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Adaptation of Chickpea in the West Asia and North Africa Region

Edited by

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Note to the Readers

Each of the country chapters in this book has maps on disease and pest incidence on chickpea. In such maps, numbers have been used to identify diseases and letters to identify insect pests. The severity of disease and pest incidence is depicted through colors (e.g., blue for low; green for medium; and red for high).

Chickpea diseases

1 = Ascochyta blight (*Ascochyta rabiei*)
2 = Fusarium wilt (*Fusarium oxysporum*)
3 = Dry root rot (*Rhizoctonia bataticola*)/wet root rot (*R. solani*)/black root rot (*F. solani*)
4 = Stunt (bean leaf roll virus)
5 = Rust (*Uromyces ciceris-arietini*)
6 = Stem rot (*Sclerotinia sclerotiorum*)
7 = Collar rot (*Sclerotium rolfsii*)
8 = Phoma blight (*Phoma medicaginis*)
9 = Powdery mildew (*Oidiopsis taurica*)
10 = Nematode diseases
11 = Necrosis of foliage (necrotic yellows virus)

Chickpea insect pests

a = Pod borers (*Helicoverpa armigera, Heliothis virescens*)
b = Leafminer (*Liriomyza cicerina*)
c = Aphid (*Aphis craccivora*)
d = Cutworm (*Agrotis ipsilon*)
e = Armyworm (*Spodoptera exigua*)
f = Mole cricket (*Gryllotalpa africana*)
g = Bruchids (*Callosobruchus* spp)

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Abstract

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This book is a result of a workshop held at ICARDA, Aleppo, Syria in Nov 1992, organized jointly by ICARDA and ICRISAT, in which researchers from 11 important chickpea-growing countries in West Asia and North Africa (WANA) participated. The book outlines the mandates of ICARDA in the WANA region, and ICRISAT in the semi-arid tropics (SAT) as they relate to chickpea improvement. The current status of chickpea production, and constraints and opportunities in WANA countries are discussed using maps developed on a geographic information system. Regional overviews summarize current knowledge on chickpea in West Asia, North Africa, and the Nile Valley countries, and overviews of biotic, abiotic, and socioeconomic constraints integrate this information across WANA and SAT. The final chapter is an overall synthesis, with suggested priorities and future areas of research to enhance and stabilize chickpea yield.

Résumé

L'adaptation du pois chiche dans la région de l'Asie occidentale et l'Afrique septentrionale. Cette publication est le fruit d'un atelier organisé conjointement par l'ICARDA et l'ICRISAT au Centre ICARDA, à Aleppo, en Syrie en novembre 1992. Des chercheurs provenant des 11 pays importants de culture du pois chiche de la région de l'Asie occidentale et l'Afrique septentrionale (WANA) y ont assisté. Après avoir rappelé le mandat de l'ICARDA (dans la région WANA) et celui de l'ICRISAT (dans les tropiques semi-arides) en ce qui concerne l'amélioration du pois chiche, on examine dans cet ouvrage les connaissances actuelles ainsi que les contraintes et les possibilités de cette culture dans les pays WANA en utilisant des cartes mises au point par un système d'information géographique.

Des synthèses régionales font le point sur le pois chiche en Asie occidentale, en Afrique septentrionale et la Vallée du Nil, et des synthèses sur les contraintes biotiques, abiotiques et socio-économiques traitent de ces problèmes à travers les régions WANA et SAT. Le dernier chapitre présente une vue d'ensemble. Des recommandations sur les priorités actuelles et sur des domaines de recherche futurs y sont égalememt proposées afin d'accroître et de stabiliser la productivité du pois chiche.

الملخص

إن هذا الكتاب هو ثمرة ورشة عمل عقدت في إيكاردا، حلب، سورية في تشرين الثاني/نوفمبر ١٩٩٢، وشاركت في تنظيمها كل من إيكاردا وإكريسات. وقد شارك في تلك الورشة باحثون من أحد عشر بلداً هاماً في زراعة الحمص في غربي آسيا وشمالي إفريقيا (وانا). ويعرض الكتاب المهام المنوطة بإيكاردا في منطقة وانا، وتلك المنوطة بإكريسات في المناطق شبه المدارية (سات) من حيث العمل على تحسين الحمص، كما يبحث الوضع الحالي لإنتاج الحمص والمعوقات التي تعترضه في بلدان وانا والفرص المتاحة له، وذلك باستخدام خرائط وضعت بموجب نظام المعلومات الجغرافية. وتلخص وجهات النظر الإقليمية المعلومات الجارية حول الحمص في غربي آسيا وشمالي إفريقيا وبلدان وادي النيل، والآراء المتعلقة بالمعوقات الأحيائية واللا أحيائية والاجتماعية – الاقتصادية في تكامل هذه المعلومات عبر منطقتي وانا وسات. ويقدم الفصل الأخير تلخيصاً شاملاً مع عرض الأولويات المقترحة ومجالات البحوث المستقبلية لزيادة غلة الحمص والعمل على استقرارها.

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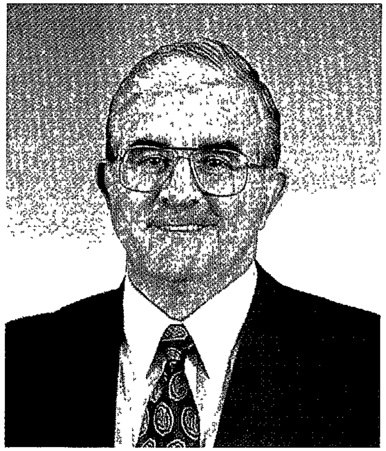

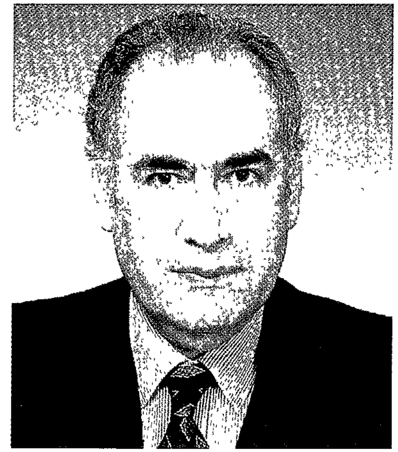

Preface

This book is an outstanding example of inter-Center collaboration; it is therefore a pleasure for us to write this joint preface on behalf of ICRISAT and ICARDA—the two CGIAR centers that share responsibility for international chickpea research.

The book 'Adaptation of chickpea in the West Asia and North Africa region' is the result of a collaborative project that brought together scientists from ICRISAT, ICARDA, and 11 important chickpea-growing countries in the West Asia and North Africa (WANA) region. The aim of the project was to analyze constraints to chickpea production in WANA and other regions, identify common problems, and discuss possible solutions in order to achieve sustainable increases in chickpea productivity. The project helped to evolve an effective synthesis of research challenges and opportunities through a closer integration of regional and global activities. The aim was to maximize spillover of knowledge and technology options amongst researchers working in different agroecologies where chickpea is an important crop.

The scope of the book is broad, since it focuses on national and ecoregional problems, placing them in a global perspective. Thematic priorities have been clearly articulated and can be used to guide future research on chickpea. It is a valuable document for both researchers and research managers in the evaluation of research project proposals on chickpea and the allocation of research resources.

James G Ryan
Director General, ICRISAT

Adel El-Beltagy
Director General, ICARDA

Foreword (ICRISAT)

The Chickpea in WANA Project has the important task of documenting and understanding the adaptation of chickpea to the WANA environment. It is fitting that the two international institutes most concerned with chickpea improvement—ICRISAT with a global mandate, and ICARDA with a regional mandate—should come together with the national agricultural research programs of the WANA countries to collate data on chickpea production and to identify constraints.

We are all aware of the importance of chickpea as a food legume for the people of WANA and of the semi-arid tropics. There is increasing appreciation of the importance of legume crops in conferring sustainability on cropping systems. Chickpea is particularly important, because of its high nitrogen-fixing capacity and its ability to acidify its rhizosphere. It is also more efficient than other crops in mobilizing native soil phosphorus. Basic aspects of phosphorus utilization efficiency are being investigated at ICRISAT Asia Center, Patancheru, India, under a special collaborative project with the Tropical Agricultural Research Center, Japan, and it is hoped that the insights gained will lead to the development of chickpeas with even greater abilities to utilize phosphorus and other nutrients.

Although we have had some success in our research on improvement of chickpea production, a lot remains to be done, especially as the global production and yield of chickpea have not changed very much in recent years. It is therefore timely to compare closely the major production constraints of WANA with those of SAT and efforts made by scientists to alleviate them. This publication offers a unique opportunity to do this and should help to prioritize better—on a global scale—research and development efforts aimed at higher production of chickpea. It also reflects a strong multidisciplinary interaction, both in the national programs and the international agencies.

Recent exercises to develop strategic and medium-term plans for research at ICRISAT have highlighted the importance of having reliable and extensive data on crop production and on biotic, abiotic, and socioeconomic constraints. In evaluating the priorities for research in Asia on our mandate legume crops—chickpea, pigeonpea, and groundnut—we have made good use of the data compiled from a workshop held at ICRISAT Asia Center, Patancheru, India, in Dec 1988 on the 'Agroclimatology of Asian Grain Legumes (Chickpea, Pigeonpea, and Groundnut)'. This 'hands-on' workshop was organized under the auspices of the Asian Grain Legumes Network [now Cereals and Legumes Asia Network (CLAN)]. It was most successful in assembling valuable data, highlighting requirements for further work, and stimulating interest in this field in national programs, in ICRISAT and other international agencies.

In the workshop at ICRISAT, the necessary cartographic work carried out by Dr Virmani and his colleagues was strenuous and expensive as maps were hand drawn. The situation has been greatly improved since then with the adoption and development of Geographic Information Systems (GIS) which facilitate production of maps and permit more effective and reliable correlation of production data with environmental factors. The present publication has benefitted immensely from these developments.

I would like to acknowledge here the role of Dr N P Saxena, in the planning and execution of this Project as part of his sabbatic at ICARDA. I hope this publication will provide the foundation for continued international cooperative research to provide solutions to serious constraints to chickpea production in the WANA region.

D McDonald

Former Director, Crop Protection Division, ICRISAT

Foreword (ICARDA)

ICARDA has always had a strong agroecological research focus, in line with the present concern of the Consultative Group on International Agricultural Research (CGIAR) system for effective management and conservation of natural resources for sustainable production.

The climate in ICARDA's mandate region is mainly Mediterranean, with rainfall in winter followed by a dry, hot, and long summer. Rainfed crops are grown both in winter and spring and are, therefore, subjected to cold during the early growth period and to terminal drought and heat stress towards maturity. In addition, the winter-sown crops are subjected to intermittent drought between the time of emergence and maturity, while the spring-sown crops experience increasing terminal drought.

The geographic mandate area of ICARDA stretches from Morocco to the highlands of Pakistan, and from Turkey to as far as Ethiopia in the south. Although Ethiopia and the Arabian peninsula do not have a Mediterranean type climate, these countries have been included in the ICARDA region because of the common bonds of culture, history, and language that they share. In order to relate the programs and activities of the Center to its mandate region, a simple description of the diverse farming systems in the regions is necessary.

When travelling from the Mediterranean sea towards the Sahara or into the Syrian desert, a gradient of decreasing rainfall is observed. The areas bordering the desert are used as grazing lands for sheep and goats. ICARDA has a small research program to assess the degree of deterioration of soils and vegetation systems due to overgrazing in such marginal zones and to find ways through agronomy and policy research to halt the degradation and stabilize it at its present level, and to increase the productivity of these systems in the long term.

In the areas with 200–300 mm rainfall, barley is the principal crop which is primarily used as a feed for livestock. The barley improvement program of ICARDA emphasizes the enhancement of both straw and grain yield.

Closer to the sea, in areas with rainfall higher than 300 mm, farmers grow wheat and legumes in rotation. Both durum and bread wheats are cultivated and ICARDA has a collaborative program with the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) for the improvement of these crops.

Farming and farming systems have developed in the ICARDA mandate region over many years, probably dating back more than 10 000 years. Although many good examples of farming and farming practices exist here, the Mediterranean region is now the largest food-importing region in the world. Some 30–40 years ago, this region was either self-sufficient or even an exporter of food. High population growth rates in many countries (over 4% per year) and the rising demand for food could not be met by expanding the agricultural area, therefore large food and feed deficits occurred. Moreover, the inadequacy of rainfall and the fragile environments impose a ceiling on the production capacity of this region. ICARDA, therefore, considers that the immediate emphasis of its strategy to increase food and feed production in the region, should be on self-reliance for food rather than on food self-sufficiency, since the latter is out of reach for the foreseeable future. The region should grow crops which are best suited to their agroecology and have an advantage in world trade. The foreign exchange generated in this way could be used for importing food, which perhaps would be much cheaper than some of the indigenous production of the region. The concept of self-reliance for food is increasingly gaining ground, despite the fact that the traditional expectation of food self-sufficiency is very much alive.

The research programs of ICARDA have, therefore, components of both crop improvement and resource management. ICARDA has the global mandate for the CGIAR system for barley and lentil crops, which goes beyond the agroecological mandate of WANA. To discharge these responsibilities, it has posted a barley breeder in CIMMYT, Mexico, to work on the problems of production in high-rainfall zones of China and Latin America. The research on wheat is part of a collaborative program with CIMMYT. Two CIMMYT wheat breeders are posted at ICARDA. Similarly, it collaborates with ICRISAT on the improvement of chickpea, a crop which is very important in the farming systems of WANA. To do such collaborative research effectively, a chickpea breeder is posted by ICRISAT at ICARDA.

Over the years the Center, in close collaboration with CIMMYT and ICRISAT, has made a considerable impact on agricultural production. A study conducted with the Syrian Government showed that the joint efforts of the Syrian National Agricultural Research Program and ICARDA increased the wheat production of the country during 1991/92 by US $240 million, 27% of which was attributed to new varieties. This is only one example of the potential impact of fruitful collaboration between international agricultural research centers (IARCs) and national programs.

The ICRISAT/ICARDA collaboration has resulted in many new varieties and management practices that allow farmers to improve yield and production of chickpea in the WANA region. A good example is the package of technology for winter sowing of chickpea—a practice that increases yield by 50–100%—with components of ascochyta blight disease resistance, cold tolerance, and effective weed control. Characterization of the farming environments is important for targeting and implementing successful and effective breeding, agronomy, and resource conservation programs. Such characterization would eventually lead to the identification of homogeneous recommendation domains and areas for potential expansion of chickpea production.

This book is a follow-up on the one on agroclimatology of Asian grain legumes. It adds a new dimension by targeting the crop commodity and agroecological mandate of the two institutes in a multidisciplinary interaction of crop and economic constraints with association of national agricultural research systems (NARS) from the WANA region and the institutes which share a common interest in the crop and its improvement.

It is hoped that this publication will contribute to the rationalization of future research and facilitate targeting of chickpea improvement and management for enhanced and stable productivity.

A van Schoonhoven
Former Deputy Director General (Research), ICARDA

1. Introduction

1.1. Chickpea in the WANA Region: An Overview

M C Saxena[1]

The WANA region, extending from Pakistan in the east to Morocco in the west, and Turkey in the north to Sudan and Ethiopia in the south, has large variations in agroclimatic conditions based on elevation and proximity to the sea. However, a common feature throughout the region is that much of its agriculture is rainfed. The region has a Mediterranean type of climate, with rainfall in winter. Cereals dominate the cropping system, and are grown in rotation with various food or feed legumes or fallow, depending upon the amount of annual precipitation.

In this region, chickpea (*Cicer arietinum*) is an important food legume because the crop originated and was first domesticated here and its cultivation and usage have evolved with human civilization. Both desi and kabuli type chickpeas are grown in WANA; however, there is a predominance of kabuli types in all the countries except Ethiopia, Iran, and Pakistan, where desi types dominate. Excluding Pakistan, kabuli chickpea accounts for nearly 90% of the total chickpea production in WANA, in contrast to the Indian subcontinent where kabuli chickpea accounts for less than 10% of the total chickpea production. Another interesting feature of rainfed chickpea production in the region is that the crop is generally sown at the onset of spring. The crop grows on the moisture conserved in the soil from rains received during winter, in contrast to the other cool-season food legumes that are sown in winter and can thus benefit from rains received during their growth. Chickpea accounts for nearly 45% of the total area and nearly 40% of the total production of the cool-season food legumes grown in WANA.

Although most of the chickpea crops in the region are grown as sole crops, they are also occasionally grown intercropped in olive plantations and vineyards, particularly in the early phases of establishment of these plantations. In parts of Sudan and Ethiopia, the crop is also grown with sorghum. Near cities, farmers grow small areas with an early crop to cater to the market for green seeds.

Importance of Chickpea in WANA

The Mediterranean origin of the crop imparts special significance to chickpea in the culture and agriculture of the Mediterranean basin, where it has multiple functions in the traditional farming systems.

Being a source of high quality protein, chickpea enriches the cereal-based diet of the people and improves their nutritional balance. The importance of kabuli chickpeas in the human diet in WANA is seen from the wide range of chickpea-based snacks and food preparations that are prevalent throughout the region (Saxena 1987b). Sandwiches made by stuffing flat bread with *Falafel* (chickpea balls) or *Homos* (chickpea paste) are popular as breakfast or quick luncheon foods. Seed appearance and size are important for a wide range of popular dishes in WANA. These traits affect the price of chickpea in the market, where as many as seven different grades may be available, based on seed size. Soaked kabuli chickpeas are also sold in North African markets, where they are used in local dishes. The most important quality traits for any improved chickpea cultivar in this region are the ability to swell after soaking and maintain its bright white color.

Chickpea is a very important component of cropping systems of the dry, rainfed areas of WANA, because it can fix 80–120 kg N per ha through symbiotic nitrogen fixation, thus increasing the input of combined nitrogen into the production system and reducing the depletion

1. Germplasm Program, ICARDA, PO Box 5466, Aleppo, Syria.

of soil nitrogen in comparison to continuous cereals (Papastylanou 1987; Saxena 1988). The crop is rotated with wheat in areas receiving more than 400 mm seasonal rainfall. In North Africa, chickpea is sometimes grown as a partial replacement of fallow in rotation with cereals. This is done by sowing chickpea in rows 1.5 to 3 m apart, which permits intercultivation with a tractor to control weeds. Such a system provides some of the advantages of fallow such as conservation of soil moisture, weed control, and mineralization of organic matter for the benefit of a subsequent wheat crop.

