渭北高原
降水资源机械化高效利用
图文集

High-efficiency Rainfall Resource Use
in Weibei Highlands by Mechanical Measures
Photo Collection

韩思明　薛少平　编著

陕西科学技术出版社

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渭北高原降水资源机械化高效利用图文集

编 委 会

序

干旱是一个世界性的问题。旱作农业在世界农业中占重要地位。目前世界耕地面积约14亿公顷，其中有灌溉条件的仅占15.8%，其余84.2%的面积都是依靠自然降水从事农业生产。近年来随着缺水威胁不断加剧，水资源日趋匮竭，干旱已成为限制农业生产可持续发展的重要因素。目前，世界上先进国家都十分重视发展旱作农业。

我国也是一个旱作农业比重很大的国家。其旱作农区分布主要在昆仑山、秦岭、淮河一线以北，包括16个省、市、自治区。据统计，仅半干旱偏旱区、半干旱区和半湿润偏旱区便有耕地3400多万公顷，占全国耕地总面积的三分之一，是我国粮、棉、油的重要产区。可见，北方旱作农区在我国农业生产和国民经济中具有非常重要的地位和意义。

北方旱作农区地下水、地表水贫乏，在3400多万公顷耕地中，无灌溉条件的旱耕地就占到70%以上，农业生产用水主要依赖自然降水，属典型雨养农业地区。可是，我国北方旱作农区由于地处大陆性季风气候带，降水不仅量少，而且也不平衡。其特点从南到北呈明显下降趋势。半干旱偏旱区多年平均年降水量250－350毫米，半干旱区为350－450毫米，半湿润偏旱区也仅有450－600毫米；而且季节分布不均，冬春少雨，60%－70%的降水集中在6月至8月份，加之降水年际间变化大，导致干旱时有发生，所以，干旱缺水便成为制约我国北方旱作农业可持续发展的重要限制因素。因此，如何将有限的自然降水最大限度地蓄积并保存于土壤之中，变不均匀的降水为比较稳定的供水，克服降水与作物需水不相吻合的矛盾，极尽可能地提高降水资源的利用率和利用效率，是过去、现在，也是将来科技界关注的焦点和进一步开展科技攻关的重点。

为了实现有限降水资源的就地拦蓄、就地入渗和雨水资源化，最大限度地提高其利用效率，长期工作在北方旱作农区的广大农业科技工作者，通过大量的科学实验，从理论到实践，因地制宜地提出许多切实可行的降水资源高效利用技术模式，对促进旱作农区科技进步，实现粮食增产、农民增收和农业可持续发展起到了重要的作用。

西北农林科技大学韩思明教授和薛少平研究员同多学科的多位专家教授一起，立足陕西渭北高原，从20世纪80年代中期开始，连续20多年，围绕有效保持水土、增加土壤贮水、改善生态环境，增强农业综合生产能力，促进农业可持续发展这一中心，以主攻粮食单产，稳定总产，确保粮食安全，增加农民收入，繁荣农村经济为目标，遵循农艺必须与农机相结合的原则，在陕西渭北高原不同类型区开展了大量的田间试验，在降资源高效利用以及与保护性耕作结合的理论与实际方面取得卓有成效的进展，同时提出了多项适合不同类型区、不同种类作物的降水资源高效利用技术模式和降水资源高效利用与保护性耕作相结合的机械化集成技术体系，在同类试验研究中具有创新性，对指导陕西渭北高原乃至整个北方地区旱作农业的可持续发展具有重要的学术价值和实用价值。

现在，众位专家教授以多年的试验研究工作为基础，将结合试验拍摄的大量科技照片，通过两年多的精选，按降水资源高效利用以及与保护性耕作相结合的技术体系，并配简要技术介绍，编辑成《渭北高原降水资源机械化高效利用图文集》一书。这部图文集的特色是利用自己拍摄的1000多幅图片，全面系统地介绍了旱作农田降水资源机械化高效利用技术体系，这在目前出版的各种图谱中还没有看到。可以说，这正是该图文集的重要创新之处。这部图文集用大量实拍照片，并配以简明文字说明，把大量的田间机械作业、核心技术和不同技术模式农作物不同时期的生长状况展示在读者面前，重点突出了形象直观和新技术含量，使读者一看就懂，内容充实，便于操作，是一本难得的、值得推荐的理论与实践结合的专著。我相信，该图文集的出版一定会受到学术界、科技人员以及基层农业科技工作者的欢迎，并将为促进我国北方旱作农区和不饱和灌区农业可持续发展做出新的贡献。

