases, to avoid early leaf senescence.

The pod-formation phase, which is when reproduction is the prime growth stage, is the time from when 10% of the plants have mature pods to the pod-forming index of a single plant being 50-70%. This takes 25-30 days in early-maturing varieties, and 35-40 days in medium-maturing varieties. The main stem is 39.0-48.0% cm high, with 4-6 leaves, lateral branches are 45.1-54.6 cm long, and plant feature index is 1.15. The increased mass of pods is 50-70% of the whole dry matter mass, and total dry matter mass is at its peak. Management for this phase includes fertilizer application, foliar sprays, irrigation, and drainage.

Agroclimatic Conditions for High Yield

Agroclimatic conditions that favor high yield in groundnuts are: approximately 1200 hours of sunshine during the crop cycle, 800-8000 lux radiation, 300-500 mm rainfall; a daily average temperature of 21.5°C or more during the life cycle, seedling phase >16°C, young seedling phase >20°C, flowering and pegging phases >22°C, pod-formation phase >24°C, and pod maturing phase >18°C. The total cumulative temperature is >3200°C. These agroclimatic conditions can generally meet the needs of groundnuts at different growth and development phases in the main groundnut-growing areas in China. But there are some limiting factors that do not promote steady and high yields, such as continuous rain in March and drought in summer, in southern China, and cooler spring season, drought before summer and autumn, or waterlogging in autumn in northern China. Therefore, polythene film mulching can improve, maintain, and adjust soil temperatures, conserve soil moisture, and compensate for the climatic variations, and thus be beneficial to achieving high and stable yields.

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Selection and Extension of High-yielding Groundnut Varieties in China

Qiu Qingshu, Wang Caixiang, Che Kepeng, Hu Wenguang, Wang Chuantang, and Miao Huarong[1]

Abstract

Groundnut breeding in China started in the late 1950s. By 1991, more than 200 high-yielding varieties had been developed and released in a cumulative cultivated area (CCA) of about 36.67 million ha. The CCAs of the 50 most promising varieties, covering over 66 700 ha each, accounted for 95% of the total CCAs of improved groundnut (CCAIG). Fuhuasheng, a high-yielding variety developed in Shandong Province, had the largest CCA of about *72* million ha, 19.6% of the total CCAIG. Haihua 1, also released in Shandong Province, covered about 3.16 million ha and ranked second. Baisha 1016, selected in Guangdong Province but evaluated and extended in Shandong Province, covered about 3.13 million ha and ranked third. The CCAs of 13 additional varieties that included Yueyou 551, Shixuan 64, Xuzhou 68-4, Yueyou 116, Shanyou 27, Hua 37, Hua 17, Tianfu 3, and Yuhua 1 were around 666 700 ha. The 16 varieties listed covered about 29.2 million ha amounting to 79.6% of the total CCAIG. A number of recently developed varieties with better productivity, seed quality, and stress resistance than those presently cultivated, such as Luhua 9, 8130, Zhonghua 4, Xuhua 5, Yuhua 3, and Yueyou 256, are being made available for widespread cultivation.

中国花生育种研究始于五十年代末．至 1991 年，全国先后选育推广高产品种 200 余个，累计推广面积 3667 万公顷．其中推广面积累计在 66．7 万公顷以上的品种有 50 个，推广面积占良种累计推广总面积的 95．5%．推广面积最大的是山东省选的高产品种伏花生，约为 720 万公顷，占良种推广面积的 19．6%，其次是山东省推广的“海花 1 号”，推广面积约为 316 万公顷；第三是广东省育成山东省鉴定推广的“白沙 1016”，推广面积 313 万公顷．粤油 551、狮选 64、徐州 68－4、粤油 116、汕油 27、花 37、花 17、天府 3 号、豫花 1 号等 13 个品种累计推广面积均在 66．67 万公顷上下．上述 16 个品种累计推广面积为 2920 万公顷，占良种推广面积的 79．6%，近年又新育成了鲁花 9 号、8130、中花 4 号、徐花 5 号、豫花 3 号和粤油 256 等一批高产、优质、抗逆的品种，正在生产上推广利用．

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Introduction

Groundnut is one of the most important cash and oil crops in China. The annual area, total output, and the export quantity of groundnut rank second, and play an important role in the world's groundnut production.

Since the People's Republic of China was established (in 1949), great improvements have been made in the production of groundnut and other crops. In 1949, groundnut was grown on 1.25 million ha and had a yield of 1020 kg ha^{-1}. Groundnut production has increased more rapidly since China pursued the policies of reform and opening to the outside world after 1978. The annual average area from 1979 to 1991 rose to 2.71 million ha, (a 49% increase) and the average yield increased by 63%, to 1834.65 kg ha^{-1}, compared with the 1949 to 1978 averages (Qiu Qingshu and Shen Fuyu 1994). Such great progress resulted mainly from selection and extension of the new groundnut varieties. This paper reviews groundnut variety development in China.

Utilization of the Improved Varieties

Groundnut breeding research in China started in the late 1950s. By 1991, more than 200 high-yielding varieties had been developed and released on a cumulative area of about 36.67 million ha. Among them there were 50 most popular varieties each covering above 66.7 thousand ha, and the area totalled about 35.01 million ha, accounting for 95% of that of the improved varieties. Table 1 shows the most popular groundnut cultivars used in production.

Additionally, the cumulative area of the nine short- or medium-duration varieties (Shanyou 27, Yueyou 22, Yuexuan 58, Hua 37, Hua 17, Tianfu 3, Xuxi 1, Yuhua 1, and Hua 28) was around 0.67 to 1.33 million ha. All the 16 varieties listed above covered about 29.2 million ha (cumulative), amounting to 79.6% of the cumulative area of the improved varieties (Qiu Qingshu and Shen Fuyu 1989, Qiu Qingshu and Shen Fuyu 1994).

In recent years, further developments have been made. Twenty-two high-yielding varieties have been developed between 1991 and 1995 by the 12 research units that participate in the National Eighth Five-Year Key Projects on developing new groundnut varieties. Among them, fourteen are high-yielding and with good seed quality, three are high-yielding and disease resistant. These varieties outyielded the local controls by over 10% and covered 1.68 million ha. Such rapid extension is rarely seen.

Breeding Objectives on the Basis of National Conditions

China is a developing country with insufficient arable land for its growing population. One problem in agriculture is the competition between grain and oil

Table 1. The most popular cultivars used in production in China.

Cultivar	Characters	Place of origin (year of release)	Area of extension	Cumulative area (million ha)
Fuhuasheng	Spanish type, early maturity	Shandong (1961)	Shandong	7.2
Haihua 1	High yield, bold seeds	Shandong (1984)	Shandong	3.16
Baisha 1016	Spanish type, short duration	Guangdong (1963)	Guangdong	3.13
Yueyou 551	Spanish type, early maturity	Guangdong (1974)	Guangdong	2.67
Shixuan 64	Spanish type, early maturity	Guangdong (1964)	Guangdong	2.33
Xuzhou 68-4	Medium duration, large seeds	Jiangsu (1959)	Jiangsu	2.00
Yueyou 116	Short duration, Spanish type	Guangdong (1981)	Guangdong	2.00

crops for land each season. Therefore, any decision on groundnut breeding objectives must be based on facilitating the increase of the cropping index and ensuring the yield increases of the crops. Selection of high-yielding varieties with short- or medium-duration is one of the groundnut breeding objectives and the majority of the over 200 varieties selected and extended in China since the late 1950s has these characters. Introduction of these varieties has enabled changes in farming systems from one crop in one year to three crops in two years or to two or multiple crops in one year, with consequent increased production.

Another breeding objective is to breed high-yielding varieties with stress resistance because about 70% of the crop is distributed on the hilly, sandy, dry or poor areas; suffers from drought; and diseases and insect pests frequently infect the crop. Fuhuasheng, Baisha 1016, Yueyou 551, Luhua 3, Tianfu 3, Haihua 1, Xuzhou 68-4, and Hua 37, selected in the past, and Luhua 9, Yuhua 3, Zhonghua 3, and Guihua 15 selected in recent years, are high-yielding and incorporate resistance/tolerance to multiple factors like drought, diseases, or poor soil. These varieties have played an important part in the increase of China's groundnut production making it one of the major groundnut exporters in the world.

The third breeding objective is to breed varieties with high yield and good quality to meet export norms. The three high-yielding varieties with medium duration (Hua 17, Luhua 4, and Luhua 10), selected and released in Shandong, have become replacements for three of China's traditional large-seeded groundnuts favored for export. Another new large-seeded variety, 8130, will soon become another exportable variety. Small-seeded, good quality varieties like Fuhuasheng, Baisha 1016, and Hua 11, known as 'Hsuji Type'® in the international market, have been developed, and recently, Luhua 12, Luhua 13 and Tangyou 4 have been released for production. Many 'Tianfu Type'® varieties have been replaced. An outstanding breakthrough has already been made in improving the quality of small-seeded varieties for export, and a few promising lines like China Runner 1, and Shandong Runner 1 have been identified for future release (Qiu Qingshu and Shen Fuyu 1994, Shandong Peanut Research Institute 1992).

Improvement of Breeding Techniques

Breeding methods in China have developed from simplicity to complexity, and from single to multiple characters by selecting high-yielding, good quality, and stress-resistant varieties. The breeding methods in the 1950s focused on collection, evaluation and identifying the local varieties; in the 1960s on intervarietal crossing plus introduction, systematic selection and mutation breeding; and in the 1970s on intervarietal crossing and induced mutation plus introduction and systematic selection. Since the 1980s, in addition to utilization of the conventional methods and mutation breeding, interspecific hybridization and biotechnological tools have also been employed. The crossing methods included single crosses to backcrosses and composite crosses, or crosses combined with induced mutation. Mutation breeding included directly-induced mutation or combining with intervarietal crossing, and interspecies hybridization. As a result of these improvements, the breeding process has been accelerated (Qiu Qingshu and Shen Fuyu 1994, Qiu Qingshu 1992).

In the last four or five years, a new development has been made in Chinese groundnut breeding. Of the six varieties released in Shandong, four were produced through the method of combination of induced mutation with crossing, and the most outstanding varieties were 8130 and Luhua 11. The former has the best integrated characteristics of high yield, good quality, stress resistance, and good adaptation. The latter is a high-yielding and drought- and disease-resistant variety and gives 10% more pod yield compared with Haihua 1. Each of the two varieties has covered over 150 000 ha. Zhonghua 4, with rust-resistance selected through composite crossing at the Oil Crops Research Institute, Wuhan, covered more than 150 000 ha in Guangxi and Hubei. Yueyou 256, a high-yielding and bacterial wilt-resistant variety developed through composite crossing in Guangdong, is being grown on about 140 000 ha.

Acceleration of Extension of the Improved Varieties

Researchers in China not only develop new groundnut varieties, but also do some extension work on these improved varieties, study the combination of the improved cultivars with improved agronomy, and conduct small or large scale demonstrations to provide the advanced technologies for groundnut producers. All this boosts extension and taps the increased potential of the improved varieties (Qiu Qingshu and Shen Fuyu, 1994). Now the coverage of the new cultivars accounts for 90% of the total groundnut area in China. For instance, Luhua 9 was extended rapidly by utilizing some of the measures stated above so that it covered about 1.2 million ha (cumulative) during the 8 years from its certification in 1988 to 1995.

Groundnut breeding has made a great contribution to Chinese groundnut production, but demands on it become greater with the development of the market economy and the continual increase in people's living standards. Though there are many difficulties and problems in breeding, we believe that another major step will be achieved in the late 1990s and early 2000s in the selection of new varieties with better comprehensive characters of high yield, good quality, and stress resistance, which will satisfy spring, summer, and autumn sowing, intercropping, and polythene mulch cultivation. At the same time, selection of special type varieties for export, nutrition or edible oil will be further strengthened and a considerable break-through will emerge in these fields, with a number of fine varieties released in production.

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Increasing Yield and Drought Resistance of Groundnut Using Plant Growth Regulators

Li Ling, and Pan Ruichi[1]

Abstract

The growth regulators PP333 (25-100 mg L^{-1}) and triadimefon (300-600 mg L^{-1}) were applied to spring groundnut at 25-30 days after floral initiation during 1986-1988. Treatments with PP333 solution increased yield by 7%, and with triadimefon solution by 10%. The degradation of PP333 in soil and in groundnut plants was rapid. PP333 residue in soil was 9-18 g kg^{-1} dry weight (within the range of maximum residue limit). It is safe for human beings. When seedings were treated with PP333, CCC, triadimefon, and methyl jasmonate (MJ), their abscisic acid and proline contents were increased, and the levels of such protective enzymes as superoxide dismutase, catalase, and peroxidase were found to be higher than those of nontreated seedlings. These regulators result in increasing seedling drought resistance.

1986－1988年，在春花生始花后25－30天分别喷施生长调节剂PP333（25－100毫克/升）或粉锈宁（300－600毫克/升）能增产7%或10%． PP333在花生体内及土壤中降解迅速，在土壤中的残留量为9－18克/千克干重，在最大残留量许可范围内，对人类安全。经PP333、CCC、粉锈宁和茉莉酸甲酯处理过的幼苗，体内脱落酸、脯氨酸水平升高，超氧物歧化酶（SOD）、过氧化氢酶（CAT）和过氧化物酶（POD）保护活性高于未处理幼苗，抗旱性明显提高。

Introduction

In Guangdong Province groundnut is an important crop. Half of its planted area is on dryland farms where drought stress has resulted in low yields. To improve drought resistance and yield of groundnut we experimented with plant growth regulators as these have shown beneficial effects as growth retardants and fungicides in agriculture and horticulture. Fletcher and Nath (1984) reported triadimefon reduced transpiration and increased yield in water-stressed plants and Lever et al. (1988) showed paclobutrazol (PP333) acted as a broad spectrum growth retardant. In the 1980s methyl jasmonate, a new growth regulator with

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similar physiological effects to abscisic acid, was reported by Curtis (1984) and Parthier et al (1992) demonstrated that jasmonic acid promoted heat and salt resistance in barley but little is known about its effect on drought resistance.

This paper presents the effects of applying plant growth regulators PP333, triadimefon, and methyl jasmonate (MJ) on the yield and drought resistance of groundnut, and the degradation of PP333 in the groundnut plants and soil.

Effects of Regulators on Growth and Yield in Groundnut

Pan et al. (1988) reported that PP333 reduced the growth rate of pot-grown groundnut seedlings and decreased their transpiration rate, but the water storage cells in treated leaves were significantly larger. These anatomical and physiological characteristics of treated plants were an advantage in tolerating drought stress (Pan et al. 1988). From 1986 to 1988, Pan et al. (1989) also applied PP333 and triadimefon at 25 days after the beginning of floral initiation to spring-sown groundnut grown in the field. Both treatments resulted in a reduction of stem and branch elongation, and increased the chlorophyll content significantly. Before harvest, the number of green leaves remaining on the main stem of PP333 treatment was less than that of triadimefon treatment (Table 1), because the latter has a stronger fungicidal power than the former. Hence triadimefon could prolong the photosynthetic period for several days and allow the leaf to synthesize more photosynthates.

By spraying the groundnut plants with 25-100 mg L^{-1} PP333 or 300-600 mg L^{-1} triadimefon, pod yields were increased (Table 1). PP333 increased the yield by about 7% and triadimefon by about 9%. The dry weight of shoots decreased, as the assimilates were utilized for reproductive (or pod) growth more than vegetative growth and therefore, the number of full pods per plant was increased, resulting in increased yield.

Study on Distribution and Degradation of PP333 in Groundnut

With increasing emphasis on the use of regulators, an understanding of their degradation in plants and soil as well as their residues in the fruit has become more important, because they must be safe for human consumption. ^{3}H-PP333 was shown to degrade rapidly in groundnut plants as reported by Early et al. (1988). Seven days after treatment, the amount of ^{3}H-label remaining as ^{3}H-PP333 was 25.4% in roots, 29.3% in stems, and 17.3% in leaves. The leaves might be the main site of degradation for PP333 in groundnut. At different intervals after the beginning of floral initiation, plants were treated with 200 mg L^{-1} PP333. Table 2 shows that the contents of ^{3}H-PP333 in all organs increased with the delay in the treatment date and when treatment numbers were increased towards maturity (Yan et al. 1994).

Table 1. Effects of PP333 and triadimefon (Tri) on the growth characteristics and yield in spring groundnut[1].

Year	Treatment	($mg\ L^{-1}$)	Plant height (cm)	Branch length (cm)	Number of green leaves on main stem	Number of full pods/ plant	Pod weight (kg)	Seed wt/ Pod wt (%)	Yield over control (%)
1986	H_2O (control)	0	73.7	75.0	1.2	7.4	668.2	72.7	0
	PP333	50	49.3	53.0	0.8	7.6	629.0	73.1	5.37
		100	48.7	50.8	0.3	8.2	713.6	72.6	8.00
	Tri	100	66.8	64.8	3.7	9.2	624.6	72.6	2.22
		200	70.0	75.7	2.1	9.0	630.2	73.2	7.84
		300	65.0	67.3	2.0	7.7	630.0	73.4	8.85
1987	H_2O (control)	0	53.9	62.2	5.8	13.5	580.8	69.3	0
	PP333	25	48.6	51.4	5.4	14.2	570.4	70.6	7.57
		50	46.4	51.3	5.0	14.1	573.7	70.8	8.66
		100	44.4	47.6	4.6	14.0	557.7	69.7	6.78
	Tri	300	51.2	53.8	6.9	14.5	567.9	71.3	9.69
		400	50.0	54.5	6.5	14.3	557.4	70.3	10.50
		500	50.2	53.7	6.0	14.2	559.8	70.0	11.38
1988	H_2O (control)	0	58.2	58.0	4.6	13.5	731.1	68.3	0
	PP333	25	52.2	52.6	3.4	13.9	711.5	70.8	6.61
		50	49.8	49.4	3.6	13.9	719.6	68.8	4.25
	Tri	500	57.9	60.8	5.4	14.2	735.8	68.3	6.71
		600	53.6	55.1	4.6	14.0	745.9	68.3	7.26

1. Experimental results are the average value of 30 plants at one experimental site in 1987, 240 plants at eight experimental sites in 1987, and 120 plants at four experimental sites in 1988, Guangdong Province, China.

Analyses of PP333 residues in the seeds and shells of groundnut given 5 mg L^{-1} PP333 treatment 25 days after the beginning of floral initiation in 1994 was 26.7 µg kg^{-1} dry weight (DW) and 36.7 µg kg^{-1} DW respectively The amount of PP333 in seed was less than the maximum residue limit, so it was safe for human consumption.

The distribution of PP333 in the soil changed with time. Three days after treatment, most PP333 was distributed 0-5 cm below the soil surface. The longer the time elapsed following PP333 application the more PP333 occurred at 6-15 cm depth. Twenty days after treatment, the PP333 residue levels in the soil had declined and could not be detected after 130 days (Fig. 1).

Effects of Growth Regulators on the Drought Resistance of Groundnut

The plasmalemma permeability reflects the extent of destruction of the cell (Dhindsa et al. 1980). Table 3 shows that the seedlings pretreated with PP333, CCC and MJ at different concentrations had changes of plasmalemma permeability. The relative electrical conductivities of seedlings treated with 150 mg L^{-1} CCC, 5 mg L^{-1} PP333, and 200 mg L^{-1} MJ were reduced compared with the control. For example, the permeability of the PP333, CCC, and MJ treatments at 4 days during drought was 65.1%, 79.7% and 69.0% of the control, respectively, and this showed that application of growth regulators to groundnut seedlings increased drought resistance.

Table 2. The content of ^{3}H-PP333 in groundnut organs at harvest.

Stages of PP333 treatment (days after beginning of floral initiation)	Number of treatments	^{3}H-PP333 content (pg g^{-1} fresh weight)			
		Roots	Stems	Leaves	Fruits
20	1	20.7	26.5	15.3	14.9
30	1	31.6	37.2	21.4	21.7
40	1	33.6	32.6	21.5	22.8
20, 30	2	31.8	28.3	21.9	22.0
30, 40	2	43.2	46.7	28.6	29.9
20, 30, 40	3	48.6	42.0	28.7	31.9

1. ^{3}H-PP333 concentration at 200 mg L^{-1} contains 7.4×10^3 Bq. PP333 was extracted with 80% methanol and ^{3}H activity was determined by liquid scintillation spectrometry.

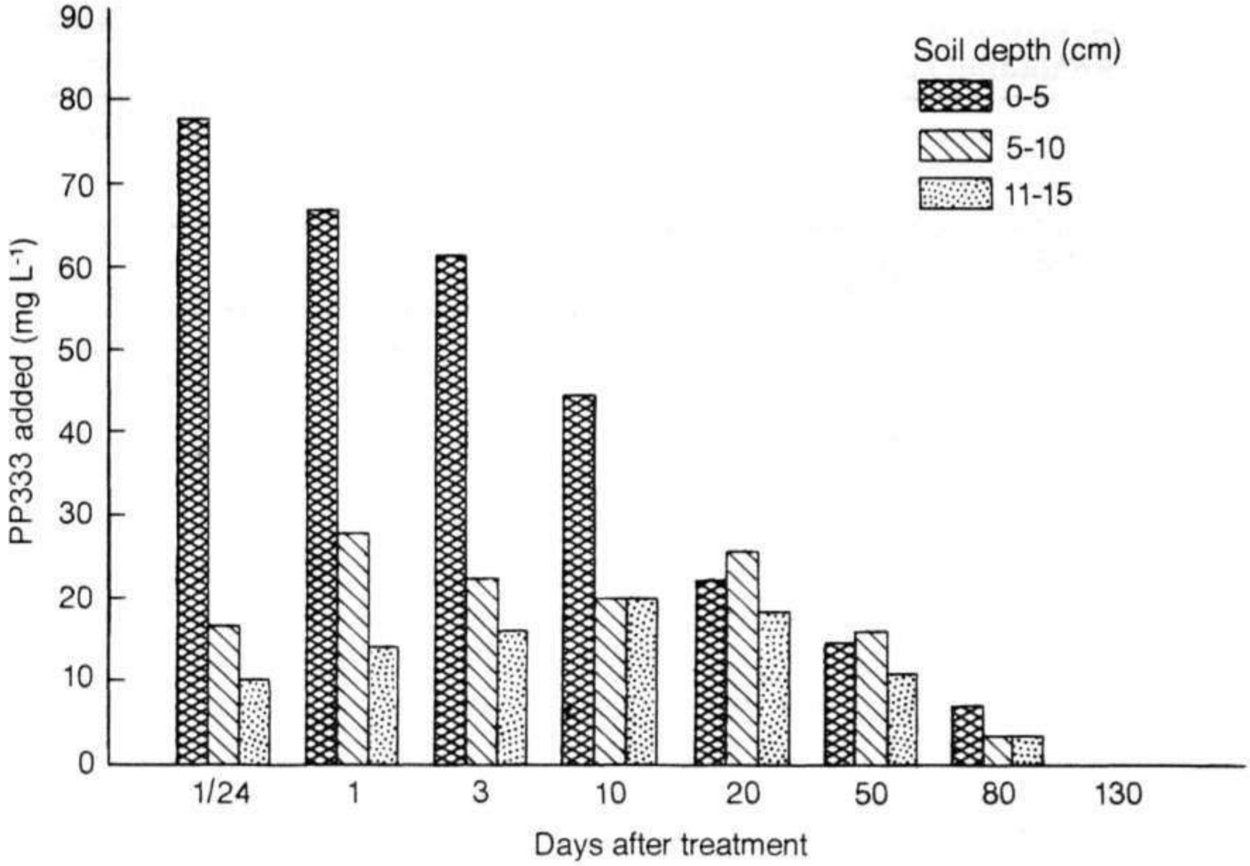

Figure 1. The degradation of PP333 in soil sown to groundnut, with 5 mg L^{-1} PP333 treatment 25 days after flowering, Guangdong Province, China, 1994.

Growth regulators affected the stomatal aperture of leaves. Triadimefon reduced the transpiration rate and water loss in shoots and maintained a higher level of water potential during drought stress (Guo and Pan 1989). MJ increased the stomatal resistance, the leaf thickness, and the size of water storage cells in leaves under drought stress (Pan and Gu 1995). In our experiments the relative water content in the leaves of seedlings treated was maintained at a higher level compared with that of the control. This suggests that these regulators have an ability to resist dehydration in leaves.

It is known that abscisic acid (ABA) is related to the growth and drought resistance of plants and plays an important role in cross-adaptation (Boussiba et al. 1975). This directly maintains the structure and function of the plasmalemma, and indirectly brings about remarkable changes in morphological, anatomical, and physiological reactions (Chandler and Robertson 1994, Pan 1990). For groundnut seedlings during drought stress, the increase of leaf ABA level varied with different concentrations of PP333 and CCC (Table 4). ABA content in the 5 mg L^{-1} PP333 or 150 mg L^{-1} CCC treatments 1 day after drought stress was about 3.37 times or 2.89 times as high as that of the control (Li and Pan 1988a, b).

Hanson et al. (1977) showed that the accumulation of proline in leaves subjected to drought stress acts as an osmoregulator, as does ABA. PP333, triadimefon or MJ increased the proline content (Li 1991, Pan et al. 1995). When

Table 3. Effects of PP333, CCC[1] and MJ[2] on the relative electrical conductivity (%) in groundnut seedlings during drought stress.

		Days after drought stress				
Treatment	(mg L^{-1})	0	1	2	3	4
H_2O (control)	0	21.6	34.7	42.6	53.7	59.7
PP333	1	23.7	27.7	40.7	44.0	46.2
	5	19.2	25.9	34.4	36.4	38.9
	25	13.6	22.4	37.1	34.8	48.4
CCC	75	23.7	26.3	34.9	46.5	50.2
	150	24.0	26.3	34.9	46.5	50.2
	300	25.3	26.8	35.2	43.7	50.4
MJ	0	21.8	35.2	ND	46.6	52.6
	100	21.4	32.7	ND	42.3	43.6
	200	19.4	26.9	ND	33.0	36.3
	400	19.6	27.9	ND	36.0	40.1

1. Seedlings at 4-leaf stage were sprayed with PP333 or CCC. After 24 h incubation period, they were transferred to 10^{-3} mol L^{-1} PEG solution, and roots were kept in dark during drought treatment.
2. At 3-leaf stage, seedlings were grown in 1/2 Knop solution containing MJ at various concentrations for 3 days and then transferred to PEG solution.

ND Not detected.

Table 4. Effects of PP333 and CCC on the endogenous ABA level (pg mg^{-1} dry weight) in leaves of groundnut seedlings under drought stress.

		Days after drought stress				
Treatment	(mg L^{-1})	0	1	2	3	4
H_2O (control)	0	445.2	971.6	1280.3	931.5*	694.1*
PP333	1	705.6*	1779.6*	3314.0*	619.7	1810.3*
	5	544.6*	4346.0	3599.9	934.6*	2363.2*
	25	385.5*	3352.3	1213.3*	600.0*	316.8*
CCC	75	892.2**	1168.3*	1585.3*	563.9*	401.8
	150	793.3**	3701.8**	2932.2**	848.9*	2811.1**
	300	930.2**	3055.6**	968.8	4820.4**	1996.3**

* Significant $P<0.05$.

** Highly significant $P<0.01$.

seedlings were treated with PP333, CCC and MJ, they increased the activities of protective enzymes such as superoxide dismutase (SOD), peroxidase (POD), and calatase (CAT) which were able to remove superoxide and H_2O_2 (Bennett et al. 1982, Li et al. 1991). The activities of SOD and POD in drought-stressed leaves treated with 5 mg L^{-1} CCC and 150 mg L^{-1} CCC are given in Table 5.

Table 5. Effects of 5 mg L^{-1} PP333 and 150 mg L^{-1} CCC on activities of superoxide dismutase (SOD) and peroxidase (POD) of groundnut seedlings under drought stress.

Days after drought	SOD activity (unit ng^{-1} protein)			POD activity (AD470 mg^{-1} fresh weight)		
	Control	PP333	CCC	Control	PP333	CCC
0	30.66	33.40	28.80	51.37	63.47	40.44
2	23.32	25.58	23.52	57.17	60.05	62.65
4	17.10	20.73	19.22	48.65	78.65	76.14

With MJ treatment the activities of SOD isoenzymic bands remained unchanged while when seedlings were treated by CCC and PP333, two new POD isoenzyme bands appeared only when seedlings were drought stressed (Li et al. 1990). Meanwhile, the accumulation of malondialdehyde (MDA), which is toxic to the membrane, was decreased by MJ (Pan et al 1995).

The regulators are able to increase drought resistance in groundnut by increasing the levels of endogenous ABA and proline as well as the activities of SOD, POD and CAT, resulting in protection of the integrity of membranes from drought damage.

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The Growth Dynamics of High-yielding Summer Groundnut in Relay Cropping with Wheat

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Abstract

A series of experiments on summer groundnut relay cropped (SGRC) with winter wheat was conducted on irrigated land in Teng Zhou county, Shandong, China, during 1989-93. Winter wheat was sown at row spacings of 27 cm in early October. Groundnuts were sown by hand between the wheat rows during 17-23 May (15-20 days prior to the wheat harvest) with a plant population of 27-30 plants m^{-2}. Groundnut cultivar 79266 was used in 1991 and 1993, and Hua 37 in 1992.

An average pod yield of 7.8 t ha^{-1} was achieved on 6.7 ha of trials during 1991-93. The highest yield was 8.5 t ha^{-1} achieved by cultivar Hua 37 in 1992. The growth period of the groundnut in SGRC was about 20 days less than that of sole-cropped spring groundnut. The LAI of SGRC was simulated by a quadratic equation, with the peak (5.22) occurring in the mid pod-setting phase (78 days after sowing, DAS). The growth dynamics of total dry mass of SGRC were simulated by a logistic equation; the peak crop growth rate occurred at mid pod-setting (81 DAS), and about 80% of the total dry mass was accumulated during pod formation. Pod dry matter accumulation was initiated at 58 DAS, and the peak growth rate of pod mass occurred at early pod-maturing (95 DAS). During the yield-formation phase, about 75% of the total dry mass was partitioned to the pods.

1989－1993年间，在中国山东滕州市水浇条件下对麦套夏花生进行了一系列试验．冬小麦于10月上旬播种，行距27厘米，5月17～23日即麦收前15－20日于麦行间套种花生，每平方米27－30株．1991年和1993年采用的花生品种是79266，1992年则采用花37．

1991－1993年间在6．7公顷的试验田上，荚果平均产量达到7．8吨/公顷．8．5吨/公顷的最高产量是1992年采用花37获得的．麦套花生生育期比春花生短20天左右．其叶面积消长动态可用二次方程拟合，峰值15．22出现于播后第78日（结荚中期），其干物质积累规律可用Logistic方程拟合，播后第81日（结荚中期）生长速率最大，干物重的80%积累于荚果形成期．荚果干物质积累始于播后第58日，荚果干重增长高峰出现在荚果成熟期（播后第95日）．在产量形成期，约有75%的总干物重分配到荚果中．

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Introduction

The traditional cropping pattern in Shandong Province is groundnut as a sole crop in the spring season. This is known as spring groundnut (SSCG) in northern China (Shandong Peanut Research Institute 1982). As groundnut-wheat double-cropping is a possible way to solve the competition between other food crops and groundnut, and to increase the production of both, three patterns of wheat-groundnut double-cropping have been developed in different areas of Shandong Province. These are relay cropping spring groundnut with winter wheat sown in broad-beds (RSGW) (Sun Yanhao et al. 1993), summer groundnut relay cropping in common narrow-row winter wheat (SGRC) (Li Xiangdong and Wan Yongshan 1992, Li Xiangdong and Zhang Gaoying 1992, Li Xiangdong et al. 1992) and summer groundnut sown directly after the wheat harvest (SGSD) (Yang Yingmin et al. 1988). The first pattern needs wheat to be sown in wider rows, which may lead to reduced wheat yield, and the latter one has a lower yield potential due to the shorter growing season for groundnut. During 1989-1993, a series of experiments was carried out to investigate the maximum yield potential of SGRC in high-yielding wheat fields, to study the growth dynamics of SGRC plants, and the key cultural practices for high yield. This paper discusses the growth dynamics and the optimum growth parameters of SGRC plants grown in experiments during 1991-93.