Chickpea Distribution in WANA

According to FAO production statistics, chickpeas were grown, on an average, on 2.076 million ha in WANA between 1981 and 1990 with a mean production of 1.396 million t (Table 1.1.1). Thus WANA accounted for nearly 21% of the total area and production of chickpea in the world. Within WANA, the Near East accounts for 84.5% of the total chickpea area and 83.3% production, North Africa 8% area and 7.3% production, and the Nile Valley 7.5% area and 9.4% production.

With more than 50% of the total chickpea area for WANA, Pakistan dominates in the region, followed by Turkey, Ethiopia, Iran, Morocco, Syria, Algeria, and Tunisia. The order is generally the same for production, except for Turkey which comes first followed by Pakistan; and Tunisia produces more chickpea than Algeria. Turkey dominates in chickpea production and trade because of its high yield, which exceeds the world average.

The mean productivity of chickpea is higher in the Nile Valley region than in North Africa or the Near East, because in the Nile Valley, chickpea is grown in more favorable moisture conditions. Efforts should be made to increase the overall productivity of the WANA region.

Table 1.1.1. Mean area, production, and yield of chickpea in the WANA region (1981–90).

Region/ Country	Area ('000 ha)	Production ('000 t)	Yield (t ha^{-1})
Near East	1753.1	1163.1	0.66
Cyprus	1.2	1.0	0.80
Iran	89.6	67.1	0.75
Iraq	12.0	8.8	0.73
Jordan	2.0	1.5	0.75
Lebanon	2.5	3.5	1.40
Pakistan	1066.5	510.2	0.48
Syria	66.1	42.5	0.64
Turkey	513.2	528.5	1.03
North Africa	166.4	102.1	0.61
Algeria	51.6	24.5	0.48
Libya	0.6	0.4	0.67
Morocco	66.4	47.0	0.71
Tunisia	47.8	30.2	0.63
Nile Valley	156.3	131.9	0.84
Egypt	8.7	14.3	1.64
Ethiopia	145.4	115.5	0.79
Sudan	2.2	2.1	0.91
WANA	2075.8	1396.1	0.70
World	9796.0	6727.5	0.69

Source: FAO 1990.

Factors Constraining Crop Productivity

In all the countries of WANA, except Pakistan, Egypt, and Sudan, chickpea is traditionally grown as a spring-sown crop, in contrast to India where the crop is grown in winter. The spring-sown crop grows on the moisture conserved in soil from winter rains and, therefore, the total length of the growing season depends on the amount of moisture conserved and on the time of onset of hot weather. Because of this, drought and terminal heat stress are the two most widespread abiotic constraints to the productivity of chickpea in WANA. In continental and plateau areas, cold at vegetative and early reproductive stages can also be an important constraint.

Amongst the major biotic factors constraining the productivity of chickpeas in the region, ascochyta blight (*Ascochyta rabiei*), wilt (*Fusarium oxysporum* and *Verticillium* spp), root and stem rots (*Rhizoctonia* spp, *Sclerotinia sclerotiorum*, etc.,), and stunt virus are the important diseases; root-lesion (*Pratylenchus thornei*), cyst (*Heterodera ciceri*), and root-knot (*Meloidogyne artiellia)* the main nematodes; and leafminers (*Liriomyza cicerina*) and pod borers (*Helicoverpa armigera*) the principal insect pests (Saxena 1990a). Weeds are also a major yield constraint, particularly in the early-sown crop. *Orobanche crenata*, a parasitic weed, can cause substantial yield reductions in winter-sown chickpea in several parts of the region.

The prevalence of, and the magnitude of damage caused by, these abiotic and biotic stress factors vary depending on location, environmental conditions, and cropping systems in which chickpeas are grown in the region. It is necessary to identify the relative importance of each of these factors in different parts of the region so that appropriate control strategies are developed and properly targeted. The joint ICRISAT/ICARDA chickpea improvement project at ICARDA, Syria, is addressing these problems through collaborative research with the national program scientists in the region.

Some Research Achievements

One of the main causes of low yield of chickpea in WANA has been the exposure of the spring-sown rainfed crop to drought. The problem of drought is further aggravated if the plant is attacked by parasitic nematodes and/or by root-rot and wilt diseases. Efforts have been made in the region to alleviate this problem by developing high-yielding, short-duration chickpea cultivars with intrinsic drought tolerance, and resistance to root diseases and pests. Such cultivars have started reaching farmers' fields.

Another approach to reduce the adverse effect of drought on the productivity and yield stability of chickpea in the dry rainfed areas of WANA is to bring about a change in the cropping system itself, advancing the chickpea sowing date from the traditional spring period to winter. Winter sowing of chickpea permits better matching of the reproductive phase of the crop with optimum temperature and moisture regimes than is possible with spring sowing. This can result in a 60–80% increase in yield and water-use efficiency (Saxena 1987a). There is almost a linear increase in yield as the date of sowing is advanced from late spring to early spring, late winter, and early winter. Thus, any degree of advancement of sowing date, permitted by the prevailing agroecological conditions, would be advantageous over the traditional spring sowing. However, the success of this technology depends on the presence of a high level of tolerance for cold and resistance to ascochyta blight in the chickpea cultivars, because the winter-sown crop is more prone to these stresses than the spring-sown crop (Saxena 1990a). Chickpea genotypes adapted to winter sowing in low altitude areas have been released by the national programs in all the major chickpea-producing countries in WANA and there is a progressive increase in chickpea area devoted to winter sowing (Saxena 1990b). To sustain the adoption of this practice, it will be necessary to incorporate such traits as increased seed size, better tolerance for wilt, cyst nematodes, and *Orobanche crenata,* and broad-based resistance to ascochyta blight because of rapid change in the pathotype population of the blight fungus.

Winter-sown chickpea not only gives high yield but also high total biological nitrogen fixation. The crop, being taller, can be easily harvested by available cereal combines with minimal alterations, thus making it economically more remunerative in those areas of the region where increasing labor costs have forced farmers to restrict the area sown to chickpea.

The winter-chickpea technology also offers opportunities for expansion of chickpea production in those parts of WANA where rainfall is not sufficient (< 400 mm) for growing a rainfed spring-sown crop. Since the winter-sown crop utilizes the water received from rain during its growth, the crop can be extended to areas receiving 300–350 mm of seasonal precipitation. The area that can potentially be brought under winter-sowing of chickpea in different parts of WANA would be easily identified from the adaptation analysis carried out for different countries in this book.

Although winter sowing of chickpea offers great potential for expanding chickpea production in WANA, spring-sown chickpea continues to be an important part of the farming system in the region. Future research in the region will, therefore, have to lay increasing emphasis on developing dual-type cultivars, which could be sown any time from early winter to late spring, to facilitate rapid adoption of these improved cultivars by farmers of WANA.

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1.2. Chickpea in WANA Project: Concepts and Approaches

N P Saxena[1]

Introduction

Increasing food production continues to be as high a priority in many national and international agricultural research programs, as in the 1960s and '70s. The task, however, has become more complex because agricultural technologies are now expected to be more profitable, sustainable, and environment-friendly in addition to being highly productive. Achieving this objective in SAT and in the dry areas of WANA is particularly challenging because these environments are poorly endowed for crop production. Also, the majority of farmers of these regions have small holdings, a poor resource base, and practice subsistence farming.

Legumes, in general, are accorded a secondary status; they receive, less funding for research and scientific manpower than cereals. Under these circumstance, greater efforts in prioritizing research activities, formulating well-focused programs, and increasing resource-use efficiency are essential to raise the production of legumes.

It is against this background that the Project 'Adaptation of Chickpea in the WANA Region' was conceived. The purpose was to review the current information on chickpea research and produce a synthesis on the subject. This would help to identify not only technology that could be transferred for enhancing yield, but also future thrust areas for research.

A brief description of the Project is presented here against the background of chickpea status in the WANA and SAT regions.

1. Agronomy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Status of Chickpea in the WANA and SAT Production Systems

Chickpea has characteristic features which enable it to adapt well to low native soil nitrogen (N) and phosphorus (P) conditions, compared with other crops including some legumes. For example, it can fix large amounts of atmospheric N_2, and add N to the cropping system (Rupela and Saxena 1987). The crop is known to be efficient in releasing P from calcareous soils (Ae et al. 1991). It is also particularly suited to dry areas. These factors together perhaps made low-input production systems with chickpea stable and profitable in the past. These systems were also more environment-friendly as low requirements for chemical fertilizer input reduced the scope for accumulation of undesirable residues from fertilizers not utilized by crops. Another aspect, which has not been quantified and is generally common to legumes in crop rotations, is their role in disrupting the cycle of soilborne diseases, insect pests, and nematodes, and recycling of soil nutrients.

However, at present, chickpea is perceived as a highly unstable, risk-prone, and unprofitable crop, because of its susceptibility to foliar disease, pod borers, and drought. Increasing labor costs for field operations have made it unprofitable to grow the crop. These factors have led to a continuously decreasing area and production of the crop in much of the WANA region.

Project Planning and Development

The Project's aim was to make use of the available information on the crop in various national and international chickpea programs. It thus did not require any resource inputs for generating new data. National agricultural research system (NARS) participants were requested to document available information on applied and adaptive research on chickpea for their respective countries. They were asked to highlight problems that required solving or upstream research that would contribute to the expansion of the crop area and its production. Interactions of NARS with a multidisciplinary team of resource scientists from ICARDA and ICRISAT were planned to review the problems and prospects of the crop and to develop integrated crop management strategies.

The 2-year Project culminated in a workshop in Nov 1992. At the workshop, scientists from NARS and the resource team presented papers, which were discussed, reviewed, and revised. This book is a compilation of those papers. Following were the key aspects of the Project:

- Review of literature;
- Framing of objectives;
- Listing of expected outputs or impacts;
- Identification of partners; and
- Implementation of the Project.

Literature Review

Chickpea is a relatively minor food crop on a global basis. It occupies around 0.07% of the world's arable area and 0.14% of the pulse area (FAO 1993). Despite this, many research publications on the crop are available. Chickpea literature published from the WANA countries was searched through bibliographies (e.g., Singh and van der Maesen 1977), and through the AGRICOLA, AGRIS, and CAB International databases. The comprehensive chickpea literature in the 'SATCRIS' database maintained by the ICRISAT Library, was especially useful.

More than 5000 publications on chickpea were available in literature from 1930 to the end of 1992 (Table 1.2.1a). In the last 2 decades, on average, 140 chickpea publications appeared every year. Findings reported in the early part of the century, such as on the acid secretions of chickpea plants (Sahasrebuddhe 1914) and on the morphology and anatomy of the chickpea plant (Holm 1920), continue to be important references even today. It also shows that chickpea has attracted research attention for a long time.

More publications originated from SAT than from WANA (Table 1.2.1b), which is not surprising because of the larger chickpea area in the chickpea-growing countries of the SAT region (FAO 1993). The SATCRIS database listed around 270 publications from the 11 WANA countries involved in this Project. A country-wise break up is given in Table 1.2.2. A literature search, using the AGRICOLA database from 1979 to Sep 1991, showed that chickpea literature covered almost all important crop disciplines (Table 1.2.3), including basic research on cell biology, physiology, and anatomy. Twenty-two publications specifically on drought were found.

Table 1.2.1a. Total number of chickpea publications from different sources.

Year	Number of publications
1930–74[1]	3146
1975–79[2]	704
1979–91[3]	1441
Total	5291

1 Singh and van der Maesen (1977).
2. SATCRIS database, ICRISAT.
3. AGRICOLA database, US National Agricultural Library.

Table 1.2.1b. Chickpea publications according to region.

Year	WANA	SAT
1979–82	1	79
1983–86	30	114
1987 to Sep 1991	25	101
Total	56	294

Source: AGRICOLA database, US National Agricultural Library.

Table 1.2.2. Chickpea publications according to WANA region and countries participating in the Project.

Region/Country	Number of publications
West Asia	141
Iran	7
Iraq	8
Jordan	17
Syria	74
Turkey	35
North Africa	50
Algeria	12
Morocco	22
Tunisia	16
Nile Valley	82
Egypt	30
Ethiopia	39
Sudan	13
Total	273

Source: SATCRIS database, ICRISAT.

Table 1.2.3. Chickpea publications according to discipline.

Discipline	Number of publications
Physiology	380
Breeding	355
Pathology	270
Agronomy	228
Entomology	106
Cell biology	30
Drought	22
Economics and marketing	10
Microbiology	2

Source: AGRICOLA database, US National Agricultural Library.

Objectives

The objectives of the Project were to:

- Document the current knowledge and understanding of chickpea cultivation, and map the production constraints of the crop in WANA, at national, regional, and global scales.
- Identify potential areas for chickpea expansion and the lacunae in our knowledge of the crop.
- Formulate and recommend short- and long-term research strategies for sustainable increases in chickpea production.

Expected Outputs

The major focus of the Project was to prepare the Project document that would synthesize present knowledge of chickpea cultivation, document progress made in research, and quantify constraints across national, regional, and agroecological boundaries. We also aimed to present and discuss technologies or methodologies that could be more widely applicable across regions.

This book is aimed as a reference for determining research priorities and resource allocation, particularly for the WANA countries. For research workers and administrators, it may be useful for developing and seeking support for selective and well-focused research projects on chickpea, both in basic and applied areas, and in decision-making.

Identification of Partners

The Project involved the participation of ICARDA, ICRISAT, and NARS. Eleven out of 23 WANA countries were identified on the basis of relative importance of chickpea (area and production) (FAO 1990). ICARDA (with an agroecological mandate for WANA and a regional mandate for kabuli chickpea), ICRISAT (with a global mandate for chickpea), and scientists of 11 chickpea-growing countries in WANA agreed to participate in this collaborative Project.

Project Implementation

A network of multidisciplinary teams of scientists was organized, and a draft of the Project proposal prepared by the coordinator was discussed and reviewed by a multidisciplinary team of resource persons from ICRISAT and ICARDA. It was recognized that identifying and retrieving required databases and maps with the help of NARS would be a major task.

A revised Project proposal was then circulated to the NARS collaborators, seeking their suggestions and inviting them to participate in the Project. Positive responses from scientists of all the 11 WANA countries were received. Formats were then circulated to them for assembling and providing data on chickpea area, production, and occurrence of abiotic and biotic stresses, and a list of various maps required. Most of the maps were identified from published sources, and those not available were prepared by NARS participants.

A mid-term review of progress of work was undertaken at an informal session convened during the Second International Food Legumes Conference, 5–13 Apr 1992, Cairo, Egypt as NARS participants from all the 11 WANA countries and the regional coordinators of ICARDA were attending. Outputs of literature searches on chickpea, photocopies of most of the relevant papers, and maps considered useful in preparing the country case studies were circulated to NARS participants. A sample report 'Chickpea in Syria' based on the format proposed by the Project was also distributed. The Project was structured around country case studies. These were presented at the workshop in three sessions:

- West Asia (Iran, Iraq, Jordan, Syria, and Turkey);
- North Africa (Algeria, Morocco, and Tunisia); and
- Nile Valley (Egypt, Ethiopia, and Sudan).

The chairpersons and rapporteurs of each session were identified and informed in advance of the need to prepare a regional synthesis and present it at the plenary session of the workshop and were given copies of the country case studies beforehand.

An overview of biotic, abiotic, and socioeconomic constraints to production was done through a critical review of the information presented in various country case studies and the knowledge and experience of the authors on the subject. The authors of the overview papers were members of a multidisciplinary resource team of scientists drawn from ICARDA and ICRISAT. Literature search outputs on chickpea, and the country case studies were provided to the authors of the overview papers. They were requested to suggest future thrust areas of research in their areas of specialization.

An overall synthesis of constraints and opportunities for increasing chickpea production in the WANA region was prepared by the editorial team. This is included here as Chapter 6.

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1.3. Geographical Information System: Its Use and Relevance in Adaptation of Crops in Varied Agroenvironments

S M Virmani[1]

Introduction

The adaptation of a crop or its cultivar and the associated production techniques are the resultant of an interplay of biological (genetic), physical (soil, climate), and environmental (management, socio-economic) factors. According to Byth and Mungomery (1981), the term adaptation has been applied to both a process and a condition. On one hand, it is used to refer to the actions or processes that keep on changing to suit new circumstances. On the other hand it may be used to refer to the state or condition of "adaptedness", i.e., to the performance of a genetic population in an environment or a range of environments. They concluded that both these aspects influence the degree of adaptedness, and that it is generally difficult to distinguish one from the other.

The central interest of this discussion is the agricultural adaptation of chickpea in the WANA region. In this study, the performance of the crop, will be assessed in terms of the physical environment to understand the causes of differences in response to biotic and abiotic factors.

The aim is to predict the outer limits of the physical environment in some well-defined terms, and compare and contrast the adaptation zones across varied "agroenvironments" within the WANA region.

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The GIS Approach

Geographical Information System (GIS) is a computer-based tool which allows overlaying of geocoordinated maps so as to relate the current intensity of the distribution of the crop and its yield to the physical environment. It is assumed that within- and across-location adaptability reflects the response to a continuum of interactions between physical, biological, and management-related environmental parameters. The software used in this study is PC ARC-INFO version 3.3 (ESRI 1990). This approach would help in understanding fully the factors underlying the differences in performance of the crop across "environments" in the WANA region. An example of this type of study for chickpea in Myanmar, a participating country in the ICRISAT-coordinated Cereals and Legumes Asia Network (CLAN), is given in order to explain the significance of GIS as a tool and to apply it to the WANA region.

Myanmar, a Case Study

Myanmar is located between 11–28° N and 93–99° E. The administrative boundaries of the country are shown in Figure 1.3.1. Chickpea, pigeonpea, and groundnut are important crops in Myanmar.

Crop Distribution in Relation to Agroclimatic Factors

Myanmar's diversity of climate and parent rocks have given the country a wide range of soils, but only Fluvisols, Luvisols, and Aerisols are agriculturally important. Fifteen agroclimatic zones are recognized. These are derived by combining five major soil zones, identified as S1 to S5 (Fig. 1.3.2), with three rainfall regimes, high, moderate, and low, identified as zones R3 to R5 (Fig. 1.3.3).