中华人民共和国农业部副部长　张宝文

二00六年二月二十日

前言

陕西渭北高原，素以旱地农业著称，在北方旱作农区具有一定代表性。

渭北高原农耕历史悠久，是中华农业开发较早的地区之一。“国以民为本，民以食为天”，农业历来是该区最大的产业，是陕西省粮、果、畜的重要生产基地，也是优质粮食、果品、畜牧生产的最佳适生区，陕西省粮、油、果、畜一半以上的生产基地都分布在这一区域范围内。可以看出，渭北高原农业生产及生态环境建设，在陕西省经济发展和西部大开发中占有非常重要的地位。

在黄土高原地区，渭北高原是比较平坦的部分。广大的黄土原、黄土台原区，土层深厚，结构疏松，渗透性好，蓄水力强，素有“土壤水库”之称。据测定1米深的黄土层可蓄存250－300毫米的水分，也就是说，每公顷在1米深的黄土层内可蓄存2500－3000立方米的水分。2米深的土层，可蓄存500－600毫米的水分，即可把全年的降水量全部蓄存起来。这是渭北高原高效利用降水资源的有利条件，得天独厚。

渭北高原除川道和南部一些地区有一定灌溉条件外，大部分地区地下水和地表水资源贫缺，农业生产用水完全依赖有限的自然降水，属典型雨养农业地区。降水量少、年际间变化大，季节分配不均，且多无效雨、微效雨、大雨、暴雨以及降雨季节与作物生长季节不吻合，是该区域降水的最大特点。因此，干旱缺水，加之土壤贫瘠和水蚀、风蚀严重，便成为限制旱作农田生产力高低的瓶颈。可是，大量的科学研究和生产实践证明，渭北高原旱作农田蕴藏着很大的生产潜力。在降水正常年份，旱地冬小麦每公顷产量可达6 000－9 000千克、旱地春玉米每公顷产量可达12 000－15 000千克；在南部不饱和灌区年每公顷产粮可达22 500千克以上。干旱缺水固然是影响该地区旱地作物生产潜力得以充分挖掘的重要限制因素，然而自然降水的大量流失和无效蒸发则是造成旱地作物产量低而不稳的根本原因。据试验测定，旱农地区总降水中，地面径流和地下径流占14%左右，也就是说86%的自然降水入渗土壤可供作物利用。但在一般耕作栽培条件下，通过作物蒸腾形成的作物生产力仅占总降水量的25%左右，60%左右的降水无效蒸发，而这些形成径流和无效蒸发的水分正是旱作农田的重要利用对象，说明渭北高原的降水资源大有潜力可挖。

造成降水地面径流和大量无效蒸发损失的原因：一是渭北高原大部分耕地大平小不平，特别是高原沟壑区，坡耕地还占一定比重，故在夏季多大雨、暴雨的情况下，很容易造成降水的大量流失，随着水的流失，土和肥也付诸东流；二是广泛应用传统翻耕技术，形成裸露的地表和疏松的耕层结