Materials and Methods

The experimental field of 6.7 ha is located in Teng Zhou county, Shandong. Soil testing showed that the field contained 1.24% organic matter, 0.094% total N, 65 mg kg^{-1} available nitrogen, 10.93 mg kg^{-1} available P and 81.34 mg kg^{-1} available K. Wheat cv Lu 215953 was sown in early October at a rate of 90 kg ha^{-1}, with a row spacing of 27 cm. Manure at 60 t ha^{-1}, 300 kg ha^{-1} urea, 750 kg ha^{-1} superphosphate and 300 kg ha^{-1} potassium sulphate were applied before wheat sowing as a basal dressing. In 1992 the wheat yield was 7.73 t ha^{-1}, and it rose to 8.19 t ha^{-1} in 1993. Groundnut cv 79266 was used in 1991 and 1993, and Hua 37 in 1992. Both cultivars had sequential branching, large pods, bunch type habit, and medium-maturity duration. Seeds were hand-dibbled between wheat rows during May 17-23, 15-20 days prior to wheat harvesting. The wheat field was irrigated 7-10 days before groundnut sowing to ensure germination and emergence. Hole-to-hole spacing was 25 cm, and the plant population of groundnut 27-30 plants m^{-2}. Fifteen kg ha^{-1} zinc sulphate, 15 kg ha-^{1} borax and 15 kg ha^{-1} ammonium molybdate were applied at sowing. Groundnuts emerged 10 days after sowing under the shade of the wheat canopy. Manure at 30 t ha^{-1} was broadcast and incorporated into the soil by hand hoe 5 days after wheat harvesting. Urea at 300 kg ha^{-1}, 750 kg ha^{-1} superphosphate and 300 kg ha^{-1} potassium sulphate were applied as side dressings before the first flowering, and cultivation to remove weeds was done 2-3 times before pegging. To prevent excessive vegetative growth (e.g., the main stem height exceeding 35 cm before pod-setting), 100 mg L^{-1} of PP333 (paclobutrazol), a plant growth retardant, was sprayed. Also, carbendazim was sprayed three times, at 15-day intervals, beginning from August, to control foliar disease. Irrigation was applied as needed.

The phenological data were visually observed in the field and recorded. Samples of 10 plants, with 3 replications, were taken at 10 day intervals for measuring plant characteristics such as leaf area index (LAI), dry mass of leaves, stems, pegs, immature pods and mature pods. The flower numbers were counted every day at the same sites.

At maturity, 15 sample plots (each of 13.3 m^2) per hectare were randomly selected. All plants within these sample plots were dug up, pods were picked, and the total mass of fresh pods recorded. Subsamples of 1 kg per plot fresh pod were taken for oven drying to get the pod mass at 10% moisture.

Results

The Yield and the Yield Construction

The mean pod yield of 7770 kg ha^{-1} (based on oven dry pod mass with 10% moisture) was achieved on the 6.7 ha experimental area during 1991-1993. The actual plant population averaged 28.5 plants m^{-2}, pod number per plant averaged 17±2.6 and single pod mass averaged 1.7+0.1 g. The total biomass was around $1.28 x l0^4$ kg ha^{-1}, and harvest index (dry pod mass/total biomass x 100) was about 60%.

The Phenology Course of SGRC

Table 1 shows the phenology days of SGRC heat unit (HU=E(daily mean temperature-10) °C d^{-1}) calculated for each phase. The data of SSCG, and SGSD taken from previous research at Shandong Agricultural University, are also listed for comparison.

The results show that the duration of the growing season of SGRC was 20 days less than SSCG, but the difference in the duration of the yield formation phase was only 13 days. Compared with SGSD, SGRC had a longer growing season and yield formation duration. This implies that the yield potential of SGRC is much higher than SGSD, and is comparable to that of SSCG.

Table 1. Phenology course of summer groundnut relay cropping (SGRC) in comparison with sole cropped spring groundnut (SSCG) and sole summer groundnut sown directly after wheat harvesting (SGSD), Shandong, China.

Cropping pattern	Emergence phase (a)	Young seedling phase (b)	Flowering and pegging phase (c)	Pod-setting phase (d)	Pod-maturing phase (e)	Yield formation phase (d+e)	Whole growing season (a+b+c+d+e)
Duration of phenological phase (number of days)							
SGRC	13	27	19	41	30	71	130
SSCG[1]	15	31	21	40	44	84	151
SGSD[1]	9	20	20	42	17	59	108
Cumulative heat unit [HU = $\sum$ (daily mean temperature-10)(°C d^{-1})]							
SGRC	149.3	409.9	311.2	645.1	350.6	995.8	1865.9
SSCG[1]	102.9	355.6	289.7	637.3	605.6	1242.9	1991.4
SGSD[1]	122.0	298.4	322.1	611.6	158.6	770.2	1513.6

1. The data are from results over several years collected by Shandong Agricultural University.

Growth Dynamics of the Main Stem

The growth dynamics of the main stem height closely follow a sigmoid curve (Fig. 1). It was well fitted by logistic equation $y=45.82/(1+360.8e^{-0.1309x})$, where y=main stem height (cm) and x=days after sowing (DAS). The growth rate of main stems was maximum at 45 DAS (at the full flowering phase). The main stems basically ceased to grow in late July (early podding phase). Final height of the main stem in SGRC was about 45 cm.

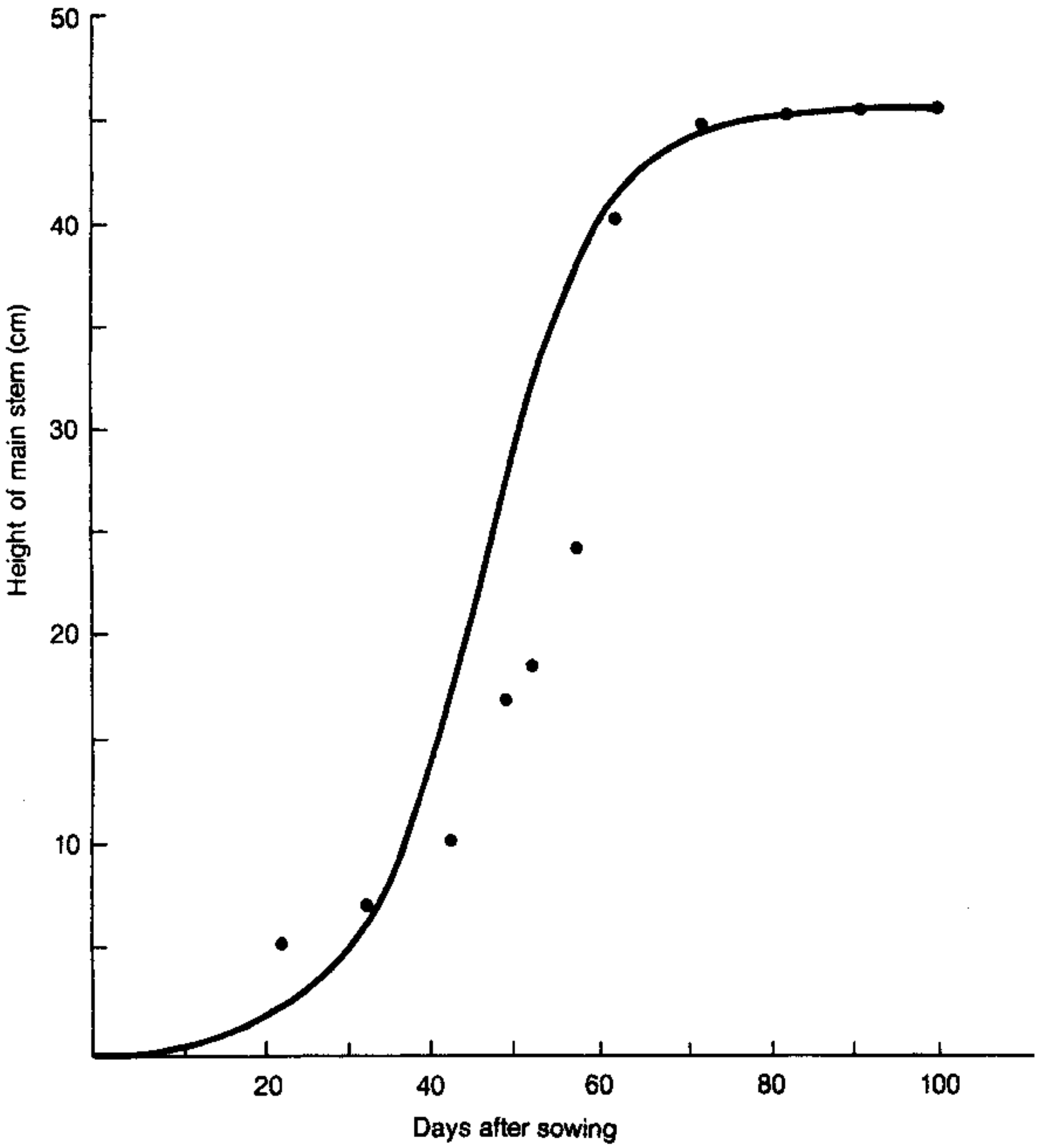

Figure 1. Seasonal change in height of the main stem of summer groundnut relay cropped with winter wheat (SGRC), Teng Zhou County, Shandong, China, 1992.

The Seasonal Change of LAI

The seasonal change of leaf area per plant of the high-yielding SGRC fitted well with a quadratic equation, $y=-33.7447 + 13668X-0.008798x^2$, y being leaf area per plant and x being DAS (Fig. 2). The peak LAI (5.2) occurred at 78 DAS (mid pod-setting phase). The LAI of high-yielding SGRC increased rapidly relatively early in the season, so that it reached a fully-closed canopy (LAI=3) by the beginning of the pod-setting phase. During the whole yield-formation phase (pod-setting phase plus pod-maturing phase), LAI was maintained at a level well above 3.

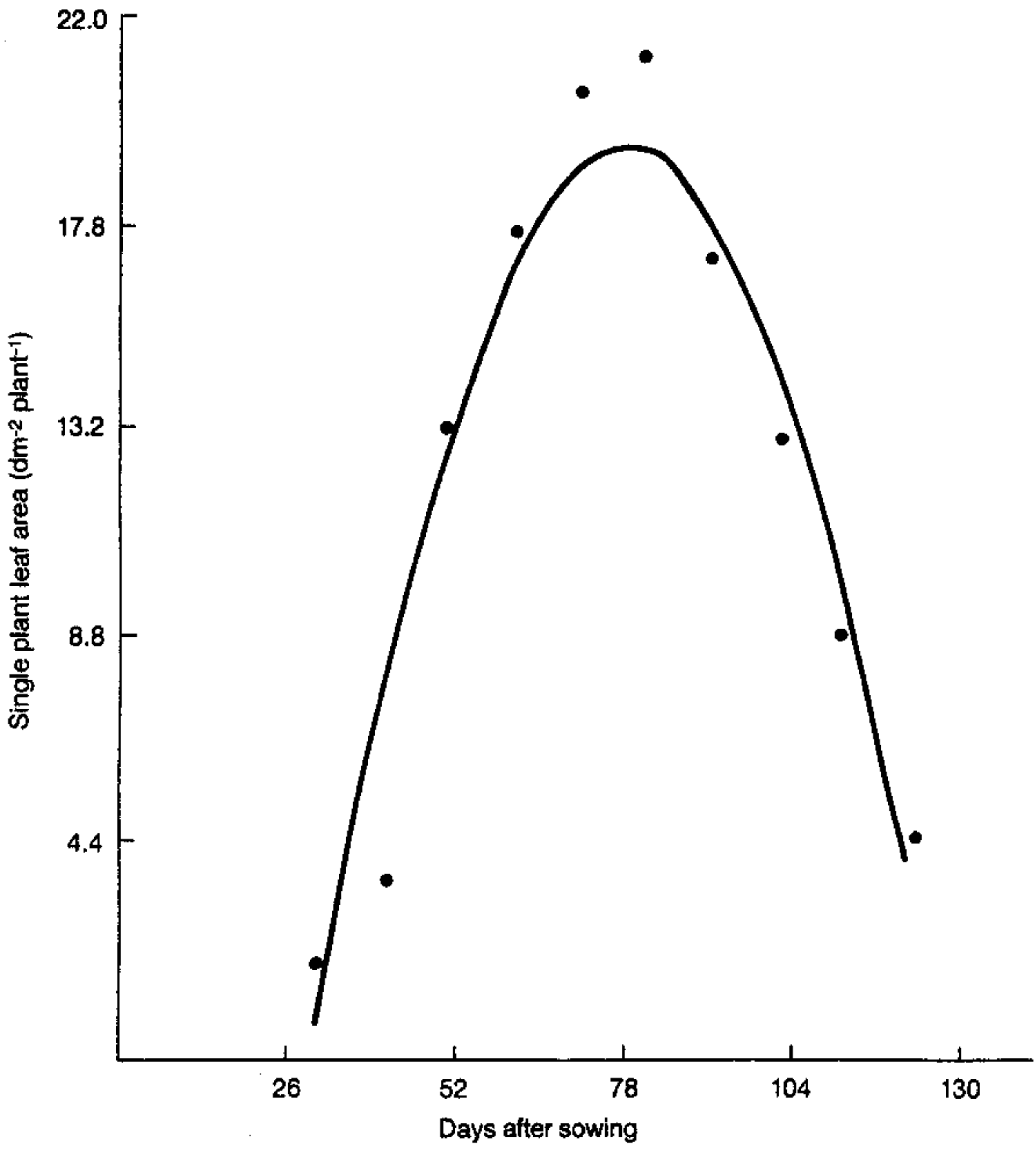

Figure 2. Seasonal change of leaf area of summer groundnut relay cropped with winter wheat (SGRC), Teng Zhou County, Shandong, China, 1992.

The Dynamics of Flowering, Peg Number, and Pod Number

SGRC started flowering at 39 DAS, quickly entered the full-bloom stage, and continued full bloom for about 15 days. Just after pod-setting, the amount of flowering per day reduced quickly (Fig, 3).

Five to seven days after the first flowering, formation of pegs started, and reached a peak at 61 DAS. Young pods (the kernel visible) were observed at 58 DAS, after which the number of young pods increased rapidly until 71 DAS, when the peak of young pod numbers occurred. Then, young pods developed to become immature pods (pod with an edible kernel but not mature). The number

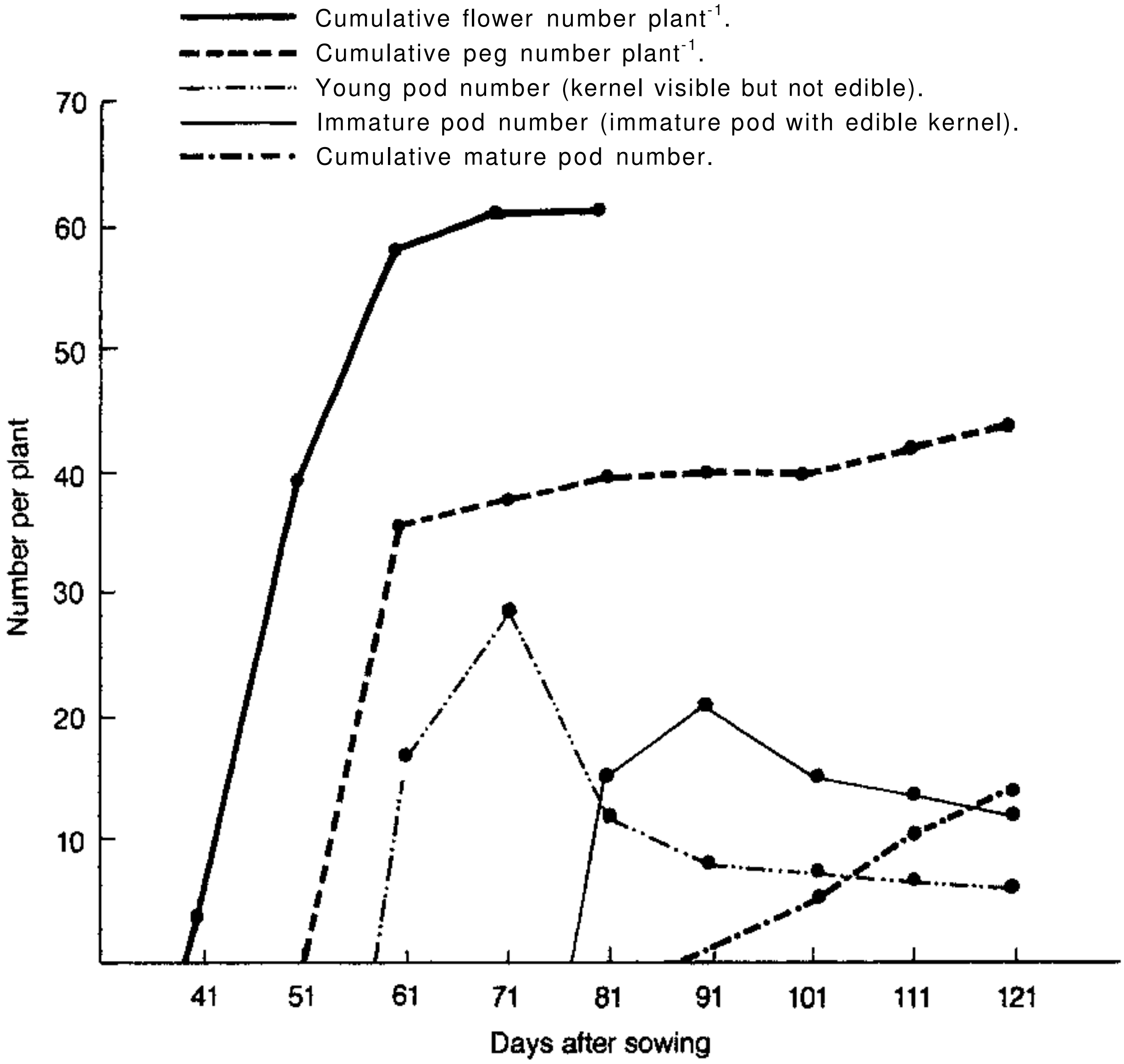

Figure 3. The dynamics of flowering, pegging, and pod formation for summer groundnut relay cropped with winter wheat (SGRC), Teng Zhou County, Shandong, China, 1992.

of immature pods had a peak at 91 DAS, although, by this time, some pods had matured. The number of matured pods increased linearly until harvesting.

The Cumulative Dynamics of Dry Mass

The dynamics of total dry mass accumulation could be closely simulated using the equation $y = 69.78/(l+124.5231e^{-0.05932x})$ ($r = 0.9734^{**}$), (Fig. 4), where y = mass of total dry matter (g $plant^{-1}$) and x being the days after sowing. The rate of

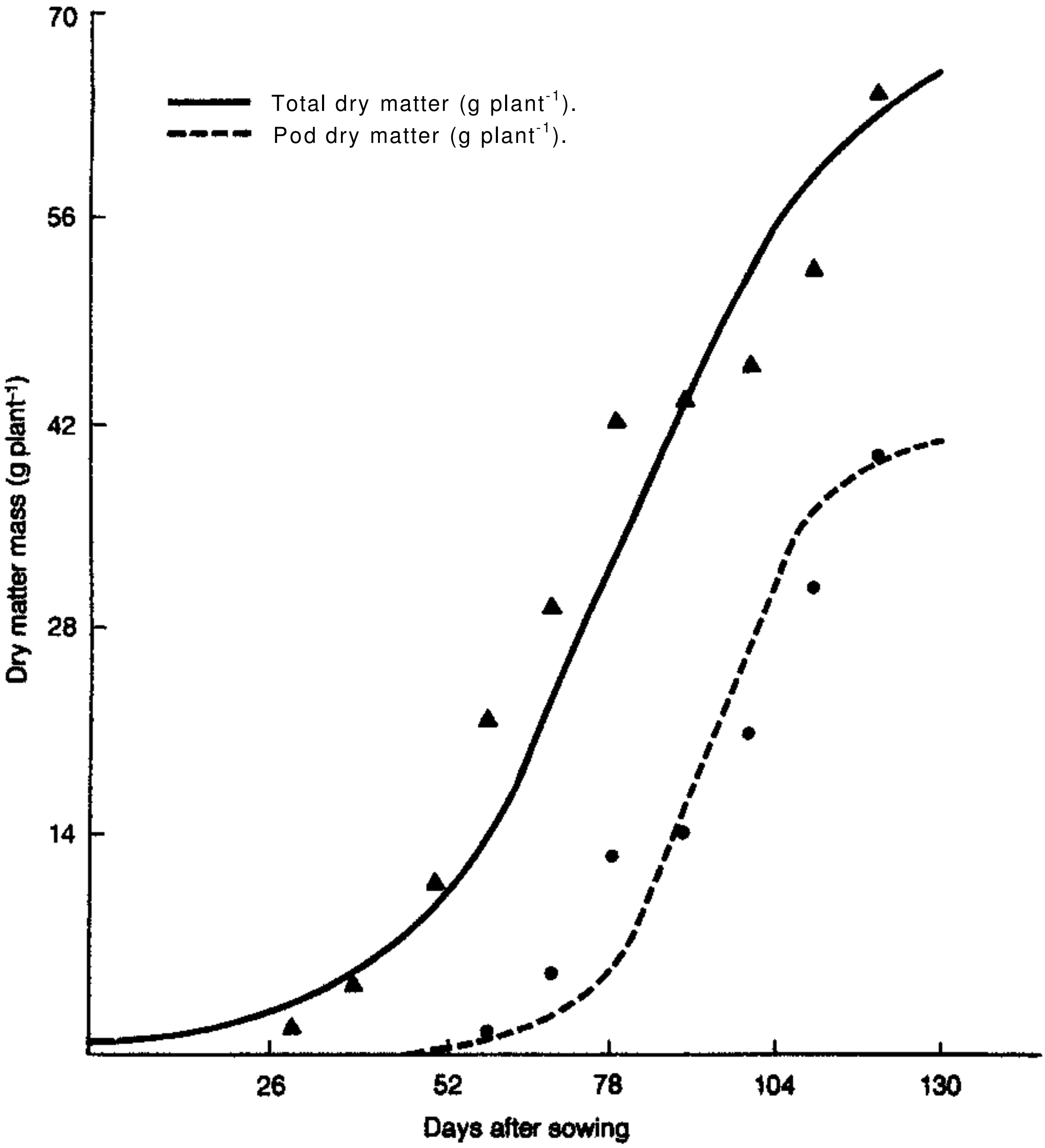

Figure 4. Dynamics of cumulative mass of dry matter of summer groundnut relay cropped with winter wheat, Teng Zhou County, Shandong, China, 1903.

increase of total dry matter (CGR) peaked at 81 DAS (mid pod-setting phase). The mean CGR during pod-setting accounts for nearly 50% of that of the total season. CGR of high-yielding SGRC plants was still maintained at a high level during the pod-maturity phase, and the amount of total dry matter accumulated during the pod-maturity phase was 34% of that of total season. Thus the total dry matter accumulated during the yield-formation phase was 83% of that of the total growth period.

Pod Yield Formation and Distribution of Dry Matter

The dynamics of daily accumulated pod yield could be well simulated by equation (Fig. 4), $y=41.925/(l+57244.17e^{-0.1152x})$ (r=0.9591 * *), where y is mass of pod dry matter per plant and x is DAS. The growth rate of pod dry weight (PGR) reached a peak of 1.21 g $plant^{-1}$ day^{-1} at 95 DAS (4 days prior to mature pod formation). During the whole yield-formation phase, PGR of SGRC averaged 0.56 g $plant^{-1}$ day^{-1}, which is much higher than that of SSCG (0.31 g $plant^{-1}$ d^{-1}). During the pod-maturity phase the mean PGR of SGRC was maintained at a high level (0.75 g $plant^{-1}$ d^{-1}), which was very much higher than that of SSCG (0.31 g $plant^{-1}$ d^{-1}).

The total dry matter was exclusively vegetative until the beginning of pod formation. Thereafter, the dry matter produced was partitioned increasingly to the pods. On average, 75% of the dry matter produced during the yield formation phase in SGRC was partitioned to pod matter, which is much higher than that of SSCG (57%) (Table 2).

Discussion

The results indicated that SGRC had a longer growing season, effective blooming stage, pod-maturity phase, and yield-formation phase compared with SGSD, and hence has a higher and more stable yield potential. The duration of the growing season of SGRC was 20 days shorter than SSCG, and SGRC was also shorter in its vegetative, flower - pegging, and pod-maturity phases. These shorter phases were disadvantageous to the vegetative growth, pod formation and pod filling, thus restricting the high yield potential of SGRC. Because of the higher temperature during the early growing season, the rate of growth and development of SGRC was more rapid in the early stages, so that the duration of the yield-formation phase was only 10 days shorter than SSCG. Furthermore, the growth rate of SGRC in both vegetative and reproductive growth was relatively high: the SGRC could attain a high level of CGR, PGR and partitioning percentage during the yield formation phase, so that the yield potential was comparable to SSCG. If favorable conditions were provided and optimum cultural practices followed, high yield could be attained with SGRC.

For achieving high yield in SGRC (above 7500 kg ha^{-1}), it is essential to realize optimal growth and development dynamics. Some critical parameters in each

Table 2. The cumulative dry matter and its distribution for summer groundnut relay cropping with wheat (SGRC) and spring sole cropping groundnut (SSCG), Shandong, China.

	Total dry matter (g $plant^{-1}$)			Pod dry matter (g $plant^{-1}$)			
Phases	Cumulation	Growth in each phase	Daily growth increment	Cumulation	Growth in each phase	Daily growth increment	Partitioning percentage[1] (%)
				SGRC			
Emergence	0.90	-	-	-	-	-	-
Young seedling	4.76	3.86	0.14	-	-	-	-
Flowering and pegging	11.38	6.62	0.44	0.07	-	-	-
Pod-setting	43.05	31.67	0.88	13.53	13.46	0.38	42.50
Pod mature	65.19	22.14	0.62	40.62	27.09	0.75	122.40
Whole growing season	65.19	64.29	0.56	40.62	40.62	-	63.18
Yield formation	-	53.81	0.75	-	40.55	0.57	75.36
				SSCG[2]			
Emergence	0.51	-	-	-	-	-	-
Young seedling	4.10	3.51	0.11	-	-	-	-
Flowering and pegging	13.25	9.15	0.44	1.05	-	-	-
Pod-setting	46.95	33.69	0.84	13.37	12.32	0.31	36.50
Pod mature	58.42	11.48	0.27	26.91	13.54	0.31	117.90
Whole growing season	58.42	57.91	0.43	26.91	26.91	-	45.20
Yield formation	-	45.17	0.54	-	25.86	0.31	57.25

1. Partitioning percentage = $\frac{\text{Phasic increment of pod dry matter}}{\text{Phasic increment of total dry matter}} \times 100\%$
2. The data were obtained at the experiment farm of Shandong Agricultural University in 1989.

phase are: (1) The flowering starts before early July (35-40 DAS), the young pod formation begins around 20 July (20 days after flowering), and harvesting in early October, to keep the duration of the yield-formation phase not less than 75 days. (2) Keep an optimum leaf area expansion rate, so that the canopy closure (LAI=3) occurs at the beginning of young pod formation and the height of main stems reaches about 35 cm. (3) Keep an optimum peak value of LAI at about 4.5, and not less than 2.5 at harvesting, and a main stem height 40-50 cm.

Fertile land, irrigation facilities, and a package of improved practices are essential for realizing optimal growth dynamics and high yield. The key practices involved are as follows: (1) High-yielding large-pod groundnut cultivars with medium duration, e.g., Hua 37, or 79266 should be used. (2) The plant population should be 27-30 plants m^{-2}. (3) Sowing should be 15-20 days prior to wheat harvesting. (4) Intensive field management during the growing season, including hoeing, side dressing of fertilizers, irrigation, application of a growth regulator (Li Xiangdong et al. 1992c), and fungicide for controlling foliar diseases should all be included in the cultural practices.

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Studies on the Growth Rate and Relations between the Groundnut Root System and other Organs

Tang Ruihua[1], He Wensong, Liu Yuqian, Wangjianjun, and Bi Keqiang[2]

Abstract[3]

Observations of the growth rate, form, distribution, and correlation between components of the groundnut root system were made on selected plants at regular intervals for several years. In addition, data were obtained from many unpublished reports and a series of functional equations developed. On good soil, the maximum root number obtained was 32 858, with a total root length of 609.6 m and dry weight of 34.58 g at the pod-maturing stage. The root system is cone-shaped from the 8th to the 23rd day, becomes semi-cylindrical from the 23rd to the 38th day, and is cylindrical after the 38th day. Root mass shows significant or highly significant positive correlation with branch mass, leaf mass, peg mass, and kernel mass. The number of roots is not significantly correlated with the number of leaves, flowers, pegs, and pods. However, it is significantly and positively correlated with the number of branches.

历时数年定期定株对花生根系生长速率、形态、分布及根系构成因素间的相关进行了观察研究，取得若干前未发表的数据，据此推导出一系列函数方程．在良好的土体条件下，饱果期根条数可高达32，858条，总长达609．6米，干重达34．58克．第8日至第23日，根系呈圆锥形，第23日至第38日与为半圆柱形，第38日后则呈圆柱形．根干重与枝干重、叶干重、果针干重、子仁干重呈显著或极显著正相关．根条数与叶、花、果针、荚果数目间无显著相关，但与分枝数呈显著正相关．

1. Center of Agricultural Science and Technology, Weihai, Shandong 264200, China.
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3. Editors' note: Despite our concerted efforts, we coult not get a revised full paper from the authors. Hence only an abstract is published.

Tang Ruihua, He Wensong, Liu Yuqian, Wang Jianjun, and Bi Keqiang. 1996. Studies on the growth rate and relations between the groundnut root system and other organs. (In En. Summary in Ch.) Page 169-169 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Studies on Light Interception, Photosynthesis, and Respiration in High-yielding Groundnut Canopies

Wang Caibin, Sun Yanhao, Chi Yucheng, Cheng Bo, Tao Shouxiang, and Chen Dianxu[1]

Abstract

Two high-yielding varieties of groundnut characterized by few branches, medium duration of growth, and large pods were studied to measure some physiological characteristics related to their canopy morphology Light distribution through the canopy, light interception rate (LIR) at different stages of the plants' development, diurnal and seasonal variations in photosynthesis, dark respiration, and the effects of water deficiencies were measured.

The major area of photosynthesis was the upper one-third of the canopy which received four-fifths of the solar radiation and contained about half of the total leaf area. The LIR of the canopy remained low (50% of solar radiation reached the ground) until the flowering-pegging stage but rose to a peak which was maintained until the early-mid pod-filling stage.

Measurements of diurnal variations in photosynthesis on a clear day showed a peak between 1100-1300 h. No sign of 'noon rest' or light saturation was evident under natural conditions so the dominant factor was intensity of solar radiation. Dark respiration was maximum at 1100-1500 h and minimum at 0300-0500 h, and strongly dependent on air temperature.

Over the growing season the net photosynthetic rate increased slowly during the seedling stage and accelerated from the flowering-pegging stage until mid pod formation when it reached a peak. Photosynthesis was more sensitive to water deficiencies than dark respiration.

From these results physiological indices for the groundnut canopy that would ensure yields of 7.0-7.5 t ha^{-1} were listed.

通过对两个分枝数少的中熟大果高产品种的研究，测定了与其冠层形态有关的一些生理性状．对光在冠层中的分布、作物不同生长时期的光截获率、光合作用、暗呼吸的昼夜和季节变化规律以及缺水条件下对其产生的影响等都进行了测定．

光合作用的主要部位是冠层的上部三分之一，它吸收了太阳辐射的五分之四，其叶面积

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Wang Caibin, Sun Yanhao, Chi Yucheng, Cheng Bo, Tao Shouxiang, and Chen Dianxu. 1996. Studies on light interception, photosynthesis, and respiration in high-yielding groundnut canopies. (In En. Summary in Ch.) Pages 171-180 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

也占全部叶片面积的一半左右。在花针期以前，冠层的光截获率较低(50% 的光照到达地面)，但在果实充实期的早期和中期，光截获率达到顶峰。

晴朗天气条件下，光合作用的昼夜变化的测定表明，其在 11 时至 13 时之间有一个峰值。自然条件下没有明显的"午休"和光饱合迹象，因此影响它的主要因素就是光照强度。暗呼吸在 11 时至 15 时之间达到最大，在 3 时至 5 时之间达到最小，与气温密切相关。

在生长期内，净光合同化率在营养生长期间上升较慢，但在花针期加快，直到成果中期达到顶峰。光合作用对于缺水反应要比暗呼吸敏感得多。

根据研究结果列出了产量水平在 7.0－7.5 吨/公顷的花生冠层生理指标。

Introduction

Over the last ten years, cultivation of high-yielding groundnut has made great progress in China. Pod yields of 7.5 t ha^{-1} have been achieved in small and medium-scale areas in some regions and a complete set of cultural practices has been determined. Relevant patterns and indices in growth and development of high-yielding groundnut have been reported by several workers. However, very little literature has been available in China on canopy characteristics related to photosynthesis. Therefore, investigations on light interception, photosynthesis, and dark respiration in the canopy of high-yielding groundnut were carried out during 1991-94.