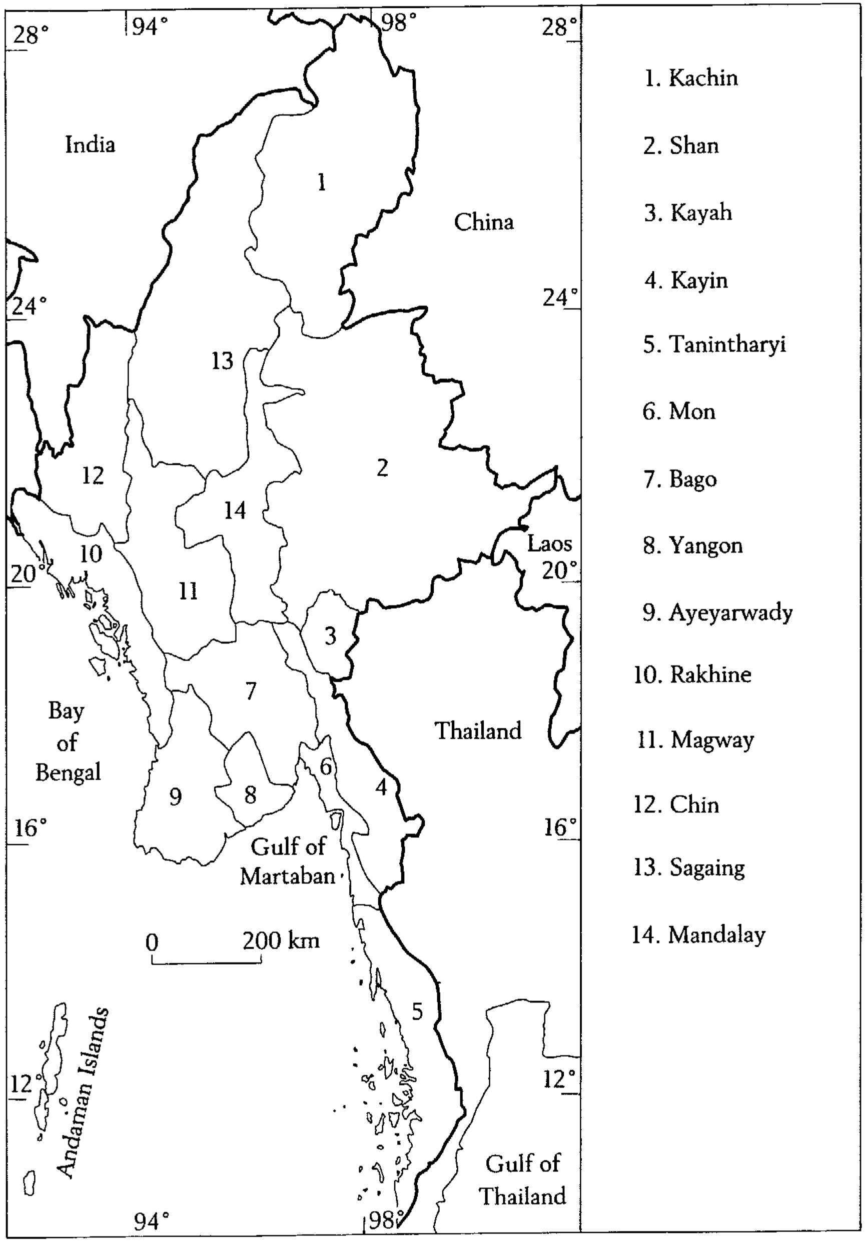

Figure 1.3.1. Administrative boundaries of Myanmar.

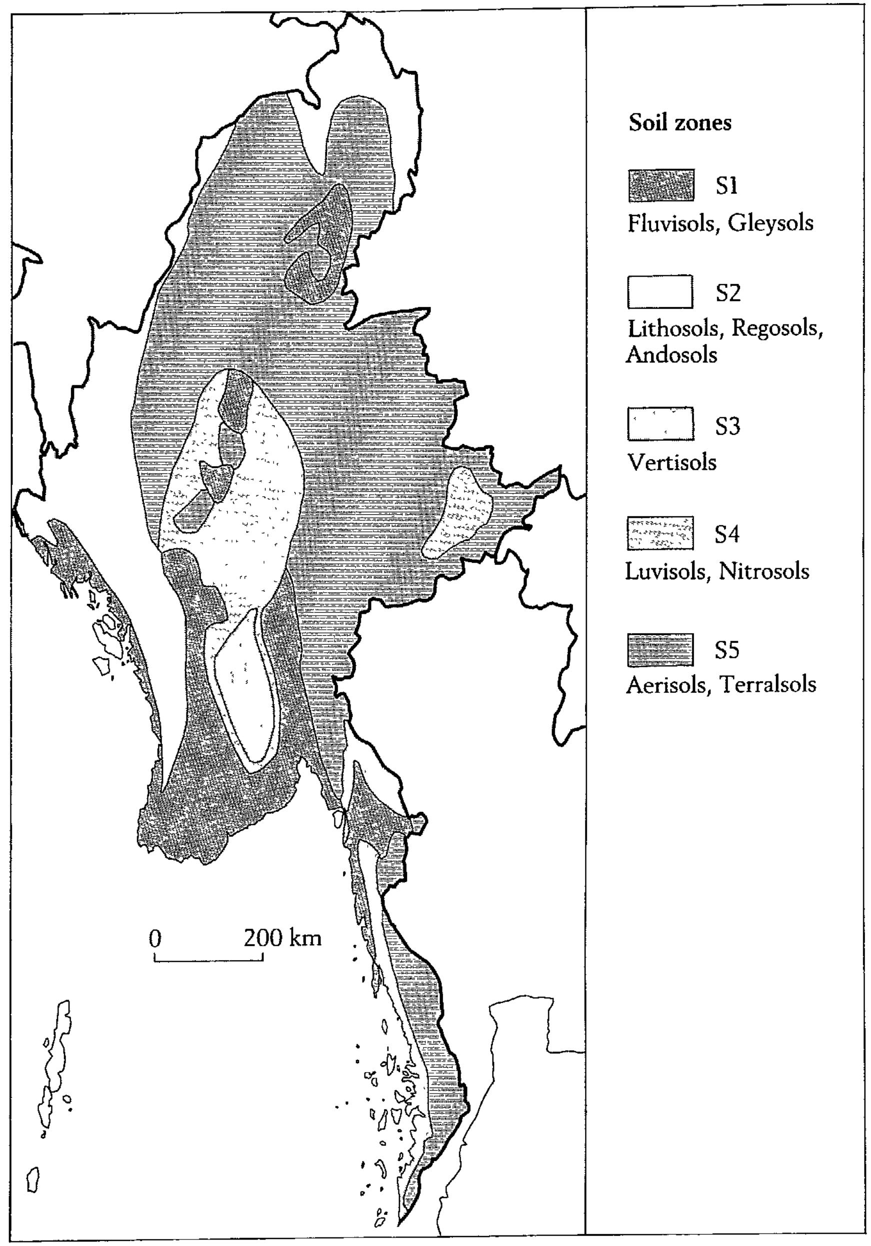

Figure 1.3.2. Major soil zones of Myanmar.

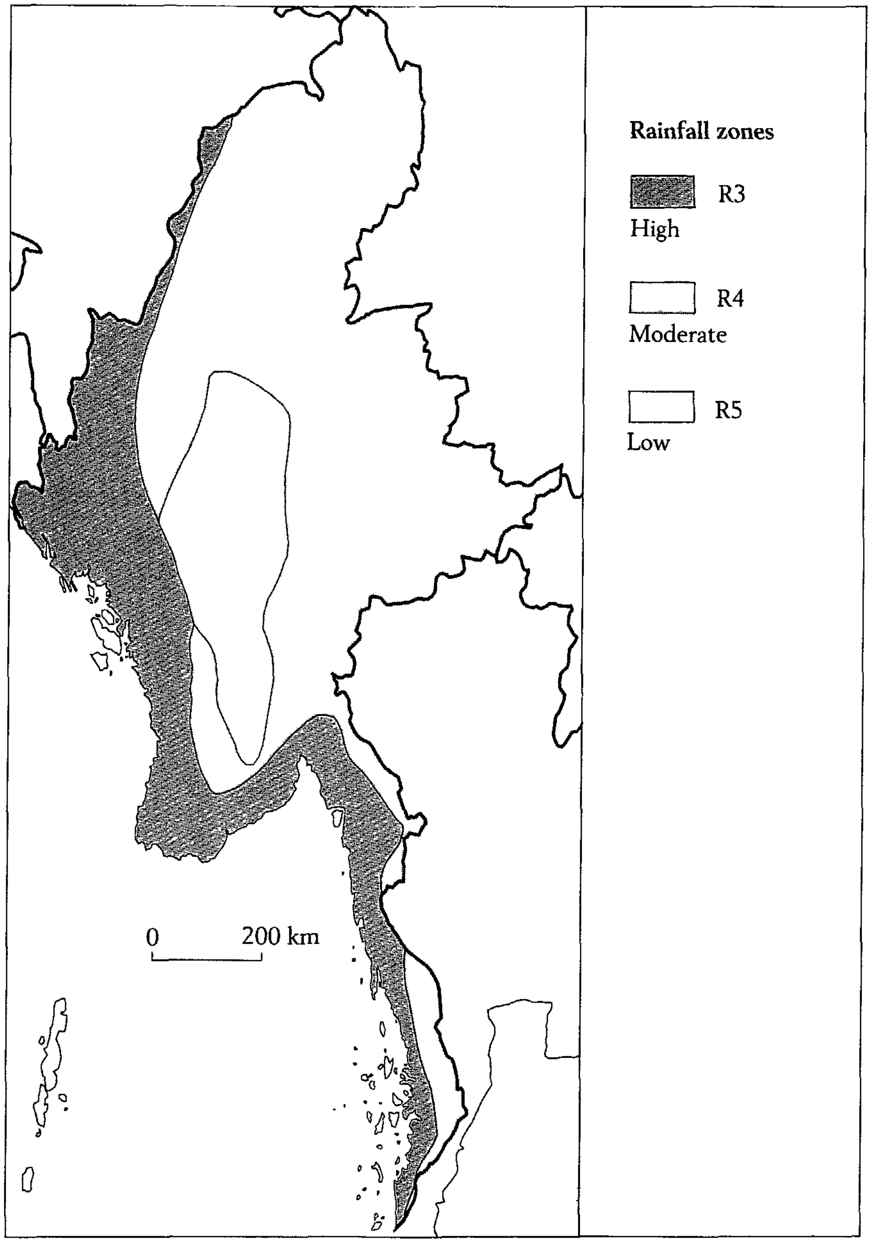

Figure 1.3.3. Major rainfall zones in Myanmar.

Chickpea, grown on 195 145 ha, occupies 31% of the total area under pulses in Myanmar, and is mainly produced in the Sagaing, Bago, Mandalay, Magway, and Ayeyarwady divisions (Fig. 1.3.4). It is chiefly grown as a relay or sequential crop after rice in the lowlands. In the uplands, it is grown mostly on soils with a good water-holding capacity, after an early, short-duration crop of maize or pulses, or after fallow, and is sometimes intercropped with wheat. On the banks of the Ayeyarwady River in the delta area, chickpea is also grown after flood waters recede.

During 1987/88, chickpea production was 163 960 t (Table 1.3.1), with an average yield of 0.75 t ha^{-1}. Chickpea in Myanmar is cultivated in winter and the crop matures in 100–110 days.

Table 1.3.1. Chickpea area, production, and yield in Myanmar, 1987/88.

State/Division	Area ('000 ha)	Production ('000 t)	Average yield ($t\ ha^{-1}$)
Sagaing	72.32	55.54	0.76
Bago	44.39	48.77	1.09
Mandalay	36.33	29.21	0.80
Magway	34.98	25.82	0.73
Ayeyarwady	6.31	4.02	0.63
Shan	0.68	0.52	0.76
Yangon	0.08	0.05	0.62
Kayah	0.05	0.03	0.60
Total	195.14	163.96	0.75

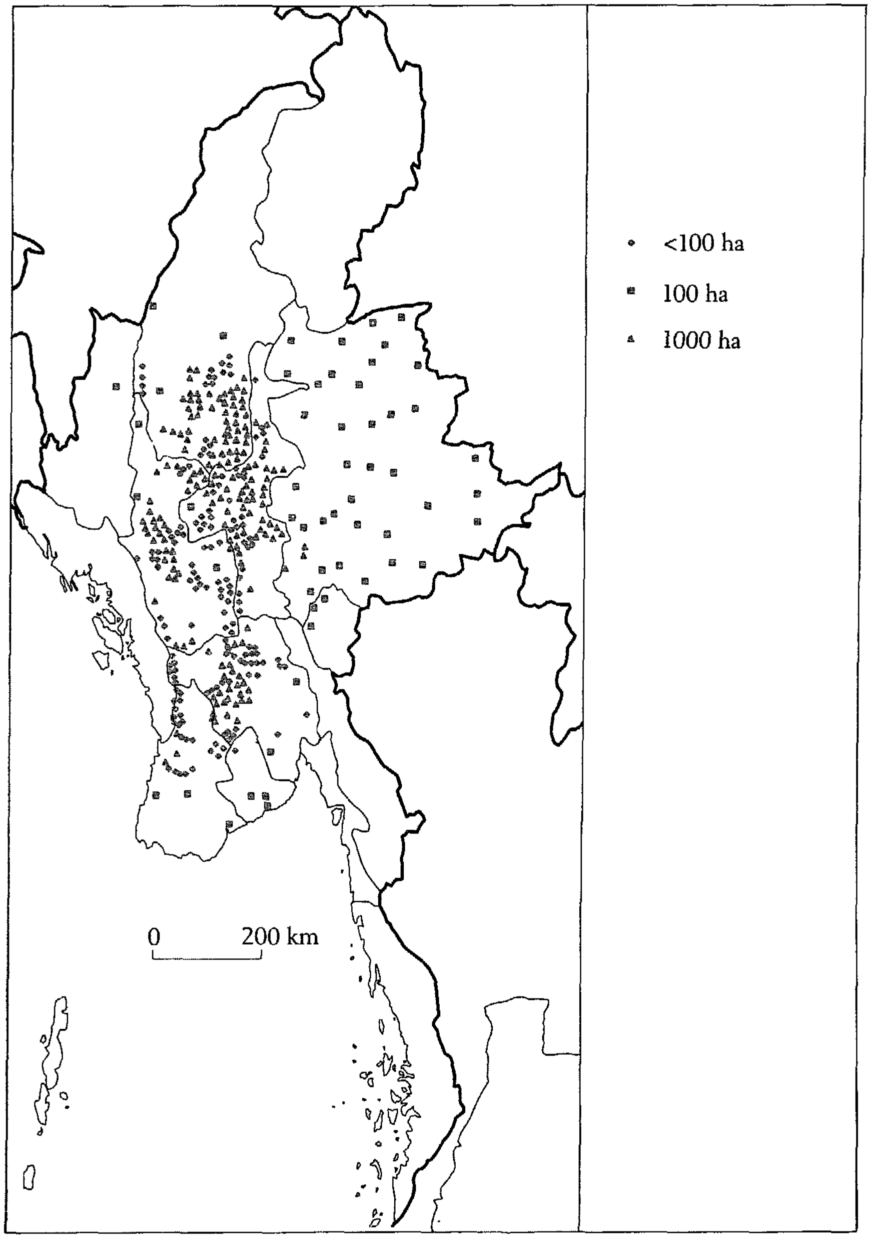

Figure 1.3.4. Chickpea distribution in Myanmar.

Major Stress Factors

The major abiotic stress is drought in the agroclimatic zone R5 S4, where rainfall is low. The soils in the zone are Luvisols and chickpea is grown under conditions of receding soil moisture. The length of the growing period here varies from less than 120 days to 180 days (Fig. 1.3.5).

Fusarium wilt (*Fusarium oxysporum*) (Fig. 1.3.6) and root rot (*Rhizoctonia solani*) diseases are moderately important in Mandalay division, and marginally important in Sagaing, Bago, and Magway divisions. Pod borer (*Helicoverpa armigera*) is the most important pest of chickpea (Fig. 1.3.7) in Myanmar.

Future Prospects

There is considerable scope for expanding the production of chickpea in Myanmar. Farmers could profitably diversify by including legumes to a greater extent in several of the country's cereal-based cropping systems. Chickpea cultivation could be expanded in agroclimatic zones R3 S2 and R4 S2, and also in lower Myanmar, provided varieties tolerant of high temperatures and acid soils become available (Fig. 1.3.8).

Conclusions

The study of the adaptation of chickpea in WANA countries will follow the general outline of the exemplified multidisciplinary analysis for Myanmar. Two main thrusts will be followed. First the development of the GIS methodology as a tool for adaptation studies, and second the identification of factors influencing adaptation, and biotic and abiotic stresses. The intention is to integrate the environmental factors contributing to differences in adaptation of a crop in a given region.