构。这样的地表状态和耕层结构，在高温多雨的夏季，不仅会造成水土的严重流失，而且会加剧土壤水分的无效蒸发。在干燥多风的冬季，既会造成狂风对土壤的侵蚀，亦会加剧土壤水分的无效蒸发损失。据1962－1963年在陕西武功测定，夏季休闲的麦田，夏闲末1.6米土层内仅能蓄存同期总降水量的37.1%－40.4%，大量的降水并没有变成底墒而损失掉了。同时连年翻耕，土壤有机质耗损多，会降低土壤潜在肥力；三是土壤瘠薄，栽培技术落后，也是影响降水资源高效利用和旱作农田生产力低下的重要因素。由此可见，高效利用有限自然降水资源，是提高渭北高原农业生产力的技术关键。如何将有限的自然降水最大限度地蓄积并保存于土壤之中，变不均匀的降水为比较稳定的供水，克服降水与作物需水不相吻合的矛盾，最大限度地发挥降水资源的生产效能，使有限的降水获得更多的粮食和其他农产品，以满足社会不断增长的需要，我们从“六五”开始，在渭北东部的澄城县、西部的武功、乾县等地，经“七五”“八五”，直到“九五”，结合国家科技部科技攻关项目“黄土高原综合治理”和陕西科委重点科技项目“渭北旱原抗旱耕作技术研究”等，开展了大量的试验研究。其研究思路是，依据土壤作物大气连续系统理论，以有效保持水土，增加土壤贮水，改善生态环境，增强农业生产能力，促进农业可持续发展为中心，以主攻粮食单产，稳定总产，确保粮食安全，增加农民收入，繁荣农村经济为目标，将传统耕作技术与保护性耕作技术相结合，残茬（秸秆）覆盖与地膜覆盖相结合，深松，翻耕与少耕、免耕相结合，农田蓄水与窖窖集水相结合，农艺技术与农机作业相结合，充分发挥渭北高原土层深厚、结构疏松、水分入渗速度快、蓄水能力强的特性，强化降水就地拦蓄，就地入渗，寓抗旱、增产、增收于水土保持之中，并经过生产性试验、示范，形成完整的“渭北高原降水资源机械化高效利用技术体系”，为大面积推广应用和产业化开发奠定基础。

研究方法，采取五个结合：一是中心试验场试验与多地点试验相结合，以充分体现试验的实用性；二是单因子试验与复因子试验相结合，以充分体现试验研究的综合性；三是小区试验与大区示范相结合，以充分体现试验研究的准确性；四是常规试验与新试验手段相结合，以充分体现试验研究的先进性；五是试验研究与大面积示范推广相结合，以充分体现试验研究的生产性。

我们经过长达20年的反复试验、探索，积累了大量试验资料，获得了多项研究成果，形成了多种适合不同地区、不同作物高产或超高产的降水资源高效利用耕作栽培技术模式。“六五”期间，承担的陕西省“渭北高原抗旱耕作技术研究”，达到国内先进水平，其中残茬覆盖深松耕作技术达到国内领先水平，1993年获陕西省科技进步三等奖；“七五”期间，承担的国家科技攻关项目“黄土台原阶地区综合治理开发优化模式建立（75-04-03-12）”、“八五”承担的“黄土台原区综合治理开发及农业持续发展研究（85-008-01-05）”和“九五”承担的“黄土台原粮食高产型农业综合发展研究（96-004-05-08）”，均达到国际先进水平。“七五”研究，1992年获陕西省科技进步一等奖，同时，1993年并获国家科技进步一等奖；“九五”研究，2002年获陕西省科技进步二等奖。

“十五”期间，我们为了将取得的大量研究成果尽快转化为实现生产力，申请了陕西省农发办示范推广项目和农业部农业科技跨越计划项目，在渭北黄土台原区的乾县和渭北高原沟壑区的黄陵两个不同生态类型区进行大面积中试与示范，同时在陕西省8个市（县）进行大面积推广。两年来共中试示范面积8500公顷，通过进一步的中试熟化使许多核心技术更加完善成熟，并形成了适合渭北不同类型地区、不同种类作物降水资源高效利用与保护性耕作相结合的机械化集成技术体系，取得了显著的经济效益、社会效益和生生态效益。