Materials and Methods

Plots of 300-1300 m^2 were prepared in experimental fields at Shandong Peanut Research Institute (SPRI) Laixi, China, each year. Seeds were sown in two-rows bed covered with polythene film (80-90 cm bed spacing and 40-45 cm row spacing) during mid/late Apr with plant densities of 135 00-150 000 hills ha^{-1} (2 seeds $hill^{-1}$). The crop was harvested during early/mid Sep yielding 7.0-7.7 t ha^{-1} (air dried to a moisture content of 8-10%). Varieties used were Luhua 11 and Haihua 1, both high-yielding varieties with few branches, medium-duration, and big pods. Regular observations (10-15 days) were made at fixed points during the growing season. The intensity of solar radiation was measured with a ST-80 Multi-probe Light Meter, and photosynthesis and dark respiration were measured with a QGD-07 Infrared-Gas CO_2 Analyzer.

Results and Discussion

Canopy Structure and Light Distribution

Distribution of leaf area index (LAI), and dry weight of leaves and stems among layers within the whole canopy were investigated by cutting the plants off at predetermined heights and measuring the appropriate plant parts (field-section methods) during the peak stage of leaf area (LAI>4). Results (Fig. 1) indicated that

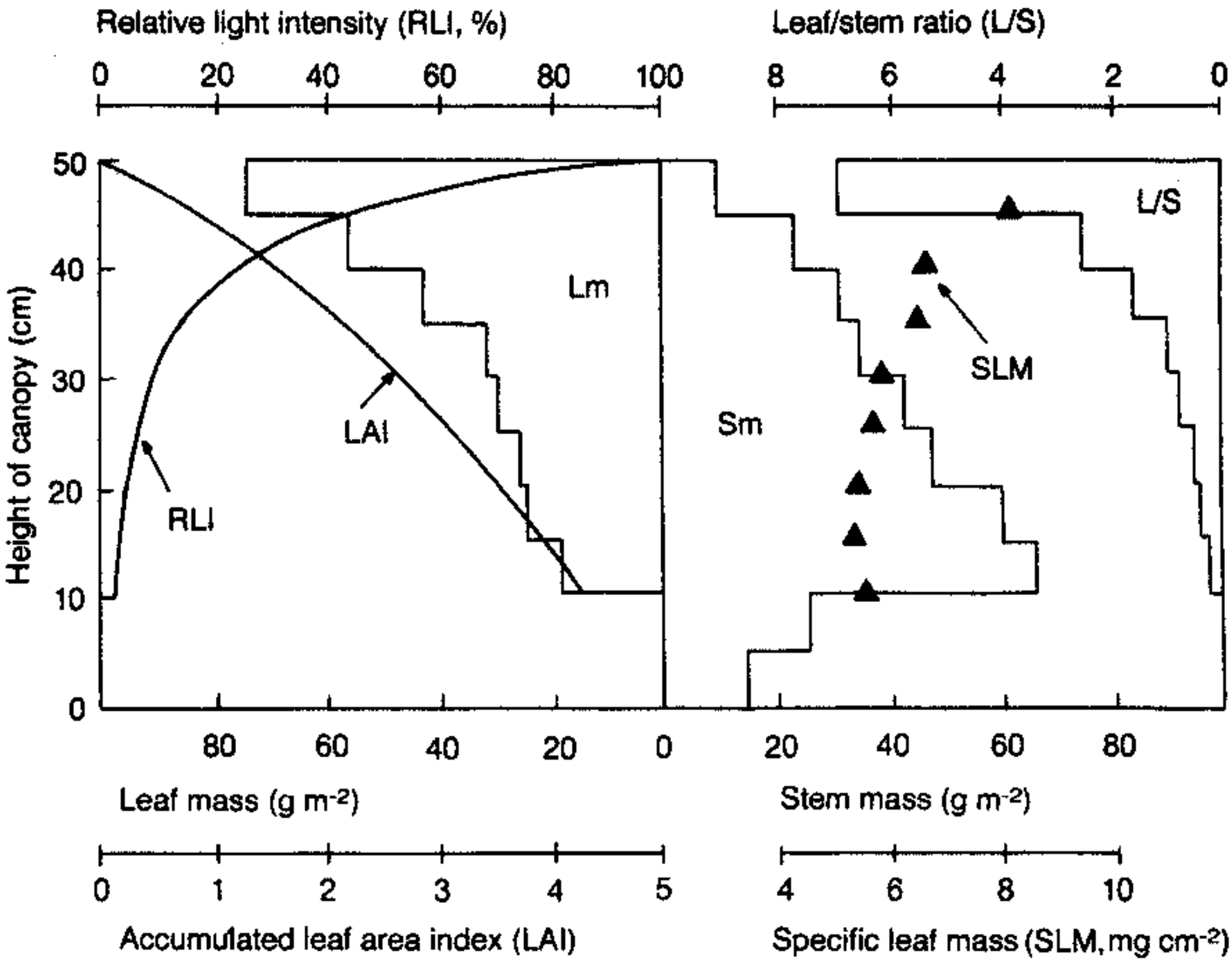

Figure 1. Canopy structure and light distribution of a high-yielding groundnut variety, Shandong Peanut Research Institute, Shandong, China, 1994.

leaf density was much higher in the upper layers. About 50% of the leaves (dry matter based) was found in the top 15 cm of the canopy and around 20% in the top 5 cm of the canopy, while only about 30% occurred in the lower half of the canopy.

Distribution of stems among the different layers of the canopy was the opposite of that of leaves: very small proportions were found in both top and bottom layers. The dry-stem mass increased quickly from the top to 10 cm height above ground level within the canopy. Around 30% of its total was found within the 10-20 cm layers.

The specific leaf mass (SLM), tended to increase from bottom to top. The SUM in the upper 5 cm of the canopy was much higher than in any other layers (21% higher than the immediately adjacent layer between the height of 40-45 cm). This phenomenon in the canopy surface layer has been shown to be significantly related to the application of plant growth inhibitor (PP333), in addition to the high metabolic activities of leaves in this layer (Wang Caibin, Shandong Peanut Research Institute, personal communication, 1995).

L/S (leaf dry mass to stem dry mass) ratio, in general, followed a similar trend to that of SLM among the different layers of the canopy L/S ratio exceeded 6 in the upper 5 cm of the canopy, again, much higher than that in any other layers. This was because 'stems' in the surface layer were only petioles.

The intensity of solar radiation dropped continuously as it penetrated the groundnut canopy due to absorption by the canopy. The canopy can be divided into two parts (Area I and Area II) according to their light interception rate (LIR). Area I, consisting of the upper 30% of the canopy, was the major light-absorption area, producing about 50% of the total leaf area and intercepting over 80% of the solar radiation absorbed by the whole canopy. Consequently its role in dry matter production was dominant. Area II, in the lower 70% of the canopy, contributed much less to plant growth and development compared with Area I, as it only intercepted a small part of the solar radiation together with the inferior assimilation potential of the leaves themselves and the open surroundings (such as CO_2 concentration).

The extinction coefficient (k) in such varieties as Luhua 11 and Haihua 1, ranged from 0.82 to 0.87 during the peak stage of groundnut leaf area (LAI>04) on the basis of multi-location investigations. The relative intensity of light near the base of the plant can be estimated by Beer and Lamb's law: $I=I_0\ e^{-k.LAI}$ (where I_0 is natural light intensity). If k was fixed at 0.85 (around mean value) and 14.4 µmol $m^{-2}\ s^{-1}$ (Shandong Peanut Research Institute 1990) was taken as the light compensation point of groundnut, the relations between levels of population LAI and EPPD (effectivephotosynthetic period during a day) can be established (Figure 2).

The EPPD of a whole canopy, on a clear day, would exceed 10 h when the LAI of the canopy is <4. If LAI increased from 4 to 5, most light would be intercepted by the upper canopy with LAI of 4. The leaves below this would have a mean EPPD of around 8.5 h. With a further increase to LAI 5.5 the mean EPPD of these lower leaves would be only 5 h. The additional LAI beyond 5.6 was ineffective and leaves in this lower layer would always be in a situation of consumption'.

Canopy Light Interception Ratio (LIR) During the Growing Period

The LIR of the canopy during the seedling stage was low, even in high-yielding groundnut fields, and generally less than 40% at the onset of flowering. Most solar radiation (over 50%) reached the ground and was wasted. A sharp increase in LIR followed the flowering-pegging stage and soon reached a peak (LIR>90). Usually this peak lasted until early to mid pod-filling stage. The light leaking rate (LLR), the opposite to LIR, decreased quickly, and could fall as low as 1.5% at the highest stage of LIR. A slight decline in LIR and increase in LLR occurred during the later growing stages. Data in Table 1 were collected from several locations where yields ranged from 7.0-7.5 t ha^{-1}.

Based on results in Table 1 it can be concluded that LIR>90 should continue for at least 45 days if groundnuts are to yield around 7.5 t ha^{-1}.

The light-reflecting rate of the groundnut canopy, during the whole growing season, was comparatively stable, ranging from 4-8%, which was in line with the

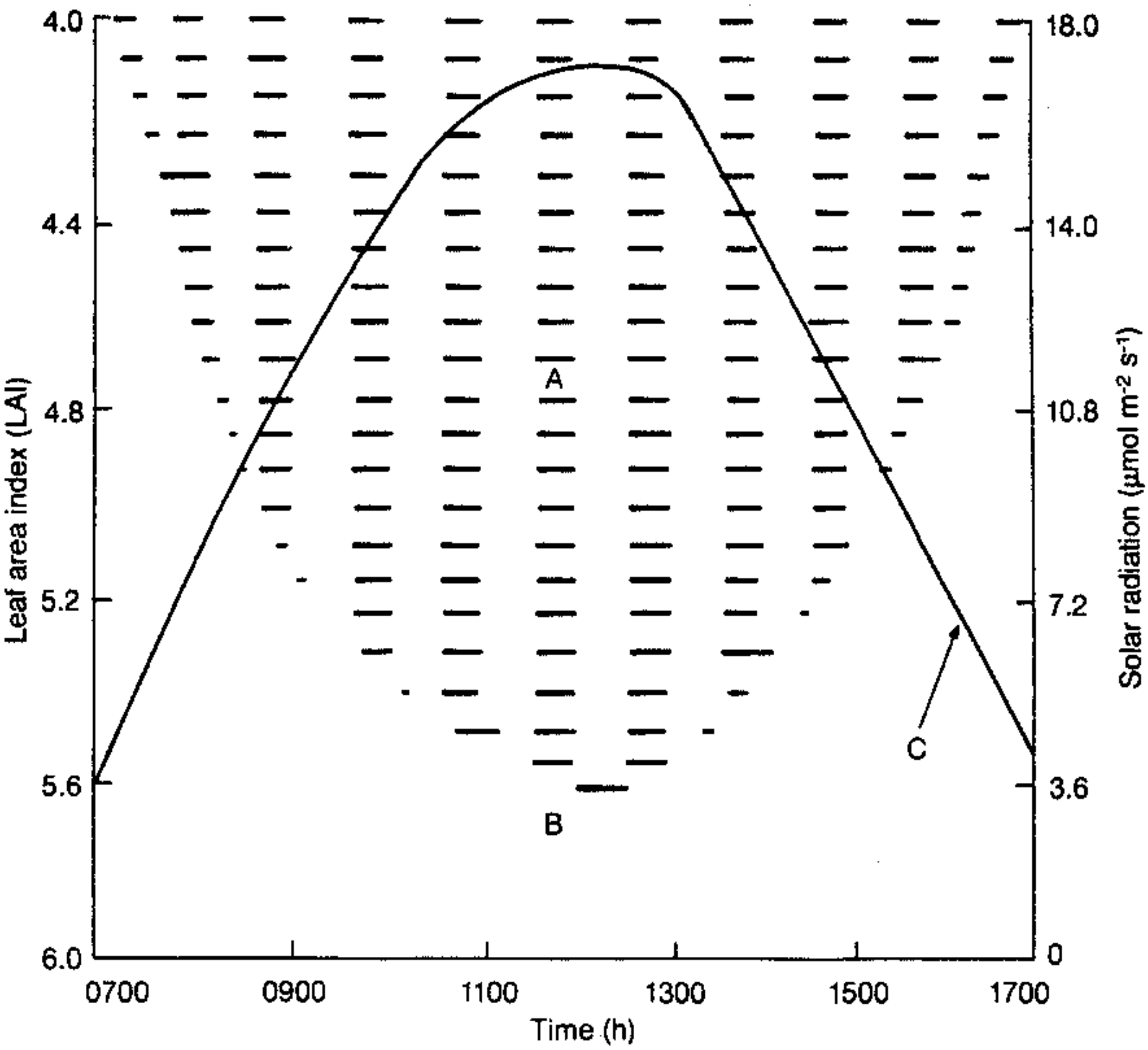

Figure 2. Relationship between levels of leaf area index (LAI) and effective photosynthetic period in a day (EPPD).

Area A : Net photosynthetic rate (NPR) >0, Area B : NPR<0, Curve C: Intensity of solar radiation (mean value from motidays measurements from late Jul-early Aug).

results for rice (4-6%) and wheat (5-7%) reported by Gao Liangzi and Yen Hongzhang (1992).

Diurnal Variation in Photosynthesis and Dark Respiration

The net photosynthetic rate (NPR) in a groundnut canopy varied with the intensity of solar radiation during a day The NPR rose constantly from about 0600 until it reached its peak around noon (1000-1300). It then decreased gradually and dropped to zero after 1700-1800. More photosynthates were accumulated in the morning than in the afternoon. A similar tendency in the diurnal variation of photosynthesis was observed during different growing seasons (Figure 3). On a cloudy day NPR was generally low and fluctuated synchronously with the intensity of solar radiation.

Table 1. Seasonal variation in light interception rate and light leaking rate, Laixi, China, 1993-94.

	Jun			Jul			Aug			Sep
	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early
LIR	26-40	34-48	53-67	64-80	88-92	92-94	92-94	90-93	89-91	86-87
LLR	55-66	44-57	25-39	12-28	3.5-7.0	1.5-2.5	2.0-3.0	4.0-5.0	6.5-9.0	8.0-9.0

The results observed in high-yielding groundnut fields indicated that during its maximum stage, NPR was able to reach as high as 4.5-5.0 g CO_2 m^{-2} land h^{-1} and the daily-accumulated photosynthate could exceed 35.0 g CO_2 m^{-2} land.

During a day-night cycle, one peak occurred between 1100 and 1500 (1-2 hours later than that of the NPR) and one valley during 0300-0500 in the dark respiration rate (DRR). The ratio of peaks to valleys in DRR was 1.6-2.0. The levels of dark respiration were higher in the afternoon than in the morning, and higher in early part of night than in the later part. Air temperature seemed to be the principle factor modifying the variation of dark respiration, and a similar varying tendency between DRR and air temperature over 24 h was observed (Figure 4).

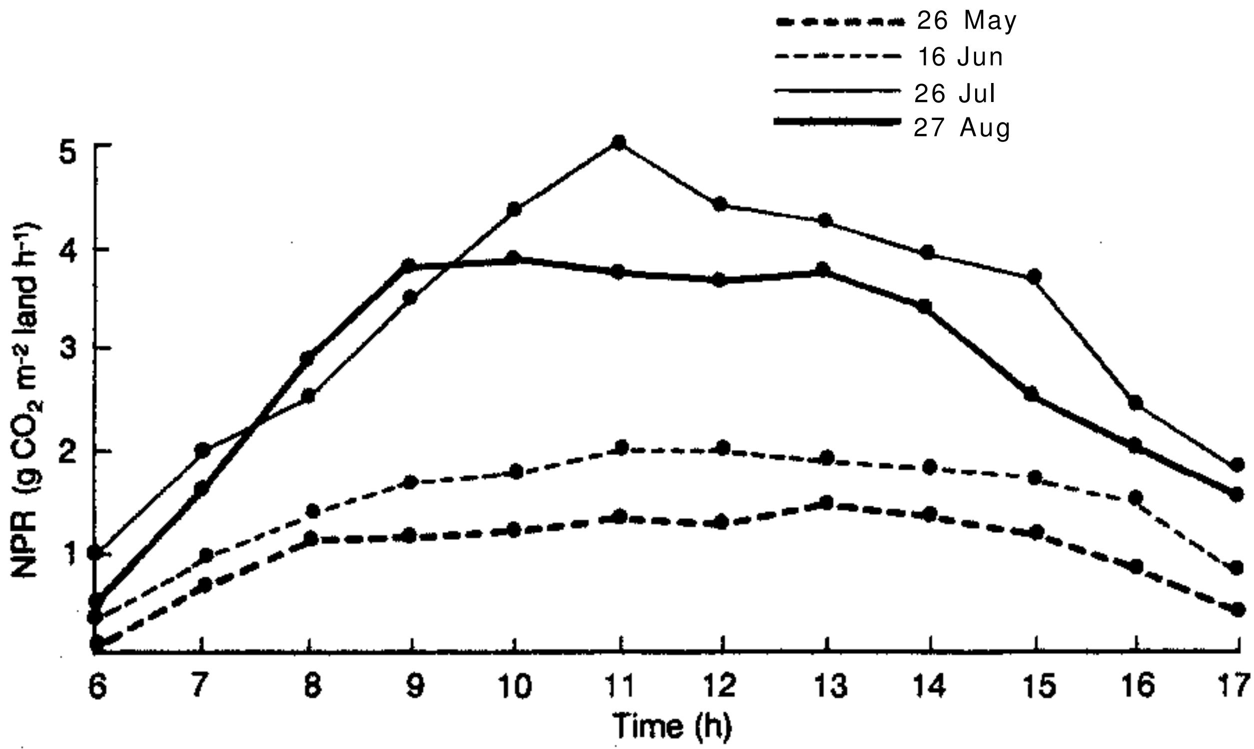

Figure 3. Diurnal variation in net photosynthetic rate (NPR) of high-yielding groundnut on a clear day, Shandong Peanut Research Institute, Shandong, China, 1994.

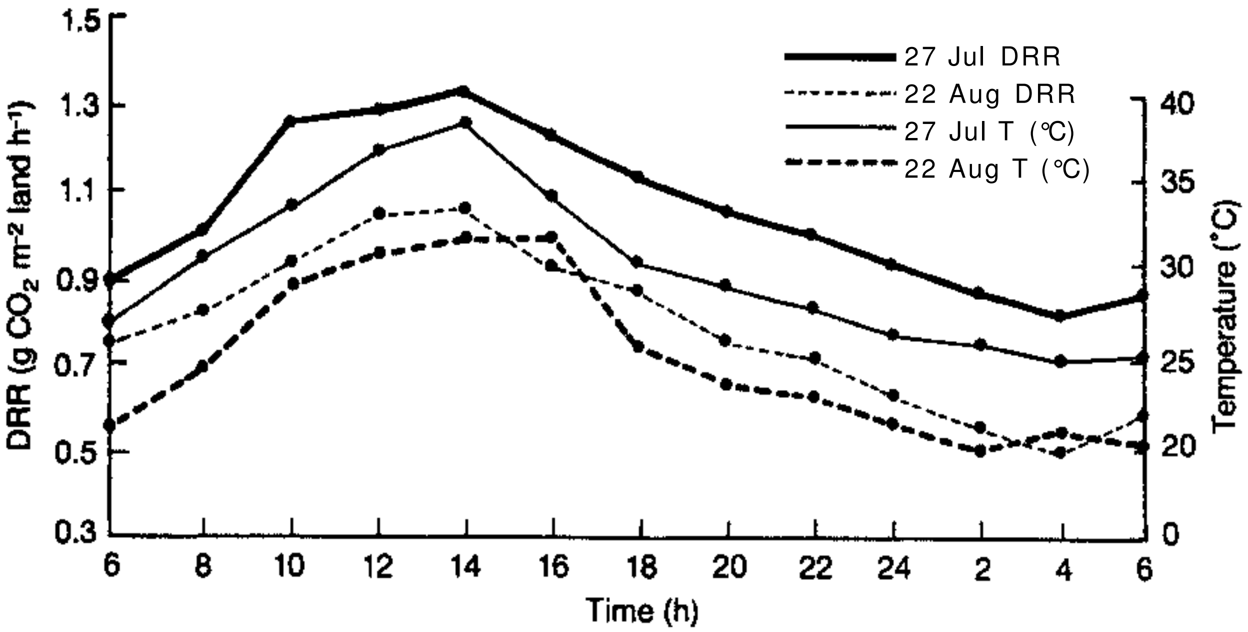

Figure 4. Diurnal variation in dark respiration rate (DRR) and temperature (T) of high-yielding groundnut at Shandong Peanut Research Institute, Shandong, China, 1994.

Seasonal Variation in Photosynthesis and Dark Respiration

The NPR rose slowly in the seedling stage, with an accelerated increase after the plants entered the flowering-pegging stage, and this lasted until the middle of the pod-forming stage, when it peaked. The peak lasted for 20-25 days, then NPR tended to decrease gradually until the plants were mature. The seasonal changes in dark respiration were similar to those in NPR, except that the range of variation throughout the whole growing season was smaller in NPR.

Based on the data collected from high-yielding groundnut fields it can be concluded that >2.5 g CO_2 m^{-2} land h^{-1} of mean NPR during the vigorous stage of photosynthesis in the groundnut canopy should be maintained for 45-50 days to obtain yields of 7.5 t ha^{-1}.

Effects of Water Deficit on Photosynthesis and Dark Respiration

The response of photosynthesis and respiration to water deficit in a groundnut canopy was assessed under varying soil moisture conditions. A range of 50-60% maximum water-holding capacity (MWHC) is considered optimal for both flowering and pod-formation stages by the Shandong Peanut Research Institute (1990). When soil moisture was controlled at 45.3%, 34.6% and 25.1% of MWHC, measured in the top 30 cm of the soil around floral initiation, the NPR was decreased by 34.1%, 67.4% and 84.8%, respectively, compared to the control (52% of MWHC). Similar results were observed at the pod-formation stage. NPR was reduced by 50.1% when soil moisture dropped to 42.5% and by 78.6% when soil moisture was 30.1% of MWHC.

Notable effects were observed not only on the level of photosynthesis, but also on the diurnal variation in NPR as a deep valley was recorded during 13004400.

The diurnal response in DRR to water deficit was noticeable though not so evident as in NPR. This meant that photosynthesis was more sensitive to water deficiency than dark respiration (Figure 5).

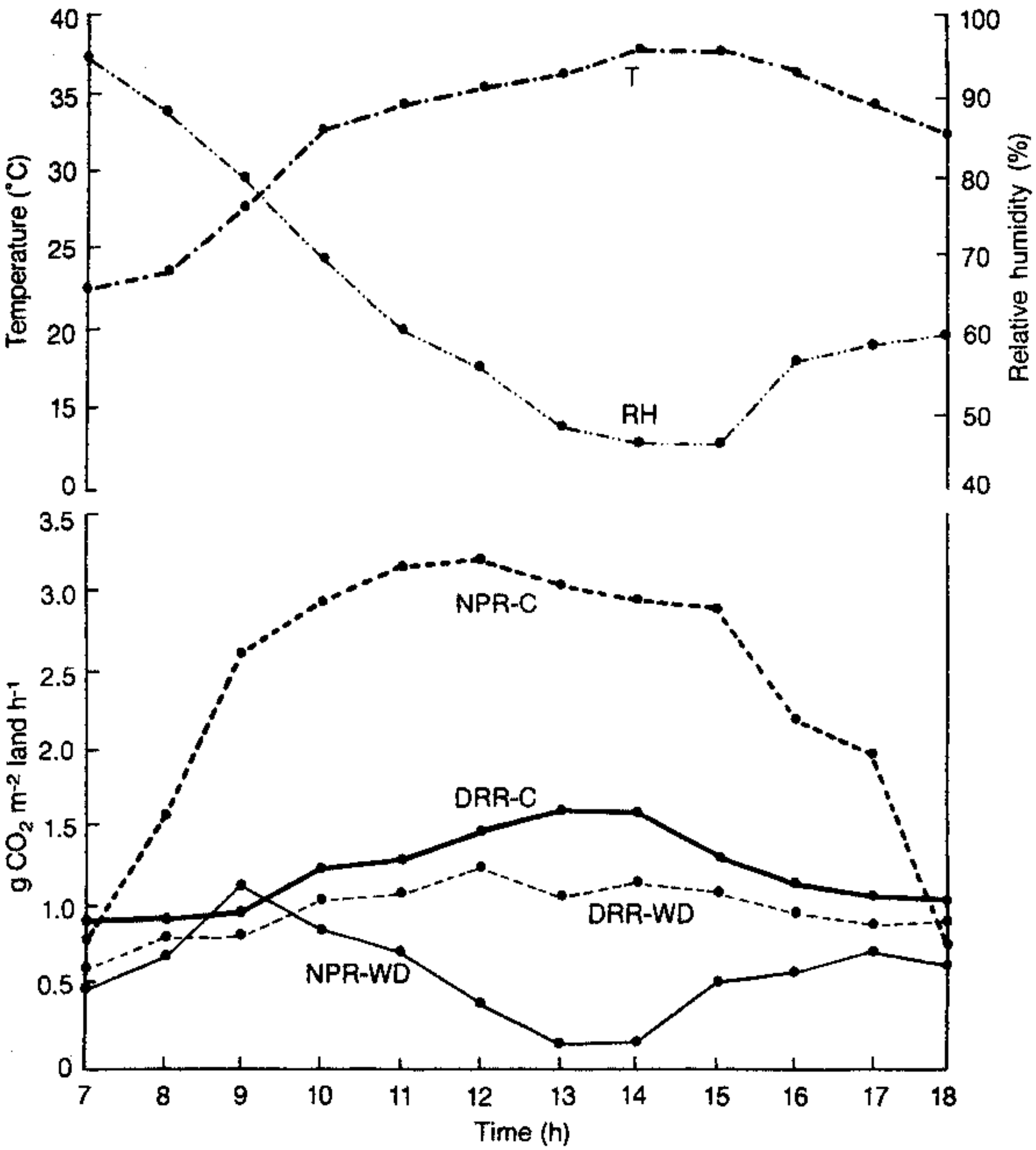

Figure 5. Response of groundnut photosynthesis and respiration to water deficit, Shandong Peanut Research Institute, Shandong, China, 1994.

**(Water deficit treatment : 36% MWHC, control 76% MWHC).

NPR (DRR)- WD = NPR (DRR) under water deficit conditions.

NPR (DRR)-C = NPR (DRR) under control.

Conclusion

The upper 30% of the groundnut canopy, during peak LAI (>4), was an intensive light-absorption area, containing around 50% of the total leaf area, and absorbing 80% of the total solar radiation. Therefore, it was the major area for photosynthesis.

The extinction coefficient (k) ranged from 0.82 to 0.87, significantly higher than that found in such cereal crops as wheat and rice (Zheng Guanghua, 1979) (k was about 0.7). The optimal value of maximum LAI was approximately 5 and the critical value was 5.5 for these varieties.

The NPR varied with the solar radiation during a day and was represented by a single peaked curve on a clear day. The peak was found around noon (1000-1300). No signs of 'noon-rest' or light saturation were evident under natural conditions (maximum 16.048.0 µmol m^{-2} s^{-1}). In high-yielding cultivation, the maximum NPR in a groundnut canopy can reach as high as 4.5-5.0 g CO_2 m^{-2} land h^{-1} and the daily-accumulated photosynthate may exceed 35.0 g CO_2 m^{-2} land on a clear day.

The diurnal variation in DRR, during a day-night cycle, presented one peak occurring from 1100-1300 h and one valley between 0300-0500 h. The ratio of peak to valley was 1.6-2.0, and the dominant factor affecting this day-night variation was air temperature.

The seasonal variation in both LIR and NPR tended to be similar during whole growing season, i.e., rising slowly in the seeding stage and quickly in the flowering-pegging stage, reaching a peak around the middle of the pod-forming stage, then resting for a period, the length of which was mainly determined by cultural practices, and decreasing slightly during the later growth stages.

The physiological indices of groundnut canopy needed to obtain stable yields of 7.0-7.5 t ha^{-1} can be established based on this study.

They are:

- Maximum LAI about 5, not more than 5.5.
- >90% LIR maintained over 45 days.
- Maximum NPR should exceed 4.5 g CO_2 m^{-2} land h^{-1} and >2.5 g CO_2 m^{-2} land h^{-1} daily-mean NPR maintained for 45-50 days during the vigorous growth phase.

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Technology Transfer

Technology Development and Transfer in Agriculture

S N Nigam and C L L Gowda[1]

Abstract

Technology development is a response of scientific knowledge to the changing needs of consumers, farmers, community, country, and world trade. In the late 1960s and early 1970s there was a need to increase total production by intensive agriculture. However, in the 1990s, the emphasis has shifted towards technology development that considers farmers' needs, uses indigenous technology to complement scientific developments, and gives due consideration to sustainability of natural resources and other environmental concerns. Technology development and transfer are dynamic, and the success of a new technology is determined by its adaptability to, and its adoption by, the client groups. It requires a good research and extension infrastructure, congenial policies, and market for the commodities. Improved technologies need not be innovations, but could be reallocations of resources, and realignments of components of existing practices to match the needs of farmers and agro-socioeconomic conditions. Involving farmers in identification and prioritization of production constraints, and in planning and managing on-farm research trials is necessary to focus on target groups' requirements. ICRISAT's experience and role in technology transfer involving national programs, with particular reference to Legumes On-farm Testing and Nurseries (LEGOFTEN) and Asian Grain Legumes On-farm Research (AGLOR) programs are discussed in the paper.

技术开发是科学知识对消费者、农民、社会、国家和世界贸易不断变化的需求所作出的一种反应. 六十年代末至七十年代初要求通过精耕细作的方式增加总产，但到了九十年代，重心已经转移到将农民的需求考虑在内，将科学的进展与当地技术融为一体，并对自然资源的可持续性和其它环境问题给予应有重视的技术开发上来.

技术开发与推广是动态的，一项新技术成功与否取决于其适应性以及用户对它的接受程度. 它需要良好的研究与推广体系，适宜的政策及其商品的市场. 优良的技术未必是革命性的，但应当对资源重新分配，对现有各种措施重新组合以期满足农民和农业社会经济状况的要求. 要重视服务对象群体的要求，应当让农民参与鉴定生产制约因素，确定应首先解决哪些问题，并参与田间试验计划的制定与管理.

本文对国际半干旱所在国家项目特别是在豆类大田测试和繁育(LEGOFTEN) 以及亚洲食用豆类田间研究(AGLOR) 项目技术推广中的经验与作用作了讨论.

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Nigam S. N. and Gowda C. L. L. 1996. Technology development and transfer in agriculture. (In En. Summary in Ch.) Pages 183-193 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Introduction

Agriculture started with the domestication of useful plants and with this began the process of technology development. What we call today 'traditional agriculture' is the accumulation of farmers' knowledge and experiences over many generations. Traditional agriculture' was dynamic and ever evolving, but also in harmony with nature and the farmer. However, increasing human population pressure and the industrial requirements of agricultural raw materials have distorted this equilibrium and the need for new knowledge and technology has increased greatly. Many technologies have evolved but the equilibrium with nature has never been restored. Incalculable harm has been done to agricultural systems, so often because of overexploitation. Recent concerns have added new dimensions to the technology development and transfer process. Efforts are now being directed towards achieving a new equilibrium with nature while making agriculture self-sustainable and increasingly productive.

Technology

Scientific knowledge, when put to routine use for the benefit of mankind, is called technology. Any new technology to find acceptance must be competitive in today's and tomorrow's environments, and bring about economic benefits at all levels of a society while maintaining eco-friendliness, self-sustainability of the system, and social and cultural compatibility.

Technology Development

Technology development is an on-going response of scientific knowledge to changing requirements of society. It focuses on a target group keeping in mind the resource base, socio-cultural factors, and government policies to exploit the available opportunities and match scientific knowledge with requirements.

A good development process should be flexible and offer options to the target group for successful adaptation and adoption of any new technology. Generation of new scientific knowledge is essential to upgrade the existing technology, so a strong and well-focused research program is a prerequisite for any technology development. This research program may involve both on-station and off-station research which complement each other and help in developing the most appropriate technology Developments in scientific knowledge do not necessarily address social, cultural, and economic issues so it is left to the technology development process (putting scientific knowledge to practical use by the society) to address these issues and improve the quality of life and the environment. Verification of the technology in the targeted system is an important part of the technology development process.

In the current agricultural context, the development of a new technology involves increasing productivity at the farm level in an eco-friendly and sustainable manner. A simplistic approach is to first identify those constraints that affect production at the farm level, and to devise appropriate solutions to overcome them. The role of farmers and extensionists in this process is crucial. Their involvement helps in maintaining the focus and relevance of the technology to the real farm situation. The role of individual components of technology and their synergism leading to a full package should be highlighted to farmers in an understandable way so that they can make their choice.