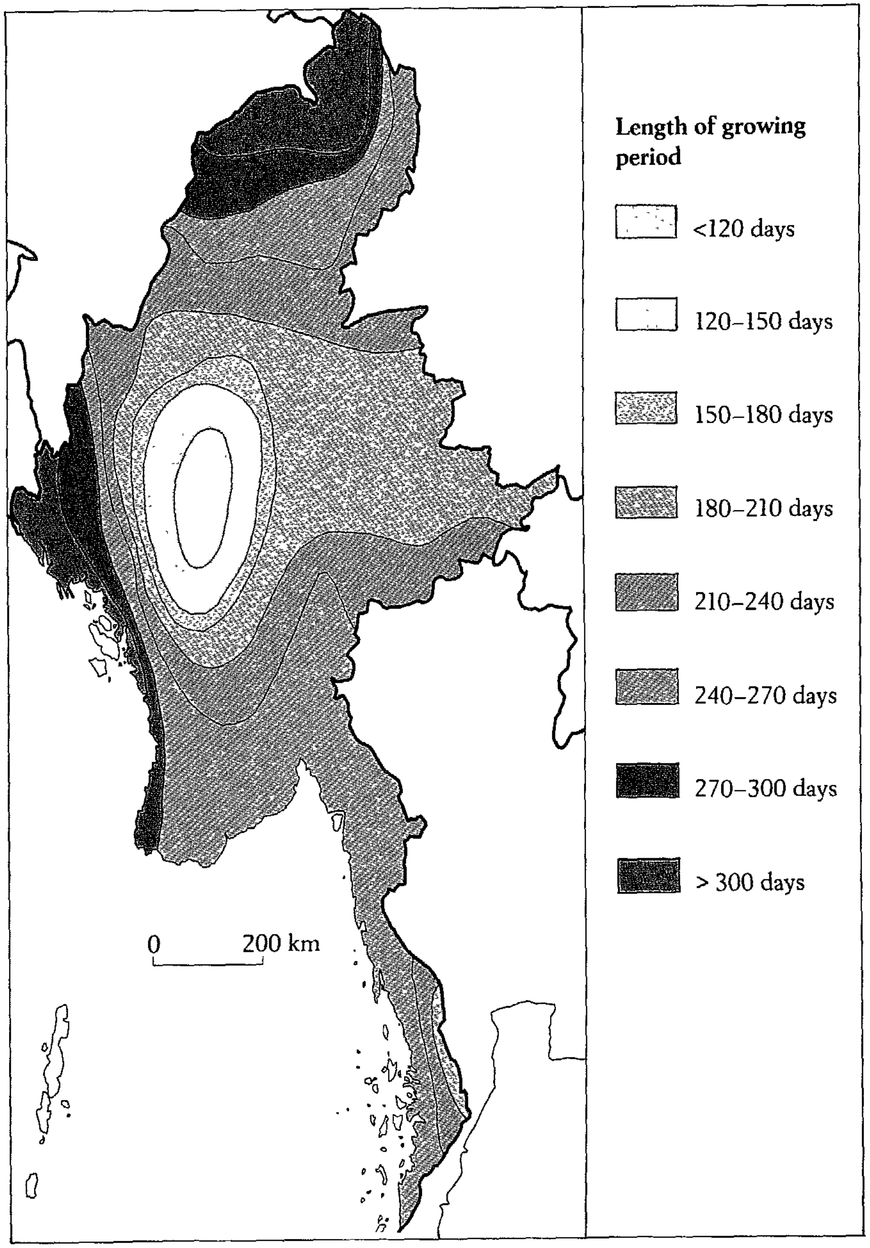

Figure 1.3.5. Length of the growing period in Myanmar.

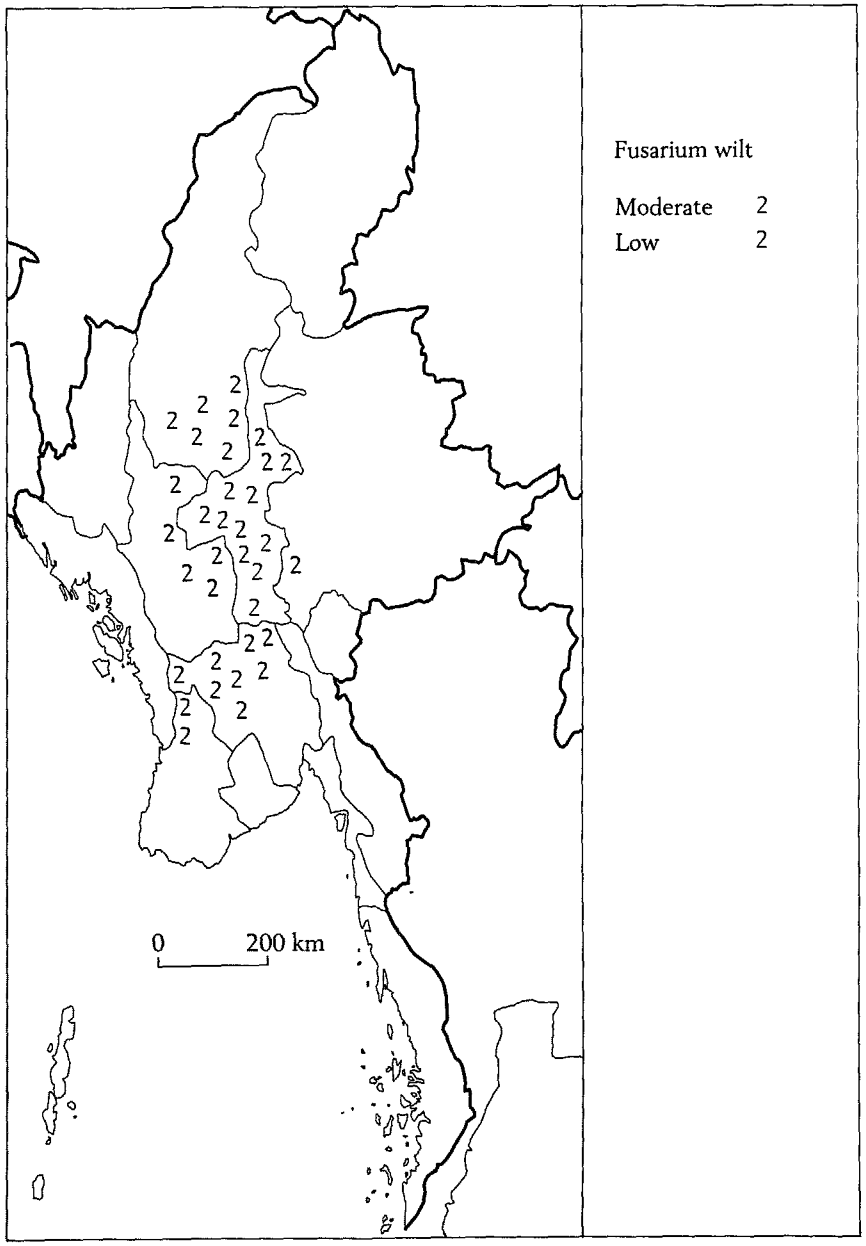

Figure 1.3.6. Disease incidence on chickpea in Myanmar.

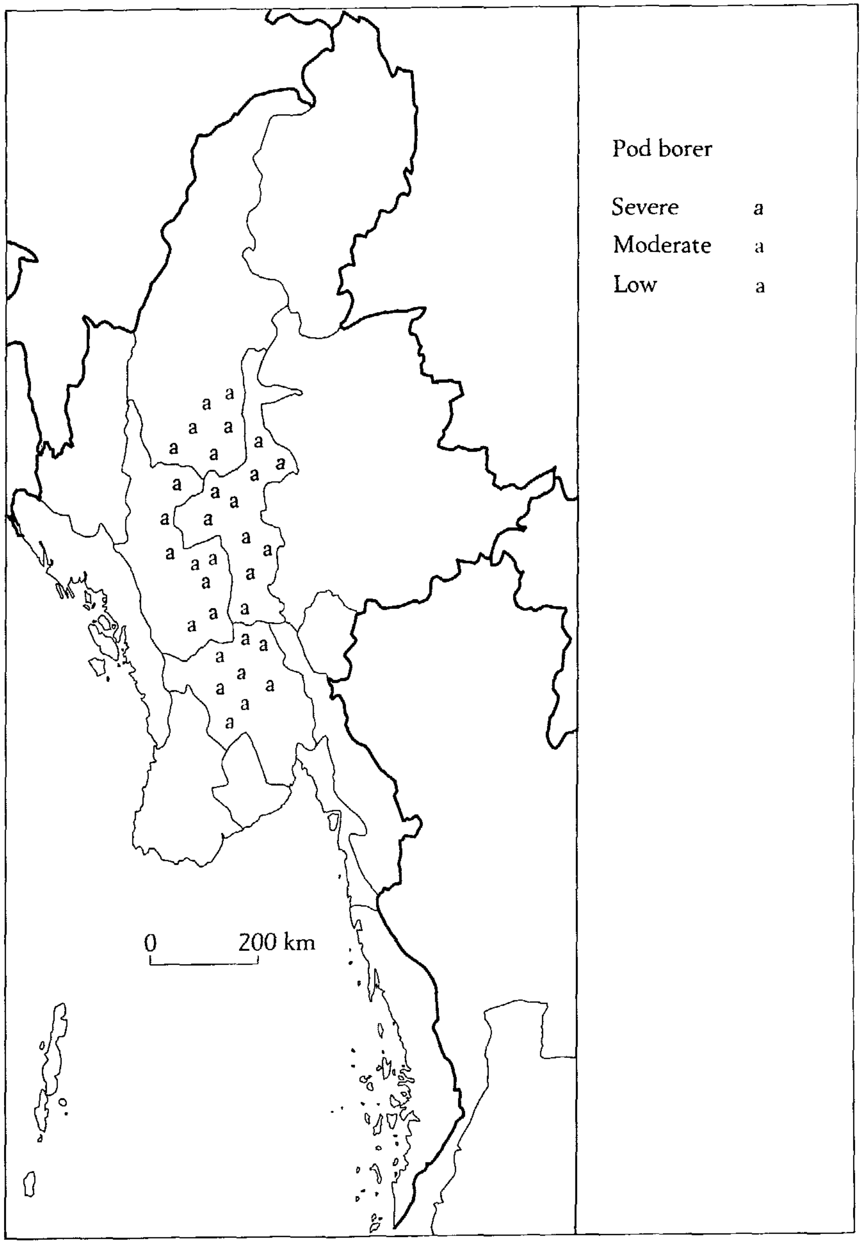

Figure 1.3.7. Incidence of pod borer, the most important pest of chickpea in Myanmar.

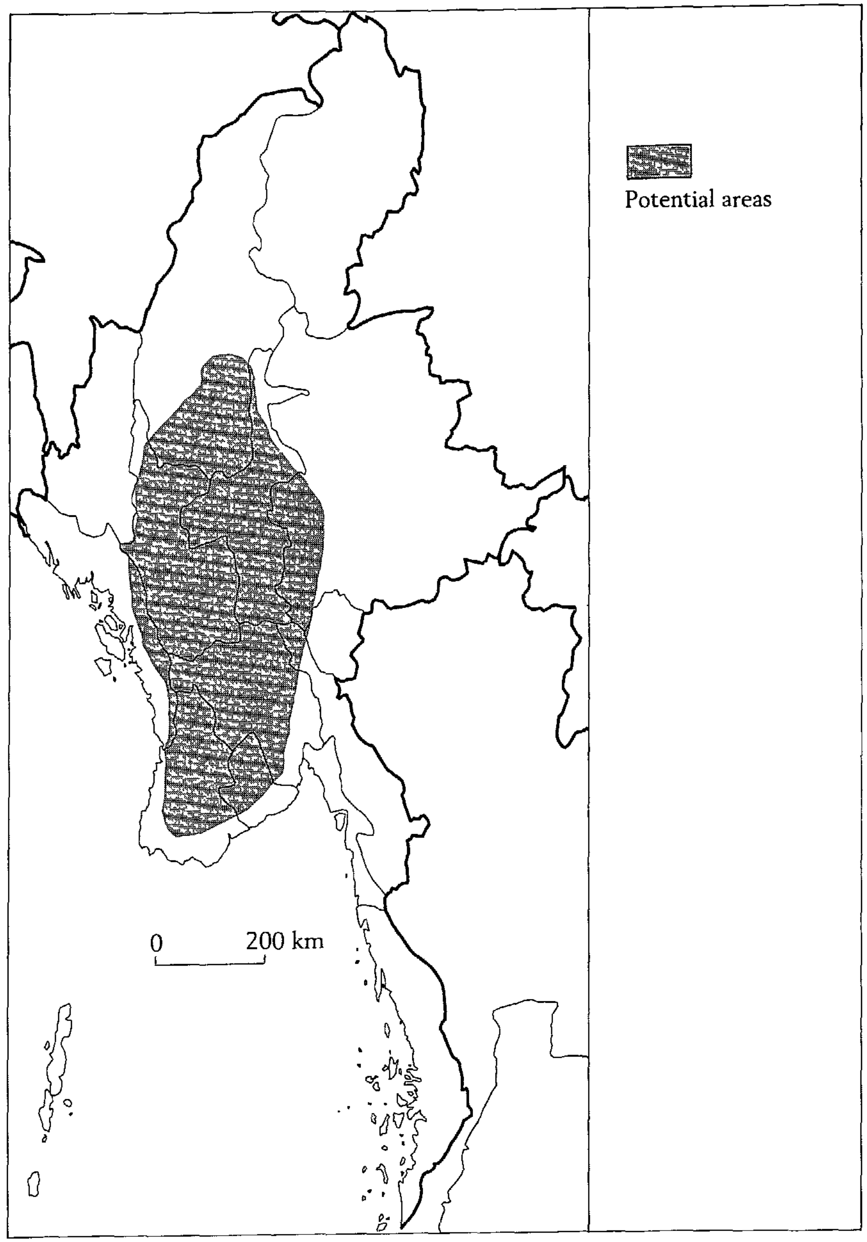

Figure 1.3.8. Potential areas for expansion and/or intensification of chickpea cultivation in Myanmar.

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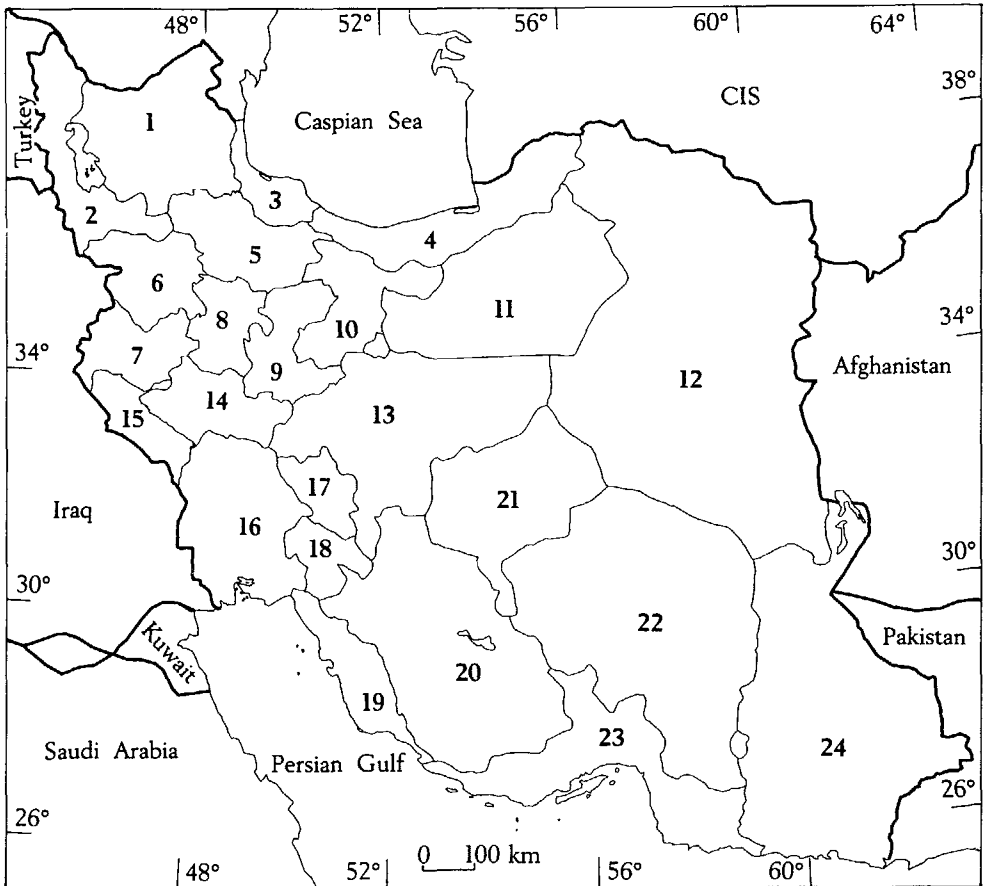
2. Country Case Studies—West Asia



1. East Azerbaijan
2. West Azerbaijan
3. Gilan
4. Mazandaran
5. Zanjan
6. Kordestan
7. Bakhtaran (Kermanshah)
8. Hamadan
9. Markazi
10. Tehran
11. Semnan
12. Khorasan
13. Esfahan
14. Lorestan
15. Ilam
16. Khuzestan
17. Chahar Mahall and Bakhtiari
18. Bovir Ahmadi and Kohkiluyeh
19. Bushehr
20. Fars
21. Yazd
22. Kerman
23. Hormozgan
24. Sistan and Baluchistan

Figure 2.1.1. Administrative boundaries of Iran.

2.1. Chickpea in Iran

B Sadri and T Banai[1]

Latitude	25–40° N
Longitude	44–63° E
Altitude	0–4500 m
Total population	63.2 million
Economically active	17.0 million
Economically active in agriculture	4.3 million
Total area	164.8 million ha
Cultivated area	15.3 million ha
Rainfed area	9.5 million ha
Annual rainfall	200–2000 mm
Chickpea rank among legumes	First
Crop season	Spring (traditional) Winter (recent)

Introduction

Food legumes including chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), dry beans (*Phaseolus vulgaris*), mung bean (*Vigna radiata*), cowpea (*Vigna unguiculata*), and faba bean (*Vicia faba*) occupy 0.61 million ha (Anonymous 1991), i.e, 4% of the country's cultivated area. Chickpea in Iran accounts for nearly 1.3% of the world chickpea area and 1.4% of the world production (FAO 1991). It is the most important legume of the country and is grown on more than 50% of the total legume area. The administrative boundaries of Iran are shown in Figure 2.1.1. and the distribution of rainfed and irrigated chickpea in Figure 2.1.2.