旱地小麦留茬覆盖深松（免耕）膜侧沟播技术模式和传统耕作技术比较，夏闲期2米土层多蓄水85.1毫米，降水保蓄率达到60.2%，提高18.5%；每公顷多增产粮食1 770.0－2 110.5千克，增产率达到40.6%－58.0%，最高产量每公顷达到7 311.0千克；水分利用效率两年平均为15.61千克/（毫米·公顷），提高25.6%；每公顷增加纯收入1 563.0元，增加20.1%。旱地春玉米倒茬（碎秆）覆盖免耕（浅旋）膜侧种植技术模式和传统耕作技术比较，冬闲期2米土层多保水26.5－43.5毫米，0－10厘米土壤水分含量高4.5%－5.0%，每公顷增产粮食3 765.0－3 819.0千克，增产率达到48.2%－49.8%，最高产量每公顷达到11 562.0千克；水分利用效率两年平均为22.8（千克/毫米·公顷），提高47.6%；每公顷增加纯收入2 570.10－2 645.70元，增加31.4%－33.4%。

两年中试示范中，我们还研制开发出与不同种类作物核心技术相配套的耕作、播种、管理机具四种，改进完善农机具五种，其中小麦免耕播种机、秸秆粉碎深松机和秸秆带状分离旋耕、施肥、整地机经大面积应用，性能良好。同时，形成与核心技术相配套的品种选择原则、施肥制度与管理措施等。

通过两年大面积中试与示范，该技术体系已被基层干部和广大农民群众所认可，普遍反映效益显著，易于操作，积极要求能大面积推广。在现场和会议验收时，专家组也建议应加大推广应用力度。

“十五”期间，我们结合“863”节水农业重大专项（2002AA2Z4021-2）和国家自然科学基金项目（30070439，30300213），首次开展了微集水种植（设施）条件下农田降水生产潜力增进的量化研究，研发的增进旱作农田降水生产潜力的微集水种植技术，经大面积生产验证，效益显著。

结合试验研究，我们在《西北农业大学学报》《西北农林科技大学学报》《干旱地区农业研究》《耕作与栽培》《中国农业科学》《农业工程学报》《麦类作物》和《中国生态农业学报》等杂志上，发表研究论文50余篇，撰写专著五部。同时，结合试验研究，还比较系统地拍摄了大量科技照片。为了给旱农研究工作者提供较为系统的实体图片和技术，我们尝试编辑成《渭北高原降水资源机械化高效利用图文集》，共十章。第一章介绍了渭北高原与降水资源高效利用和机械化保护性耕作有关的基本概况；第二章针对渭北高原耕地少、质量差的实际，介绍了稳定持续提高耕地综合生产能力的关键技术与措施；第三、第四章介绍了夏闲地和冬闲地如何将有限降水资源最大限度地蓄积

并保存于土壤之中的关键技术；第五章介绍了旱地作物生育期采用沟垄种植技术、地膜覆盖栽培技术和农田微集水种植技术提高降水资源利用率的增产机理与关键技术；第六章介绍了几种主要作物全程降水资源高效利用与保护性耕作相结合的机械化集成技术体系的增产机理与关键技术；第七章介绍了旱作麦田利用全程微型聚水地膜覆盖技术使夏闲地高效用成为可能的增产机理与关键技术；第八章介绍了一年两熟地区以保护性耕作为中心的回茬小麦和复种玉米实现降水资源高效利用的主要技术措施、机械化工艺体系和配套作业机具；第九章介绍了设施栽培技术在土地、季节和水资源利用中的作用以及利用大、中、小型塑棚种植西瓜、黄瓜、番茄实现高产高效的关键技术；第十章介绍了雨水资源化变被动抗旱为主动抗旱的意义和集雨补灌的技术要点。以上介绍的多项技术模式中，有些技术体系具有开创性，对指导陕西渭北高原乃至整个北方旱作农区降水资源高效利用的发展具有重大的学术价值与实际应用价值。

本图文集是在陕西省农业机械管理局的领导和支持下完成的，所收编的各项研究成果是在国家科技部、农业部、国家自然科学基金委，陕西省农办发、科技厅、农业厅、农机局等主管部门的大力资助和关怀下取得的，因此这里首先向各级科研管理部门给予我们的支持和指导表示衷心感谢，同时向长期支持、关心我们试验、示范、推广工作的校、院、组的领导、专家、老师致以诚挚的谢意。