Instead of aiming for green revolutions which will be difficult to implement in rainfed resource-poor agricultural areas, a step-wise progression in upgrading technology may be more appropriate to achieve sustainable agriculture. A full package of technology, though more beneficial, may not find wide acceptance. Farmers will choose the whole package, or selected components of the technology, depending on their perception of the benefits. For sustainable development, a balance has to be struck between the short-term and long-term gains, and awareness of the long-term gains will have to be created through education. Costs of community actions and also of individual actions leading to community benefit will have to be borne by the community or government.

Technology Transfer

An effective technology transfer system requires a carefully thought out plan, clearly communicable ideas, and a cooperative effort. It should be capable of dealing with a wide spectrum of ground realities. In each situation, the fundamentals of the process remain the same, only operational considerations and implications vary. Technologies compatible with felt needs, economic and socio-cultural factors, and government policies are amenable to effective transfer.

Partners in Technology Development and Transfer

Agriculture in the developed world is fast advancing and the adoption of technology occurs at a rapid rate. However, in many developing countries, agriculture is yet to be influenced by the rapid change and progress of science and technology in many areas. A few 'revolutions' have occurred in developing world agriculture, but they largely remain confined to assured irrigated areas and capital-intensive production systems.

Over the past 40 years, various reasons have been given for the failure of resource-poor farmers to adopt new technology. In the late 1980s and early 1990s, it was realized that the available technology did not match the goals of resource-poor farmers because they did not participate in planning and evaluation of technology (Chambers et al. 1989). The current emphasis, therefore, is on farmers' participation in the process of technology development and adaptation. The farmer is better equipped to give appropriate input to the process of technology development, adaptation, and transfer as he or she is the only integrator of all factors (scientific, economic and social) at the farm level.

The need for innovation and change should originate from farmers. Imposed change will not be long-lasting. Extension workers and researchers can only help farmers to articulate their demand for innovation. Researchers should offer a choice of technology options and realize that technology based on and using indigenous know and resources is likely to be more appealing to farmers. Both farmers and extension workers can help the researcher in understanding indigenous knowledge. Involvement of both farmers and extension workers in the complete process of technology development is essential if one is to gain their confidence and acceptance of the technology As success of a technology is judged by its adoption, the farmer is the ultimate judge.

Experiences with Technology Transfer in Agriculture

Legumes On-farm Testing Nurseries (LEGOFTEN) in India

Edible oil imports into India during the 1981-86 period rose to US$2 billion per year. The Government of India launched a Technology Mission on Oilseeds' in 1986 to increase indigenous production of oilseeds and make the country self-sufficient in the edible oil sector. ICRISAT was invited by the government to help in testing, adapting, and disseminating improved groundnut production technologies in collaboration with the national research and extension programs in India. The LEGOFTEN Unit at ICRISAT Asia Center was created in 1987 in response to this request from the government (ICRISAT 1993). An initial joint-planning meeting was held to assess the production technologies used by farmers and to formulate an improved technology package with local variation for testing in different agroclimates (Table 1).

Selected extension staff and managers of seed farms participated in an orientation-cum-training course on the conduct of on-farm trials and the use of various components of improved technology before initiating on-farm trials. Although the first year's verification trials were conducted on seed farms, the subsequent testing was on-farm involving farmers.

The on-farm trials had four treatments at each location and each treatment covered 0*2 ha.

T_1: Improved cultural practices + improved variety (Improved technology).

T_2: Improved cultural practices + local variety.

T_3: Local cultural practices + improved variety.

T_4: Local cultural practices + local variety (Farmers' practice).

During 1987-90, 141 trials (83 in rainy seasons and 58 in postrainy seasons) were conducted. The improved cultural practices gave 20.2% more pod yield and improved varieties gave 263% more pod yield over local cultural practices and local varieties (Table 2). The improved technology (improved cultural practices + improved varieties) gave, on average, 61% more pod yield than farmers' practice (existing cultural practices + traditional varieties), showing the synergistic effect of improved cultural practices and

Table 1. Improved and local groundnut production technologies[1] for on-farm trials/demonstrations, India.

Field operation/input	Improved package	Local package (general)
Land preparation	Plowing, clod crushing, and harrowing to obtain a fine tilth	Deep plowing once, light plowing twice, harrowing twice
Basal fertilizers (ha"[1])	FYM[1] = 10 t Ammonium sulphate = 100 kg SSP = 300-400 kg MOP[1] = 0-80 kg $ZnSO_4$[1] = 10-20 kg (once in 3 years)	FYM = 5-12 t DAP = 100 kg MOP = 100 kg $ZnSO_4$ = 20 kg
Sowing date	Jun with monsoon (rainy season)/Nov (postrainy season)	Jun/Nov, Dec
Seedbed	Broadbed[1] (or narrow bed)	Flat
Variety	ICGSs 11,21,37,44,65,76, ICG(FDRS) 4 or ICG(FDRS) 10	TMV 2, TMV 7, JL 24, SB XI, Co 2, S 206, KRG 1, GG 2, VRI 2, AK 12-24
Seed rate (ha^{-1})	120-125 kg	125-150 kg
Spacing	30 x 10 cm	30 x 10 or 45 x 10 cm
Weed control	Stomp®[1] 30 EC 3.0-3.5 L ha^{-1} (or hand weeding)	Hand weeding
Seed dressing (kg^{-1} seed)	Thiram[1], Bavistin® or Dithane M 45® @ 2-3 g	Thiram @ 2g
Sowing method	Dibbling[1]/drilling	Behind plow/drilling
Gypsum (ha^{-1})	400 kg at flowering	200 kg at flowering

Continued......

Table 1. *Continued....*

Field operation/input	Improved package	Local package (general)
Plant protection	Bavistin®[1] 50 WP 250 g + Dithane[1] M 45® or chlorothalonil (Kavach®) 75 WP 1 kg ha^{-1} for leaf spots and rust, as required Dimethoate 30 EC 660 mL ha^{-1} for thrips, jassids, and leaf miner Monocrotophos 36 EC 1 L ha^{-1} or Endosulfan 35 EC 2 L ha^{-1} for *Spodoptera* and *Helicoverpa*	Need based
Nutrients	1-2 sprays of $FeSO_4$[1], 2.5 kg + 5 kg ha^{-1} urea, 30 and 45 days after emergence (In black soils where plants show yellowing)	
Irrigation	Sprinkler[1] (or furrow)	Flooding
Harvest	With 65-70% pod maturity	With maturity

1. The above practices in the improved package were compulsory for on-farm trials in the first year. Later on, with increased knowledge and experience, several of the practices were made optional and alternatives were suggested.

(Source: Legumes On-farm and Nursery Unit (LEGOFTEN). A brief report of work. January 1987 - January 1991. ICRISAT, unpublished report).

Although the recommended improved cultural practices were rigid in the first year, to assess their full potential, they were modified/improved upon based on the feedback from extension staff and farmers, and backup on-station trials. The backup trials involved studies on benefits due to land preparation and land configurations, fertilizer use, irrigation systems, pest management, and appropriate cropping systems. Farmers themselves experimented and modified a few components. For example, the width of the broadbed was reduced from 1.5 m to 0.75 m so that furrow irrigation could be effective in red lateritic soils. Similarly,

Table 2. Economic analysis of groundnut production following improved and local cultural practices and varieties in India, 1987-90.

	Pod yield mean ($t\ ha^{-1}$)			
	Improved cultural practices		Local cultural practices	
No. of Trials	Improved variety	Local variety	Improved variety	Local variety
Rainy season 83	1.96	1.47	1.53	1.21
Postrainy season 58	2.87	2.13	2.26	1.79

Yield benefit (over farmers' practices)[1]		
	Rainy season	Postrainy season
Improved cultural practices (%)	21.5	19.0
Improved variety (%)	26.4	26.2
Improved cultural practices + improved variety (%)	62.0	60.3
Extra cost and benefit of improved technology[2]		
Extra production cost (Rs. ha^{-1})	1590 (6220)3	1420 (6990)
Extra net benefit (Rs. ha^{-1})	4410 (3460)	7220 (7330)

1. Farmers' practices = Local cultural practices + Local varieties.
2. Improved technology = Improved cultural practices + Improved varieties.
3. Normal cost or benefit following farmers' practices; average selling price of groundnut pods for seven seasons was Rs. 8000 t^{-1}

(Source: Legumes On-farm and Nursery Unit (LEGOFTEN). A brief report of work. January 1987 - January 1991. ICRISAT, unpublished report).

farmers developed a few implements to make broadbeds, seed drills, diggers, etc. Such active participation and involvement of the farmers enriched the on-farm research process.

Another salient feature of the LEGOFTEN Project was the involvement of the National Dairy Development Board (NDDB), Anand, India, with its well-established network of State Cooperative Oilseed Growers' Federations (SCOGF) to help farmers in production, distribution, and marketing of oilseeds. The joint effort of NDDB and ICRISAT was instrumental in transferring improved groundnut production technology to farmers through the SCOGFs. Now India has almost achieved self-sufficiency in the edible oilseeds sector with groundnut, among other oilseed crops, making a significant contribution to this achievement.

Asian Grain Legumes On-farm Research (AGLOR) in South and Southeast Asia

The success of LEGOFTEN in India prompted other Asian countries to undertake similar projects in collaboration with ICRISAT. The FAO/RAS/89/040 project approved funding for AGLOR Projects to be undertaken in Indonesia, Nepal, Sri Lanka, and Vietnam in 1989. Meetings were held in each of the project countries to review and document the available technology and decide on the target areas for research. Diagnostic surveys using rapid rural appraisal were conducted in each target area (at least two areas representing diverse cropping systems) to identify and prioritize farmer-perceived constraints (Gowda et al. 1993). They were grouped into socioeconomic, biotic, and abiotic constraints.

The joint team of NARS and ICRISAT scientists prepared plans for experiments to address and alleviate the identified biotic and abiotic constraints. Suggestions were made to concerned administrative departments and governments to address the socioeconomic constraints. The on-farm experiments were planned keeping in mind the resource base of farmers, the local availability of required inputs, and the existing/available production technology in the country. Backup and supportive on-station research was also planned to find appropriate solutions to some of the problems before embarking on on-farm experiments.

The on-farm experiments varied across the project countries. For example, in Indonesia (Saleh et al. 1993), the scientists had sets of improved technology that could be tested directly on farmers' fields (Table 3). On the other hand, in Nepal (Sharma and Koirala 1993), the team decided to evaluate single factors (plus and minus) in diagnostic experiments to evaluate and demonstrate the effect of individual technology options (Table 4). Individual components that were beneficial (in increasing pod yield) were combined and tested as a set of technology options in later years.

In Indonesia, both low-input and high-input packages of improved technologies were compared with farmers' practices during 1991 and 92 (Saleh et al. 1993). Although the high-input technology gave higher yields than low-input and farmers' practices, the farmers preferred the low-input technology as it was more economical. Therefore, the low-input technology (as improved practices) was tested on a large scale (21 ha involving 72 farmers) during 1993 in Subang district, west Java, The improved practices gave 1.72 t pods ha^{-1} compared with 1.30 t ha^{-1} of farmers' practice. In a similar large scale (25 ha involving 89 farmers) adoption study in Tuban district, east Java, the improved practices gave 1.81 t pods ha^{-1} compared with 1.05 t ha^{-1} in farmers' practices. These improved technologies are now being extended to other areas in Tuban and Subang districts.

In Nepal, and Sri Lanka, groundnut is considered a low-input crop by the farmers (Sharma and Koirala 1993, Jayawardena et al. 1993). Therefore, careful consideration was given to low-cost inputs such as improved cultivars, fungicidal seed dressing, rhizobial inoculation, and land preparation (tillage). Although the

Table 3. Improved groundnut production technology for evaluation on farmers' fields in Indonesia.

Input	Farmers' Practices	Improved Technology: Level of input — Low	High
1. Ullage	+	+	+
2. Broadbeds[1]	-	+	+
3. Sowing with plow	+	-	-
- irregular spacing			
- regular spacing	+	-	+
4. Fertilizers			
a. (kg ha^{-1})	-	25	50
-Urea			
- TSP	-	50	100
- KC1	-	50	100
- Manure	-	2000	5000
b. Micronutrients spray	*	-	+
5. Weeding	Ix	2x	2x
6. Pest control	-	-	Need based, supervised
7. Disease control	Ix	2x	Need based, supervised
8. Plant population (ha^{-1})	175,000	250,000	250,000
9. Seed treatment	-	+	+
10. Variety	Kelinci/Local	Kelinci/Local	Kelinci/Local

1. = Broadbeds 1.5 - 2.0 m wide accommodating 4 or 6 rows each.
(Source: Saleh et al. 1993).

initial set of improved practices in Nepal had a whole range of inputs, it was later realized that two sets of technology - a low-input and a high-input - were needed for different groups of farmers. In Sri Lanka, although the major groundnut area is cultivated as a rainfed, low-input crop, there was need for developing a high-input technology option for the confectionery groundnut varieties in irrigated areas.

In southern Vietnam the diagnostic survey team found that the farmers were already getting high yields (around 3 t ha^{-1} for a 90-day crop). Under such circumstances/there was limited scope to increase yield levels. Therefore, the emphasis was on reallocation of resources and reducing the cost of cultivation (Dan et al. 1993). For example, farmers usually sow 2 seeds $hill^{-1}$. Diagnostic trials indicated that there were no yield differences between 1 or 2 seeds $hill^{-1}$. On the contrary, one seed $hill^{-1}$ at 15 x 15 cm spacing gave 11% more yield than 2 seeds

Table 4. List of single factor diagnostic treatments for groundnut on-farm research in Nepal.

Purpose/Factors	Treatment[1]
Effect on pod yield of:	
• Seed dressing fungicides	Thiram + Vitavax® (carboxin) (50:50) 3g kg[4] (just before sowing)
• Seed dressing insecticide	Chloropyriphos (12.5 ml kg^{-1} seed)
• Rhizobial inoculation	Rhizobial inoculation (NC 92)
• Foliar diseases control	Daconil® (chlorothalonil) 50-60 days after sowing or when around 10 spots plant[1] appear
• Insect pests control	Folithan/Sumithion® 0.5% at 40 days or when insects appear
• Micronutrient spray	Swarnafal® (micronutrient mixture) spray, 30 days after sowing
• Seed rate (plant population)	60 kg ha^{-1}; 40 x 20 cm spacing
• Gypsum	400 kg ha^{-1} at peak of flowering with second weeding. Placed near the base of plant on both sides of a row

1. These treatments were compared with appropriate controls.
(Source: Sharma and Koirala 1993)

$hill^{-1}$ at 20 x 20 cm. Thus, farmers could reduce the seed cost (which is comparatively high in groundnut) by about 50%, and increase profits by adopting 15 x 15 cm spacing. Rhizobial inoculation in post-rice groundnut cropping systems gave 12 to 112% increase in pod yield. Split application of lime (at sowing and at flowering) was also found to increase pod yields by up to 10% compared with a single application at sowing. These low-cost input changes, and resource reallocations have been tested across many farmers' fields and the farmers are adopting them.

Conclusions

In the case studies described above, the technology development and adoption were effective because of:

- Perceivedneedofthefarmerforthetechnologytoincreaseproduction;
- Political will and support by research and extension staff in the country;
- Involvementoffarmersinconstraintidentification;
- Availability of technology locally or regionally for adaptive testing to alleviate identified

- Cooperation and interaction among scientists, extension staff, and farmers; and
- Individual components and technology being amenable for adaptation and adoption by formers.

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A Preliminary Discussion on Further Development of Groundnut Production in Shandong Province

Chen Dongwen, Wang Enxun, and Cheng Junlan[1]

Abstract

Shandong is one of the main groundnut-growing provinces in China, and groundnut is its major oil crop. In the past 45 years since the establishment of the People's Republic of China, Shandong groundnut production has undergone three stages: development, a decline and then plateau in production, and redevelopment. The main stimuli to redevelopment have been the establishment of favorable policies to mobilize the enthusiasm of farmers to improve production; experimenting with and extending the polythene mulching technique; organizing programs to promote high yield by raising the technological level of groundnut production; developing double-cropping with wheat and groundnut, to enlarge both the growing area and output of food and oil crops; and improving conditions by the extension of advanced technology to the 60% of the production area that is on sloping, infertile soils.

山东省是我国花生主要产区之一，花生又是我省主要油料作物．建国 45 年来，山东省花生生产大体经历了发展、下降徘徊、再发展三个阶段．其再发展主要经验：制定优惠政策，调动农民种好花生的积极性；试验、推广地膜覆盖栽培技术；提高花生生产科技水平，促进花生高产；发展麦田套种花生，达到粮油种植面积双扩大、产量双增加；推广先进技术，改变生产条件，大力改造中低产田．

Introduction

Shandong Province is the main groundnut-growing area in China. It produces 35% of the total national yield on 25% of the area sown to groundnut in China, and 70% of the country's exports. During the 45 years since the establishment of the People's Republic of China, Shandong groundnut production has undergone three stages: development (1950-57), decline and plateau (1958-85), and redevelopment (1979-94).

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Stages of Production

Development stage (1950-57): During this period, the annual sown area was 653 800 ha annually, unit yield was 1448 kg ha"1, and the total production was 887 million kg, which is respectively 36.9%, 18.4% and 62.2% more than those in 1949.

Decline and plateau stage (1958-78): As a result of a reduction in agriculture and grain shortages after 1959, the groundnut-growing area and output dropped drastically. In 1960, the area sown was only 260 000 ha, with a low unit yield of 810 kg ha^{-1}, and a total output of 210 million kg. However, with a 3-year adjustment in 1963-65, groundnut production was restored to some degree, but it was still only a very gradual improvement. During 1958-78, the annual average growing area was 472 000 ha, with a unit production of 1418 kg ha^{-1}, and a total output of 670 million kg. Therefore, the edible oil supply continued to be limited.

Redevelopment stage (1979-94): Since 1979, groundnut production in Shandong Province has developed very rapidly. In 1980, the average yield reached 2250 kg ha^{-1}, and the total output 1400 million kg. Moreover, the sown area increased more quickly, to 669 000 ha in 1981, and to 919 000 ha in 1985. Generally, from 1979-94, the mean annual area was 667 000 ha, an increase of 38.4%, while the mean yield was 2835 kg ha^{-1}, a rise of 47.7%. The total production was 100% greater than in 1978. These improvements during the past 16 years resulted from specific policies and from improvements in technology

Policies and Practices Giving Greater Production

Establishment of Favorable Policies

The Shandong provincial government has always paid considerable attention to groundnut production, introducing favorable policies as early as 1978. Seed cake (48 kg) was returned to farmers when they sold 100 kg groundnut seed to the government. N fertilizer (40 kg) was given to farmers for every sale of 100 kg groundnut seed. Foreign trade organizations rewarded growers with US$ 4 for better variety, and US$ 0.7 for seed grade, for each sale of 100 kg groundnut seed. Farmers were also allowed to sell the produce in the open market.

Organization of Research to Increase Groundnut Production

The aim was to reach yields of 7500 kg ha^{-1} in Shandong Province. In order to realize this, many programs were organized to extend high yield techniques to improve the technology of groundnut production. In 1978, the provincial government issued an order that scientists should strive to attain the goal of producing 7500 kg ha^{-1} within a few years. Accordingly, the Agricultural Department and Agricultural Academy began to carry out projects. Within two years, 51 fields, covering 7.9 ha, had achieved the goal, and by 1983, 293.1 ha produced yields of 7500 kg ha^{-1}, and a world record yield of 11 200 kg ha^{-1} was achieved on 0.1 ha. The Shandong Peanut Research Institute, Laixi, summarized these experimental results into a series of improved management practices in 1981-1983, and produced high yields in larger fields. The main technologies were: (1) to use a high-yielding variety; (2) to plant groundnut in fertile fields with good irrigation and drainage conditions; (3) to apply fertilizers more rationally, using less N and K, and applying at different depths; (4) to use polythene mulch covering; and (5) to pay more attention to field management to regulate vegetative and reproductive growth. All these technologies have greatly improved Shandong groundnut production. In 1994 the unit yield was 81.3% more than in 1978, and total output was 2.2 times greater than 1978.

Use of the Polythene Mulch Covering Technology

Utility of polythene film mulch covering was studied for vegetables and groundnut as early as 1979. Results obtained in 1980-1982 indicated that polythene mulch covering increased soil temperature, conserved soil moisture, and improved physical and chemical characters of the soil, stimulating early seedling vigor, more flowers and fruits, early maturity, high yield, and good quality seeds. During the past 16 years from 1979 to 1994, the total groundnut-growing area covered by polythene mulch has risen to 1 878 000 ha, with a unit yield increase of 1371 kg ha^{-1} compared with nonmulched fields. The technology has been demonstrated and extended with good coordination and collaboration among different agencies, and provision of machines and polythene film to farmers.

Development of Double-cropping of Wheat and Groundnut

It is very difficult to grow two or more crops each year due to limitation imposed by the frost-free period (180-220 days). However, arable land is decreasing and the population is increasing constantly, making a double-cropping system (e.g. wheat+groundnut) a necessity. By improved growing conditions and management practices and extending double-cropping, improved harvests of both crops were achieved. In the study areas (152 000 ha in 7 counties in 3 years) yields of wheat were 3645 kg ha-^{1}, an increase of 564 kg ha^{-1}, and groundnut produced 2627 kg ha^{-1}, a 366 kg ha^{-1} increase. These practices were extended to farmers, with resultant stimulation of double-cropping in Shandong Province. In 1994, the area of double-cropping reached 308 662 ha, amounting to 35.7% of the total area. In order to raise the output further, many new technologies were applied in double-cropping, for example, polythene mulch covering and changes to the farming system. Experiments have begun on triple-cropping systems in groundnut fields, with successful results in 1994. They were extended on 667 ha in Ningyang county, and the average unit yields of wheat, groundnut and maize increased by 20%.

Extension of Advanced Technology to Improve Low-and Middle-yielding Groundnut Fields

Generally, 60% of groundnut fields are infertile and occur in hilly areas. In such fields with shallow soil, poor fertility, and drought conditions, the unit yield is only about 1500 kg ha^{-1}. Therefore, it is necessary to improve such low- or middle-yielding fields. In 1990, 1.5 million yuan (US$0.18 million) from Provincial President's Funds was used to implement a project over 3 years which produced good results in 13 counties. The improved area was 713 000 ha and the average unit yield was 3173 kg ha^{-1}, an increase of 25.7%.

Transfer of Integrated High-yield Techniques to Increase Groundnut Yield by the Harvest Plan

In order to transfer scientific achievements into higher production, part of the Harvest Plan' was used as the key factor and implemented widely in. the province to extend the advanced technologies to farmers. Since 1987, there have been 36 counties covered by the Harvest Plan. According to the statistics, 3.51 million technicians were trained, and 7 million copies of technical bulletins were released for field guidance, as a practical means of extension of technologies. During 1988-1994, the national and provincial Harvest Plan covered 619 000 ha, and was responsible for a large increase in the yield.

Future Developments

In the future planning of groundnut production in Shandong Province, it is generally believed that the triple-cropping system will be greatly extended to obtain higher unit yields and benefits. Other projects include management of farm land to prevent damage by natural disasters, extension of a series of high-yield technologies and breeding and selection of good groundnut varieties. By the year 2000 the total output of groundnut in Shandong Province is predicted to reach 3.2 million t

Breeding a High-yielding and Rust-resistant Groundnut Cultivar Zhonghua No. 4, and its Application

Tang Guiying, Wang Yuying, Liao Boshou, Li Dong, Xia Xinming, Duan Naixiong[1], and Wang Zhizhao[2]

Abstract

Zhonghua No. 4 was bred from a cross involving four parents, through modified pedigree selection. It significantly outyielded local control groundnut cultivars in various yield trials. Its duration was 125 days, and seed protein content was over 30%. It was moderately resistant to rust caused by *Puccinia arachidis,* and bacterial wilt caused by *Pseudomonas solanacearum,* and tolerant of acid soil. This cultivar could be grown in most regions of central and southern China. Zhonghua No. 4 has been formally released by Guangxi, Hubei, and the National Crop Varietal Committee. It has been grown on 200 000 ha in recent years. The genetic background of Zhonghua No. 4, and the nature of its disease resistance are discussed.

中花 4 号是一个从 4 亲本复式杂交后代中以改良系谱法选育而成的花生新品种．该品种比同类对照品种有显著的增产潜力，全生育期 125 天左右，种子蛋白质含量 30% 以上，中抗花生锈病和青枯病，对酸性土壤有一定耐性，适合我国淮河以南广大地区种植，先后通过广西、湖北和全国农作物品种审定委员会的审定命名，已在全国累计种植 20 万公顷．本文还从育种的角度对中花 4 号抗病性的遗传背景进行了讨论．

Introduction

Groundnut varieties grown in China can be divided into two groups depending on seed or pod size. To the north of the Hui River, large-seeded varieties, mainly of the Virginia type, are cultivated extensively, while in the south the Spanish type with small seeds is grown almost exclusively In the vast groundnut-producing regions to the south of the Hui River, the production conditions including soil fertility, climate, and farming systems vary greatly, and groundnut is also relatively scattered in its distribution. However, early-maturity and tolerance of

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acid soil are generally necessary for groundnut cultivars in the south to fit into the multi-cropping systems and to grow well in the low calcium soils. As rust, caused by *Puccinia arachidis,* and bacterial wilt, caused by *Pseudomonas solanacearum,* are extensively distributed in central and southern China, resistance to these two diseases is also a necessity of groundnut cultivars. With the increase in importance of groundnut in the national economy and in sustainable agricultural practices, yield potential and quality traits in groundnut varieties are also major breeding objectives for these regions. Several years of breeding efforts have resulted in the development of Zhonghua No. 4, an early-maturing, high-yielding groundnut cultivar with a high protein content and multiple resistance. This paper describes the breeding procedures, characters, and genetic background for disease resistance of Zhonghua No. 4.

Origin and Development

Zhonghua No. 4 was bred from a multi-way cross [(E Hua 4 x Taishan Sanlirou) F_2 x (E Hua 3 x Xiekangqing) F_2] through a modified pedigree method. The original line, 84-2117, was selected in 1984 and was then tested in preliminary yield trials in 1985 and 1986. From 1987 to 1989 it was further tested in regional trials in central China, and evaluated in large scale cultivation in different locations in 1990. It was introduced to Guangxi and other provinces and grown in demonstration trials in many localities during 1990-92. Zhonghua No. 4 performed well across the locations and seasons. It was released in Guangxi Autonomous District and Hubei Province in 1993 and released by the National Crop Variety Committee (NCVC) in 1994.

Performance

Yield

The yield of Zhonghua No. 4 in various trials is presented in Table 1. It significantly outyielded the local cultivars or controls. In Beihai, Guangxi Province, Zhonghua No. 4 yielded up to 6.3 t ha^{-1} which was the highest record in Guangxi. In Hong'An, Hubei Province, Zhonghua No. 4 yielded 6.9 t ha^{-1} under polythene mulch cultivation in rice fallow which was a record high yield for groundnut in this province.

Stability of yield

The yield data of eight varieties from the regional trials (central China) conducted in 1988-89 were used to estimate the parameters of yield stability of each variety by a regression analysis. The regression coefficient of Zhonghua No. 4 was 0.9428 (less than 1) which indicated that Zhonghua No. 4 was more stable than other cultivars, with wide adaptability

Table 1. Yield of Zhonghua No. 4 in various trials during 1985-1994 in China.

Trial	Year	Locations	Yield (kg ha^{-1})	Increase over control (%)
Preliminary	1985-86	2 (Hubei)	4035	14.8
Regional	1987-89	24 (C. China)	3510	10.3
Demonstration	1990	7 (C. China)	3855	18.6
Demonstration	1990	1 (Hepu)	4800	49.6
Demonstration	1991	1 (Qingzhou)	4695	11.4
Demonstration	1990	1 (Beihai)	6375	18.0
Demonstration	1992	1 (Hong'An)	6915	8.9
Demonstration	1994	1 (Pinjiang)	5250	30.0
Demonstration	1994	1 (Tongren)	5415	31.0

Resistance

In various trials across locations and seasons, the rust score of Zhonghua No. 4 was less than 5.0 in a 1-9 point scale (ICRISAT 1987) with an average score of 3.5. In 1987 and 1991, when rust disease was very severe in Hubei Province, the rust score of Zhonghua No. 4 was 4.5 while that of the susceptible control was 9. With artificial inoculation, Zhonghua No. 4 was moderately resistant to rust. Across seasons, on the naturally infested nursery in Hong'An, the bacterial wilt incidence of Zhonghua No. 4 was 50-70% which indicated it was moderately resistant to bacterial wilt. When artificially inoculated, it was also moderately resistant.

Zhonghua No. 4 was subjected to aluminum (Al) toxicity under laboratory conditions to test its tolerance. Its roots were evidently not affected by Al toxicity.

Quality

In the regional trials during 1987/88, 24 samples of Zhonghua No. 4 were collected from 10 locations for oil and protein analysis. The average content of seed protein was 30.34% and the average oil content was 50.8%.

Other characteristics

Zhonghua No. 4 is an early-maturing Spanish type cultivar. It matures in 125 days in spring sowing and 105 days in summer-sowing. It has an erect growth habit, sequential flowering, medium, elliptic, dark green leaves, and has 2-seeded medium-sized pods with slight reticulation and constriction. Its seeds are tan-colored and 100-seed mass is 65 g and 100-pod mass 155 g with a shelling percentage of 72%. The seed dormancy is short to medium.

Genetic Background for Disease Resistance

Zhonghua No. 4 was bred from parents that were not highly resistant to rust. Several research papers have reported that the resistance to rust in cultivated groundnut was controlled by recessive genes and there might be interaction among the recessive genes (Liao 1991). Among its parents, Xiekangqing and Taishan Sanlirou possess some tolerance to rust. The increase in the level of rust resistance in Zhanghua No. 4 might be attributed to interaction among the recessive genes. The rust resistance of Zhonghua No. 4 was mainly determined by its physiological features. Under high disease pressure, the infection frequency was high especially on the lower leaves, but its latent period was longer and the leaf area damaged was less than that of the susceptible genotype.

Among the parents of Zhonghua No. 4, Xiekangqing and Taishan Sanlirou are highly resistant to bacterial wilt with desirable stability (Mehan et al. 1994) but Zhonghua No. 4 is only moderately resistant. This might be because it originated from a four-way cross of two F_2 segregating progenies, which could decrease the gene dosage. However, the medium resistance of Zhonghua No. 4 has proved to be stable and could be inherited.

Adoption of Zhonghua No. 4

Zhonghua No. 4 has desirable traits of early maturity, high yield, high protein, and multiple resistances with wide adaptability, and therefore could be extensively grown in various regions. In recent years, rotating groundnut with long-duration rice has been more popular. Zhonghua No. 4 is suitable for this cropping system because of its high-yielding traits and resistance to rust which can be a serious problem under rice-fallows with high moisture. Up to 1995, Zhonghua No. 4 has been grown over a cumulative area of 200 000 ha in central and southern China.

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Research and Development of Technologies for Groundnut/Wheat Intercropping in Henan Province

Zhang Xinyou[1], Tang Fengshou[1], Wang Baohua[2], and Wang Yujing[3]

Abstract

Henan is one of the major groundnut-growing provinces in China, currently with an area of about 670 000 ha and total annual production of 1.6 million t pods. Since the early 1980s, wheat/groundnut intercropping systems have become increasingly important in groundnut production, and have resulted in a dramatic area expansion and significant yield increases in groundnut.

Studies on both varieties and cultural techniques have been conducted in an effort to further improve groundnut yield. The yield potential of the varieties used ranges from 6.0 t to 8.0 t ha^{-1}. Appropriate cultural measures such as sowing date, plant density, fertilizer application, and field management were recommended in accordance with local agricultural production levels after a series of experiments. Groundnut production was significantly enhanced, and vast economic benefits obtained through effective extension of these yield-improving techniques.

The difficulties involved in sowing groundnuts in wheat fields, and low levels of mechanization were identified as common problems of groundnut production in wheat/groundnut intercropping systems.

河南是我国最大的花生生产省份之一，目前播种面积约 67 万公顷，年产荚果 160 万吨．八十年代初期以来，麦套花生发展迅速，有力推动了我省花生面积的扩大和产量的显著提高．

为了进一步提高麦套花生的产量，在品种和栽培技术方面开展了一系列研究．选育、推广的花生品种生产潜力一般在每公顷 6.0－8.0 吨．根据各地的农业生产水平，经过广泛试验，制定了适宜的套种方式、播期、密度、地膜覆盖及田间管理技术．通过上述增产技术的推广和应用，显著提高了花生生产技术水平，并取得巨大社会经济效益．

目前麦套花生生产中普遍存在的问题是：套种困难、机械化程度低．

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Introduction

Henan is an important agricultural province and one of the major groundnut *(Arachis hypogaea* L.) producers in China. The groundnut production in Henan dates back to the 16th Century and its products have been enjoying good reputations in both domestic and international markets. The current area under groundnut cultivation is around 670 000 ha and about 1 600 000 t pods are produced annually Groundnut ranks first among all the oilseed crops grown in Henan in terms of area and total output, and plays a very important role in the vegetable oil supply, food processing industry, and export trade.