1. Food Legume Research Department, Seed and Plant Improvement Institute, Ministry of Agriculture, Mard-Abad Avenue, Karaj, Iran

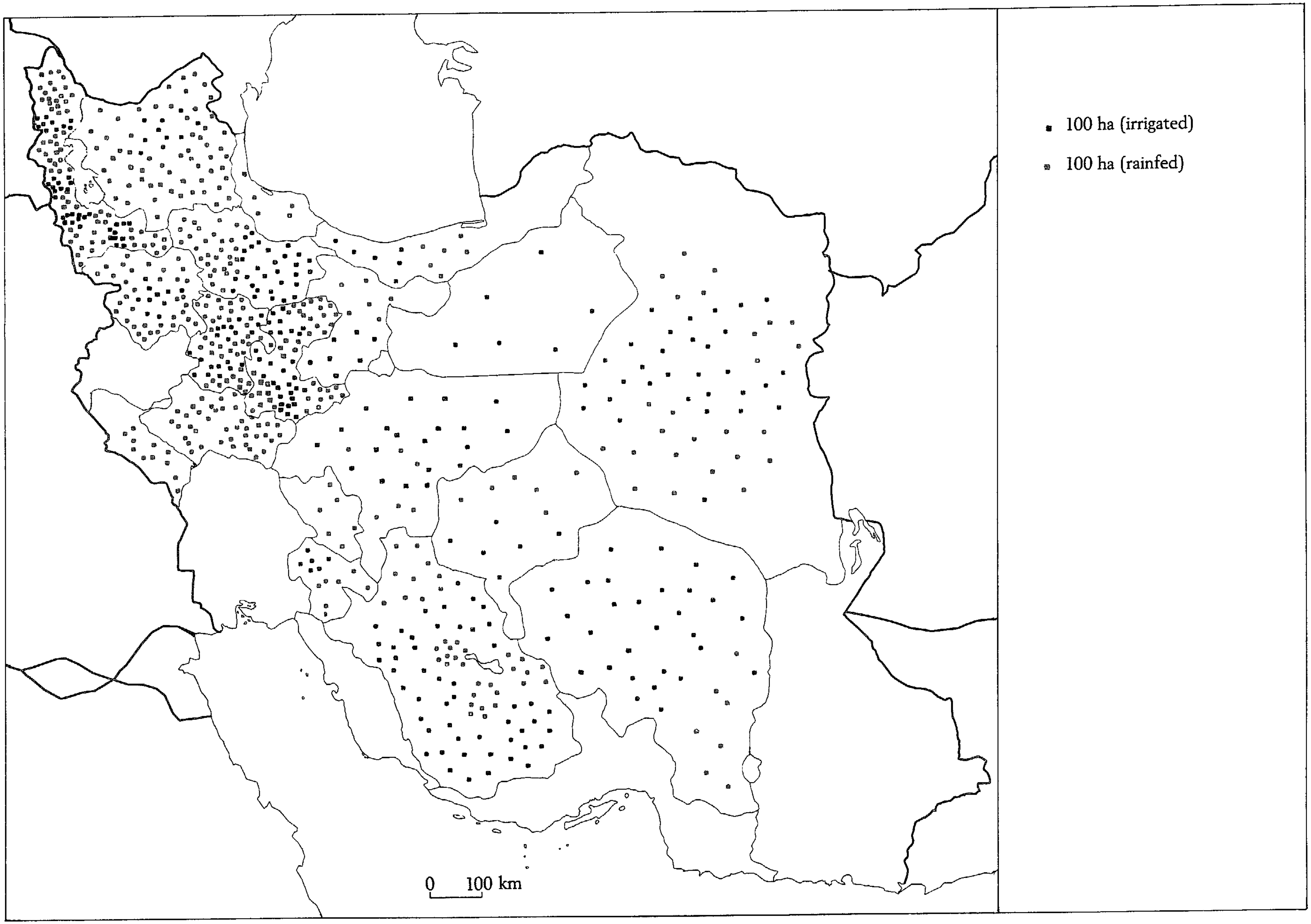


Figure 2.1.2. Distribution of rainfed and irrigated chickpea in Iran.

Uses

Chickpea is an important food legume with a high protein content. Demand for it has been increasing steadily with population growth and reduction in per capita availability of other sources of protein. Most of the chickpea produced in Iran is consumed within the country and production is generally sufficient to meet the country's demand. A popular chickpea dish is *abgosht*. In *ghymeh khoresht*, a traditional delicacy eaten with rice, a desi-type chickpea, mainly in the form of split peas, is used. Chickpea price has increased from US$ 0.3 to more than US$ 0.5 per kg in the last few years.

Area, Production, and Productivity

The crop is predominantly rainfed (Bakhtaran, Lorestan, and Kordestan) and only 10% is grown with irrigation. Annual data are not available to determine trends in area and production of chickpea in Iran. Its cultivation is distributed across the country, except in the north (Caspian Sea area) where humidity is very high, and in the desert area. It occupies 51% of the total legume area in East Azerbaijan, 83% in West Azerbaijan, 66% in Kordestan (completely rainfed), and 50% in Hamadan. The major production areas are in the western and northwestern parts of Iran (Fig. 2.1.2). Nearly 50% of total chickpea production in Iran is concentrated in 4 out of 24 provinces (Table 2.1.1). The largest chickpea area, rainfed and irrigated, is in West Azerbaijan. Kabuli chickpea is grown primarily in the Bakhtaran and Lorestan provinces, while the desi types are preferred in Kordestan.

Productivity is low in the four major chickpea-growing provinces (Table 2.1.1) because of drought, frost, salinity, diseases, and insect pests. In East Azerbaijan, productivity is low because low seed rates are used. In West Azerbaijan and Kermanshah (Bakhtaran), the two most important chickpea-growing areas, salinity and cold seem to be probable reasons for low yield of irrigated chickpea.

Annual chickpea production in Iran is around 0.15 million t. Average yields of rainfed chickpea range from 0.40 to 0.60 t ha^{-1}. Irrigated yields are around 1.0 to 1.5 t ha^{-1}.

Table 2.1.1. Area and production of chickpea in some important chickpea-growing provinces in Iran (mean of 1987–90).

	Area (ha)			Yield (t ha^{-1})	
Provinces	Irrigated	Rainfed	Total	Irrigated	Rainfed
East Azerbaijan	1532	41 979	43 511	1.42	0.61
West Azerbaijan	3980	65 000	68 980	0.67	0.42
Bakhtaran	577	89 363	89 940	0.75	0.36
Lorestan	1474	40 125	41 599	1.12	0.42

Source: Anonymous (1991).

Climate, Soil, and Crop Distribution

Seven crop ecological zones are recognized on the basis of climate, rainfall, and soil type (Fig. 2.1.3 and Table 2.1.2). Chickpea is mostly cultivated in Zones 5 and 6 (Fig. 2.1.3) with rainfall ranging between 250 and 400 mm (Fig. 2.1.4). Minimum temperatures during the crop season at some places in these zones, especially in Hamadan and East Azerbaijan, may fall below 0°C, and occasionally reach as low as –20°C, and the soil is covered with snow.

The soil salinity map shows that most of the soils on which chickpea is grown in the western and northwestern regions of Iran have moderate to severe levels of salinity (Fig. 2.1.5). Since chickpea is

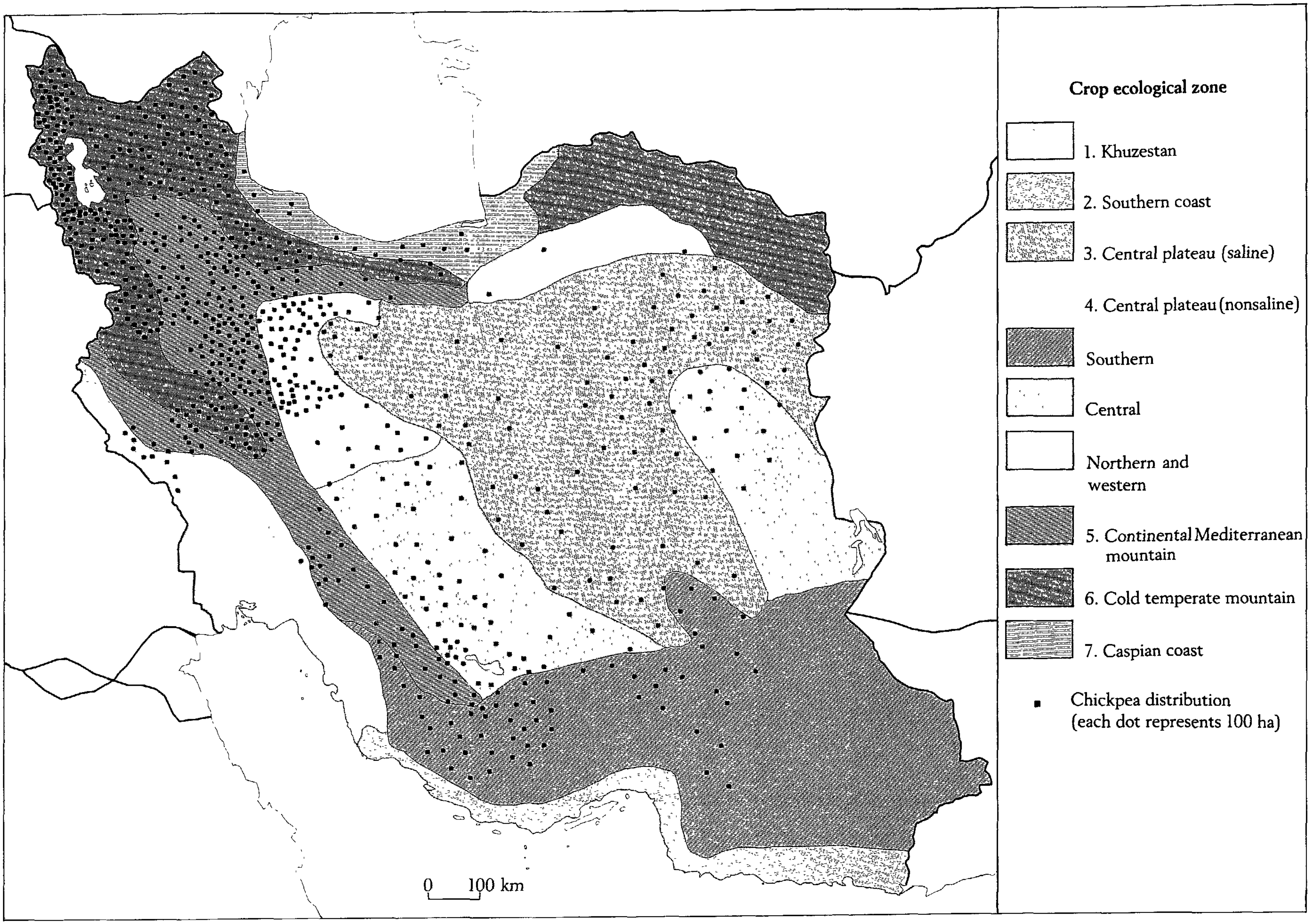


Figure 2.1.3. Crop ecological zones in relation to chickpea distribution in Iran.

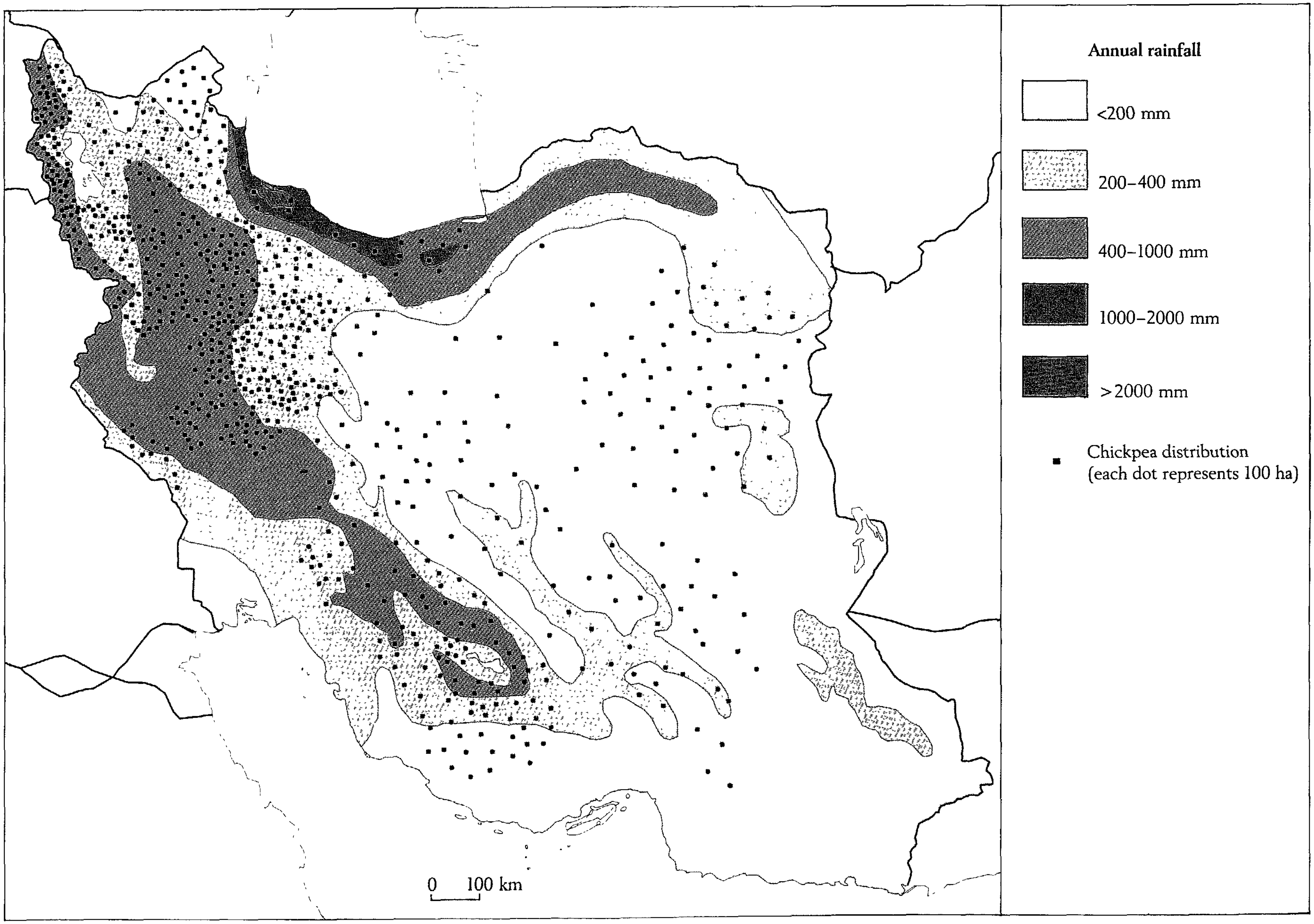


Figure 2.1.4. Mean annual rainfall in relation to chickpea distribution in Iran.

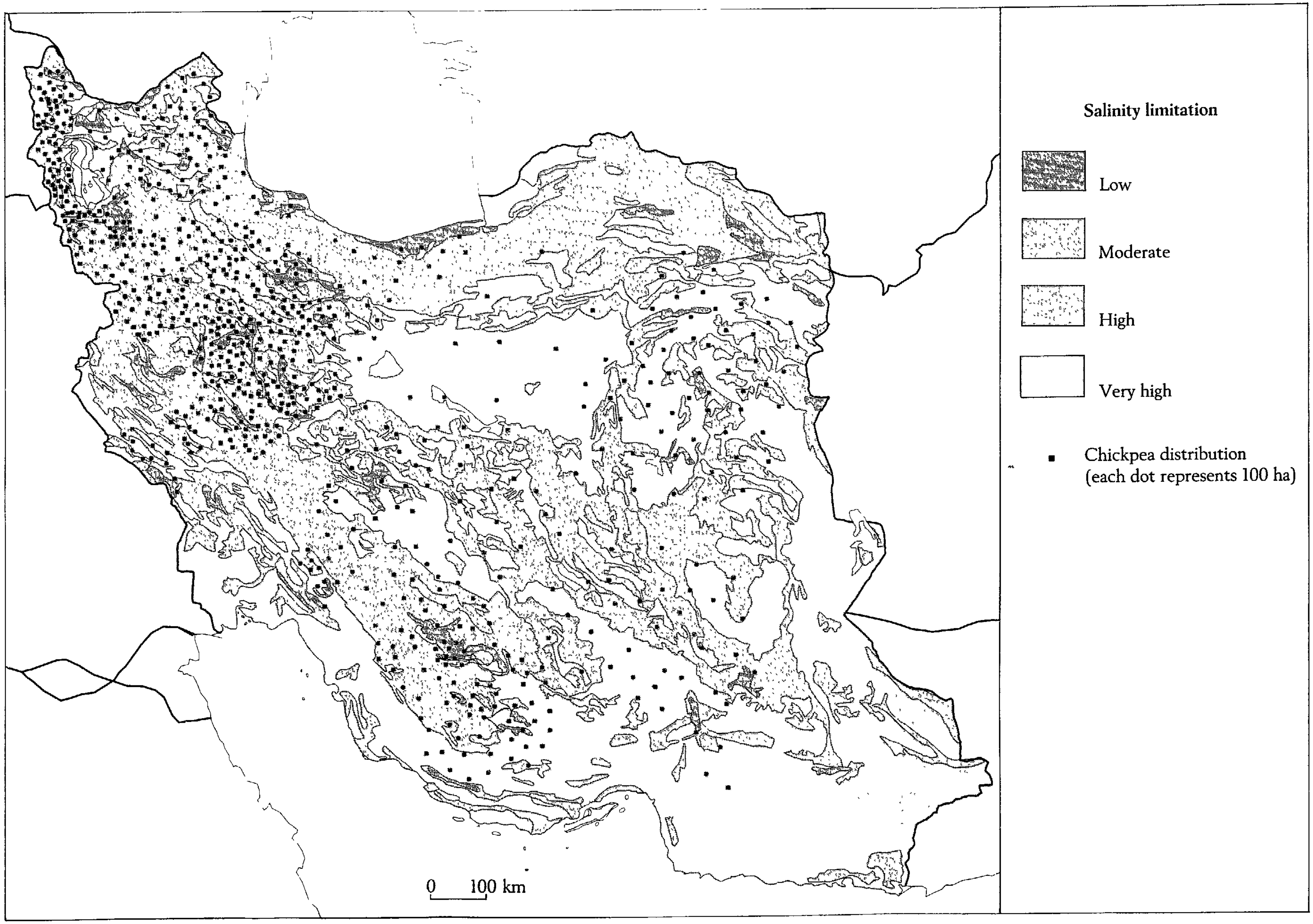


Figure 2.1.5. Soil salinity limitations in relation to chickpea distribution in Iran.