本图文集虽然说主要是选用我们多年从事科研推广实践取得的成果和拍摄的照片编辑而成的，但在编撰过程中也参考引用了很多专家、学者的著作和学术论文，并从有关杂志、书籍上搜集了部分照片资料，故在本图文集付梓出版之际，特表致谢。

科学技术发展日新月异，各地情况千差万别，图文集中收编的各种“技术体系模式”可能会存在一些这样那样的问题，加之编著者水平所限，错误与不足之处在所难免，敬请广大读者不吝批评指正。

编　著　者

二00五年十二月

Preface

Weibei highland in Shaanxi province, which has been regarded as dryland farming for a long time, is typical dryland agriculture in northern China. It was one of the earliest areas during the development of agriculture in China, and as a result, agriculture has been the biggest industries in Weibei highland. Based on the thoughts of "People Foremost" and "Food is the First Necessity of Man" of ancient Chinese, Weibei highland became the production base of food, fruits and livestock products. Almost over 50% production base of grains, fruits, animal husbandry in Shaanxi province are located in Weibei highland. Eco-environment construction and agriculture sustainable development in Weibei area has been one of the important parts in economic development and the Great West Exploration.

Weibei highland is relatively more flat than other areas in the region of Loess Plateau. The loess highland and loess platform land are known as "soil reservoir" due to deep soil, loose structure, strong permeablity and strong capability of moisture-holding. Research indicated that 250 ~ 300 mm moisture could be stored within 1 m depth soil, it was to say that 2500~3000 m^3 water could be holded in 1 m depth soil per hectare. 500 ~600 mm water, which was almost the amount of the annual rainfall in Weibei areas, could be stored in 2 m depth soil layer. And it is the unique character of Weibei highlang and the base of higher water-use efficiency in Weibei highland.

Weibei highland is a typical rainfed agriculture area. Agriculture depends on finite rainfall completely because of deficiency of underground water and surface water, with some irrigation supplied in the valley and southern. The rainfall in this region is characterized by inadequate rainfall and vast variation year to year, uneven distribution in seasons and non-coordinate with crop growing periods. So the agriculture development bottleneck of this area are water shortage, poor soil fertility, serious water and wind erosion. But lots of researches and production practices had certificated that Weibei highland had great potential in dryland farming production. In the year with normal rainfalls, the yield of

winter wheat could be 6000～9 000 kg per hectare, and the yield of spring corncould be 12000～15000 kg per hectare, while the annual yield of grains could be 2250 kg per hectare in southern areas with some irrigation. Though water shortage and drought are the main limiting factors to explore the full potential, the massive loss of rainwater and ineffective evaporation are the key factors leading low and unstable crop yield. Experimental results showed that underground flow and surface flow were only 14% of the total rainfall in arid areas, which means, 86% rainfall could be holded in soil for crop growth. But the application of classic cultivation could only use about 25% moisture of total rainfall, almost 60% of rainfall was lost through ineffective evaporation. How to increase water-use efficiency and to develop the potential of soil is the main targets of our effects.

Some reasons for surface rainfall flow and ineffective evaporation were followed as: 1. Most plantation soil in Weibei highland were not level, especially in Gullied Loess Region of the Loess Plateau. Slope farmland leads rainfall loss fast in summer, at the same time, soil and fertilizer were lost with the water erosion. 2. Traditional planting technique made soil surface bared and soil layer loosen, then soil and moisture easy lost in rainy and high temperature season, as well as the ineffective evaporation increased. In winter, less water and windy could enhance soil erosion and soil moisture ineffective evaporation. The data of Wugong County in Shaanxi Province during 1962 and 1963 indicated that moisture contents in 1.6 m depth was only 37.1%～40.4% of total rainfall after summer fallow, a large amount of water was lost before being converted into soil moisture. And plough with traditional ways leads soil organic matter reduced. 3. Most plantati on soil was poor in fertility and plough technique was laggard. Thus it was necessary to increase water use efficiency in Weibei highland for agriculture development. From the 6th to the 9th Five-Year Plan, many experiments had been done in Chengcheng, Wugong, and Qian counties of Weibei. Aimed at increasing water use efficiency in Weibei, two projects were founded, one was the Sci-Tech key program of the Ministry of Science and Technology of China: "Comprehensive Control of the Loess Plateau". The other was the Sci～Tech Project of Ministry of Science and Technology of Shaanxi Province: "Study on water- saving plough technology in Weibei highland" Experiments based on the soil-crop-atmospheric continuity system theory were excuted and focused on holding soil and water efficiency,