The Importance of Groundnuts Intercropped with Wheat

Groundnut in Henan was traditionally confined to the regions along the Yellow River, and to mountainous and hilly areas where the agricultural conditions were so poor that very few other crops could survive. It was usually sown in the spring season as a sole crop in a year and has long been regarded as a low-yielding crop. Since the early 1980s, the wheat-groundnut intercropping system has become increasingly important with the development of double- or multiple-cropping systems in accordance with the growth of population pressure. Wheat *(Triticum aestivum* L.), as the most important staple crop in Henan, is always allotted to the fertile land and its area remains unchallenged. So it is not feasible to develop other crops at the cost of wheat production. The key point of the wheat-groundnut intercropping system is to advance groundnut sowing by sowing groundnut seeds in between wheat rows before wheat harvest to provide groundnut with a longer growing season so that a better yield can be achieved. The wide adoption of this cropping system by farmers led to a rapid expansion of the groundnut-growing area and significant increase in total production (Table 1). The average area and production in 1980-1984 were 176 200 ha and 217 000 t respectively, representing increases of 130% in area and 232% in production over those of the 1970s. In the first five years of the 1990s (1990-1994), the area expansion and production increase were even more significant. By 1994, the area and production were 757 300 ha and 1 798 200 t respectively, which doubled the area and nearly tripled the production of 1985. At present, the area under the wheat-groundnut intercropping system accounts for about 65% of the province's total groundnut-growing area and 78% of its summer groundnut area. Another prominent change brought about by the wheat/groundnut intercropping system is the gradual increase of the groundnut yield in spite of minor fluctuations. The average yield in 1990-1994 was 2290 kg ha^{-1}, representing 56% increase over that of the 1980s and 168% increase over that of the 1970s, respectively

Table 1. Area, production, and yield of shelled groundnuts in Henan Province, 1970-94.

Year(s)	Area ('000 ha)	Production ('000 t)	Yield (kg ha^{-1})
1970-79	76.6[1]	65.4	854.2
1980-84	176.2[1]	217.0	1231.5
1985	360.5]	600.2	1665.0
1986	379.0]	534.4	1410.0
1987	421.3] 406.1[1]	647.7	1537.5
1988	434.3]	794.8	1830.0
1989	435.2]	894.3	2055.0
1990	441.1]	1058.6	2400.0
1991	449.1}	936.4	2085.0
1992	481.7} 545.0[1]	953.8	1980.0
1993	596.0}	1555.6	2610.0
1994	757.3}	1798.2	2374.5

Source: Henan Yearbooks 1970-1994.
1. Mean.

With the effective implementation of the yield improvement techniques recommended by researchers, farmers are able to achieve a wheat yield of 6000 kg ha^{-1} and a groundnut yield of 5250 kg ha^{-1} on a large area. The intercropping system has been widely accepted and appreciated by farmers due to its economic importance.

Varietal Improvement

Among all the yield-improving measures, varietal improvements have always been given the top priority. Our efforts are mainly directed towards breeding high-yielding, early- to medium-maturing, disease resistant, and market-oriented groundnut varieties. In the past decade, seven varieties were developed and released at several institutions of the province by the Crops Variety Appraisal Committee of Henan Province (Ma Kuiwu 1982, Wang Yijun et al. 1993, Ge Xiurong 1994). Test results indicate that all the varieties are suitable for intercropping with wheat, adaptable to different agroecological conditions, and serve various commercial purposes. The yield potentials of these varieties range from 6.0 t ha^{-1} to 8.0 t ha^{-1} on high soil fertility lands under average input conditions. The major characteristics of the released varieties are shown in Table 2.

In addition, some groundnut varieties introduced from other provinces are also recommended to farmers after a series of adaptability tests. The introduced varieties once grown extensively and/or still covering large areas currently include Haihua 1, Xuzhou 68-4, Hua 28, Luhua 9, Baisha 1016, and Tianfu 3.

Table 2. Groundnut varieties developed and released in Henan in 1985-95.

Variety	Year of release	Institution of release[1]	Attributes
Yuhua 1	1985	HAAS	High-yielding, large-seeded pods desirable for export, medium-maturing (120-130 days)
Yuhua 2	1988	PMIAS	Large-seeded, medium-maturing (125-140 days), tolerant to drought and iron chlorosis, wide adaptability
Yuhua3	1991	KMIAS	High-yielding, large-seeded pods desirable for export, early-maturing (110-125 days), high oleic/linoleic ratio (1.33), tolerant to iron chlorosis
Yuhua 4	1991	HAAS	Medium-sized pods desirable for shelled groundnut processing, early-maturing (100-120 days), high shelling percentage (74-76%)
Yuhua 5	1993	KMIAS	Large-seeded, medium-maturing (115-130 days)
Yuhua 6	1993	HAAS	Medium-sized pods, super-early-maturing (100 days or less), high shelling percentage (80%), dwarf and compact plants
Yuhua 7	1995	HAAS	High-yielding, large-seeded pods desirable for export, medium-maturing (120-130 days), tolerant to iron chlorosis, high protein content (28.6%)

1. HAAS = Henan Academy of Agricultural Sciences, KMIAS = Kaifeng Municipal Institute of Agricultural Sciences, PMIAS = Puyang Municipal Institute of Agricultural Sciences.

Cultural Techniques

Plant populations and planting formats of the intercropped groundnut

Plant population imposes great influences on other yield components. Maintaining an appropriate plant population is critical to achieve the desirable yield. Since the plant productivity of the intercropped summer groundnut is generally low due to its shorter growing season, a larger plant population is needed (Wang Baohua 1991). Factors that must be considered in designing the groundnut population include the soil fertility, climatic conditions, and varietal characteristics such as the growth habit, plant height and vigor, and the number of branches. Planting formats, or the ways in which the two intercrops are arranged, are primarily determined by the soil fertility, and to some extent by local practices for wheat planting, and the sowing implements. A number of innovations have been made in the planting formats in accordance with the increase of wheat yield level. At present, the following plant populations and planting formats are recommended by researchers for areas of different soil fertilities (The Coordinating Group for the Popularization of the Intercropped Summer Groundnuts, unpublished data, 1994).

- For high soil fertility areas (with a wheat yield of over 5250 kg ha^{-1}). Groundnuts are sown in bunches with 2 seeds each bunch, a bunch space of 40 x 20 cm, and a population of 125 000 bunches ha^{-1} (Figure 1).
- For intermediate soil fertility areas (with a wheat yield of 4500-5250 kg ha^{-1}). Groundnuts are sown with a bunch space of 25 x 27 cm, and a population of about 150 000 bunches ha^{-1} (Figure 2).
- For low soil fertility areas (with a wheat yield of below 4500 kg ha^{-1}). Groundnuts are sown with an average bunch space of 35 x 18 cm, and a population of about 160 000 bunches ha^{-1} (Figure 3).

Sowing time and successful emergence

The recommended sowing time for the intercropped groundnut is 15-20 days before the wheat harvesting. If a wider row space is maintained in wheat planting, the sowing of groundnuts can be advanced by 5-10 days (Zai Zhongliang et al. 1989). If the soil moisture is not sufficient at sowing, irrigation just before or immediately after the groundnut sowing is always advisable. Inappropriate advanced sowing of groundnut forces the crop to share a longer growing period with wheat, which usually hinders the development of the groundnut seedlings by delaying the flowering stage, reducing the number of flowers, and finally affecting the yield. On the other hand, when groundnuts are sown later than the recommended time, it is hard to achieve the full emergence by the time of wheat harvesting, and heavy damage to the germinating groundnut seeds or emerging seedlings is unavoidable during harvest of the wheat. For rainfed land, the soil moisture is the most important factor to be considered at sowing. So groundnut sowing is usually done whenever sufficient rain falls when temperatures are suitable.

In order to achieve good emergence, groundnut seeds need to be carefully selected and possibly coated with pesticides before sowing to curb seedling diseases. Attention should also be given to the control of underground insect pests to ensure the successful establishment of the seedlings.

Fertilizer application

A balanced fertilizer application is recommended to farmers in most groundnut-growing areas. The amounts and ratios of N, P, K, and the requirements of

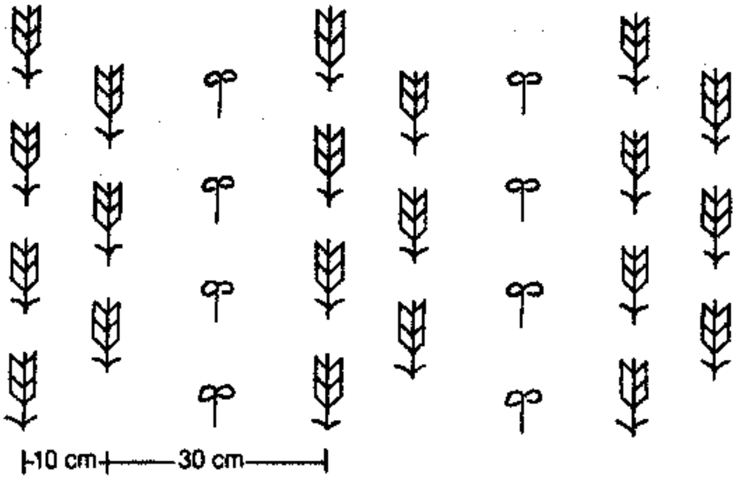

Figure 1. Sowing pattern for soils of high fertility.
Spacing : 40 x 20 cm, Population : 125 000 bunches ha^{-1},
2 seeds per bunch.

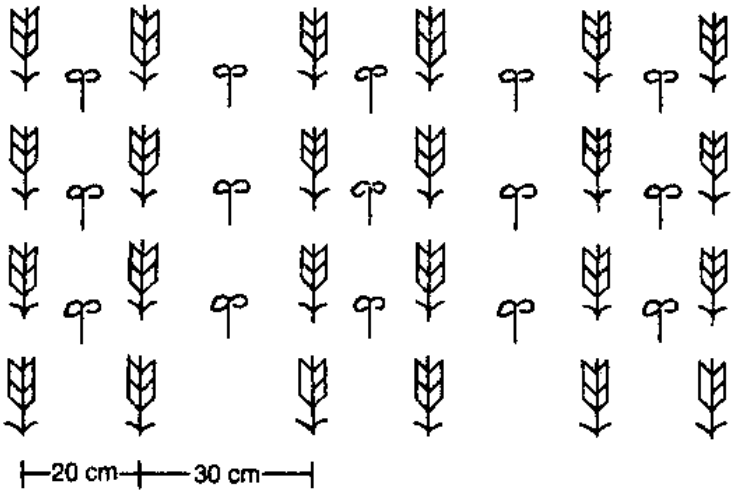

Figure 2. Sowing pattern for soils of intermediate fertility.
Spacing : 25 x 27 cm, Population : 150 000 bunches ha^{-1},
2 seeds per bunch.

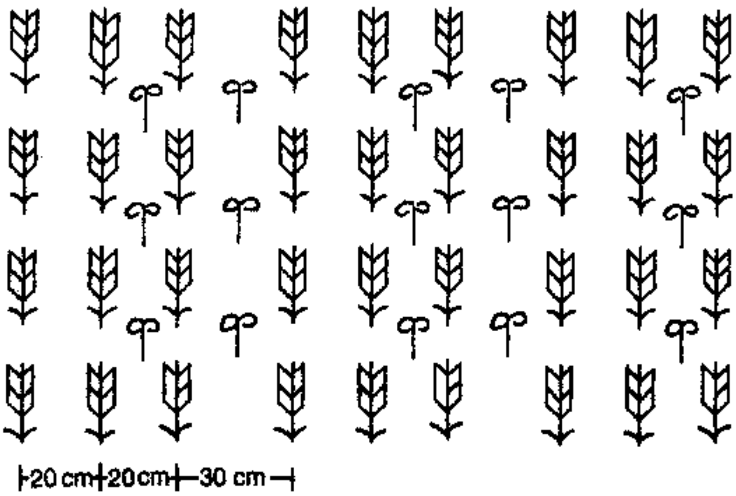

Figure 3. Sowing pattern for soils of low fertility.
Spacing: 35 x 18 cm, Population : 160 000 bunches ha^{-1},
2 seeds per bunch.

micronutrients are chiefly determined by the soil fertility of a particular area. The formulae of the major nutrients and the application practices for most areas of intermediate to high soil fertilities in Henan are recommended as follows (The Coordinating Group for the Popularization of the Intercropped Summer Groundnuts, unpublished data, 1994):

- Basal application. Basal application of fertilizers when sowing the intercropped groundnut is usually difficult due to the closure of the wheat canopy. So a single basal application of the fertilizers before wheat planting, at an increased dose, is proposed, and the nutrients are shared by both crops. The recommended doses are 60 m^3 farmyard manure, 300-375 kg urea, 450-600 kg superphosphate, and 150-225 kg potassium chloride or potassium sulphate ha^{-1}. Recently, with the improvement of the planting formats, 2 split basal applications have been proposed for fields where a wider wheat row space is maintained. The first application at normal doses is conducted before wheat sowing, while the second application is performed in the wider row spaces of the wheat field in the following spring at the dose of 15000-22500 kg farmyard manure, 150 kg urea (or 225 kg ammonium bicarbonate), and 300-450 kg superphosphate ha^{*1}.
- Mid-season application. Applying 150 kg ha^{-1} urea at the seedling stage helps to promote vegetative growth of the groundnut; applying 300-450 kg ha^{*1} gypsum into the top 10 cm soil layer at the flowering stage in combination with the earthing up of the crop provides a sufficient supply of calcium.
- Foliar spray Spraying 1% urea solution twice during the seedling stage, 0.2% borax twice at the flowering stage, and 0.1% potassium dihydrogen phosphate plus superphosphate solution at the late development stage ensures the groundnut a rapid access to the nutrients needed in its different developmental stages.

On calcareous soils, iron chlorosis frequently occurs due to high soil pH. Research results indicate that spraying 1% ferrous sulphate can correct the iron deficiency to some extent.

Control of diseases, weeds, and excessive plant growth

Early leaf spot *(Cercospora arachidicola)* and late leaf spot *(Phaeoisariopsis personata)* have been the most common groundnut diseases in Henan Province. In recent years, web blotch *(Didymella arachidicola)* has become very damaging. Groundnut stem rot also occurs frequently and usually causes heavy yield losses when seeds are not properly dried and stored. Two effective pesticides, carbendazim and chlorothalonil, as well as a number of preventive agronomic practices such as deep plowing, removal of infected residues, appropriate crop rotation etc. are recommended to farmers to control the above diseases.

Traditional hand weeding is very labor intensive. Convinced by demonstrations conducted by various researchers, many farmers now have adopted herbicides as an effective measure for weed control. At present, butachlor and haloxyfop (Gallant(R)) are the two important herbicides extensively used in Henan Province.

Excessive plant growth is a common problem prevailing now in most groundnut-growing areas of intermediate to high soil fertilities. The increased plant density, rain water, and the high summer temperatures are the major factors causing excessive plant growth which is usually followed by lodging and heavy yield losses. Farmers are recommended to spray 1000 mg L^{-1} daminozid (B9) or 100450 mg L^{-1} paclobutrazol (PP333, Cultar®) at the peak flowering stage when the plant height exceeds 45 cm to control the excessive growth of the plant.

Application of Yield Improvement Techniques

An extension network has been established throughout the province with collaborations of scientists, technicians, extension workers, and officials from different institutions and government organizations. A coordinating group is established at the Agricultural Department of the province to coordinate the integrated technology transfers. The major activities of the collaboration include:

- Identification of the major production constraints and the possible solutions;
- Propagation and supply of quality seeds of the improved varieties;
- Establishing demonstration fields and organizing high-yield competitions;
- Training local technicians and farmers, and supplying information.

The extension activities have proved to be very fruitful. In 1994, for example, a project was initiated to popularize the integrated yield-improving techniques for groundnuts in the wheat/groundnut intercropping system in 69 townships of 16 counties, where the projected area was 173 000 ha. A yield increase of 525 kg ha^{-1} and a total output increase of 72 100 t pods were achieved, The farmers' net income was increased by 135.96 million Yuan (about 15.2 million US dollars).

Problems of the Wheat/Groundnut Intercropping System

The wheat groundnut intercropping system is a relatively new cropping system. There is much work to be done to improve the performance of both intercrops, especially to further explore the yield potentials of the intercropped groundnut. Common problems in most areas under the system, particularly in those of intermediate or high soil fertility are as follows:

- The difficulties involved in groundnut sowing. When groundnuts are sown at the recommended time, the wheat fields are usually covered with wheat plants of full height, so the sowing of groundnuts is obviously very difficult and labor intensive/With the gradual increase of the wheat yield, the above difficulty becomes even more prominent. The lack of efficient sowing implements further complicates the situation. The sowing difficulties cause insufficient plant density, and finally yield reduction. The practical ways to reduce such difficulties to some extent include the careful designing of the planting formats, and the breeding of new varieties of both crops that best fit the intercropping system. There is a tendency to develop the post-wheat summer groundnut (sown immediately following the harvest of wheat) in areas where heat and light are sufficient.

- Poor germination and low emergence rate of the intercropped groundnut. Sufficient soil moisture is a crucial requirement for successful germination and emergence. In the rainfed areas of Henan Province, however, such a requirement is rarely met due to the high evapotranspiration by wheat, and the unreliable rainfall in the early summer season. So groundnut sowing has often to be either advanced or postponed depending on the receipt of sufficient rain. Inappropriate sowing time obviously results in poor germination and emergence. In irrigated areas, even though the soil moisture can be manipulated through timely irrigation, the germination and emergence of the intercropped groundnut are often affected by the lower soil temperature in the wheat field, which usually increases the time needed for germination and emergence, and thus increases the chance of disease infection and insect damage to the seeds or seedlings. The germination and emergence of the intercropped groundnut may be improved through the selection of desirable intercropping formats and the adoption of advanced cultural techniques such as the polythene film mulch cultivation.
- The lack of efficient machinery. Groundnut cultivation is generally labor intensive as compared with many other crops, especially the sowing and harvesting operations. The low level of mechanization in groundnut production has been bothering China's groundnut growers for quite a long time. It is estimated that the labor involved in the cultivation of the intercropped groundnut is significantly more than that needed for the cultivation of a sole groundnut crop (Wang Baohua, personal communication), so the demand for efficient machinery for the intercropped groundnut is much stronger. The further development of groundnut production will be hindered to a certain extent in the future if the mechanization problem cannot be solved properly.

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Technologies for High Yield of Groundnut in Pingdu County

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Abstract

Groundnut is cultivated on about 34 000 ha in Pingdu county. Guided by the scientists of Shandong Peanut Research Institute (SPRI), the technicians of Pingdu county used various techniques to increase groundnut yield. Since the 1980s, good results have been achieved. During 1981-85, in comparison to the 1970s, the harvested area, the yield, and production have all increased markedly and took first place among the counties in China. In the early 1990s, the county yield had increased again probably because of techniques introduced from SPRI. Average yield in 1993 was 4.64 t ha^{-1}, and in 1994 was 5.03 t ha^{-1}.

The technologies contributing to these improvements include the use of medium-duration varieties with stable high yields, polythene mulching, new cropping systems, split application of fertilizers, optimal plant populations, application of growth regulators, and control of pests and diseases.

山东省平度市常年种植花生 3.4 万公顷. 进入八十年代以来，在山东省花生研究所指导下，应用推广高产栽培技术，收到较好增产效果. 1981－1985 年间，平度市花生种植面积、平均单产、总产量均有显者提高，位居全国县(市)油料总产之首. 进入九十年代，不断引进新技术、新成果、使全市花生单产又有提高，1993 年平均每公顷产量达 4635 公斤，1994 年达到 5025 公斤.

平度市实现大面积高产的主要经验是：选用高产早熟大果品种；推广地膜覆盖栽培技术；实行大区优化轮作体系；合理施肥；合理密植；适时喷施生长调节剂，及时防治病虫害.

Introduction of Improved Groundnut Varieties

From the 1950s to the 1960s, the traditional Virginia runner and late-maturing groundnut varieties were replaced by good, early-maturing, Spanish varieties. This was the first introduction of good groundnut varieties in the county. In the 1970s, Bai Sha 1016 was the main variety popularized: this was the second introduction of improved groundnut varieties. That these two introductions were

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both Spanish, early-maturing types was a limitation. In the 1980s Hua 37, a medium-duration groundnut variety, which belongs to the Virginia bunch type, was widely popularized in Pingdu county. Its unit output was about 20% higher than that of Spanish type varieties. With the utilization of the polythene mulching technique the unit output of Hua 37 in a small area in 1981 was as high as 7500 kg ha^{-1}. In 1983 the mean unit output of Hua 37 in an area of 600 ha in both Liangmu and Zhanggezhuang towns, was 7500 kg ha^{1}. By the end of the 1980s the cumulative area over which Hua 37 and other Virginia type varieties were being grown was up to 16 000 ha, about 80% of the total. The goal of the fourth introduction of new groundnut varieties in the 1990s was to realize stable high yields economically. The main popularized varieties included Lu Hua No. 11, 79-266, Lu Hua No. 9, and 8130. The total area under these new varieties was about 23 300 ha, about 85% of the total.

Popularization of Polythene Mulching

The polythene mulching technique from Japan was introduced and recommended in Pingdu in 1979 with the help of the Shandong Peanut Research Institute. In 1981 the unit output of groundnut with the polythene covering in 0.08 ha was 8790 kg ha^{-1}, about 24.1% higher than the control. In 1982, in an area of 2.1 ha the yield had risen to 7477 kg ha^{-1}, or 20.4% higher than the control. According to the data from 1979-84 the seedling emergence with the polythene mulch was about 4.6% higher than the control, and the two-seeded pods and full pods about 4% and 11.6% higher than the control, respectively. However, the pod number kg^{-1} was 15% lower, and the pod number per unit area and the unit output were about 12.75% and 26.4% higher than the control, respectively.

Since 1983 the technique of groundnut cultivation with polythene mulching has been widely adopted in Pingdu. The total area was 333 ha in 1984 and was about 25 333 ha in 1994, around 85% of the total area.

Introduction of New Cropping Systems

Before the 1970s the cropping system was mainly single crops of sweet potato, soybean or groundnut in about 60% of the cultivated area in Pingdu. This resulted in problems arising from continuous cropping such as the occurrence and spread of groundnut diseases. Since then, the cropping system of 3 crops in 2 years, such as spring groundnut-winter wheat-summer maize, was introduced and widely accepted. Up to now the area of the 3-crop system is about 24 000 ha, about 80% of the total area of groundnut cultivation. The results showed that the system could efficiently use the soil nutrients to increase the output of groundnut and obviously reduce the damage due to groundnut diseases including root nematode, and harmful pests like white grubs. Recently, for the purposes of increasing the cropping index and the production efficiency of the cultivated land, the cropping system of winter wheat-summer maize-winter wheat-summer groundnut- four crops in two years- has been gradually introduced and popularized in Pingdu.

The present total area of the system is about 4000 ha. The unit output of groundnut, which was relay-cropped with winter wheat, was up to 5250 kg ha^{-1}, and wheat output about 6000 kg ha^{-1} in large areas. The unit output of groundnut sown directly after the winter wheat was up to 4758 kg ha^{-1}, and the winter wheat output about 7440 kg ha^{-1}. With the breeding of the early and very early-maturing wheat and groundnut varieties, and with the enhancement of the level of mechanization in wheat and groundnut production the future of the cropping system is very bright.

Fertilizer Application

Split application of organic manures and chemical fertilizers was adopted to meet the nutrient requirements of high-yield production technology. The amount of organic manure application was about 6000 kg ha^{-1}, plus 78.7 kg ha^{-1} P, 62.25 kg ha^{-1} K, and 100 Kg ha^{-1} N. A part of the organic manure and nitrogen fertilizer was applied by broadcasting in the winter or spring with deep plowing. Most of the remaining part of organic manure and NPK fertilizer was applied in early spring with ridge making, and the remainder at the stage of flowering-pegging around the groundnut ridges within the depth range of podding. This kind of fertilizer application could not only meet the needs of groundnut growth and development but also improve the environment of the podding soil zone, promote the development of pods, increase the output of groundnut, and improve soil nutrition overall.

Achievement of Optimal Plant Population

The close sowing of groundnut, with an optimal number of hills for a full stand of seedlings, had to be adjusted according to the groundnut varieties cultivated. For instance, Lu Hua No. 11 and 79266 needed about 135 000-165 000 hills ha^{-1}, with two seeds per hill, while Lu Hua No. 9 and 8130 needed about 120 000-150 000 hills ha^{-1}, with two seeds per hill. The high-fertility soils were suitable for sparse planting, while the low-fertility land was suitable for close planting.

For the purposes of ensuring a full stand of seedlings the following were implemented:

1. To ensure good quality, the seeds were stored carefully to avoid fungal infection, carefully graded prior to sowing, (the first and the second grade of seeds were sown, the third grade of seeds and the rest put aside for other uses), and seeds were soaked in warm water before sowing to enhance sprouting.
2. To make the environmental conditions optimal for seed sprouting, seeds were sown in time, usually about the middle 10 days of April when the soil temperature within 5 cm depth was about 12°C with polythene mulching. Sowing was done while there was sufficient moisture in the soil, and a mixture of pesticide 812® was added to protect seeds from soil pests, and to reduce later damage to groundnut seedlings by aphids and the spread of virus disease carried by aphids.

Management of the Crop

Assisting the seeds to sprout earlier and making the sprouts strong

Removal of the soil around the sprouts. After the emergence of sprouts, soil was removed from around the sprouts by hand to make the two cotyledons of each sprout emerge from the soil. This resulted in the first pair of lateral branches being produced much earlier. This may have helped the basal nodes to form more pegs and pods.

Irrigation. Generally there is a spring season drought in Pingdu every year. Thus irrigation along the furrows assisted the even emergence of seedlings.

Fertilizer topdressing. Results showed that the topdressing of 150-180 kg ha^{-1} compound fertilizer or 98-130 kg ha^{-1} P in the early flowering stage could meet the needs of the growth and development of pegs and young pods.

The regulation of growth

Spraying 50 mg kg^{-1} paclobutrazol (PP333) solution on the leaves about 30-35 days after flowering could effectively control the height of plant, and make the leaves much thicker, the pods fuller, and increase the pod yield by about by 13%. The foliar application (2 sprays at 10 day intervals) of titanium (Ti) compound fertilizer enhanced photosynthetic rate, and prevented early senescence of leaves.

Management of diseases and pests

In the middle stage of growth and development of groundnut the main harmful pests were cotton bollworms *(Helicoverpa armigera),* white grubs *(Lachnosterna* spp.), etc. The prevention and control should be done in time, by selecting the most effective pesticides. For instance, for underground pests it was better to apply 7.5-15 kg ha^{-1} Isofenphos - methyl pesticide to the hills of groundnut.

The most damaging disease of groundnut in its late stages of growth and development was late leaf spot disease *(Phaeoisariopsis personata),* which caused early senescence of leaves and decreased the pod yield. Thus in the early podding stage it was better to spray with appropriate fungicides, and pesticides to kill aphids *(Aphis craccivora)* which spread virus diseases.

Harvesting at the most appropriate time

When about 60-70% pods were mature was the best time to harvest, otherwise the quality of pods and seeds was affected.

Status of Groundnut Cultivation and Production in Guangdong

Liang Xuanqiang[1]

Abstract

Groundnut is an important crop in Guangdong Province, where it is cultivated on about 350000 ha. There are normally two sowings per year. Farmers follow several good management practices including the use of high-yielding cultivars Yueyou 223 and Shanyou 523 in paddy fields, high-yielding and bacterial wilt resistant cultivars Yueyou 256 and Yueyou 200 in upland areas, sowing and harvesting in time, rotation with rice in paddy fields and with sweet potato in uplands, using the optimum rates and ratio of NPK fertilizers, judicious use of irrigation, good weed control, and integrated pest and disease management.

花生是广东省的主要油料作物，常年种植面积35万公顷。一年可种春秋两季。农民采用的一些好的管理措施包括：在稻茬轮作田中选种高产的粤油223和汕油523；丘陵旱地选用高产抗青枯病的粤油256和粤油200；与甘薯等作物轮作；优化配方施肥；适时排灌；及时除草和对病虫害进行综合治理。

Introduction

Guangdong, southern China, has a land area of 178 000 km^2, and varies in latitude from 20°09' to 25°31'N and in longitude from 109°45' to 117°20'E. The annual rainfall varies from 1500 to 2000 mm. The annual solar radiation energy varies 99-136 Kcal cm^{-2}. There is a frost-free period of more than 300 days.

Production

In Guangdong, groundnut is the second most important crop after rice and occupies 13% of the area of all crops and above 95% of the area of oilseed crops. The ratio of groundnut area to rice area is 1:8.4.

Groundnut is grown in two seasons; the spring season (80% of total production) being for commercial uses, and the autumn season (20% production)

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being largely for seed. As shown in Table 1, the average harvested area for 1980-1989 was 358375 ha while the average harvested area for 19904994 was 328694 ha showing a decrease of approximately 29681 ha. In contrast, average production in the 1980s was 0.55 million t and in 1990-1994 0.61 million t, an increase of almost 11% over the 1980s average production. This significant increase in the 1990-1994 period is attributable to higher yields. The yields increased from 1.53 t ha^{-1} in 1980s to 1.85 t ha^{-1} in 1990-1994, a 21% rise. Cantonese farmers have a long history of groundnut cultivation and groundnut is widely grown all over Guangdong. According to climatic conditions, and economic and social characteristics, Guangdong groundnut production can be divided into four regions. (1) The southwest, including Dinbai, Wuchuan, Huazhou, Yangchun, Yangjiang, Shuixi, Lianjiang, Haikang, and Xuwen, is the major groundnut-producing area. The annual harvested area in the southwest was 100 000 ha and the yield was 1.60 t ha^{-1} in 1994. (2) The east, including Chenhai, Chaojian, Puning, Chaozhou, and Haifeng, is the high-yield area. The annual area sown is about 60 000 ha and the yield is 2 t ha^{-1}. (3) The north,

Table 1. Guangdong groundnut harvested area, yield, and production.

Year	Harvested area ('000 ha)	Yield (t ha^{-1})	Total production ('000 t)
1980	368.88	1.35	500.0
1981	396.94	1.44	573.9
1982	392.01	1.57	619.0
1983	326.49	1.47	480.8
1984	349.04	1.53	534.0
1985	365.18	1.57	570.7
1986	373.87	1.62	604.0
1987	355.42	1.50	535.0
1988	331.88	1.56	518.0
1989	324.03	1.71	553.8
1990	323.97	1.78	579.5
1991	334.71	1.68	562.6
1992	314.57	1.92	603.9
1993	333.32	1.98	660.3
1994	336.90	1.89	637.7
Average 1980s	358.38	1.53	548.8
Average 1990-1994	328.69	1.85	608.8
Change over 1980s			
Absolute	-29.68	0.32	60.0
Percentage	-8.28	20.74	10.9

including Yingde, Qujiang, Techang, Poluo, Huiyang, Heyuan, and Huidon, is the largest area of groundnut production. The annual harvested area is over 120 000 ha and the yield is 1.5 t ha^{-1}. (4) The central zone includes Guangzhou, Taishan, Xinhui, Kaipin, Sanshui, and Nanhai. Here the harvested area is about 50 000 ha and the yield is about 1.9 t ha^{-1}.

Approximately 98% of the groundnut in Guangdong is Spanish type, maturing in 110420 days. At present, the high-yielding, rust-resistant varieties Shanyou 523, Yueyou 223, and Shanyou 71 are widely sown in paddy-fallows. The high-yielding, bacterial wilt-resistant varieties Yueyou 256, Yueyou 200, and Yueyou 92 are widely sown in uplands.

In Guangdong, about 80% of the groundnut produce goes for oil extraction, 20% as seed and for direct consumption as roasted, fried, or boiled groundnut/or in confectionery.

Cultural Practices

Considerable research has been done in the 1980s on cultural practices for groundnut. Many experimental stations have conducted studies on intercropping, crop rotation, fertility, time of planting, varieties, weed control, and crop protection. Results from these studies have led to recommendations for obtaining high yields which have been adopted by farmers.