Table 2.1.2. Rainfall and altitude of seven crop ecological zones in Iran.

Zone	Rainfall (mm)	Altitude (m)
1. Khuzestan	50–300	<100
2. Southern coast	100–200	200–500
3. Central plateau (saline)	0–200	500–1000
4. Central plateau (nonsaline)	200–300	500–2500
5. Continental Mediterranean mountain	250–300	1000–2500
6. Cold temperate mountain	300–400	600–1400
7. Caspian coast	800–1700	Sea level

very sensitive to salinity, this could be one of the important reasons for low yield even when the crop is irrigated (Table 2.1.1).

Cropping Systems

Chickpea is mostly grown in rotation with cereals and is sown in Mar-Apr. Harvesting of the spring-sown chickpea is done in Jul-Aug; crop duration ranges from 90 to 120 days. Winter chickpea is grown in Gorgan in Zone 7 and in the Khuzestan province in Zone 1.

In the high altitude areas, with an extended winter season followed by spring rainfall, yields are low because spring sowing of chickpea is often delayed as it is difficult to prepare the seed bed in time.

Entezari is a system where chickpea is sown in late autumn to overcome delays in spring sowing. The seeds overwinter beneath the soil (*entezari*), and then germinate and emerge when the soil temperature rises above freezing point in early spring. Since the crop is already established by early spring, it benefits from melting snow and spring rainfall. Some climate parameters during crop growth of a typical spring chickpea are shown in Figure 2.1.6. In areas where cold is severe and seeds die due to freezing in the soil, *entezari* sowing is not recommended.

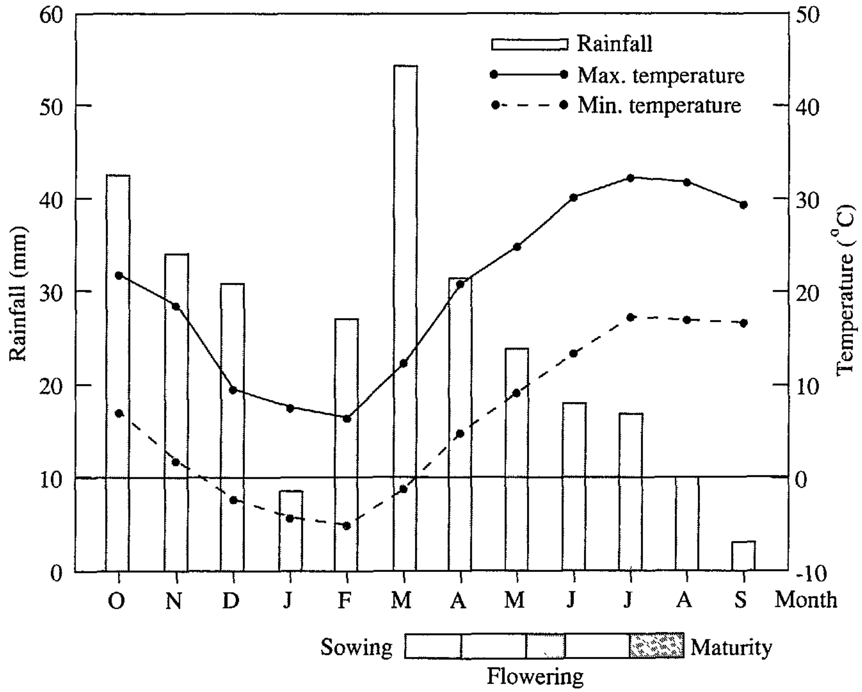


Figure 2.1.6. Crop phenology of spring-sown chickpea in relation to climatic conditions, Oroumieh, Iran, 1985–90.

Production Constraints

Abiotic Constraints

Since most of the chickpea is grown as a rainfed crop, drought is a major constraint across the entire country and particularly in East and West Azerbaijan provinces. Preliminary experiments on irrigation in Kordestan province showed seed yield losses of 30–50% due to drought. Frost is a constraint in Hamadan, Archabil, Azerbaijan, and Mashad, while heat could be an important limitation in Zone 1. Salinity although widespread across the country, is a severe limiting factor for chickpea mainly in Gorgan, Shiraz, and Tabriz.

No systematic analysis and surveys have been conducted to estimate the extent to which chickpea yield is limited by the various abiotic constraints.

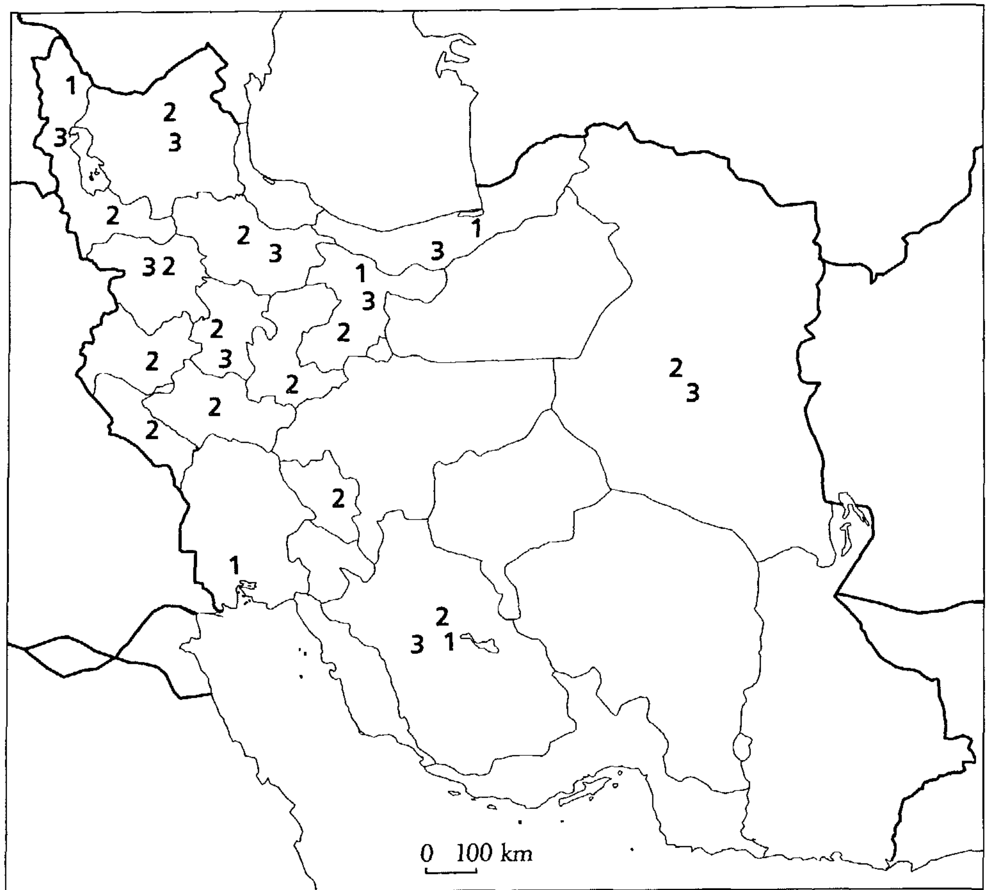
Biotic Constraints

Diseases

Almost all the important fungal and viral diseases known to affect chickpea have been observed in Iran. Occurrence and severity of these diseases depend largely on the cultivar and weather conditions in a given year. The severity of various diseases is shown in Figure 2.1.7. Fusarium wilt (*Fusarium oxysporum*) is a major yield reducer in spring chickpea in many parts of Iran. It is the most important disease in East Azerbaijan region. Ascochyta blight (*Ascochyta rabiei*) is localized in the northeast (Gorgan), northwest (Oroumieh), and in southern parts of Iran in both winter and spring chickpea, but it is more severe in winter chickpea. Chickpea root rots (*F. solani* and *Rhizoctonia solani*) have also been reported in some areas (Oroumieh, Hamadan, Karaj, Tabriz, Mashad, Arak, and Shiraz). In such areas as Karaj, Kermanshah, and others where winter is less severe, germinating seeds die mostly due to fungal diseases.

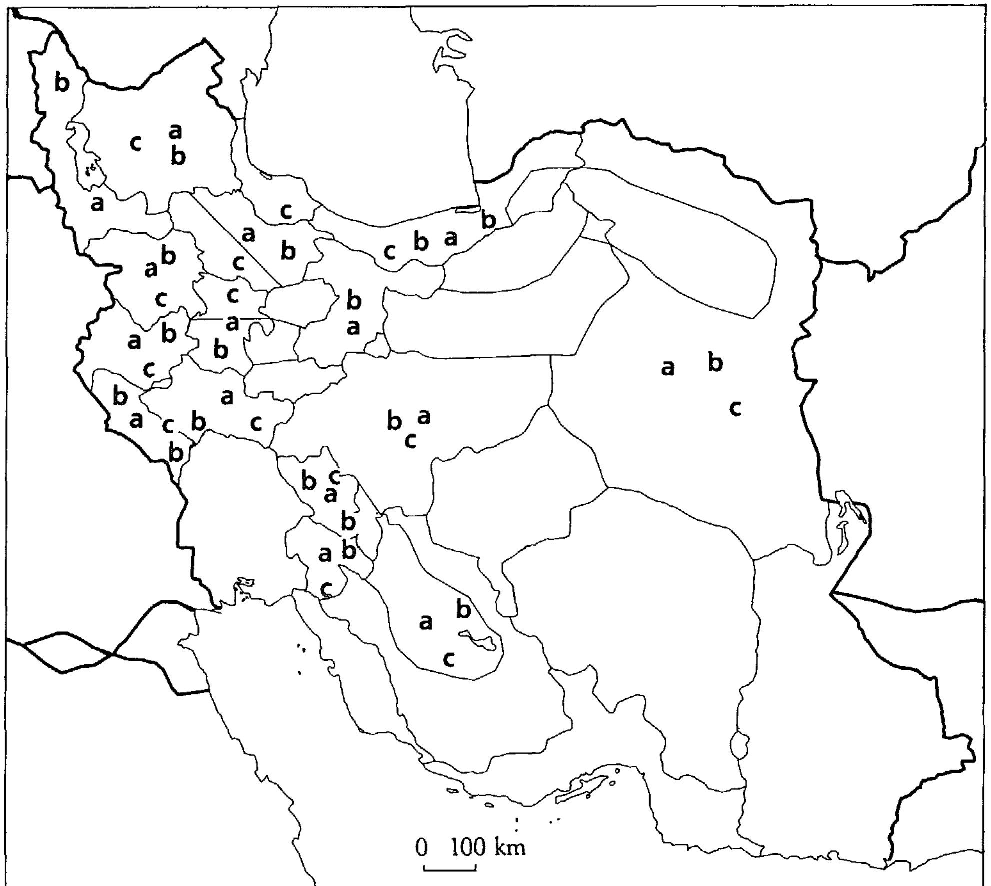
Insect pests

The distribution and severity of incidence of various insect pests are shown in Figure 2.1.8. Pod borer (*Helicoverpa armigera*) is the most important insect pest that causes substantial yield losses. Cutworms, *Agrotis* spp , are also important. Leafminer (*Liriomyza cicerina*) and aphid (*Aphis craccivora*) although present do not cause damage of economic importance.



	High	Moderate	Low
Ascochyta blight	1	1	1
Fusarium wilt	2	2	2
Root rot	–	–	3

Figure 2.1.7. Disease incidence on chickpea in Iran.



	High	Moderate	Low
Pod borers	a	a	a
Leafminer	–	b	b
Aphid	–	c	c

Figure 2.1.8. Insect pest incidence on chickpea in Iran.

Other biotic stresses

Weeds are a major constraint, especially in winter chickpea in Gorgan and Khuzestan areas. Use of herbicides is not yet common. Nematodes are not recognized as a major constraint.

Mechanical Harvesting

Most of the chickpea in Iran is hand-harvested, but combines are now being used by farmers with large holdings. The availability of mechanized harvesting possibilities would help to increase chickpea area.

Future Prospects

Chickpea cultivation can be introduced to fallow land in rainfed zones which are presently under fallow-cereal rotations. Farmers would replace fallow if mechanized harvesting could be popularized. The scope for introducing this new practice is most promising in Kermanshah (Bakhtaran), the most important rainfed kabuli chickpea-growing province in Iran.

Entezari sowing is potentially a very productive system. Field surveys are being made to examine the potential for expanding the area under *entezari* sowing in Karaj, Bakhtaran, Lorestan, and Ilam regions. Potential areas for intensification and expansion of chickpea cultivation in Iran are shown in Figure 2.1.9.

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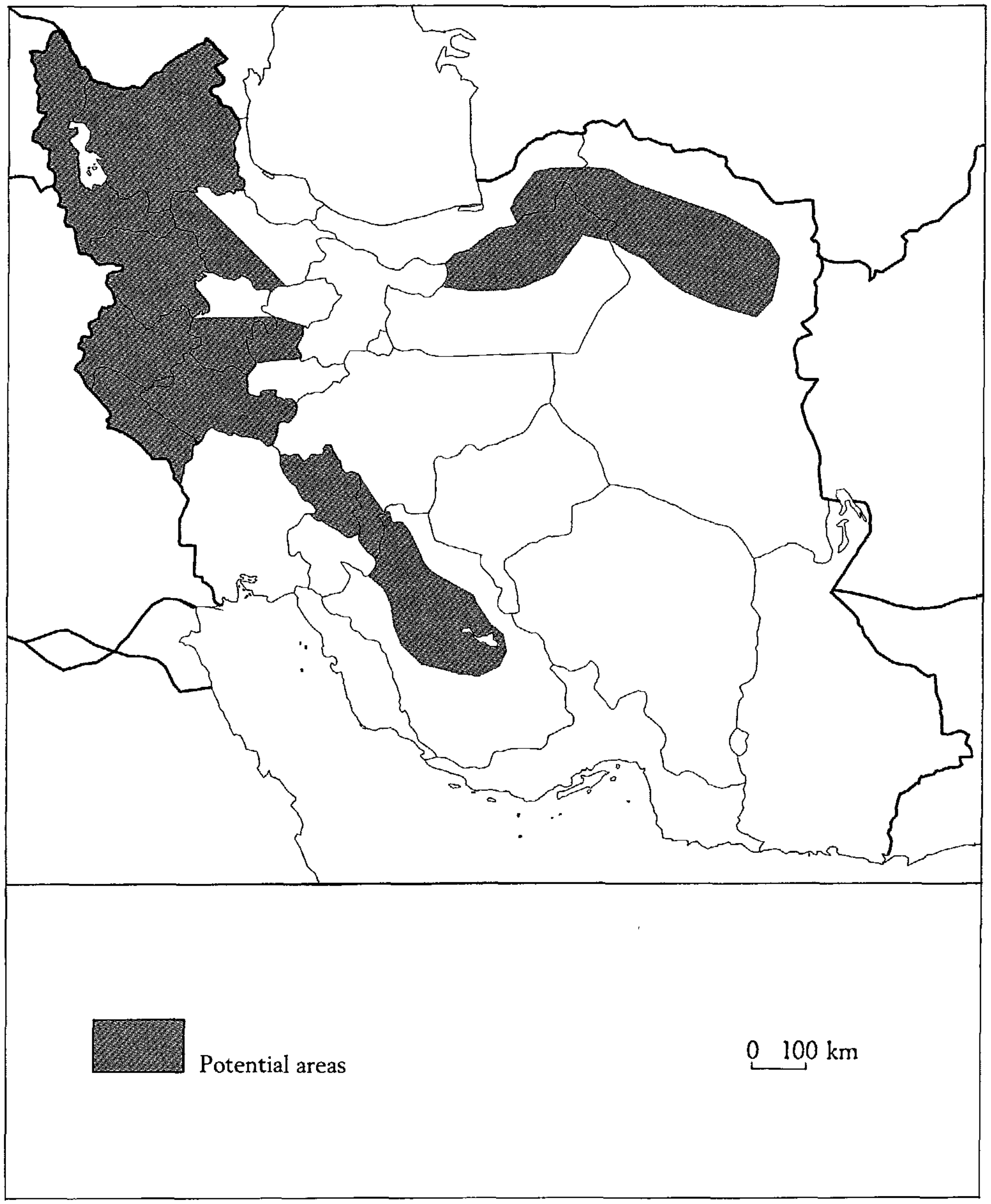

Figure 2.1.9. Potential areas for expansion and/or intensification of chickpea cultivation in Iran.

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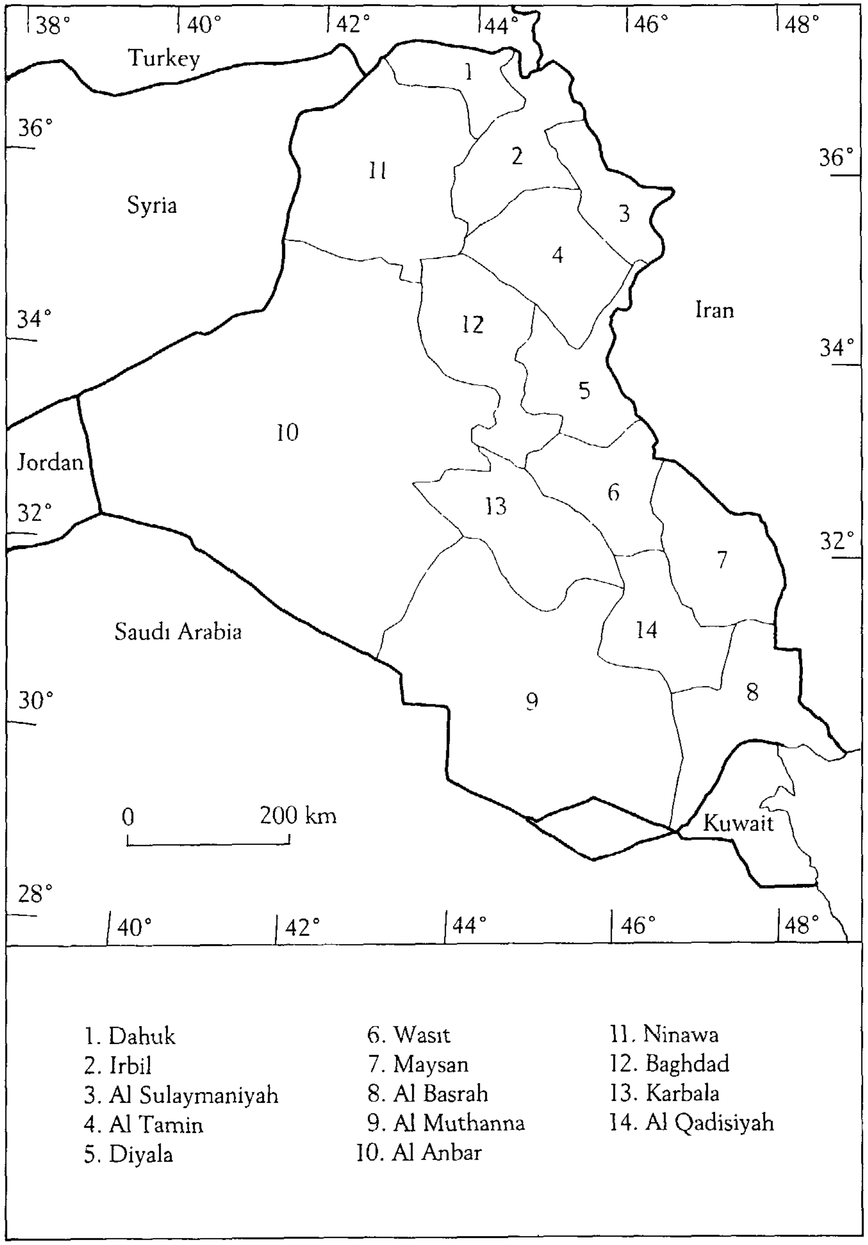


Figure 2.2.1. Administrative boundaries of Iraq.