increasing moisture storage, I mproving ecological environment, enhancing agriculture production, advancing agricultural sustainable development, etc., through combining tradition plough technique and protective farming technique, stubble mulching and film Mulching, subsoiling and plowing, minimum tillage and no-tillage, soil moisture storage and rainfall collection, agronomic technology and agro-machinery, to ully explore the production potential of Weibei highland, which with deep soil, loosen soil structure, well permeablity and high moisture holding. Finally the technology system of rainfall resource mechanization and high efficiency utilize in Weibei highland was established and used as the base for extending and industry.

The research methods were five combination in brief: 1. Combining experiments in key location and multi-locations to achieve practibility of the experiments. 2. Combining factors test with multi factors test to ensure the integrity of the experiment. 3. Combining plot trials with field demonstration to certify the accuracy of experiments. 4. Combining traditional trials with new technique to demonstrate advancement of research. 5. Combining research with extension to demonstrate the productivity of experiment.

After almost 20 years research many achievements were obtained and multi cultivation models, which suitable to be used in different water resource and yield potential, different regions and different crops. During the 6th Five-Year Plan,the Sci-Tech Project in Ministry of Science and Technology of Shaanxi Province "Study on water-saving plough technology in Weibei highland" reached the advanced level in China. The stubble mulching and subsoiling is in the advanced level in China, and won the Third Grade Awards on Science and Technology Progress issued by Shaanxi Province government. The achievements of the project on "the model establishment of comprehensive control and exploration of the loess tableland" (75-04-03-12), the project on "comprehensive control and exploration with sustaining agriculture in loess tableland" (85-008-01-05), and the project on "comprehensive development of high yield agriculture in the loess tableland" (96-004-05-08) were all at the advanced level of the world. The project in 7th Five-Year Plan was awarded as the First Grade Prize on Sci-Tech Progress by Shaanxi Province in 1992 and the First Grade Prize on Sci-Tech Progress issued by the Ministry of Science and Technology in 1993. The achievements during the 9th Five-Year Plan was awarded the Second Prize by

Shaanxi Province.

During the 10th Five-Year Plan, founded by the pilot extension project of Agriculture Developm ent Office in Shaanxi Province and agriculture Sci-Tech cross over plan of the ministry of agriculture, to use our experiment results into true productive forces. We selected Qian County and Huangling County in Weibei highland as representative areas and pilot base, which represented loess platform areas and gully areas respectively. At the same time, the achievements were extended to 8 different counties in Shaanxi Province.The techniques were practiced in 8500 hectare within two years, through the pilot experiments, some core technology had been further developed in multi mechanization plough technical systems with high water use efficiency of combined with protective farming technique. Economic effects, ecological benefits and social effects were all increased reasonably by using this technical system.

For dry-land wheat, compared with the traditionalplanting, the film mulching technique, with furrow sowing with subsoiling stubble, had high water storage. During summer fallow period, water contents in 2 m depth soil was 85.1 mm higher using this new technical than that of traditional planting, and the rate of rainfall storage was 60.2%, increased 18.5% than that of common technique. For yield, additional 1770～2110 kg products was harvested per hectare, 40.6%～50.8% more than that of normal planting.The highest yield was 7311kg per hectare. The average WUE of two years was 15.61 kg • $mm^{-1}ha^{-1}$, increased by 25.6%, that net income increased by 20.1%, 1563 yuan per hectare. Planting spring maize, the film mul ching of furrow sowing with zero tillage also had reasonable effect of water storage. During winter fallow period, additional 26.5-43.5 mm moisture was hold in 2 m depth soil, water contents at the 0 and 10 cm soil was 4.5%-5.0% higher than that with traditional planting. The net yield increase was 3765-3819 kg per hectare and the increase rate was 48.2%～49.8%, the highest yield was 11562 kg • ha^{-1}. The average WUE of two years was 22.8 kg • mm^{-1} • a^{-1}, increased by 47.6%, net income was 2570.1～2645.7 yuan per hectare, increased by 31.4%～33.4%.