Crop rotation and intercropping

Since the 1960s, groundnut rotation with rice (paddy-fallows), and with sweet potato or jute in uplands had been widely used in Guangdong, Rotation has many advantages: it can maintain and increase soil fertility, and reduce soil-borne pests and diseases, especially bacterial wilt. The major groundnut production in the northern and southwestern regions is mostly in upland in rotation with sweet potato, soybean, mung bean, small red bean, maize and tobacco. After the high-yielding and bacterial wilt-resistant varieties Yueyou 92, Yueyou 256, and Yueyou 200 were released, groundnut has been grown in uplands or hilly areas as a sole crop. In the eastern and central region, 80% of groundnut is rotated with rice, and gives high yields. In some areas, groundnut is intercropped with young sugarcane, fruit trees, maize, or sorghum. The ratio of groundnut to intercrop varies from 1:1 to 1:10 depending on the soil type, climatic conditions, and intercrop species.

Sowing time

Results from experiments by many agronomists on date of planting of Spanish groundnuts in Guangdong showed that farmers could increase their yield by sowing earlier than was customary. For spring season groundnut, the optimum sowing time is about 20 Feb ('RAIN FALL') in the southern region, 20 Feb-5 Mar ('RAIN FALL' to 'EXCITED INSECTS') in the central region, and 5 Mar-20 Mar

('EXCITED INSECTS' to 'VERNAL EQUINOX') in the northern region. For autumn season groundnut, the optimum sowing time is about 20 Aug ('LIMIT OF HEAT') in the southern region, 8 Aug ('AUTUMN BEGINS') in the central region, and 20 Jul-8 Aug ('GREAT HEAT' to 'AUTUMN BEGINS') in the northern region.

Land preparation and sowing method

Good tilth is essential to obtain the best germination. In Guangdong, the sowing time is often during a rainy period, and as turn-around time in the rice-fallows is short, land preparation must be done as early as possible. Deep plowing and intense harrowing are the keys to obtaining high yield. In order to get rid of waterlogging problems, the narrow raised bed (13-2 m wide, 0.2-0.25 m high) and furrow system (two furrows of 03 m width on either side) must be prepared with flat surfaces on both the raised bed and furrow/pan. Each raised bed will accommodate 4-5 rows with 23-26 cm spacing between rows. The sowing depth in paddy fallows is 3 cm and in upland 3-4 cm. It is necessary to treat the selected kernels before sowing with 40% Carbendazol® (methyl 2-benzimidazole carbamate) to control collar rot *(Selerotium rolfsii)* and other soilborne diseases.

Plant density

The research results showed that rational plant density not only increases plant yield but also increases shelling percentage. A population of 330 000 plants ha^{-1} gives a 17% increase in yield over the yield of 150 000 plants ha^{-1}. The optimum density varies from 270 000 - 330 000 plants ha^{-1} in the spring season, and from 300 000 - 375 000 plants ha^{-1} in the autumn season depending on the land fertility, availability of irrigation, and growth habit of the variety. The most common spacing recommended is 23-26 cm x 17-20 cm for two seeds $hill^{-1}$ and 23-26 cm x 10-13 cm for one seed $hill^{-1}$.

Fertilizer application

Scientists from the Industrial Crops Research Institute found that two thirds of the nitrogen required by groundnut can be fixed by rhizobia. Phosphorus is easily fixed in soil, and the utilized coefficients are 40-50% for N and P, and 50-60% for K. The content of potassium in soil in Guangdong is low (0.16-0.87%). The NPK fertilizer doses recommended in Guangdong are 60-90 kg N, 60-90 kg P and 75-90 kg K ha^{-1}. The NPK ratio = 1 : 0.8-1 : 1-1.2. In practice, 7.5-11.25 t burned soil, 3.75-7.5 t farmyard manure, 225-300 kg groundnut meal, 60 kg urea, 225-300 kg superphosphate, 100-120 kg potassium sulphate (or 750-900 kg plant ash), 375-750 kg lime, and 7.5 kg boron fertilizers are mixed and incorporated in soil before sowing as the basal manure per hectare. A side dressing of 60 kg ha^{-1} is applied at the four leaf stage and 300 kg ha^{-1} lime is applied as top dressing at flowering.

Water management

A groundnut crop requires on an average 3375-3750 t ha^{-1} of water. The optimum soil moisture content is 50-60% at seedling stage, 60-70% from flowering to the pegging stage, and 50-60% at podding. The critical stages are flowering, pegging, and pod development. As excessive irrigation must be avoided, a three level drainage ditch system, where the surrounding ditch of the field is 5-7 cm deeper than the furrow ditch, and the outside drainage ditch is 30 cm deeper than the surrounding ditch, is the best method for irrigation.

Weed control and earthing-up operation

Application of herbicides followed by 1-2 hoeings controls weeds effectively. The recommended herbicides for groundnut in Guangdong are 25% Ronster® 1.5 L ha^{-1}, 48% Lasso® 2.25 L ha^{-1}, or 72% Dual® 1.5 L ha^{-1}, in 600-750 L of water as pre-emergence sprays applied within 2 days of sowing. In Zhangjiang city, experimental results on earthing-up indicated a yield increase of 25.5% over the control. The earthing-up is done at the flowering stage.

Crop protection

A wide range of pests and diseases attack groundnut and cause considerable losses in yield in Guangdong. Among the diseases, rust *(Puccinia arachidis),* leaf spots *(Cercospora arachidicola* and *Cercosporidium personatum),* bacterial wilt, peanut stripe disease, collar rot, and stem rot are common. Aphids, armyworm, white grubs, and thrips are the common pests.

Rust and leaf spots control. Integrated control is the best approach, but cultural measures such as early sowing in the spring crop and late sowing in the autumn crop, low water table and improved drainage, application of P and K fertilizers and destruction of volunteer plants are effective to reduce the incidence. Use of resistant cultivars e.g., Yueyou 223 and Shanyou 523, and chemical control by Daconil®, Bordeaux Mixture®, and colloidal sulfur sprayed on the crop can control the diseases.

Bacterial wilt control. This is the second most important disease in Guangdong. Rotation with sugarcane for 2-3 years has been found to reduce bacterial wilt incidence to under 10%, while rotation with rice can reduce incidence to below 1%. Tobacco, tomato, eggplant and pepper should not be rotated with groundnut if bacterial wilt is to be controlled. Bacterial wilt-resistant cultivars Yueyou 256, Yueyou 92 and Yueyou 200 should be grown.

Collar rot and stem rot control. Daconil®, Topsin®, Bavistin®, and other fungicides have given effective control.

Pest control. Sprays of dimethoate, malathion, and pirimicarb are effective to control insect pests.

Optimum cultural practices for medium and low-yielding areas

Although the yield level in some areas of Guangdong province (Taishan, Gaozhou, Dongyuan, Nanxiang, Chenhai, Qujiang) approaches 2100 kg ha^{-1}

(national average) it is less than the national average in 70% of the area. The causes of low yield are drought, poor soil fertility, bacterial wilt, foliar diseases, and poor farming practices. A project for the development of low- and medium-yielding groundnut areas was carried out during 1990-1993. The area with low-yielding fields improved to give medium yields of 1800 kg ha^{-1} in 70 000 ha, while areas with medium-yielding fields became high-yielding in 140 000 ha and the yield reached 2600 kg ha^{-1}. The main cultural practices that resulted in these improvements were the introduction of high-yielding cultivars, adoption of narrow raised beds, and deep furrows, the increased application of basal manures and fertilizers, the preparation of a fine tilth, and harvesting at the optimal time.

Ecoresources and Cultural Practices of Groundnut in the Loess Plateau of Shaanxi Province

Zhang Qihua, Gao Xiang, and Guo Yonghua[1]

Abstract

In the Shaanxi Province of China, 61% of the land area is a loess plateau; 85% of this is suitable for groundnut production. This was calculated primarily on the basis of suitable temperature conditions for growth, water availability (rainfall and irrigation potential), soil characteristics, and incident radiation. Compared with cultivation in open fields, using polythene film during cultivation can increase groundnut yields by over 38.2%. Data from groundnut-producing regions showed that production in Shaanxi province in 1984-88 was much higher than it was 5 years earlier.

黄土高原占陕西省土地面积的 61%，综合考虑温度条件、水分利用状况、土壤特性、光能利用等因素，85% 的地区适于花生种植。同露天栽培相比，塑料薄膜覆盖栽培技术可使花生产量提高 38.2% 以上。产区的资料表明，陕西省在 1984－1988 年间，花生生产较 5 年前有了很大的提高。

Introduction

The loess plateau of Shaanxi Province lies adjacent to the middle section of the Yellow River. It includes the central zone of the loess plateau which lies to the north of the Qin Ling mountains and is in the warm temperate zone, with a semi-arid monsoon climate. Few economic crops are grown and the economy of the region is lagging. Groundnut has been produced in Shaanxi Province for almost 200 years and is mainly concentrated on the lower reaches of the Wei River where about 20000 ha of groundnut is grown. However, yields are low in this region. Research on groundnut aims at increasing the productivity and production to enhance self-sufficiency in edible oil, and to improve the economic condition of farmers in the region.

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Zhang Qihua, Gao Xiang, and Guo Yonghua. 1996. Ecoresources and cultural practices of groundnut in the Loess Plateau of Shaanxi Province. (In En. Summary in Ch.) Pages 223-232 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Research Methods

Comprehensive investigations on production of oil crops were carried out in the counties of the loess plateau. The results showed that some farmers grew groundnut and obtained good economic returns in the loess soils.

Using available knowledge, the ecological factors affecting groundnut cultivation and growth have been identified. Research, demonstration and extension of high-yield technologies were conducted at Mizhi and Heyang Experiment Stations located in the North and Central part of Shaanxi Province, respectively.

Results and Discussion

The Evaluation of Ecological Factors Affecting Groundnut Production

Temperature

Groundnut seeds need a temperature of 12°C for germination. The temperature summation of the whole growing period of groundnut is expressed as 12°C temperature summation. During the growing season from Apr-Sep, the temperature summation is more than 3000°C. From Jul-Aug, the mean temperature day^{-1} is 22°C. The daily mean temperature in the early days of June needs to be >20°C. The number of frost-free days should be at least 150. The counties of the loess plateau of Shaanxi Province have been divided into six districts according to the results of the comprehensive analyses considering the above four temperature factors, as shown in Table 1.

Qin Ling Mountain: This area lies in the northern foothills of the Qin Ling Mountains, where the temperatures are unsuitable for groundnut cultivation, and suited only to spring wheat, spring rapeseed, buckwheat, and rye that need lower temperatures. Therefore, groundnut is not grown.

Low temperature district: This area includes 12 counties lying to the northwest of Bai Yu Mountain and Zhi Yu Mountain in Shaanxi Province. Temperatures tend to be low. Using polythene mulching techniques, short duration groundnut varieties can be cultivated. This area is unsuitable for good economic returns from groundnut.

Mid-low temperature district: This area includes 10 counties of the northern Shaan Ben. The temperatures are sufficient to produce one crop per year. By the use of polythene film mulching good economic returns can be obtained from groundnut cultivation.

Mid-temperature district: This area covers the counties near the Yellow River and the northern part of Shaanxi province. The climatic conditions are suitable for large-podded medium-duration varieties. In general, they are sown in spring and harvested in autumn. By using polythene mulching high yields can be achieved. This is the major district for developing groundnut production.

Table 1. The values of the temperature factors in the six areas of the loess plateau, China.

Areas	Value of comprehensive evaluation	Temperature summation (°C) (TS)	80% probability value under ≥12°C TS (°C)	≥15°C safety of TS (°C)	Mean temp Jul and Aug (°C)	Mean temp for June (°C)	Assured rate under ≥20°C June (%)	Frost-free days (No.)
Qin Ling Mountain	0.0691	2080.0	1986.8	495.5	17.83	16.28	-	169.7
Low temp. dist	0.2597	2917.7	2774.8	577.5	21.15	20.00	52.28	166.5
Mid-low temp dist	0.3288	3331.7	3186.4	746.6	22.35	21.12	81.19	182.9
Mid-temp dist	0.3738	3571.4	3488.4	858.0	23.26	22.04	97.73	196.2
Mid-high temp dist	0.4338	4134.7	3993.3	1176.2	25.26	24.29	100.0	216.2
High temp dist	0.4659	4468.5	4362.6	1320.9	26.05	24.37	100.0	242.0

Table 2. The precipitation regions and their characteristics in the loess plateau, China.

Region	Comprehensive evaluating value	Precipitation (mm) (Aug-Sep)	80% probability (Aug-Sep) (mm)	Probability ≥20°C mean for 10 days of April	≥20mm probability in 10 days of April (%)	Mean rainfall in June and August (mm)	Probability of drought in June and August
Arid region	0.1897	357.89	261.84	28.17	20.30	210.70	24.63
Semi-arid region	0.2692	437.45	343.45	31.20	37.28	241.10	21.93
Hot arid region	0.2788	455.45	361.48	34.15	61.29	193.63	37.52
Suitable rainfall region	0.3213	477.20	337.00	34.88	61.87	224.35	21.45

Mid-high temperature district: This area mainly involves 26 counties of the Weibei tableland and Guanzhong plains where the temperature regime is suitable for all varieties of groundnut Generally, crops are planted in spring, and three crops can be harvested in two years. Groundnut of high yield and quality can be cultivated.

High temperature district: The confluence area of the Wei, Fing, Lou, and Yellow Rivers is the zone of highest temperatures in the loess plateau of Shaanxi Province, and this is the area where groundnut was traditionally grown. Generally, groundnut and wheat are planted in rotation, in one year. This area produces high yields of both wheat and groundnut.

In the loess plateau, the mountainous and low temperature area is 28% of the total, and the remaining area (72%) is suitable for groundnut cultivation.

Moisture

The loess plateau of Shaanxi Province is a semi-arid region of the temperate zone, and precipitation is less than evaporation. The main limiting factor during groundnut growth is soil water deficiency. However, for most of the loess plateau, the total precipitation meets the needs of groundnut as the rainfall occurs during the groundnut growing season. The water-holding capacity of soil is good and can compensate the water deficiencies for groundnut growth to some extent. The loess plateau has been divided into four regions on the basis of precipitation (Table 2).

Arid Region: This mainly includes the counties that lie near the line of the Great Wall and Yellow River, a region prone to wind storms. The rainfall is sufficient for the needs of the short-duration groundnut varieties. This region is rich in underground water, and the production of all crops can be increased by developing irrigation.

Semi-arid region: The rainfall of the semi-arid region in the summer season is higher than in other seasons. The higher temperatures can meet the needs of the medium-duration groundnut varieties.

Hot-arid region: This mainly includes the counties that are near the valleys of the Fing and Wei Rivers. Although the combination of high tempartures and low rainfall is severe, irrigation systems are very good, which ensures groundnut production.

Suitable rainfall region: This rainfed farming region occurs in the northern Wei Ben and the southern Shaan Ben areas. As high rainfall and high temperatures coincide, this region is suitable for groundnut production.

Soil

Soil is a main factor that has limited groundnut production in the past. Based on the researches of Shandong Peanut Research Institute, the soil volume can be divided into three layers where the top 040 cm is the root bearing layer, 10-30 cm is the nutrient supply layer, and the soil below 30 cm is the deep rooting layer. The bulk density of the 040 cm layer is less than 1.3 g cm^{-3}. Soil porosity is 50%, and soil clay content is approximately 25%. Characteristics of the soil in different counties is given in Table 3. Most soils have clay rich in calcium, and are easily tilled. Loess soils have high water-holding capacity. The amount of stored water in the 2.0 m depth is 450 mm (when the maximum field capacity is 28%). The medium-fertility soils are suitable for groundnut cultivation.

An analysis of the soils in the region indicates that soils in 80-90% area of the loess plateau, 60-80% of eastern Guanzong plain, and 40-80% of western Guanzhong are suitable for groundnut cultivation.

Radiation resources

Groundnut requires high light intensity for growth. Abundant light radiation and adequate temperatures are beneficial to the accumulation of plant photosynthates. In comparison with groundnut in Shandong Province, the main stem of groundnut plants in Mizhi county of Shaan Ben have fewer leaves, and the plant height is 15.25 cm shorter than that in Shandong, so that the plant growth is healthy and not prone to lodging, and similar high yields can be obtained. The loess plateau is a high light radiation region, 7-15% more than in the southeast region along the coast. The duration of sunshine is between 1195.1 and 1598.4 hours during the growing season (Apr-Sep), the total light radiation is 74.15-93.16 Kcal cm^{-2}, and the potential productivity is 8.4 t ha^{-1} (See Table 4).

These measurement indicate that there is a greater potential for high yields where there are higher levels of radiation.

Tolerance of Groundnut to Abiotic Factors

Under the adverse ecological conditions of the loess plateau, groundnut has shown tolerance to drought, reduces runoff and soil loss, and is less affected by hailstones. Iron deficiency symptoms are clearly visible in soils of pH 8.5 in the loess plateau. However, application of organic manure usually overcomes this problem.

The Groundnut Sowing Region Delimitation in the Loess Plateau of Shaanxi Province

Results of comprehensive evaluations indicate the boundaries for groundnut sowing in the loess plateau of Shaanxi Province. This is shown in Figure 1.

The total area in the loess plateau of the northern Qin Ling Mountains is about 135 654 km^2, and 61.7% of the area is suited to sowing groundnut, approximately 83 700 km^2. This is 85% of the arable land used for cropping.

Table 3. The soil fertility and soil physical characteristics in some counties of the loess plateau, China.

County	Organic matter (%)	Total N (%)	Alkali hydrolysic N (mg kg^{-1})	Total P (%)	Available P (mg kg^{-1})	Total K (%)	Exchangeable K (mg kg^{-1})	Substitute value (ml 100 g^{-1} soil)	pH	Rate of loessial soil (%)	Bulk-density (g cm^{-3})	Soil porosity (%)
Yu Lin	0.7996	0.044	39.87	–	7.03	–	110.4	–	–	18.9	1.19	56.0
Shun Oe	0.4108	0.032	22.72	0.185	2.88	–	97.7	4.90	–	95.4	1.19	55.1
Yan An	0.6291	0.046	38.50	0.096	4.20	–	157.5	–	8.5	68.9	1.24	58.2
Shun Yi	1.1760	0.077	43.46	0.132	6.23	2.5	161.6	9.47	8.3	55.5	1.24	53.2
Qian Xai	0.9300	0.064	36.77	0.136	4.85	2.62	178.9	9.67	–	28.8	1.30	50.0
Wu Gong	1.1550	0.098	49.00	0.253	8.50	–	–	9.25	–	–	1.40	48.0
He Yang	1.0960	0.074	29.60	0.140	4.72	1.88	148.6	–	8.2	62.5	1.24	54.0
Hei Nan	0.8550	0.065	49.90	0.250	6.70	3.46	188.3	8.7	–	–	1.30	52.0

Table 4. Radiation and its effects on potential productivity in some counties of the loess plateau, China.

Name of county	Mean duration of sunshine (h) (Apr-Sep)	Total radiation (Kcal cm^{-2}) (Apr-Sep)	Photo-synthetic active radiation (Kcal cm^{-2})	Potential yield (t ha^{-1})	Highest yield achieved (t ha^{-1})
Yu Lin	1598.4	93.16	45.58	9.02	8.08
Shun De	1425.4	84.62	43.06	8.98	7.74
Yan An	1308.8	80.16	41.17	8.68	8.60
Cheng Cheng	1411.9	83.35	41.18	8.80	-
Fu Ping	1409.6	82.34	40.65	8.62	8.97
Da Li	1365.3	79.10	38.94	8.42	7.98
Lan Tian	1240.0	75.66	37.72	8.39	-
Xian Yang	1237.1	75.98	37.93	8.40	6.72
Qian Xai	1258.6	76.06	37.88	8.40	-
Qi Shan	1195.1	74.01	37.10	8.30	6.87

Groundnut cultivation and practices

Preliminary observations on groundnut growth. Comparisons were made between experiments in open land and under polythene mulch covering in Quan village, He Yang county of Wei Ben in 1984, using the variety Xuzhou 68-4 (150 days duration). During the growing season, the temperature summation (12°C in the open cultivation was 2983°C, and the temperature summation measured 5 cm below the surface in the polythene mulch cultivation was as high as 3287°C, 304°C higher than in the open land. The yield in the open conditions was 3660 kg ha^{-1} compared with 5059 kg ha^{-1} under the polythene mulch cultivation, 38% higher than the open land (Table 5). The yield per plant was 30% higher than in the open land, and the filled pod and groundnut seed yields were 26% and 3.5% higher than in the open land. These results showed the polythene mulch technique was a key factor in increasing the groundnut productivity in the region where 12°C temperature summation satisfies the requirements for groundnut growth in the loess plateau.

In 1984, parameters of groundnut growth under the polythene mulch technique in different counties of the loess plateau were compared, and the results are presented in Table 6. Radiation intensity, temperature, and evaporation increased as one moved from south to north. The height of the plants, and the number of branches were reduced as one moved from south to north, but the economic coefficients of groundnut production progressively improved.

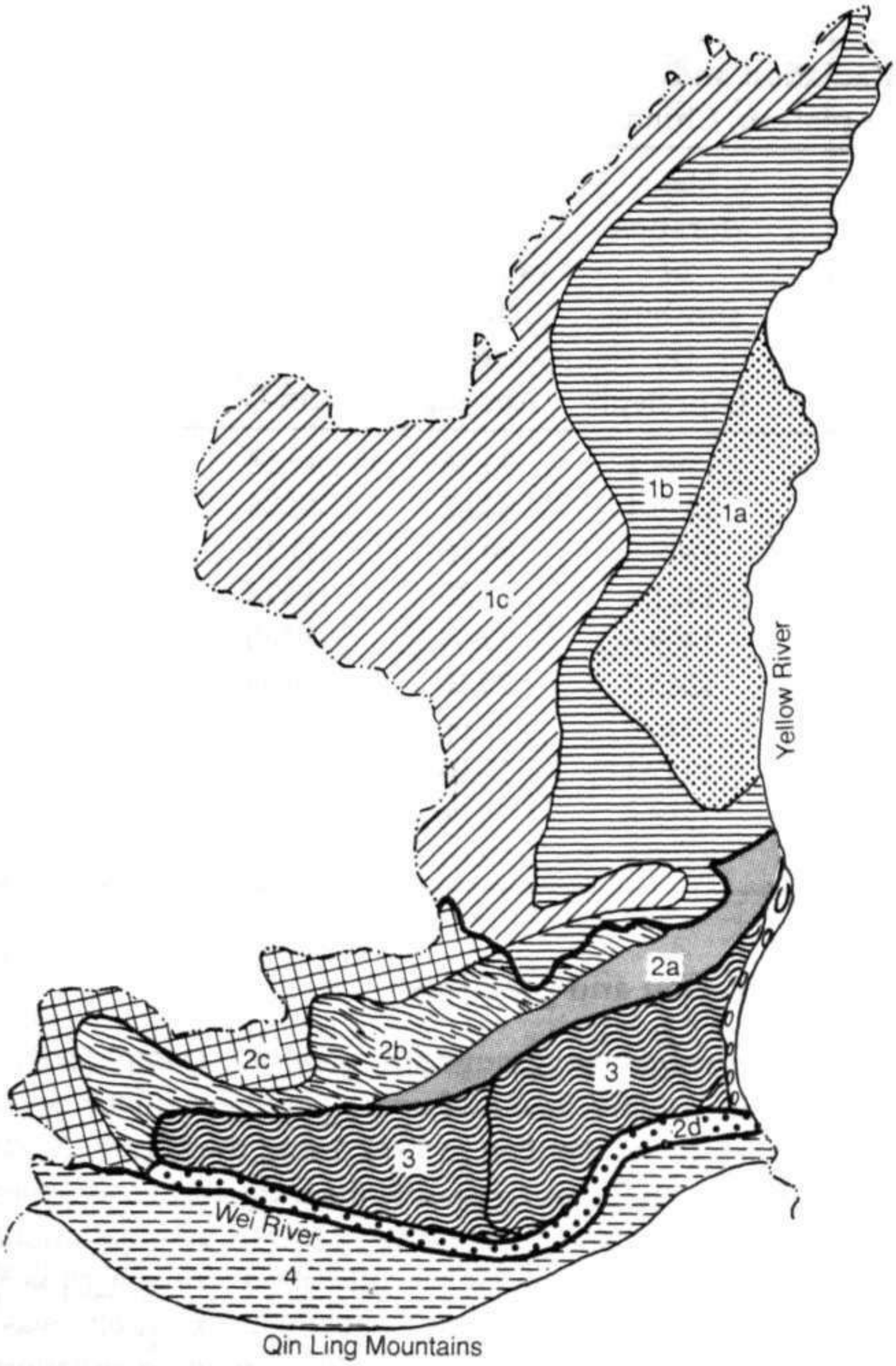

Figure 1. The boundaries for groundnut cultivation in the loess plateau of Shaanxi Province, China.

1. Shaan Ben

1a. Eastern area suitable for medium-duration groundnut.

1b. Central area suitable for short-duration groundnut.

1c. Western area suitable for varieties tolerant of low temperatures.

2. Wei Ben

2a. Area suitable for three crops in two years.

2b. Area suitable for spring sowing and autumn harvest.

2c. Area suitable for varieties tolerant of low temperatures.

2d. Area on the northern slopes of Qin Ling mountains.

3. Area irrigated on Guan Zhong flatlands.

4. Area cultivated on the Qin Ling mountains.

Table 5. Comparison of temperature summations for groundnut growth in open conditions and under polythene mulching, Wei Ben, Shaanxi, China.

Duration of groundnut growth	No. of days	Temperature summation (>12°C)	
		Open conditions	Polythene mulch covering
Sowing-emergence	15	231.16	254.14
Emergence-flowering	38	544.43	746.02
Flowering-fruiting	36	881.04	925.30
Fruiting-ripening	59	1326.31	1361.31
Summation	148	2982.94	3286.77
Yield (kg ha^{-1})		3660.00	5058.6

Groundnut cultural practices: Research on the groundnut ecoresources in the loess plateau during 1983-1984 has resulted in the groundnut sowing region limits being defined and the area suited to groundnut development being specified, so that higher economic returns have been achieved on a regional basis. Groundnut cultural techniques in the loess plateau have been widely extended to farmers with the support of the government. Compared with 1979-1983, the area of groundnut production of Shaanxi Province has increased by 4 times in 1984-88, and the yield has increased by 52%. These are great developments in groundnut production in Shaanxi Province.

Table 6. Groundnut characteristics under polythene mulch technique in different counties of the loess plateau, China.

Location	Latitude	Radiation intensity (kcal cm^{-2})	Seed rate (kg ha^{-1})	Plant height (cm)	Branch number per plant	Fruit number per plant	Mass of pod per plant (g $plant^{-1}$)	Economic co-efficient (%)	Yield (kg ha^{-1})
Oa Li	34° 52′	179.9	263.3	48.0	11.0	15.7	29.18	44.0	6615
Fu Ping	34° 52′	182.3	235.2	40.0	11.0	19.4	37.64	53.6	8955
He Yang	35° 14′	133.8	240.0	40.0	9.2	22.1	22.79	52.5	6633
Van Chang	36° 35′	182.6	217.5	–	–	17.8	–	61.2	7869
Yan Chuan	36° 53′	185.2	240.0	–	9.3	18.4	21.68	54.7	7150
Mi Zhi	37° 46′	186.8	238.5	28.03	8.0	19.1	31.94	60.6	7626
Fu Gu	39°02′	192.5	240.0	27.14	9.4	22.9	35.04	56.1	7314

The Occurrence and Control of Diseases, Insects; Weeds, and Rodents of Groundnut in China

Song Xiesong and Dong Weibo[1]

Abstract

Distribution, damage, incidence, control, and present research status of diseases, insects, weeds, and rodents as groundnut pests in China are reviewed. Effective management strategies have been developed for the major constraints. Based on the factors limiting groundnut production, tentative proposals for future research are suggested.

本文主要概述了中国花生重要病虫害的种类、分布、为害及防治. 提出了花生上主要有害生物的治理策略，及尚需研究的问题.

Causes of Economic Losses in Groundnut Production

A number of diseases, insects, nematodes, and rodents affect groundnut in China, and cause severe economic losses. Until the 1950s, neither the distribution nor yield losses caused by these yield reducers was known, let alone studies on the pathogens, their occurrence, and control methods. Since that time the Shandong Peanut Research Institute, in cooperation with some of the provincial universities and extension services, has conducted extensive surveys on the distribution of major pests and yield losses resulting from their activity (Table 1).

More than 50 pathogens causing diseases in groundnut have been reported in China. Major groundnut diseases are given in Table 2. In the past three decades control strategies were formulated and studied and some progress has been made (Song 1990a, Song et al. 1994, Wang 1983, Xu et al. 1992, and Xu 1991). With few exceptions, all important insect pests and diseases can now be effectively controlled to reduce or avoid damage to groundnut.

More than 60 species of insects have been reported on groundnut. Important ones are white grubs *(Holotrichia oblita* Faldermann, H. *morosa* Waterhouse, *Anomala corpulenta* Motschulsky), wire worm *(Pleonomus canaliculatus* Fald), false

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Song Xiesong and Dong Weibo. 1996. The occurrence and control of diseases, insects, weeds, and rodents of groundnut in China. (In En. Summary in Ch.) Pages 233-238 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Major pests and diseases and their damage to groundnut in China.

Pest	Distribution	Affected Area (%)	Yield Loss (%)
Diseases			
nematode	Shandong, Shanxi, Hebei	25	30-50
leaf spots	All China	100	10-20
rust	South China	50	10-40
virus	All China	100	5-50
bacterial	South China	20	30-50
others	All China	20	20-30
Insects			
white grubs	Mainly in north China	60	20-50
aphids	All China	100	5-20
leaf miner (surul)	South China	20	10-30
others	All China	30	10-30
Weeds	All China	100	20-50
Rodents	All China	80	10-30

Table 2. Major diseases of groundnut in China.

Diseases	Pathogens
Nematode disease	
Root knot	*Meloidogyne hapla* Chitwood
	M. *arenaria* (Neal) Chitwood
Bacterial disease	
Bacterial wilt	*Pseudomonas solanacearum*
Fungal diseases	
early leaf spot	*Cercospora arachidicola* Hori
late leaf spot	C. *personatum* Deighton
web blotch	*Didymella arachidicola* Marasas
stem rot	*Selerotium rolfsii* Sacc
black mold (collar rot)	*Aspergillus niger* Van Tiegh
rust	*Puccinia arachidis* Spey
Virus diseases	Peanut stripe virus (PStV)
	Cucumber mosaic virus - China Arachis (CMV-CA)
	Peanut stunt virus (PSV)
Mycoplasmas	
Witch's broom	Mycoplasma-like organism (MLO)

wire worm *(Opatrum subaratum* Fald), aphids *(Aphis craccivora* Koch), thrips *(Taeniothrips distalis* Karny), mite *(Tetranychus bimaculatus* Harvey), leaf eaters *[Helicoverpa armigera* (Hubner), *Spodoptera litura* (Fabricius)], and groundnut leaf miner or sural *(Stomoperyx subsecivella* Zell).

Over 80 species of weeds have been found in groundnut fields in China, including *Digitaria adscendens* (HBR) Henr., *Eleusine indica* (L.) Gaertn, *Chenopodium album* L., *Amaranthus viridis* L., *Portulaca oleracea* L., *Acalypha indica* L., and *Cyperus rotundus* L.

In addition, there are many rodents which damage groundnut in the field.

Control of the Major Pests

Generally, one or several species of pests are dominant in the same field, or in an area, or at a particular growth stage. Hence, at any stage of groundnut growth, control measures should be directed against the major ones. But other pests which occur simultaneously should also be considered. Application of such strategies has many advantages, such as reducing the use of chemicals, reducing input costs, and decreasing environmental pollution. Substantial economic benefit has been obtained by using such strategies in the last few years.

Control measures of some pests which are widely distributed and cause serious damage are as follows.

Control of white grubs

In the mid-1970s, grubs were epidemic in China (Song 1990a). In Shandong Province alone the affected area was 300 000 ha, amounting to 76.4% of the area under groundnut. The pod losses caused by grubs reached 0.1 million t pods annually. In order to develop effective measures to control this pest, many institutes cooperated in research, and rapid progress was made (Song and Qi 1982, Song 1990a). On the one hand, action thresholds were put forward (i.e., at seedling stage of groundnut, 2 third-stage larvae per square meter; while at growing period 5 eggs per square meter) for control measures to be taken. On the other hand, chafers (beetles) were considered as the main control target. The methods included: covering seeds with carbofuran (Furadan®), 812, or aldicarb (Temik®)) at sowing, and applying these chemicals on the top soil of the rhizosphere at the growth stage. Grubs can be controlled effectively during the crop period of groundnut by these measures. Other pests which occur at the same period, such as wire worms *(Ploenomus canaliculatus),* false wire worms *(Opartrum subaratum),* aphids *(Aphis craccivora),* and thrips *(Taeniothrips distalis),* can also be controlled.

In addition, other measures, such as crop rotation, and application of natural enemies of grubs, are useful agricultural practices (Song and Qi 1982).