2.2. Chickpea in Iraq

A I Abbas, A H Ali, and K S Ibrahim[1]

Latitude	29–37° N
Longitude	38–48° E
Altitude	0–1000 m
Total population	19.9 million
Economically active	5.7 million
Economically active in agriculture	1 million
Total area	43.8 million ha
Cultivated area	5.5 million ha
Rainfed area	2.9 million ha
Annual rainfall	100–1400 mm
Chickpea rank among legumes	Second
Crop season	Spring (traditional) Winter (recent)

Introduction

Farmers in Iraq have traditionally known the importance of chickpea (*Cicer arietinum*) as a crop with high economic returns. They also appear to know of its nutritional value and its role in maintaining soil fertility in crop rotations. Chickpea is the second most important food legume after faba bean (*Vicia faba*) in the country. Present areas under legumes are: faba bean (6000 ha), chickpea (2500 ha), and lentil (*Lens culinaris*) (1500–1800 ha). The administrative boundaries of the country are shown in Figure 2.2.1 and the chickpea distribution in Figure 2.2.2.

1. State Board for Applied Research, Forage and Legume Division, Abu-Ghraib, Baghdad, Iraq.

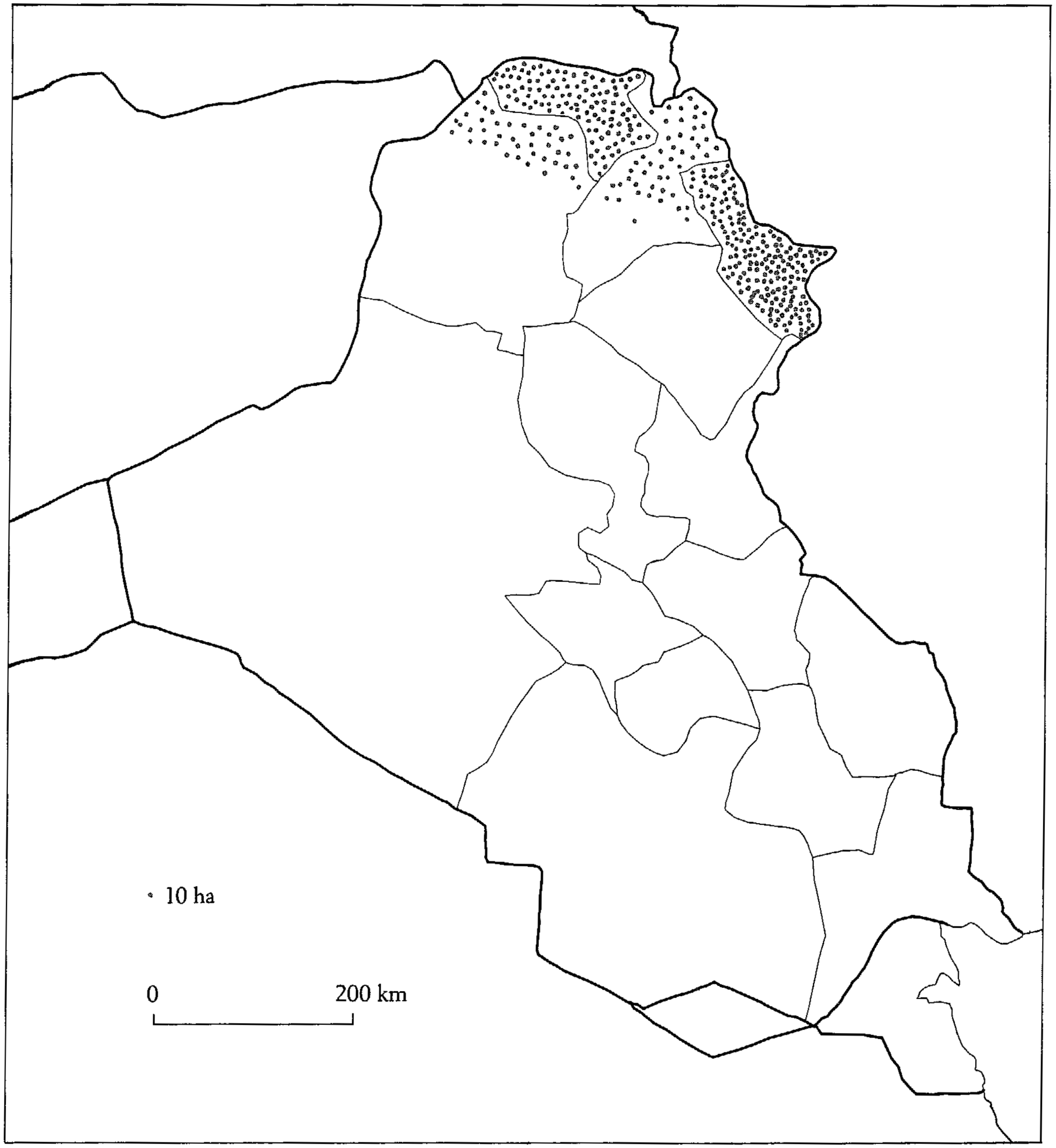


Figure 2.2.2. Chickpea distribution in Iraq.

Uses

Popular chickpea preparations in Iraq are *lebleabiye* (puree), *keyma* (chickpea with minced meat), *tashrieb* (chickpea boiled with meat and served with unleavened bread), and *falafel* (fried spicy cakes). Chickpea production is not sufficient to meet the country's demand and the gap between production and consumption has been increasing steadily over the years (Fig. 2.2.3).

Area, Production, and Productivity

Abbas (1990) gives a detailed description of chickpea production in Iraq. Before 1980, the crop used to be grown on more than 22 000 ha in the country (Fig. 2.2.3). However, the area under chickpea has declined over the years and the lowest area (675 ha) was recorded in 1991. Among the provinces, Al Sulaymaniyah accounts for about 50% of the total chickpea area, Dahuk (28%), Irbil (12%), and Ninawa (10%) (Fig. 2.2.2). Annual production ranges from 13 000 to 14 000 t (Fig. 2.2.3). In general, chickpea production meets less than 10% of the demand, and the balance is made up through imports. For example, in 1987, Iraq had to import about 36 860 t of chickpea, as its production only met 6.4% of the country's demand (Anonymous 1988). Kabuli chickpea is preferred, but seed size is not a serious limitation to the acceptance of new varieties.

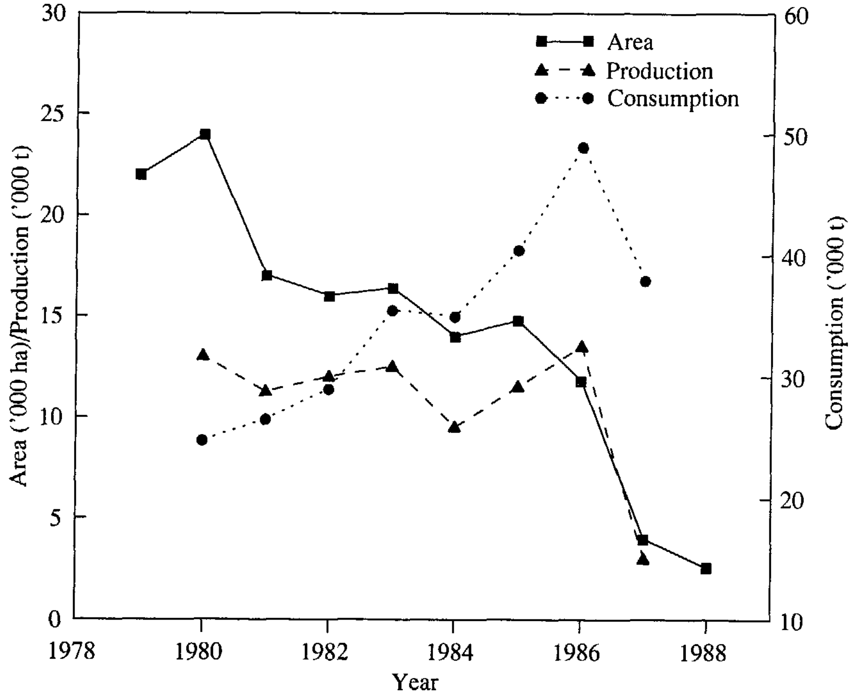


Figure 2.2.3. Trends in chickpea area, production, and consumption in Iraq, 1979–88.

Table 2.2.1. Seed yield of winter and spring chickpea varieties in demonstration trials in farmers' fields, Iraq, 1991.

Location	Seed yield (t ha^{-1})		Increase over spring chickpea (%)	Crop duration (days)	
	Winter	Spring		Winter	Spring
Al Sulaymaniyah	1.80	0.80	125	185	90–110
Dahuk	1.80	0.80	125	185	90–110
Irbil	1.50	0.60	150	178	90–100
Ninawa	1.50	0.60	150	178	90–100

Yield of spring-sown chickpea (1987–91 mean) is around 0.76 t ha^{-1} (Anonymous 1991). However, productivity varies considerably across agroecological regions. For example, average yield in Dahuk (500–600 mm annual rainfall) is about 0.70 t ha^{-1} and in Al Sulaymaniyah (740 mm annual rainfall), 0.40–0.50 t ha^{-1} (Najjar 1980). Yield of varieties adapted to winter sowing is relatively very high, ranging from 1.20–2 t ha^{-1} in demonstrations conducted in farmers' fields, depending on rainfall and crop management (Abbas 1991) (Table 2.2.1).

Climate, Soil, and Crop Distribution

Only 13% of Iraq exceeds an altitude of 500 m (Meliczek 1982). The country can be divided into four distinct regions:

Alluvial plain. The plain covers 132 000 km^2 and is spread in the form of a rectangle (650 km long and 250 km wide) between Balad on the river Tigris and Ramadi in the Tal Al-Aswad region on the Euphrates river in the north, the Iranian frontier on the east and the desert plateau on the west. Marshlands and lakes are also included in this area.

Desert plateau. The plateau is situated in the west and together with the Aljazira area covers nearly 198 000 km^2. The altitude in the region ranges between 100 and 1000 m.

Mountainous region. This region, covering 134 000 km^2, is situated in the north and northeast of Iraq, bordering Syria in the west, Turkey in the north, and Iran in the east.

Terrain region. This is a transition zone between the lowlands in the south and the high mountain region in the north. It accounts for nearly 50% of the mountain region and is approximately 67 000 km^2 (42 000 km^2 with an altitude of 100–200 m and 25 000 km^2 with an altitude of 200–450 m) (Anonymous 1991).

Rainfed chickpea is grown in the north and northeast of Iraq. Major soil types in this region are Luvic Yermosols, Albic Arenosols, and Chromic Vertisols (Fig. 2.2.4). These soils are generally deep with a high moisture-holding capacity (around 100 mm m^{-1} soil depth). Chickpea grows mostly in the mountain and the terrain regions.

The climate of Iraq is continental and subtropical, with rainfall occurring mostly in winter, autumn, and spring, a distribution pattern that is similar to that of the Mediterranean region. Isohyets for rainfall are shown in Figure 2.2.5. Chickpea is concentrated in the 400–1000 mm rainfall zone. Three distinct climatic zones can be identified in Iraq (Anonymous 1991):

Mediterranean climate. The climate in the mountainous area of the northeast is Mediterranean. It is characterized by cold winters with snowfall at high altitudes. Annual rainfall ranges between 400 and 1000 mm. Summer temperature is moderate and does not exceed 35°C in most parts. Chickpea is a major crop in this region.

Steppe climate. The terrain area with annual rainfall ranging between 200 and 400 mm (adequate for seasonal pastures) has a steppe climate.

Hot desert climate. In the sedimentary plain and western plateau which cover 70% of Iraq's area, the climate is hot and arid. Annual rainfall here ranges between 50 and 500 mm.

Cropping Systems

Chickpea is cultivated in rotation with wheat and barley (Fig. 2.2.6) as a spring crop. Sown from mid-Feb to mid-Mar, it flowers in the first fortnight of Apr and is harvested in Jun (Najjar 1980). Temperature and rainfall conditions during the growing periods of the spring- and winter-sown chickpea crops are shown in Figure 2.2.7. In the last few years, farmers have started growing wheat and barley continuously without including a fallow period or a legume in the crop rotation, as the demand and prices for cereals are high. Moreover, it is expensive to grow legumes as they are hand-harvested and labor costs have been steadily increasing.

But farmers are realizing the value of cereal-legume rotations, because due to continuous cropping of cereals, nematodes and new races of diseases are affecting the barley crops (Al-Talib et al. 1986), and new species of weeds are increasing.

In spite of its low yields and short plant height which makes mechanized harvesting difficult, farmers prefer spring chickpea as winter chickpea is susceptible to ascochyta blight and frost which may sometimes cause total crop failure. A large number of chickpea genotypes suitable for winter sowing provided by ICARDA have been evaluated in the past 10 years. The two- to three-fold yield increase of winter-sown over spring-sown chickpea has been convincingly demonstrated in trials (Table 2.2.1.) Two promising ascochyta blight resistant and frost-tolerant winter varieties, ILC 482 (as Rafedian) and ILC 3279 (as Dejlah), have now been released to the farmers (Abbas 1991). Seeds of these varieties are being multiplied to extend the area under winter-sown chickpea.

Crops are normally fertilized with a compound fertilizer at 200 kg ha^{-1}, supplying 54 kg ha^{-1} of both N and P_2O_5. No seed dressing is currently used. But, in 1993, seeds dressed with captan for protection against soilborne disease were distributed to farmers.

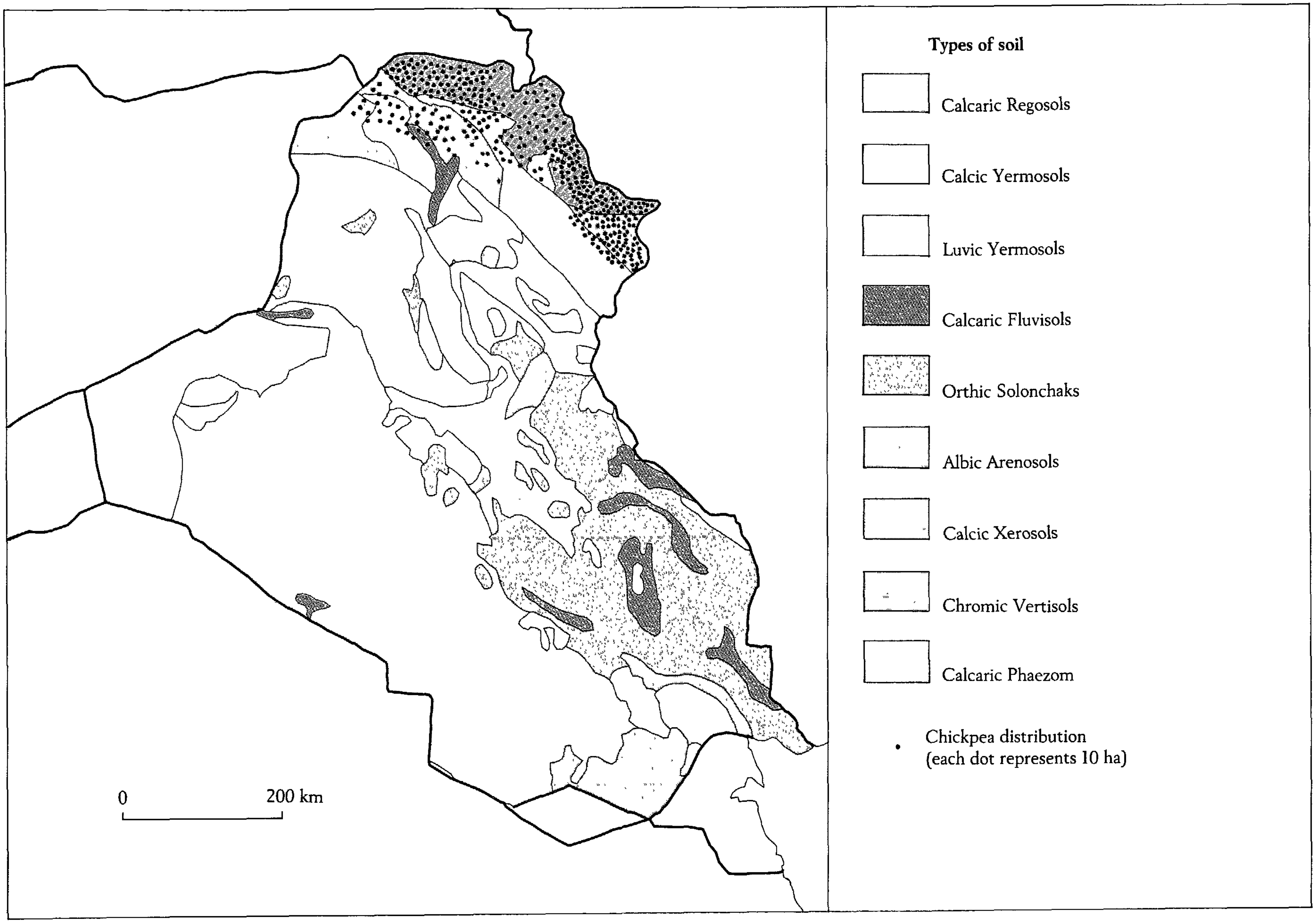


Figure 2.2.4. Soil types in relation to chickpea distribution in Iraq.