From the two years demonstration at the pilot scale, four techniques on planting, sowing and management equipment had been developed for different crops, five types of agriculture equipments were improved. Many kinds of machines, which could be used in

wheat no-tillage planter, straw crushed subsoiler, fertilizer, soil tillage, were used efficiently and widely. At the same time, core techniques were developed according to cultivar selection, fertilizer application methods and management.

Since the technique system had been piloted and demonstrated for two years, farmers could accept this technique system and think this system was better to operation and efficiency. Experts also advised to extend the system widely. During the 10th Five-Year Plan, we got funds from the national "863" program(2002AA2Z4021-2) and projects of NSFC(30070439, 30300213), more experiments in enhancing potency of rainfall with micro-collecting technique had been conducted. The water high efficiency was obtained during pilot-experiments in southern Ningxia and Zhidan county of Shaanxi province. Combined with our experiment results, two monograph had been published and more than 50 papers had been published on "Acta Universitatis Agriculturalis Boreali-Occidentalis", "Journal of Northwest Sci-Tech University of Agriculture and Forestry", "Agricultural Research In The Arid Areas", "Agriculture Sciences in China", "Transactions of the Chinese Society of Agricultural Engineering" and "Chinese Journal of Eco-Agriculture". During the research, many photos had been taken for arid agriculture study and technique extension. Now we tried to compile them in this book "Photo Collection on High-efficiency Rainfall Resource Use in Weibei Highland by Mechanical Measures". There are 10 chapters in the book. Chapter 1 was mainly focused on the basic condition of Weibei highland, high efficiency rainfall use and mechanized protective farming technique. Chapter 2 was the introduction of some key techniques and measures on increasing the integrated production capacity of soil. Chapter 3 and chapter 4 were expatiated high efficiency technique on rainfall resource storage during summer and winter fallow period. Chapter 5 was about high efficiency technique on rainfall resource storage during growth period in dry farmland. Chapter 6 was to narrate the key techniques on high efficiency use of rainfall resource during growth period in dry farmland. Chapter 7 was to describe key technique on high efficiency rainfall use of wheat during summer fallow period in dry farming. Chapter 8 introduced briefly in high water efficiency use technique on summer and autumn double cropping. Chapter 9 was mainly on high efficient and high yield technique of protected cultivation, such as early-maturing watermelon, overwintering cucumber and tomato. The

Last chapter was a summary of key technique on water collecting and high efficiency rainfall use technique on yield. These techniques were inaugurator to agriculture development in Weibei Highland and other arid areas.

Without the support from the Central Government and Shaanxi province, Ministry of Science and Technology and Ministry of Agriculture, the productions referred to this book would still be a dream or idea. We appreciate the support, understanding, help, and encouragement.

Some other expert's literatures and protocols were referred to proof and explain our production, all of us wish to express our appreciation to the craft brothers.

Since science and technology developing rapidly, and different conditions in different areas, our technology system would still be have some problems. Please do not hesitate to contact us when you have any question about our production.

Authors

Dec, 2005

20世纪80年代试验基地设在渭北东部的澄城县，西部的乾县和原西北农业大学试验农场。图为试验农场“渭北旱原抗旱耕作技术研究”试验现场

20世纪90年代试验基地设在黄土台原西部的乾县。图为“旱作农田自然降水高效利用”旱地冬小麦试验示范区

1996年参加乾县试验区“八五”专题鉴定会的专家组在试验区旱地小麦降水高效利用试验田现场考察