Control of Aphids, Bollworm, and Groundnut Sural

Aphis craccivora is widely distributed on groundnut in China. It not only damages groundnut directly, but is also a vector of some groundnut virus diseases. Thus, it should be controlled in time. Although the economic threshold is 1000 aphids per hundred hills, applying chemicals prior to occurrence of the insect to protect plants from virus diseases is desirable. The control methods include covering seed with 812 (dimethoate), packaging seed with seed-dressing insecticides, and spraying piricarb or dimethoate. These treatments also have an effect on thrips, and mites. In addition, natural enemies such as ladybug, green lacewings, and *Bracon chinensis* should be encouraged and used to control aphids.

Bollworm *(Helicoverpa armigera)* is mainly distributed in northern China, while groundnut sural mainly occurs in the south. Both of them can cause serious damage to groundnut. Economic and effective control can be obtained by using phoxim, parathion (1605®), and methomyl when the pest population densities are over 40 on 100 hills. These insecticides should be applied alternately to avoid insecticide resistance, and chemicals should be used at the early stage of the pest development. Spraying such chemicals also can control other leaf-feeding pests.

Control of root-knot nematodes

In China, the major nematodes known to damage groundnut are groundnut root-knot nematode *(Meloidogyne armaria)* and northern root-knot nematode (M. *hapla).* M. *hapla* primarily occurs in the northern groundnut-growing areas, including Shandong, Hebei, and Liaoning (Song 1990b), while *M. arenaria* is mainly distributed in the southern groundnut-producing areas, including Guangdong, Guangxi, and Fujian. The area infected by the two species of nematodes may exceed 25% of the total area of groundnut.

Root-knot nematode is a serious disease which may even lead to crop failure. The control measures of this disease are: (1) rotating with nonhost crops of M. *hapla* or *M. arenaria;* (2) deep tillage and using more organic manure; (3) applying chemicals, such as Temik® (aldicarb) and Nemacur® (fenamiphos), when the nematode population densities are over the economic threshold (31.14 infective larvae and eggs per kg of soil) of M. *hapla,* or applying some insecticides, such as isofenphos-methyl, to less-infected fields (Song et al. 1994). Application of these chemicals can also control grubs, aphids, wireworm, and virus diseases which occur at the seedling stage of groundnut.

Control of leaf spots

There are several leaf diseases that damage groundnut throughout China. These include early leaf spot, late leaf spot, and web blotch. Since the 1980s, measures have been taken to control leaf spot diseases. The control methods are; (1) deep tillage, mulching, and spraying fungicides and herbicides to eliminate the primary infection sources; (2) rotating with sweet potato, maize, or wheat; (3)

spraying carbendazim, chlorothalonil, zineb, mancozeb, and Baycor® to control the pathogens. Most of these fungicides can effectively control early leaf spot and late leaf spot, while only Baycor® and mancozeb are effective on web blotch. Spraying protective fungicides such as Bordeaux mixture® punctually can lead to effective control of leaf spots and significant yield increase (Xu et al. 1995).

Control of virus diseases

Virus diseases occur in every groundnut-producing area of China (Zhang et al 1989). In general, more than one virus disease occurs in an area, even on the same plant. Continuous dry spells and aphids have caused virus disease epidemics in 1976 and 1986 in some northern groundnut-producing areas. The control measures (Xu 1991) include; (1) establishing virus-free seed multiplication fields and planting virus-free seed to eliminate primary infection sources; (2) controlling insect vectors, such as aphids and thrips.

Control of bacterial wilt

Groundnut bacterial wilt disease caused by *Pseudomonas solanacearum* mainly occurs in the southern groundnut-producing area. However, it can be found in some northern provinces also (Wang 1983). In some years, this disease may cause severe damage to groundnut, as there are no effective chemicals to control it. But control can be obtained by the following measures : (1) rotating with rice in southern China, or with sweet potato, maize and wheat in northern China; and (2) cultivation of resistant cultivars, such as Luhua 3 and Yueyou 256.

Control of rust

Groundnut rust disease caused by *Puccinia arachidis* also occurs mainly in the southern groundnut-producing areas. Control can be obtained by: (1) reduction of inoculum, including eradication of volunteer plants before sowing groundnut, and burning plant debris after harvesting of groundnut; (2) early sowing and early harvesting of spring groundnut, and late sowing of autumn groundnut to avoid the serious attacks by P. *arachidis* in the rainy season; (3) growing resistant cultivars, such as Yueyou 551, Yueyou 22, Shanyou 523, and Enhua 1; (4) spraying fungicides, such as zineb, mancozeb, chlorothalonil and sodium-p-aminobenzenulfonate.

Control of weeds

Until the 1970s the only way to remove weeds in groundnut fields in China was to pull them by hand or to uproot them by hoe. Eliminating weeds by hand or hoe needs much labor, but is not very effective in the rainy season. With the development of polythene mulch techniques on groundnut fields, chemical control of weeds was developed. Many herbicides not only can be used on mulched fields, but also on unmulched fields. As well as using herbicides before emergence, some can be used after seedlings emerge. Many herbicides, such as metalochlor (Dual®), alachlor (Lasso®), acetochlor (Acenit®), oxadiazon (Ronstar®), and haloxufop-ethoxyethyl (Gallant®) can be applied to control weeds. However, their selection should be based on the species, population of weeds, and environmental conditions, to have the desired level of control.

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Summary of Comprehensive Techniques of High-yield Cultivation of Groundnut in Laixi Municipality

Zhang Wei, Wang Lifu, and Wang Huasong[1]

Abstract

Since the 1980s, the per unit area yield of groundnut in Laixi municipality has increased significantly as a result of adopting comprehensive techniques for high-yield cultivation, including rational rotation, polythene mulching, development of improved varieties, appropriate fertilizers, improved management trials, and extension. During 1986 to 1994, the average yield was 3.97 t ha^{-1}, 70% higher than during 1974 to 1985, and the total annual output has increased to 360 000 t. The main techniques, and the benefits of their adoption are discussed.

莱西市自八十年代以来，在花生种植中，通过试验、示范推广了合理轮作换茬、地膜覆盖栽培、优化配方施肥、选配优良品种、加强田间管理等综合高产栽培技术，使花生生产有了大幅度的提高. 1986～1994年全市花生平均单产每公顷3.97吨，比1974～1985年花生平均单产增加70%，总产增加到36万吨. 本文对我市花生综合高产栽培技术推广应用中的技术要点及其增产效果和效益进行了簡结.

Introduction

Laixi city is located in the center of Jiao Dong peninsula of Shandong Province. The total population is about 710 000 and total cultivated land area of the city is about 69 400 ha. So per capita land is about 01 ha. The cumulative annual temperature is about 3947.3°C with a frost free season of about 180-200 days. The mean annual precipitation is 732 mm, most of which falls in July and August. Groundnut is one of the most important oil and economic crops in Laixi with an annual average cultivated area of approximately 26 000 ha, which accounts for about 33% of the total cultivated area of Laixi.

Before the 1980s the average unit output of groundnut was around 2.25 t ha^{-1} because of the traditional cultivation systems and some economic factors. Since 1980, under the direction of the Peanut Research Institute of Shandong and through the popularization of a series of comprehensive high-yield cultivation

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technologies, the unit production and the total groundnut output both increased greatly, especially from 1985 to 1994. The mean annual groundnut yield reached 3.97 t ha^{-1}, which was about 70.5% higher than that during 1974-1985. In 1994 the average yield was up to 4.45 t ha^{-1}, which was about 653 kg ha^{-1} higher than that of 1990.

This paper reports on how these improvements have been made in recent years in Laixi county.

The Establishment of Wheat-Groundnut Rotation Systems

The Status Before the Introduction of Rotation

Before the 1980s, the annual continuous cropping area of groundnut in Laixi was about 13 000 ha, and that of the wheat-maize cultivation system about 23 000 ha. There was a gradual decrease in groundnut output due to continuous cropping and the spread of wheat take-all disease *(Gaeumannomyces graminis* Sace). According to surveys in 1985, the area of wheat affected by take-all disease was up to 7100 ha, which resulted in a decrease of wheat grain output of about 4500 t. In addition, under conditions of continuous cropping of groundnut for two years, the output declined by about 10%, and with three years sole cropping, by about 20-30%. As a result, the annual decrease of groundnut output in Laixi was up to 60 000 t.

The Establishment and Popularization of Groundnut-Wheat Rotation

The establishment and popularization of a crop rotation system of three crops in two years: spring groundnut-winter wheat-autumn maize.

In 1980 the introduction of crop rotation was done in about 2.4 ha fields in Biao Zhuang village of Shuiji town, where wheat take-all disease had had a serious impact

The results showed that the mean unit output of wheat sown in the fields where groundnut had been grown continuously reached 5831 kg ha^{-1}, and there was no take-all disease in wheat grown after groundnut cultivation. This resulted in the wheat output being about 2200 kg ha^{-1} higher than it had been after maize (Table 1).

Therefore, since 1985, peanut-wheat-maize crop rotation over two years has been encouraged over larger areas. In 1986 about 12 400 ha changed to this cropping system and in 1987 the area increased to 13 667 ha. By 1990 the cropping systems of spring groundnut-winter wheat-summer maize (three crops in two years) and winter wheat-summer groundnut relay-cropping (two crops a year) were practiced in 24 000 ha and the wheat take-all disease was generally also under control. The productivity of groundnut, wheat and maize all increased greatly.

Table 1. Effect of different crop rotations on the output of wheat (kg ha^{-1}) in Biao Zhuang village, Shuiji town, China, 1983-1984.

	Previous crop rotations		Difference in yield	
	groundnut	maize	(kg ha^{-1})	(%)
1.	5386	2022	3364	166
2.	6435	3954	2481	63
3.	5674	4918	756	15
Mean	5831	3631	2200	81

Introduction and popularization of relay-cropping of wheat-groundnut with polythene mulching.

In order to solve the competition for cultivated land between wheat and groundnut, and the limitations imposed by light and heat in summer groundnut cultivation, the popularization of wheat-groundnut relay-cropping with polythene mulch cultivation system has been carried out in Dian Bu town since 1990. The results showed that the average unit output of wheat was about 4758 kg ha^{-1}, that of groundnut, about 3304 kg ha^{-1}. The net income was about 9128 yuan ha^{-1}, about 2024 yuan ha^{-1} higher than that before the utilization of the system (Table 2).

Adoption of the Polythene Mulch Covering Technique

Since the technique of polythene mulching could increase the soil temperature, prevent soil water evaporation, protect the soil structure, promote the activity of soil microorganisms and improve the field environment, it resulted in a higher and more stable groundnut production. By 1994 the total area under polythene mulch covering groundnut was 21 330 ha, which accounted for 93% of the total area of groundnut cultivation in Laixi (Table 3).

The Transformation of Medium- and Low-yielding Land

The Characteristics of Medium- and Low-yielding Land

About 50% of the total area of groundnut cultivation in Laixi had poor or medium yields. Average yield was 750 kg ha^{-1} lower than the mean over Laixi county. This land mainly consisted of two types: brown loam and sandy clay loam. Brown loam soils are poor and have a hard plow pan; while the sandy clay loams are poor soil structure with a hard impervious layer and low fertility.

Table 2. Comparison of the income from wheat-groundnut relay-cropping with polythene mulch covering with other systems, Dian Bu town, China, 1993.

	Unit output (kg ha^{-1})			Output value (yuan ha^{-1})[2]			Investment (yuan ha^{-1})[2]			Income (yuan ha^{-1})[2]		
Treatment[1]	Wheat	Ground-nut	Total	Wheat	Ground-nut	Total	Wheat	Ground-nut	Total	Wheat	Ground-nut	Total
A.	-	3954	3954	-	7908	7908	-	1554	1554	-	6352	6352
B.	5733	2044	7778	5733	4089	9822	856	1110	1966	4886	2980	7866
C.	4758	3304	8062	4758	6609	11367	852	1320	2172	3872	5256	9128

1. A = Spring groundnut
B = Summer groundnut sown directly on ridges
C = Wheat-groundnut relay-cropping with polythene mulching.

2. 1 US$ = 8.5 Yuan (approximately).

Table 3. The developmental status of polythene mulch for groundnut cultivation in Laixi municipality, China, 1991-94.

Year	Total (ha)	Area with polythene mulch (ha)	Area with polythene mulch % of the total	Increase of pod output ($kg\ ha^{-1}$)	Increase of pod output (%)	Cumulative increase of pod yield (million t)
1991	24950	16470	66	1170	18	0.019
1992	22400	17830	80	975	32	0.017
1993	21060	18270	87	1080	31	0.020
1994	23000	21330	93	1125	31	0.024
Total	91410	73900	81	1088	28	0.080

The Transformation and Enrichment of Soil Fertility of Medium- and Low-yielding Fields

Deep plowing

Deep plowing could deepen the fertile soil layer, promote the activity of soil microorganisms and the growth of groundnut roots, and eliminate weeds and harmful pests. To do this the soil was plowed before winter or in early spring to a depth of 25-50 cm to break the plow pan.

Adding sand and fertilizer to the clay soil

In addition to deep plowing, sand and quick-acting fertilizers were incorporated which resulted in improvement of the soil structure and soil fertility

Formation of drainage systems and irrigation

Ridges and furrows were prepared for efficient irrigation, and cross-ditches were provided to drain excess water.

The Effect of Transformation of Medium- and Low-yielding Soils

During 1983 to 1986, average groundnut yield increased by 980 to 1404 kg ha*[4] (or 23-54%) in the improved soils. The yield of subsequent crops was also improved: wheat by 35-47%, and maize by 35-48%.

Sowing with Sufficient Soil Moisture

The sowing date for spring groundnut was generally from 15 April to 10 May in Laixi, and for summer groundnut was usually before 20 June. According to meteorological data the climate in the middle ten days of April and the first ten days of May in Laixi is generally dry and windy. In order to ensure a full stand of groundnut seedlings sowing was undertaken only if there was sufficient soil moisture. If there was inadequate moisture, then irrigation was necessary. The results showed that when groundnut was sown with sufficient soil moisture the seedling emergence was about 8.2-15.8% higher than that of dry conditions.

Application of Fertilizers

On the basis of soil tests and the fertilizer requirements of groundnut, three kinds of fertilizer application regimes were worked out (Table 4).

Table 4. Recommended fertilizer applications for Laixi municipality soils growing groundnut.

Soil fertility level	Organic manure ($t\ ha^{-1}$)	N fertilizer[1] ($kg\ ha^{-1}$)	P fertilizer[2] ($kg\ ha^{-1}$)	K fertilizer[3] ($kg\ ha^{-1}$)	Expected pod yield ($t\ ha^{-1}$)
High fertility	37.5	-	375-450	225-300	5.25
Medium fertility	45.0	75-150	450-525	150-250	4.50
Low fertility	60.0	150-225	650-750	75-150	3.75

1. Urea.
2. Combination of $Ca(H_2PO_4)_2.\ H_2O$(50-60%) and $CaSO_4.2H_2O$ (40-50%).
3. K_2SO_4 or KCl.

The organic manure was applied by spreading before plowing. The N, P and K fertilizers were all applied as basal fertilizer. Then in the later stages of development a mixed macronutrient and micronutrient (N, P, K, Zn, B....) solution was sprayed on the leaves.

Breeding and Selection of Good Groundnut Varieties

Groundnut varieties were chosen on the basis of cropping system and technologies in the area. For example, medium-maturity varieties (Hua 37, Lu Hua No. 10, Lu Hua No. 11) were found suitable for spring-sown groundnut with polythene mulch, while early- to mid-maturity varieties (Lu Hua No. 8, and Lu Hua No. 9) were suitable for summer groundnut with polythene mulching. However, varieties such as Baisha 1061, Lu Hua No. 8, and Lu Hua No. 12 were suitable for direct sowing, without polythene mulch.

Continuous selection for plant and seed characters was found necessary to maintain genetic purity of varieties around 90%. New varieties were introduced, tested, and demonstrated by researchers, and popularized by extension staff. The popular varieties grown in Laixi have been changed twice since 1988. At present, improved varieties Lu Hua No. 9, -No. 10, -No. 11, 79266 and 8130 have been widely adopted and account for at least 96% of the total groundnut area.

Improvements in Field Management

With the enlargement of the area of groundnut cultivation with polythene mulch covering, chemicals have been widely adopted for groundnut production in Laixi.

Seed Dressing with Pesticides

A mixture of phoxim (812) and phorate (MPP) pesticides was used to coat the seeds to deter harmful pests. The results showed that the mixing of the MPP (10% MPP 7.5 kg ha^{-1}) and the soil to cover the sown seeds could not only prevent damage from harmful underground pests but also killed the harmful pests on the ground, such as aphid, thrips and red spiders. The area where this technology was adopted in Laixi reached 7300 ha, 34.7% of the total, in 1993.

The Utilization of Herbicides

The spraying of acetochlor at 0.5-0.7 g kg^{-1} (50% acetochlor, 0.75-1.05 kg ha^{-1}) to the soil where groundnut seeds were sown, before covering with polythene mulch, gave the best results. This practice almost completely eliminated the weeds. The adoption of this technique in 1993 covered 20 000 ha, about 83% of the total.

The Utilization of Growth Retardant

The results showed that application of growth retardant PP333 at 0.5-0.6 g kg^{-1} (15% PP333, 0375-0.45 kg ha^{-1}) sprayed on the leaves of groundnut 35-45 days after flowering could not only regulate the vegetative growth of groundnut organs above the ground, but also promoted the growth and development of pods. The technique could increase the percentage of full pods by about 5.2%. Between 1991 and 1994 growth retardant was used on a cumulative area of 50 000 ha.

The Prevention and Cure of Leaf Diseases

Leaf diseases caused defoliation in the early stage of groundnut growth. In later stages of development, spraying of carbendazim and mancozeb on groundnut leaves at about 10-15 day intervals (1 to 3 times) resulted in a healthy crop and also increased the full pods by 5.0%, and the pod yield approximately 10%. From 1990 to 1994 the area where the technology was adopted covered 36 000 ha.

Future Prospects for Groundnut Production

The goal of Laixi farmers is to increase their economic situation. To do this, several strategies will be necessary:

- Enlargement of the multiple-cropping areas of cereal crops and groundnut.
- Extension of mechanization of agricultural practices so that a much larger scale of rotational cropping is possible.
- Continued breeding of groundnut varieties for high quality, multiple resistance to pests and diseases, and for special purposes.

By the end of the year 2000, it is predicted that in Laixi county the mean annual yield of groundnut will be about 5 t ha^{-1}, and net income will have increased by 20%.

Poster Papers

Studies on Selection Efficiency of Different Breeding Methods in Groundnut

Cao Yuliang, Gu Shuyuan, Xue Huiqin, and Gan Xinmin[1]

Selection efficiency of the major economic characters was studied in the F_3 and F_4 generations derived from five groundnut crosses using different breeding methods. Heritability in both the broad and narrow senses was estimated by different methods. As heritability estimates from the bulk method are low, even in F_4 progenies, selection pressure should be relaxed to a reasonable extent. In the pedigree method, selection of groups and families can commence in F_4, but with general emphasis on groups. Heritability from the derived-line method was higher than that from the bulk method. Narrow-sense heritability, removing influences of dominance and environment, is more reliable. The heritabilities of 100-pod mass, number of total branches, height of the main stem, and length of primary branches were high, while those for the number of pods plant*[1] and pod-mass plant[1] were low.

以 5 个杂交组合为材料，对花生杂种不同选育方法提高 F3 和 F4 代主要性状的选择效果进行了研究。用广义法、狭义法、方差分析、回归法和相关法估算了遗传力，并鉴定了遗传力的可靠性。结果指出：混合法 F_4 代主要性状的遗传力仍较低，选种尺度宜宽；系谱法 F4 代可进行系统群的选择，但仍以系统间的选择为主；派生法遗传力略高于混合法；狭义法除去显性和环境的影响，估算的遗传力可靠性较高；百果重、总分枝、主茎高和侧枝长的遗传力高，单株果数和单株果重的遗传力低。

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Integrated Management of Groundnut Root-knot Nematode Disease Caused by *Meloidogyne hapla* Chitwood

Dong Weibo, Song Xiesong, and Min Ping[1]

Occurrence, distribution, damage, life cycle, and spread of the northern root-knot nematode *(Meloidogyne hapla* Chitwood) on groundnut have been systemically investigated over the past decade. An Integrated Pest Management (IPM) program to manage groundnut root-knot disease has been developed. Cultural practices, such as rotation with nonhost crops (e.g., cotton, wheat, and sweet potato), soil amendments such as the application of chicken manure, and rational late sowing, play a key role in the IPM system. Chemicals are needed when the initial population densities of M. *hapla* are above the economic thresholds. Two highly resistant and three moderately resistant groundnut lines have been selected from more than 4000 germplasm accessions. These lines should be used to develop groundnut varieties resistant to M. *hapla* as soon as possible. The use of this IPM system has resulted in significant economic and social benefits to groundnut farmers in China, especially to those in Shandong Province.

过去的几年中，对北方根结线虫(*Meloidogyne hapla* Chitwood)在花生上的发生、为害、传播途径、生活史等进行了系统地调查研究，并以此为依据提出了当前花生根结线虫病的综合防治策略。主要内容：以与非寄主作物或非正常寄主作物如棉花、小麦及甘薯进行合理轮作、增施鸡粪进行土壤改良和适当晚播等措施构成的农业防治为基础；在初始虫口密度超过防治指标时辅以合理的化学防治；以从4000余份花生种质资源中筛选出的2份高抗和3份中抗资源为原始材料，积极培育生产上可用的抗*M.hapla*的花生品种。该综合防治系统已被广泛推广应用，并为中国，尤其是为山东省的花生种植者带来了显著经济效益和社会效益。

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Drought Stress Physiology in Groundnut: A Review

Gao Guoqing[1]

Water deficit can have strongly negative effects on groundnut growth, development, and production. Drought effects on leaf water relations, metabolism, growth, development, and yield components in groundnut; groundnut adaptative mechanisms for drought escape, avoidance, and tolerance; and evaluation and selection of groundnut cultivars for drought resistance are reviewed.

水分胁迫对花生生长、发育和产量极为不利。本文阐述了干旱对花生叶片水分新陈代谢、生长发育和产量构成的影响；花生对干旱的适应机制，包括逃避干旱和耐旱机制；以及花生抗旱品种的评价与筛选．

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Gao Guoqing. 1996. Drought stress physiology in groundnut: a review. Page 251 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds,). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Abstract in En. and Ch.)

The Breeding and Extension of Nonghua 22, an Early-maturing High-yielding Groundnut Variety

Gao Liushen, Jiang Zixin, Long Biguang, Feng Fuzhen, and Deng Fangdi[1]

The North Plain of China is an important groundnut-growing area, but in the past its productivity was low because old unadapted varieties were grown. In the 1980s productivity improved following the introduction of such varieties as Basha 1016 x Xuzhua 68-4, Haihua 1, Hua 37, and Luhua 9. But these long-duration varieties did not fit into intercropping systems. In 1979, the breeding group at Beijing Agricultural University started varietal improvement work aimed at developing suitable varieties for the North Plain. After 10 years, varieties Nonghua 10, 16, and 22 were developed. Nonghua 22 originates from a cross between Fu50 and Hua 31. It was developed by the pedigree method. It produced 15% more pod yield than Hua 37 in trials conducted for 3 years. Nonghua 22 has the outstanding advantages of being early-maturing (in 125 days), stable, high-yielding, drought-resistant, and adapted to poor soil. This variety is suitable for intercropping in northern China, and summer cultivation south of Shijiazhuang City, Hebei Province. A seed production system has been established for extension of the variety, and has produced excellent results. The system focuses on concentrating seed-production locations and recycling seed for multiplication before a sizeable quantity is produced for general distribution. All seed producers, including the breeding institution, are linked through a seed-production network, and each of them has an industrial seed business.

华北平原是重要的花生产区，但过去由于品种生育期长致使产量一直较低。80年代引种了白沙1016× 徐州68－4、海花1号、花37和鲁花9号之后，产量得到提高．但这些品种的生育期仍较长，不适于套种．1979年，北京农业大学的育种组开始着手培育适宜在华北平原种植的新品种．10年之后，培育出了农花10号、16号和22号．农花22号是福50和花31的杂交后代，通过系谱法选育而成．3年试验产量比花37高15%。农花22具有早熟(125天)、稳定、高产、抗旱及耐瘠薄等突出优点，适于华北地区套作及石家庄以南地区夏播．已为该品种的广泛推广建立了种子生产系统，并收到了良好的效果．这一体系主要是种子定点大量繁殖然后推广应用，包括种子培育单位在内的种子生产者都通过种子生产网络联系起来，承担各自的任务．

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Correlation Studies on Agronomic Traits in Groundnut

Guo Jinming, Li Fengxia, and Yang Yingjuan[1]

Correlations between nine agronomic traits and pod yield in groundnut have been estimated. Pod yield is significantly correlated with the total number of branches plant^{-1} (r = 0.236), the diameter of the main stem (r = 0.494), and the number of pods plant^{-1} (r = 0.574). The path coefficients were 0.1194 (branches plant^{-1}), 0.2923 (diameter of main stem), and 0.5711 (pods plant*^{1}). These three traits could be used in breeding programs that aim to increase the yields of groundnut.

本文对花生 9 个农业性状与荚果产量的相关性进行了研究．结果表明花生单株分枝数、茎粗、以及单株结果数与单株产量显著相关，偏相关系数分别为 0.236、0.494、0.574．通经分析总分枝数、茎粗、单株果数与单株产量的通经系数分别为 0.1194、0.2923 和 0.5711．这三个性状可做为花生育种的选择指标，为花生的高产育种提供了选择依据．

1. Jinzhou Agricultural Research Institute, Liaoning, China.

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An Experimental Study on High Yield Cultivation of Early-season Groundnut in Rice Fields

He Xingwen, Song Laiqiang, and Xiong Renxiang[1]

Three yield-limiting factors; fertilizer needs, topdressing rate, and sowing density were investigated in groundnut that was sown early in rice fields. According to analysis of variance, the differences in yields among all the treatments and factors at different levels were not significant. The largest economic benefit was realized from the lowest input level.

本文对水田早花生施肥量、施肥方式及种植密度等三个高产制约因素进行了研究。结果表明，三个因素在试验范围内对产量没有显著影响，最低投入水平可获得最佳经济效益。

1. Upland Crops Institute, Jiangxi Academy of Agricultural Sciences, Nanchang 330200, China.

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Study and Extension of Multiple-cropping Techniques for Groundnut with Wheat and Vegetables

Liu Guoqiang, Song Shoucai, Liu Jianjun, and Liu Guoshen[1]

Intercropping groundnut with wheat and vegetables is a new agricultural production system for Zhaoyuan County, Based on the normal cultural practices, a four-crop system was developed using groundnut as a main crop, intercropped, or multiple cropped with wheat and vegetables. Use of this system has resulted in annual profits of 30 000 yuan (US$ 3530) ha^{-1} from 5.061 t ha^{-1} of wheat, 5114 t ha^{-1} of groundnut, 16.341 t ha^{-1} of spinach, and 15.728 t ha^{-1} of cucumber. Since 1991, a cumulative area of 17 333 ha has been cultivated by this technique in Zhaoyuan County from which profits of US$ 36.8 million have been obtained.

花生与粮菜作物间套复种技术是招远市一项新的作物种植制度，在常规花生栽培的基础上，确立了一种以花生为主体，与小麦、蔬菜套种的4熟模式。应用这一体系每公顷土地每年可产小麦5.061吨、花生5.114吨、菠菜16.341吨及黄瓜15.728吨，总产值30000元(合3530美元)。1991年以来，招远市采用这一种植技术种植的黄瓜面积已达17333公顷，创社会经济效益3680万美元。

1. Agricultural Extension Service Centre, Zhaoyuan County, Shandong 266601, China.

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Development of an Early-maturing, High-yielding, Quality Groundnut Variety, Hai Hua 3

Liu Shukai, Li Yurong, Cheng Zengshu, Liu Shaoxing, and Xu Guizhen[1]

Hai Hua 3, derived from the cross 7603-10-124 x Xing 4081, was developed through pedigree selection. It is a Virginia type with good comprehensive attributes, short duration (about 130 days), and produces high and stable yields. Field trials showed that it produced 8.9% more pods, and 9.1% more kernels than the local control, Jiyou No.4, In the demonstration plot, a pod yield of 4608 kg ha^{-1} was achieved. Hai Hua 3 has a 100-pod mass of 243 g, a 100-kernel mass of 97.4 g, 73-74% shelling percentage, contains 55.76% oil, and 25.27% crude protein. It has good resistance to drought, late leaf spot *(Phaeoisariopsis personata* (Berk. & MA. Curtis) van Avx, and pod rot diseases, and wide adaptability.

以 7603－10－12－1 做母本，邢 4081 为父本，通过有性杂交，系谱选择法选育形成 H 花－3 花生新品种．该品种综合性状优良，生育期短(130 天左右)，高产稳产．试验中荚果、籽仁比对照冀油 4 号分别增产 8.9% 和 9.1%．示范田荚果产量 4608 公斤/公顷．荚果普通型，百果重 243 克、百仁重 97.4 克，出米 73.0－74.0%; 含油量 55.76%，粗蛋白含量 25.27%; 抗旱性好，抗病性好，适应性广．

1. Institute of Cereals and Oil Crops, Hebei Academy of Agricultural and Forestry Sciences, Shijiazhuang 050031, China.

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Growth and Development of Xuhua No. 5 Summer Groundnut and Cultivation Techniques to Achieve Yields of 6 t ha^{-1}

Zhang Zuming[1], Jiang Fu[1], Lu Zhaoying[1], and Li Qinghua[2]

Xuhua No. 5, developed by Xu Zhou Agricultural Research Institute, was released for spring and summer cultivation in Jiangsu Province by the Provincial Varietal Committee in April 1993. In spring-sown trials, yields of around 4.5 t ha^{-1} and yield increases of 10% over existing cultivars were obtained. In summer sowing with polythene film mulching the vegetative growth of the variety is fast in the early phase, steady in the mid-phase, and stable at the later stages. Xuhua No. 5 flowers and sets pods early, is of medium duration, produces a high percentage of well-developed pods, and has high productivity $plant^{-1}$. The combined effects of deep tillage, adequate nutrition, early sowing with rational plant spacing on ridges, polythene film mulching, spraying with growth retardants, and timely field management to improve light and thermal conditions can result in yields of 6 t ha^{-1} in summer sowings that follow the wheat harvest.

"徐花五号"是徐州农科所育成,1993 年 4 月通过省品种审定的春、夏播兼用型花生品种. 在春播试验中,比现有品种增产 10% 以上,达 4.5 吨/公顷. 在夏播覆膜条件下,营养体有前期生长快,中期生长稳,后期不早衰的特点. "徐花五号"开花结果早,成熟期适中,饱果率和单株生产力高. 栽培上采用深耕增肥,力争早播,起垄种植,合理密植,地膜覆盖和及时的田间管理等配套技术,改善光热条件,麦后夏直播可达到 6 吨/公顷的产量水平.

1. Xu Zhou Agricultural Research Institute, Xu Zhou City, China.
2. Anhui Extension Station for Agricultural Techniques, Xinyi City, Jiangsu, China.

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Studies on Breeding Groundnuts for Arid Red Earth Soils in Hilly Areas of Hunan Province, China

Li Lin, and Xia Xiaonong[1]

In Hunan Province groundnut is grown on the arid red earth soils in hilly areas. In 1994 the area sown to groundnuts in Hunan was 117 800 ha, 4% of the total groundnut area in China. A major breeding objective is to develop high-yielding cultivars with the ability to avoid or resist drought. Well-adapted Spanish types are used as parents in the breeding program. Varieties such as Xianghuasheng Nos. 1 and 3, and Fu 91-130 have been successfully bred from Spanish types introduced from Guangdong, Shandong, and Fujiang Provinces. They possess such good characters els high yield (3.3-4.95 t ha^{-1}), early maturity (122-130 days), good quality, and resistance/tolerance to drought, lodging, early leaf spot *(Cercospora arachidicola* Hori), rust *(Puccinia arachidis* Speg.,), and soil acidity. But these varieties are sensitive to bacterial wilt. When selecting for high yield and adaptation to the arid red earth soils in the hilly areas of Hunan Province, in addition to resistance/tolerance to biotic and abiotic factors, the following characteristics are highly desirable: compact plant type (40-50 cm height), robust plants with a moderate number of branches (5-7), dark green leaves, a concentrated short flowering period, clustered fruiting, and late senescence, and many pods $plant^{-1}$ with small to medium sized seeds.

The future objectives of groundnut breeding at the Institute are to breed varieties that mature extremely early in less than 120 days, have high levels of resistances to diseases, especially to bacterial wilt and rust, the ability to emerge through the hard crusts of Hunan's soils, and suitability for special uses.

湖南省是中国典型的丘陵、红壤旱地花生产区,1994 年花生种植面积达 11.8 万公顷,约占全国花生总面积的 4%. 主要育种目标是高产、抗(避)旱,主要亲本来自广东,其次是山东(珍珠豆型中粒种). 选育的新品种(系)如湘花 1-3 号、福 91-130 具有高产(3.3-3.45 吨/公顷)、早熟(122-130 天)、抗旱性强、抗倒伏、抗叶斑病较强,抗锈病中等、耐酸性强,但抗青枯病弱等特点. 选育高产品种的有效途经是增加单株饱果数和单株生产力,而荚果,籽仁以中等或较小为宜.

今后的育种方向是培育早熟或特早熟(120 天以内)、抗性尤其是高抗青枯病、锈病,种子出土前对缺氧条件耐性强的品种,以及专用型或综合性状优良的品种.

1. Hunan Upland Crops Research Institute, Mapoting, Changsha, Hunan 410125, China.

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Study and Development of Polythene Film Mulching for Groundnut Cultivation in China

Tao Shouxiang, Sun Yanhao, and Chen Dianxu[1]

Groundnut cultivation using polythene film mulching is a new agricultural technique introduced into China from Japan in the late 1970s. In the past 10 years, research on many aspects of its application has been carried out. Topics covered include high yield and efficiency, the development of the technique on a large scale, its effects on intercropping, soil, fertilizer, plant protection, and the management of film residues. The research has been conducted in close cooperation with agricultural extension services, research institutes, and universities. A polythene film mulching cultivation system for China has been formulated.

花生地膜覆盖栽培是 70 年代末引进的一项农业技术. 近 10 年来,在有关科研单位、大专院校和农技推广部门的通力协作下,对地膜覆盖进行了多领域、多学科的研究,内容涉及高产高效、大面积技术推广、间作套种效应、土壤与施肥、植保、残膜污染等方面. 目前,具有中国特色的花生地膜高产栽培体系业已形成.

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Research and Development of a Double High-yielding Cultural Technique in Wheat/Groundnut Intercropping

Wan Shubo, Yu Shanxin, Feng Haisheng, and Min Ping[1]

The basic concept, development, and present situation of double high-yielding cultural techniques in wheat/groundnut intercropping in Shandong are outlined. Three major intercropping systems are described, as are cultural techniques appropriate to:

Sowing two rows of groundnut on 90-cm wide beds, with two rows of wheat in 20-cm furrows, for areas of medium soil fertility where wheat is harvested late;

Sowing single rows of groundnut on 34-cm wide beds with two rows of wheat in furrows, on highly fertile soils

Sowing a single row of groundnut between wheat rows at 23-27 cm spacing, on highly fertile soils.

本文论述了山东省小麦套种花生双高产栽培技术的基本概念、发展与现状。描述了三种主要套种模式，其栽培技术为：

90cm 垄距的垄上播种两行花生，20cm 宽的垄沟内播种两行小麦，适于小麦收获期较晚的中等肥力地块。

34cm 垄距的垄上播种一行花生，垄沟内播种两行小麦，适于高肥力土壤。

23－27cm 行距的小麦行间播种一行花生，适于高肥力土壤。

1. Shandong Peanut Research Institute, Laixi, Shandong 266601, China.

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Utilization of Wild Groundnut Relatives at Shandong Peanut Research Institute

Wang Chuantang, Miao Huarong, Shen Fuyu, and Duan Shufen[1]

Since the 1980s, several techniques have been developed at the Shandong Peanut Research Institute to facilitate the use of wild *Arachis* species in groundnut improvement. These techniques include; (1) somatic doubling of chromosomes of triploid interspecific derivatives using colchicine and DMSO, (2) hastening the process of stabilization and involving the frequency of desirable segregants in interspecific breeding by exposing hybrids to gamma-ray irradiation, (3) embryo rescue and aseptic peg culture in crosses between incompatible *Arachis* species, and (4) DNA transfer through injection in the calyx tube. Application of these techniques has resulted in hybrids derived from *A. hypogaea* crosses with compatible species, and with A. *glabrata* using a number of elite germplasm accession lines with good productivity, quality, and stress resistance, as incompatible species have been bred. Using the DNA transfer technique drought-tolerant segregants have been obtained. These segregants also show improvement in their oil and protein contents, and amino-acid composition. Utilization of the tertiary gene pool will remain the top breeding priority in the next decade. Efforts should be directed towards intensive selection of derivatives, and elucidation of the mechanism and genetics of resistance to economically important pests and diseases. Attention must also be paid to high-efficiency regeneration, molecular cloning, and gene mapping.

自八十年代以来，山东省花生研究所已开发出几项旨在加速花生野生种在品种改良中利用的技术，其中包括：利用秋水仙素和二甲亚砜对三倍体种间杂种进行体细胞染色体加倍的技术，伽玛射线处理远缘杂种加速稳定，提高选育效果的技术，花生属不亲和杂交果针离体培养的胚拯救技术以及通过花萼管注射的 DNA 转移技术．运用以上技术已获得了亲和种及不亲和种 Aglabrata 与栽培种的杂种后代．运用 DNA 转移技术已获得了耐旱分离子，这些分离子在油分、蛋白含量和氨基酸组成方面得到改良．第三基因库的利用仍将是今后十年的研究重点．应加大种间衍生材料选择力度，弄清为害严重的病虫害的抗性机制和遗传规律，并在高频再生、分子克隆，遗传图谱方面开展研究．

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Effects of N, N-dimethyl piperidinium chloride (DPC) on Plant Endogenous Hormones during the Development of Groundnut Pods and Seeds

Wang Minglun[1], He Zhongpei[2], and Li Peiming[2]

The effect of different concentrations of N, N-dimethyl piperidinium chloride (DPC), sprayed on groundnut leaves, on the levels of endogenous ethylene (C_2H_2) production in pods during their development, and the amount of cytokinin (CTK) and abscisic acid (ABA) in seeds during their early development stages were studied. DPC increased the amount of C_2H_2 in pods, and CTK and ABA in seeds at the early development stages, and in plumules. Treated plumular axes and radicles had higher levels of CTK and ABA than nontreated ones during the mid and late stages of seed development, but the amounts of CTK and ABA in cotyledons were much lower than those in the control treatment. It is proposed that ABA promotes pod and seed development. However, the effects of application of compounds like DPC on endogenous hormones remain very complex, and further studies are needed to unravel the physiological consequences.

研究了花生叶面喷施不同浓度的DPC,对荚果发育过程中乙烯(C_2H_2)释放量、花生种子发育前期种子中细胞分裂素(CTK)和脱落酸(ABA)含量的影响.DPC可以增加荚果中C_2H_2释放量以及种子发育前期种子和胚芽中CTK与ABA的含量. 在种子发育中后期,处理的胚轴和胚根CTK和ABA水平高于未处理的,但子叶中二者的含量均低于对照. 认为ABA促进荚果和种子发育. 然而,施用DPC等化合物对内源激素的保持非常复杂,为揭示其生理效应尚需进一步研究.

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Studies on the Control of the Major Groundnut Foliar Diseases in China

Xu Xiujuan, Shi Yanmao, Chi Yucheng, and Cui Fenggao[1]

Of the many groundnut foliar diseases in China, only web blotch *(Didymella arachidicola* (Chock.) Taber Petit and Philley), and early leaf spot *(Cercospora arachidicola* Hori) have caused severe damage in recent years. They often occur together, and can decrease yields by 20-30%. From 1985-94, the control of diseases that occur together has been systematically studied. An integrated management method that mainly involves control of primary and secondary infection has been suggested, and the most effective fungicide LXM9201® developed and manufactured. The demonstration of this management method in 108 000 ha of groundnut fields showed that the average control achieved was 79.6%, and that direct economic benefits amounted to 220 million yuan (US$ 25.9 million) per annum. The ecological and social benefits were also significant.

中国花生叶斑病种类较多，但近年为害较重的主要是网斑病(*Didymella arachidicola* (Chock)Taber Petit & Philley)和早斑病(*Cercospora arachidicola* Hori)，二者通常混合发生，可以导致减产20－30%。1985－1994年间对二者混合发生的防治技术进行了系统研究，提出了控制初侵染和再侵染为主攻方向的综合防治技术，并研制出最有效的LXM9201复制剂。该防治方法经108000公顷花生田示范，平均防治效果79.6%，直接经济效益每年达2.2亿元(0.259亿美元)，生态和社会效益也很显著。

1. Shandong Peanut Research Institute, Laixi, Shandong 266601, China.

Xu Xiujuan, Shi Yanmao, Chi Yucheng, and Cui Fenggao. 1996. Studies on the control of the major groundnut foliar diseases in China. Page 263 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Abstract in En. and Ch.)

Studies on Critical Soil Moisture Content at Different Growth Stages of Early- or Medium-maturing Groundnut

Yao Junping, Lo Yaonian, and Yang Xindao[1]

The critical soil moisture content at different growth stages of early- or medium-maturing groundnuts was studied under controlled irrigation at Shandong Peanut Research Institute during 1979-81. The influence of soil drought on the main agronomic characters and the yield of groundnut were ascertained. Some physiological efficiencies were noted, and the critical moisture indexes at different growth phases determined. Plants were not sensitive to drought stress at the seedling stage. Fields should be irrigated when their soil moisture content is less than 40% of the maximum water-holding capacity of soil The critical soil moisture indexes for both early- and medium-maturing groundnut varieties were 33.7% for the flowering and pegging phase, 32.1% for fruit setting, and 31.8% for the pod-filling stage.

1979～1981年，在山东省花生研究所借助于全控池栽法研究了早、中熟花生不同生育阶段的土壤临界水分，摸清了土壤干旱对花生主要农艺性状以及产量的影响，探索了一些生理效应，初步明确了不同生育阶段的临界水分指标，认为苗期对干旱胁迫不敏感，当土壤水分含量低于最大土壤持水量的40%时应适量浇水； 早、中熟花生花针期土壤临界水分为33.7%结果、饱果期分别为32.1%、31.8%。

1. Shandong Peanut Research Institute, Laixi, Shandong 266601, China.

Yao Junping, Lo Yaonian, and Yang Xindao. 1996. Studies on critical soil moisture content at different growth stages of early- or medium-maturing groundnut. Page 264 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Abstract in En. and Ch.)

Study on the Nitrogen Nutrition of Groundnut Using Labeled ^{15}N-Fertilizer

Zhang Sisu and Wan Shubo[1]

When nitrogen (N) was applied at a rate of 120 kg ha^{-1} (37.5-225 kg ha^{-1})[2], using ^{15}N-labeled fertilizer, the utilization coefficient (UC) was 36% (42-32%), the residual rate (RR) in soil was 22% (27-18%), and the loss rate (LR) of N fertilizer 42% (31-50%). UC and RR were significantly negatively correlated with the amount of N fertilizer, while LR was positively correlated. Groundnut yields were maximum when around 100 kg N ha^{-1} was applied, but declined at higher application rates. The N content of the plant was 16% (6-26%) derived from ^{15}N-fertilizer, 36% (23-49%) from soil, and 48% (25-71%) from nodulating bacteria. The N-supply rates from both fertilizer and soil were significantly positively correlated with the amount of N applied, while the N-supply rate from nodules was negatively correlated. The rate of N-supply was 81% from nodule bacteria, and 19% from soil in the treatment without applied nitrogen.

应用^{15}N标记氮肥，氮素(N)施用量为120公斤/公顷(37.5－225公斤/公顷)时氮肥利用率(UC)为36%(42－32%)，在土壤中残留率(RR)为22%(27－18%)，损失率(LR)为42%(31－50%)；UC和RR与施氮量呈极显著负相关，而LR与施氮量呈极著正相关。花生产量在N施用量为100公斤/公顷时最高，但施用量再增加产量反而下降。花生植株体内总N中来自15N肥料占16%(6－26%)，来自土壤占36%(23－49%)，根瘤固N占48%(71－25%)，肥料供N率和土壤供N率与施N量呈极显著正相关，根瘤固N率与施N量呈极显著负相关，不施氮肥时根瘤供N占81%，土壤供N占19%。

1. Shandong Peanut Research Institute, Laixi, Shandong 266601, China.

2. Values in parentheses are ranges.

Zhang Sisu and Wan Shubo. 1996. Study on the nitrogen nutrition of groundnut using labeled ^{15}N-fertilizer. Page 265 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, (Abstract in En. and Ch.)

Studies on Gaming High Yield of Groundnut in Henan

Wang Baohua[1]

Henan Province is one of the main groundnut-growing regions in China with more than 700 000 ha cultivated there in 1994.

Research on improving yields involved studies of plant population densities, growth characteristics and patterns, cultivation techniques, and inter-cropping wheat with groundnut. Yields of 4.5-5.25 t ha^{-1} have been obtained. These results have contributed to increases in groundnut production and extension in the province.

河南省是中国主要花生种植区之一,1994 年种植面积超过 70 万公顷.

高产研究包括种植密度、生长特性及长相、栽培技术和小麦套种花生. 获得了 4.5－5.25 吨/公顷的产量. 这些研究结果促进了全省花生的生产和推广.

1. Zhengzhou Institute of Agricultural Sciences, Zhengzhou 450005, China.

Wang Baohua. 1996. Studies On gaining high yield of groundnut in Henan. Page 266 *in* Achieving high groundnut yields: proceedings of an international workshop, 25-29 Aug 1995, Laixi City, Shandong, China (Renard, C., Gowda, C.L.L., Nigam, S.N., and Johansen, C. eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Abstract in En. and Ch.)

Group Discussions and Recommendations

Group Discussions and Recommendations

Group 1. Genetic Enhancement

Breeding strategy-high yield vs resistance breeding

Both breeding for high yield potential and breeding for resistance were considered important depending on the situation. In Africa, bridging the yield gap between realized and potential yield was more important than breeding for high yield potential, while Chinese scientists considered that breeding for stress resistance was of lesser importance. However/in environments where the stresses could be managed culturally, breeding for high yield potential was considered important. In long-term breeding programs, a balance between these approaches is desirable.

Prioritization of constraints

Abiotic and biotic stresses affecting groundnut production in south and southeast Asia and southern Africa were prioritized (Table 1). In southern Africa, drought, long-duration cultivars, and early and late leaf spots were rated highly. In south Asia (India), drought, early and late leaf spots, rust, long-duration cultivars, leaf miner, and white grubs were rated highly. In south Asia the rankings of stresses varied among countries.

Exchange of germplasm and breeding material

The availability of sources of resistance to various stresses among the national programs was explored, and the following national programs in possession of sources of resistance in cultivated groundnut identified.

Drought / short-duration	China, India, ICRISAT
Spodoptera	ICRISAT (tolerance only)
Early leaf spot	ICRISAT (tolerance only)
Late leaf spot	India, ICRISAT
Aflatoxin	ICRISAT
Web blotch	China, Zimbabwe
PStV	China (tolerance only)
Rust	China, India, ICRISAT
Cold temperature	Korea
Bacterial wilt	China, Indonesia, ICRISAT
Leaf miner	India, ICRISAT (tolerance only)
Acid soils	Philippines, China
White grub	Nil

It was emphasized that germplasm exchange has to be a two-way process. The unrestricted availability of germplasm and breeding materials from ICRISAT was appreciated by all participants.

Breeding for improved seed quality

The major gains to date have been in improving the physical appearance of the seed. Efforts should now be concentrated on improving the chemical and nutritional quality of the seed.

Table 1. Ranking[1] of constraints to groundnut production.

	Constraints														
Country	Drought	Acid soils	Cold temperature	Long duration	Early leaf spot	Late leaf spot	Web blotch	Rust	Aflatoxin	Bacterial wilt	PStV	Leaf miner	*Spodoptera*	Aphids	White grubs
China	1	3	4	5	3	3	2	2	6	3	5	6	6	3	4
Vietnam	1	3	3	2	6	2	6	2	3	3	5	6	2	4	3
Korea	6	6	4	1	3	2	1	6	6	6	5	6	6	6	4
Indonesia	1	3	6	1	1	2	4	2	5	2	2	4	2	4	3
Philippines	5	4	6	6	6	3	6	3	3	4	3	6	6	5	6
Thailand	1	5	6	6	6	2	6	3	6	6	6	4	5	5	6
Myanmar	1	4	5	6	3	2	6	6	4	6	6	4	6	4	2
India	1	4	4	3	2	1	6	2	5	6	6	3	4	5	3
Southern Africa	2	3	6	2	3	5	6	6	3	6	6	6	6	5	5

1. 1 = High and 6 = Very low.

Suitable plant type for mulch technology

Polythene mulch groundnut production technology was considered most suitable for large-seeded cultivars with a harvest index of 0.5 to 0.6.

Seed production

Large-scale seed production of improved cultivars was rated a high priority activity. It was emphasized that the seed should always be produced under good management conditions.

小组讨论与建议

第一组　遗传改良

育种策略——高产育种与抗性育种

与会专家认为，在目前情况下，高产潜力育种和抗性育种都很重要。非洲的专家认为通过提高花生抗性而发挥花生高产潜力来提高花生实际产量更为重要，而中国的科学家则认为高产育种更重要。但是，大家都认为在可以运用栽培措施控制生产逆境的条件下，高产潜力育种则是最重要的。从长远来看，抗性育种与高产育种协调发展才是最理想的。

限制因素排序

专家们将影响南亚、东南亚和南部非洲花生生产的生物及非生物的限制因素进行了排序（表 1）。在南部非洲，干旱、品种晚熟以及早斑病和晚斑病影响较严重。而南亚（印度），则以干旱、早晚斑病、锈病、晚熟品种、潜叶蝇和蚜虫影响较为严重。在南亚，限制因素的排序在各个国家之间有所不同。

种质和育种材料的交换

专家们探讨了国家计划中获得各种抗逆性资源的可能性，以下国家所拥有的花生抗性资源已进行了鉴定。

干旱、早熟	中国，印度，ICRISAT
粘虫	ICRISAT（仅有耐受性）
早斑病	ICRISAT（仅有耐受性）
晚斑病	印度，ICRISAT
黄曲霉毒素	ICRISAT
网斑病	中国，津巴布韦
条纹病毒病	中国（仅有耐受性）
锈病	中国，印度，ICRISAT
低温	韩国
青枯病	中国，印尼，ICRISAT
潜叶蝇	印度，ICRISAT（仅有耐受性）
酸壤	菲律宾，中国
蚜虫	Nil

专家们强调种质交换必须是双向的。国际半干旱作物研究所在无条件地提供种质和育种材料方面受到了与会者的一致赞赏。

优质育种

到目前为止，品质育种的主要成就在于提高了种子的表观物理性状。专家们认为品质育种现在应以改善种子的化学营养成份为重点。

表1　花生生产限制因素排序[1]

国家	干旱	酸壤	低温	晚熟	早斑病	晚斑病	网斑病	锈病	黄曲霉毒素	青枯病	条纹病毒病	潜叶蝇	粘虫	蚜虫	蛴螬
	限制因素														
中国	1	3	4	5	3	3	2	2	6	3	5	6	6	3	4
越南	1	3	3	2	6	2	6	2	3	3	5	6	2	4	3
韩国	6	6	4	1	3	2	1	6	6	6	5	6	6	6	4
印尼	1	3	6	1	1	2	4	2	5	2	2	4	2	4	3
菲律宾	5	4	6	6	6	3	6	3	3	4	3	6	6	5	6
泰国	1	5	6	6	6	2	6	3	6	6	6	4	5	5	6
缅甸	1	4	5	6	3	2	6	6	4	6	6	4	6	4	2
印度	1	4	4	3	2	1	6	2	5	6	6	3	4	5	3
南非	2	3	6	2	3	5	6	6	3	6	6	6	6	5	5

1. 1＝严重　6＝很轻

适于地膜覆盖的株型

产量指数在0.5－0.6的大花生品种，最适合于应用地膜覆盖技术。

良种繁育

优良品种的大规模种子繁育应当放在重要位置。专家们强调种子繁育应当具备良好的管理条件。

Group 2. Soils, Agronomy, and Cultural Management

The group discussed major production constraints, existing technology for their alleviation, and future research needs and areas for research collaboration. Discussion on constraints and management technology concentrated on three main target production zones.

High yield potential zones

In temperate areas with the potential to produce 4 t ha^{-1}, these zones are characterized by generally adequate available soil moisture, summers with long days, and mild to warm temperatures during the cropping season. Shandong Province was taken as an example.

Major constraints to groundnut production

Shallow, sandy, infertile soils, relegation of groundnut to rainfed areas, low temperatures in spring and autumn, and foliar diseases can be limiting.

Solutions available

Existing technology, if demonstrated and extended, could improve yield in high potential zones. Procedures such as classifying soils suitable for groundnut production, deep plowing, increasing the irrigated areas, increasing and optimizing the use of fertilizers, amendments, and organic manures, using polythene mulching to establish crops earlier, controlling pests, diseases and weeds by using chemicals, host-plant resistance, and crop rotation would all contribute to higher yields. Groundnut should be incorporated as a crop of equivalent status (i.e., level of care) to other major crops in the rotation (e.g. wheat, maize).

Intermediate yield potential zones

In the tropics and subtropics, with the potential to produce 2-4 t ha^{-1}, these zones generally have adequate water available from irrigation or sufficient rainfall. Irrigated groundnut in southern China, southern Vietnam or in rice-growing areas of Indonesia were considered as examples.

Major constraints

Soil chemical problems such as nutrient deficiencies, toxicities (acidity, alkalinity, salinity), soil physical problems, unreliability of irrigation, waterlogging resulting from poor drainage, low temperature in the subtropics, and excessive vegetative growth all limit yield. Other constraints are caused by defoliation and other damage by insects, foliar diseases (leaf spots, rust, viruses), weeds, poor establishment, and shortage of seed of improved varieties.

Solutions available

Yield could be improved by using appropriate fertilizers and soil amendments (e.g. lime), genotypes suitable for delayed sowing, and improving the use of pesticides and host-plant resistance. Extending the areas where groundnut can be irrigated, and improving soil drainage are also solutions.

Low yield potential zones

These production systems occur from tropical to temperate regions and produce <2 t ha^{-1} in short-season, rainfed, or drought-prone conditions. Examples were rainfed areas of Gujarat and Andhra Pradesh in India, and East Java in Indonesia.

Major constraints

As in the intermediate yield potential areas there are various soil problems and poor yields resulting from low plant populations and lack of seed of improved varieties. Drought can be devastating and pests such as aphids, mites and thrips, and foliar diseases, bacterial wilt, and aflatoxin contamination also cause low yields.

Solutions available

Yields could be improved by using short-duration and drought-resistant varieties, with maximum supplemental irrigation and application of appropriate fertilizers, soil amendments, pesticides, and sowing of disease-resistant varieties.

Future research needs and areas for collaboration

All groundnut production zones would benefit from information exchange by the circulation of newsletters, access to publications, and involvement in networks, working groups, and regional meetings.

Germplasm exchange of host-plant resistant material, and dissemination of useful genes among potential users could be achieved by bilateral exchange (this is encouraged) and facilitated by CLAN/ICRISAT and other international organizations.

Possible areas for research collaboration

Collaborative approaches to agroclimatic analysis of drought environments, increasing water acquisition and water-use efficiency, improving soil structure by soil modification, soil organic matter studies, and diagnosis of mineral nutrient imbalances to develop corrective measures would all be beneficial.

Integrated pest and disease management could concentrate on development and utilization of host plant resistance, appropriate use of agro-chemicals, pesticide resistance studies, crop rotation effects, and the ecology of natural predators and antagonists (fungi and bacteria).

Cropping system studies would benefit from collaborative research into the use of groundnut in rice-based cropping systems, intercropping options, and residual effects in rotations.

Other areas of research of general application include studies on the chemical regulation of plant growth, how to maximize the partitioning of photosynthate into pods, optimizing nitrogen fixation, particularly when using nitrogenous fertilizers, further development and dissemination of polythene mulch technology for use in sub-tropical winters, and mechanization to improve efficiency and reduce costs.

第二组　土壤、农艺和栽培管理

该小组讨论了生产上的主要限制因素、缓解这些限制因素的技术措施以及将来的研究方向和合作研究领域．关于限制因素和管理措施的讨论集中于以下三个主要区域．

高产潜力区

具备 4 吨/公顷生产潜力的温带地区，该区域的特点是通常有充分的可利用的土壤水分，夏季日照时间长，播种季节温度适宜．山东省即属此列．

花生生产的主要限制因素

土壤土层浅、沙性大、贫瘠少肥、没有水浇条件、春秋两季温度低以及叶部病害等都是影响花生生产的重要因素．

解决途径

目前已有的技术如果能够加以示范推广，在高产潜力区域内产量是可以得到提高的．诸如划分适于花生生产的土壤类型，实行深耕，扩大水浇地面积，增加并优化施用化肥、土壤添加剂和有机肥，采用地膜覆盖技术提早播种，利用化学药品控制病虫草害，提高花生植株抗性及合理轮作等措施都有助于提高产量．花生在与其他粮食作物（如小麦、玉米）轮作时应加强对花生的管理．

中产潜力区

在产量潜力为 2－4 吨/公顷的热带和亚热地区，由于灌溉和降雨，通常能有充足的水分可以利用．中国南部，越南南部和印尼的水稻种植区即属此列．

主要限制因素

包括土壤化学问题诸如养分缺乏、毒性（酸性、碱性、盐性）、土壤物理性状不良、灌溉无保障、排水不畅、亚热带地区的低温，以及营养生长过盛等，这些因素都限制了产量水平的发挥．其他限制因素有还落叶和虫害、叶部病害（叶斑病、锈病、病毒病）、杂草、群体结构不合理以及良种缺乏等都影响花生生产．

解决途径

合理施用化肥和土壤改良剂（如石灰），采用适于晚播的品种，提高植株抗性和杀虫剂使用效果以及扩大花生田的水浇面积，提高土壤排水能力，都是克服上述限制因素的有效途径．

低产潜力区

从热带到温带地区都存在这种生产体系，这类地区在生长期短、缺乏灌溉条件以及旱为主的环境下产量水平低于 2 吨/公顷．印度的 Guiarat 和 Andtraprodesk，以及印尼的东爪

哇等雨养地区即属此类.

主要限制因素

与中产潜力区相似，栽培土壤存在的各种问题，以及种植密度低，缺乏优良品种造成了花生产量很低，干旱有可能是毁灭性灾害，虫害如蚜虫，螨和蓟马以及叶部病害，青枯病和黄曲霉毒素污染能导致低产.

解决途径

通过采用早熟抗旱品种，改善灌溉条件，合理施用化肥，土壤改良添加剂、杀虫剂，种植抗病品种等措施可以达到增产的目的.

未来的研究方向和合作领域

通过发行《花生通讯》、印刷出版物、参加合作研究网、研究组织、地区性会议等信息交流活动，所有的花生产区都将因此而受益.

抗性种质材料及有用基因交流都应该是双向的，而且这项工作应得到 CLAN/ICRISAT 及其他国际组织的推动.

有可能合作研究的领域

在以下方面进行合作将会是有益的：干旱环境的农业气象分析，提高水份获取和利用率，利用土壤改良剂改善土壤结构，土壤有机质研究，矿质养分不平衡的分析诊断及其纠正措施实施.

病虫害的综合防治应着重于推广应用抗性品种，合理使用化学农药，昆虫抗药性研究，作物轮作效果，以及自然天敌和拮抗物(真菌和细菌)的生态研究.

对在以水稻为主的种植体系中花生的应用，套种方式的选择，以及轮作残效等方面的协作将有利于种植体系的研究.

其他可以进行协作研究的应用领域包括植物生长调节剂，如何将光合产物更多地转移至果实，增强固氮作用(尤其使用氮素化肥时)，在亚热带地区的冬季进一步推广地膜覆盖技术，实行机械化作业提高效率，降低成本.

Group 3. Technology Transfer

The group identified constraints, needs, and opportunities for technology transfer; technologies available, and related these to technology transfer experiences in Asia; and areas for adaptive research and research collaboration in Asian countries.

Constraints, needs, and opportunities for technology transfer

At the country or regional level there are low incentives for agricultural production although some have policies, prices, and markets that encourage farmers to increase production. Such policies need to be implemented more widely. The availability of credit/loans to buy seed and other inputs is an incentive for farmers to adopt high-yield technologies more rapidly China has established a good system of making inputs easily available at appropriate times at village level. This system needs to be emulated in other national programs.

The extension service in many countries, although present, is not efficient or has bottlenecks in providing necessary services in farming communities. New technologies need to be demonstrated to farmers, and shown to be economically attractive, and simple to use, if they are to be accepted. New approaches, like integrated pest management, crop rotation, or land reclamation, may need the cooperation of several farmers, and farmer associations and technical service groups can also help to foster joint action.

The transfer and adoption of technologies must be supported by the improvement of infrastructure such as roads, communications and markets.

Solutions available

These include the selection and use of adapted cultivars for each zone/cropping system, and the use of medium grade seeds for sowing (best quality seeds can be used in food or confectionery, poorest for consumption or oil extraction). In each area depending on the cropping system, crop rotations that maintain fertility and discourage the build up of pests, diseases, and nematodes should be encouraged. The soils should be enriched by organic manures and the rational application of chemical fertilizers. The plant population should be optimal for the soil type and moisture availability.

To assist crop establishment, where appropriate, polythene mulch should be used, and plant growth regulators applied to assist partitioning, if these are economical. Wherever water is available, crops should be irrigated at critical stages.

The use of small machines for sowing and harvesting should be encouraged to save labor costs, and losses due to pests and diseases minimized by improvement in storage facilities and techniques. The local demand for groundnut could be increased by improving local processing or importing and modifying the processing technology for local use.

Areas for future adaptive research and research collaboration in Asian countries

Development of improved cultivars (high yield, quality), improvement in stress tolerance (to both biotic and abiotic stresses), management of stress factors (IPM, etc.), and research on irrigation management, nutrient balances, and nutrient cycling will all lead to improved crop production. The development of small machinery according to national needs, or the use of available machines, modified for multiple purposes will encourage production over larger areas.

Emphasis on farmer participatory on-farm research and exchange programs for scientists/technicians/extension personnel to study in leading countries, and to extend the knowledge gained to their own countries, will ensure a long term improvement in groundnut production in Asia.

第三组　　技术转化

该小组讨论了技术转化的障碍，必要性和可行性；现有的技术及亚洲地区与这些技术转化有关的经验；技术的地区适用性研究和亚洲地区国家的合作研究。

技术转化的障碍、必要性和可行性

在某一国家或地区之内，尽管在政策、价格和市场方面鼓励农民提高生产，但对于农业生产的实质性影响仍然有限，因此有关政策应具有更广泛的适用性。提供信用贷款购买种子和其他生产资料是鼓励农民加快采用高产技术的有效途径，中国已经在村一级水平上建立起了及时方便的投入机制，这种机制是值得其他国家仿效的。

目前，许多国的基层服务效率还不高，或者在种植区内向农民提供必要的服务方面还存在着瓶颈效应。新技术要让农民接受，就必须向他们示范，表明该技术有经济上的吸引力，而且操作简便。有些新措施，如有害生物的综合治理、作物轮作或土地开垦，可能需要若干农民的协作，农民组织和技术服务小组有助于促进这种协作。

技术的转化与采用还必须有更完善的基础环境设施，如道路、通讯和市场等方面的支持。

解决途径

包括选用适合于各个产区和栽培体系的品种和用中级米播种（高级米可用于食品或糖果加工，低级米用于直接消费或榨油）。根据每个地区种植体系的不同，应该提倡采用能够保持土壤肥力而不利于病虫害和线虫发生的轮作制度。应该通过合理施用有机肥和化肥来增加土壤肥力。根据土壤类型和水份获取条件来确定最佳种植密度。

采用地膜覆盖，建立合理的作物群体结构。在经济有效的前提下应用植物生长调节剂改善植株的养分分配。在有水的地方，作物生长关键期应补充灌溉。

鼓励使用小型机械进行播种和收获以节约劳动力；通过改进贮藏设备和技术来降低病虫害造成的损失。建立当地的加工厂和引进改善加工技术可以增加当地对花生的需求。

未来可行的研究领域及亚洲国家间的协作研究

良种（高产、优质）的推广，抗逆性（包括生物和非生物胁迫）的提高，限制因子(EPM 等）的治理，以及灌溉管理、养分平衡和养分循环的研究都会使作物生产得到提高。推广适合地方需要的小型机械，或者将已有机械改造成多用途机械都会在更广阔的范围内提高生产。

让农民参与田间研究，让科学家、技术员和推广人员到先进国家学习交流并把先进的知识带回本国，将确保亚洲花生生产的长期持续发展。

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国际花生高产学术研讨会
中国 山东 莱西 九五年八月二十五日

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About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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