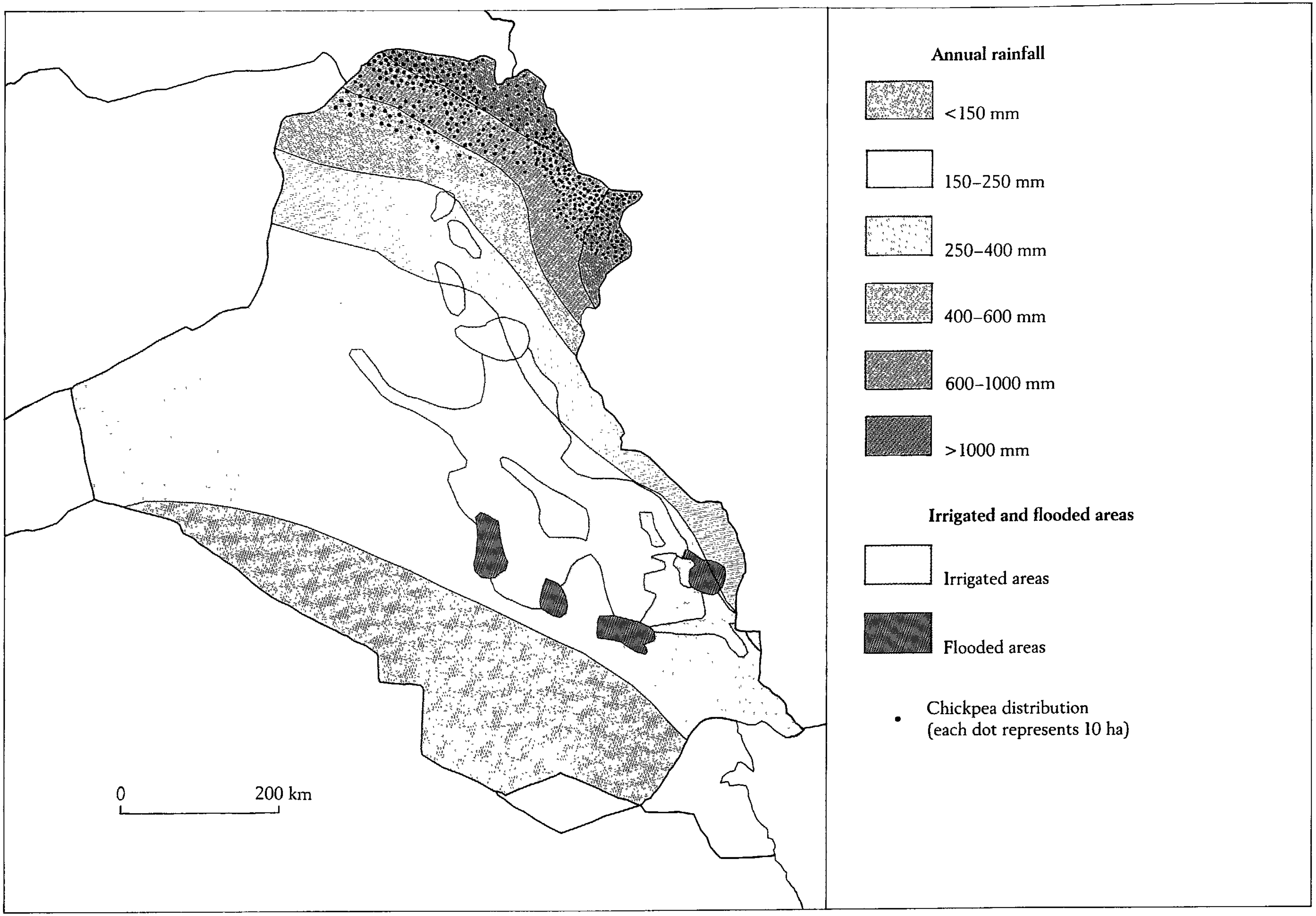


Figure 2.2.5. Annual rainfall, and irrigated and flood-affected areas in relation to chickpea distribution in Iraq.

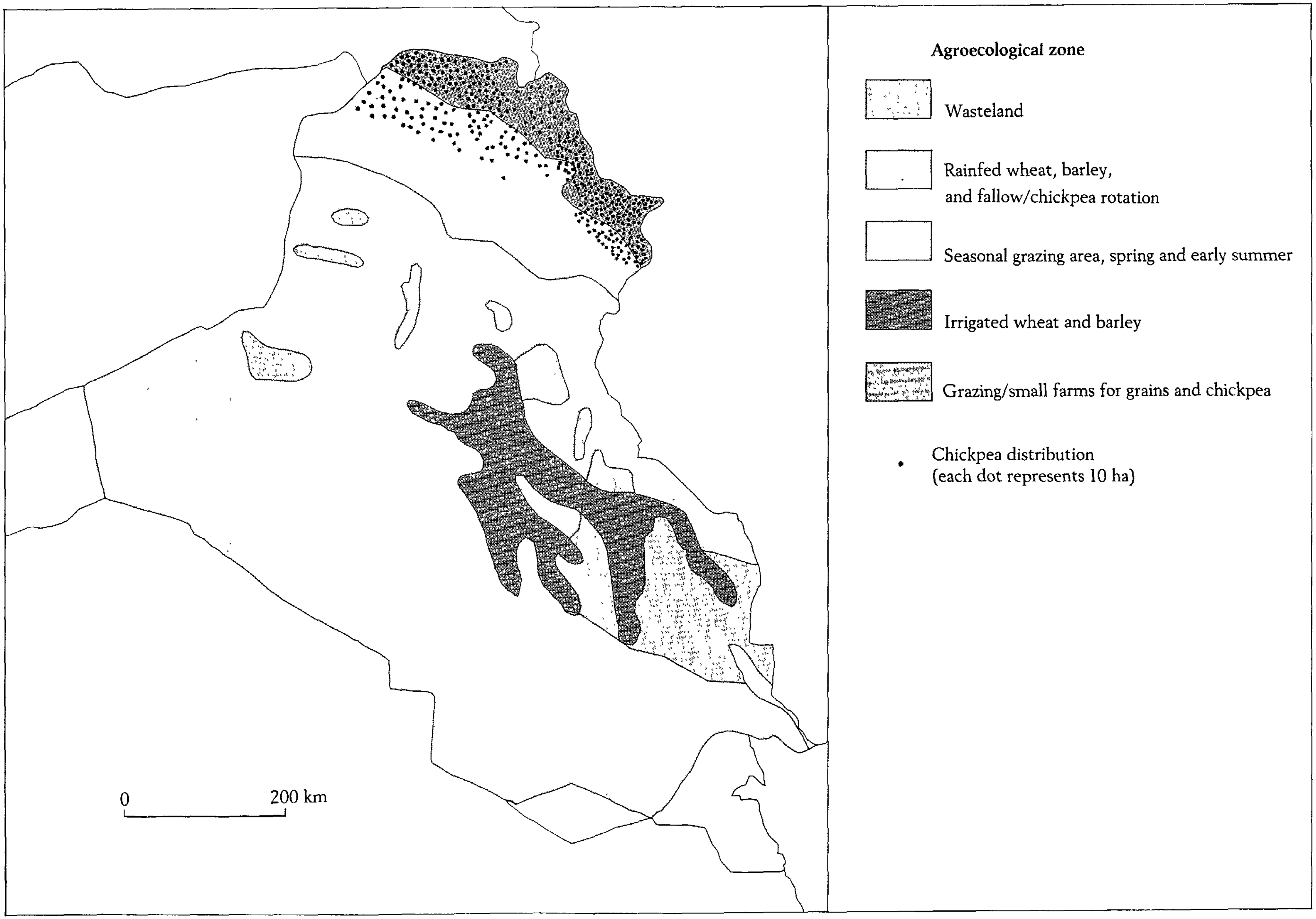


Figure 2.2.6. Agroecological zones in relation to chickpea distribution in Iraq.

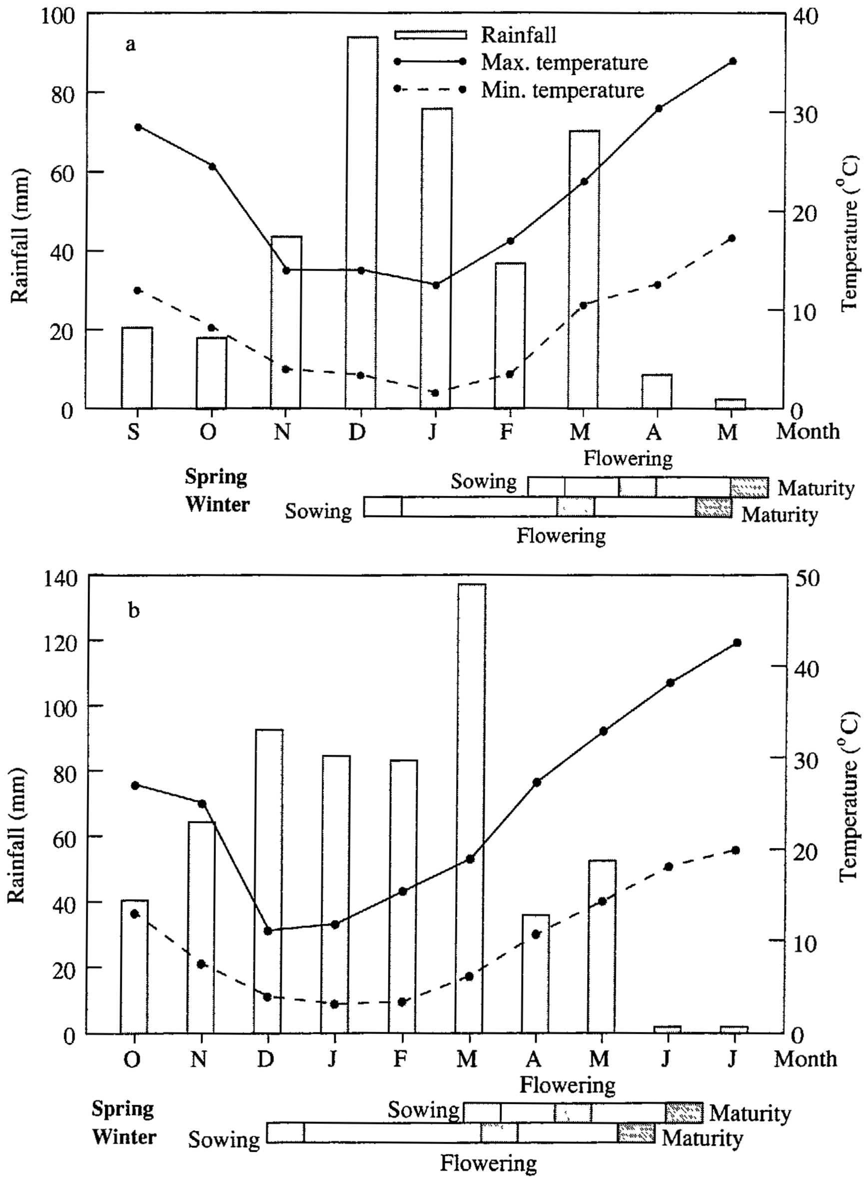


Figure 2.2.7. Crop phenology of spring and winter-sown chickpea in relation to climatic conditions in two provinces of Iraq: (a) Irbil; and (b) Dahuk, 1985–89.

Production Constraints

Abiotic Constraints

Drought

Drought is a major constraint to spring chickpea production in northern Iraq as more than 70% of the rainfall is received from Nov to Feb. Early-season drought is a serious limitation during germination and plant establishment, and later during the flowering and pod-filling stages.

Frost

Frost tolerance is an important trait and is required for expanding the chickpea area at high altitudes, where temperatures may reach as low as –10°C.

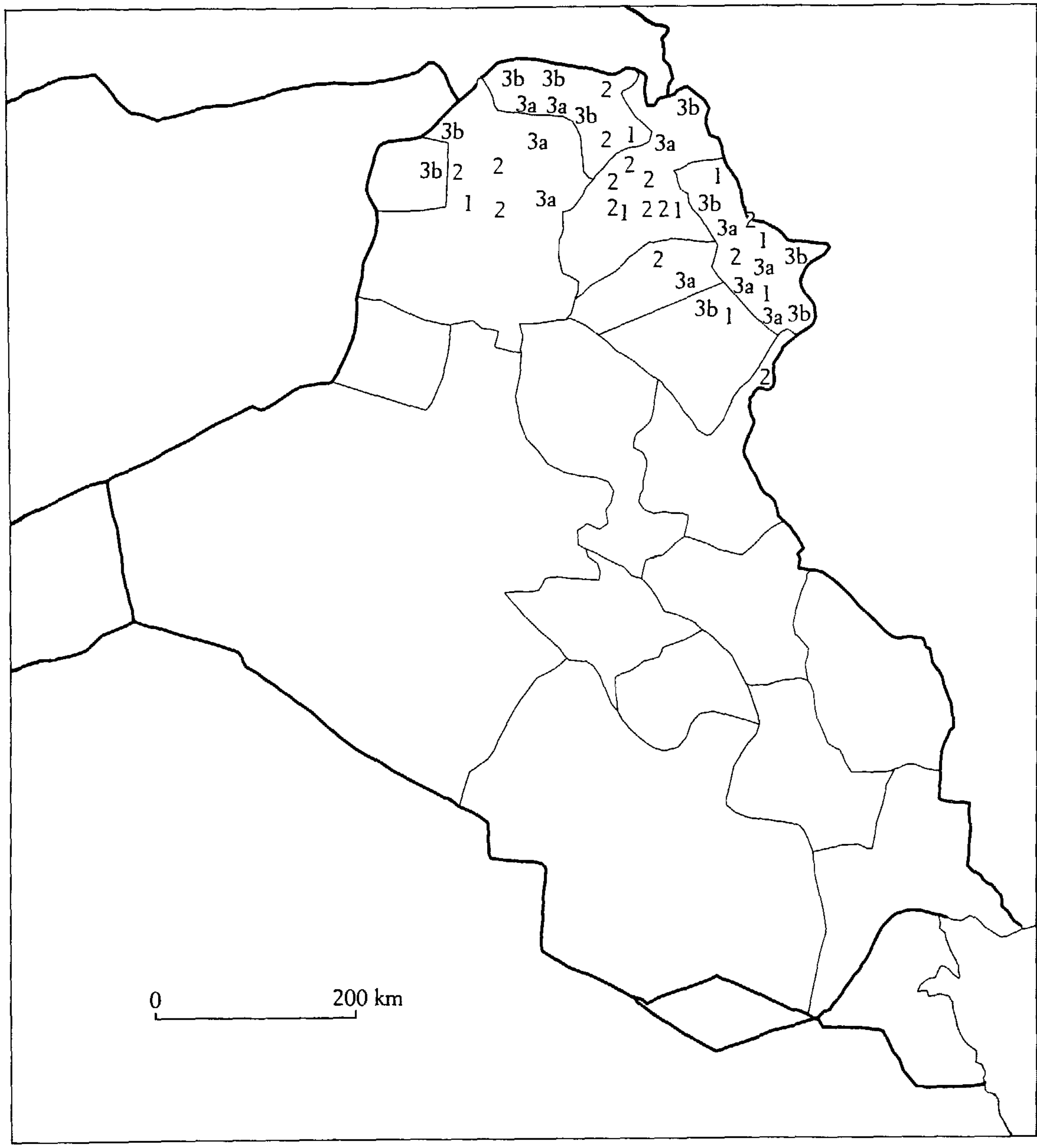
Salinity

Soil salinity will be a serious constraint to chickpea production if proper attention is not paid to drainage in the flood irrigation system projects proposed in the Kirkuk and Ninawa regions.

Biotic Constraints

Diseases

Both fungal and viral diseases of chickpea are important in Iraq (Fig. 2.2.8). The incidence of black root rot (*Fusarium solani*) is highest during Apr and May. Temperatures of 22–27°C increased black root rot incidence from in some areas of the Ninawa province (Al-Talib 1988). In the Dahuk province, the incidence was about 3% at 18–19°C. Dry root rot caused by *Rhizoctonia bataticola* generally appears



	Moderate	Low
Ascochyta blight	1	
Fusarium wilt		2
Dry root rot	3a	
Black root rot	3b	

Figure 2.2.8. Disease incidence on chickpea in Iraq.

in May during the flowering and pod-filling stages. The disease increased from about 1% at 24–26°C to 8% at 27–31°C (Al-Talib 1988).

Ascochyta blight (*Ascochyta rabiei*) is one of the most important and widespread diseases of chickpea in Iraq. It occurs in all the provinces where chickpea is cultivated. Yield losses due to this disease are very severe in some seasons, especially when no control measures are adopted. Phyllosticta blight (*Phyllosticta rabiei*) could be potentially a damaging disease. It caused more than 30% damage in Al Sulaymaniyah province during Apr-May in 1979 (Al-Baldawi et al. 1979). However, this has been the only incidence recorded until now.

Fusarium wilt (*Fusarium oxysporum*) occurs in some areas but is only of minor significance. Among the viral diseases, chickpea stunt is very important. Damage due to nematodes has not been recorded so far.

Insect pests

Leafminer (*Liriomyza cicerina*), and pod borers (*Helicoverpa armigera* and *Heliothis viriplaca*) are important chickpea insect pests in Iraq. Pod borer incidence is particularly severe on winter varieties of chickpea. Estimates of yield losses due to the bruchid *Callosobruchus chinensis* are not available, although this insect can cause major damage to chickpea in Iraq.

Weeds

Weeds are a major constraint of chickpea production in Iraq, especially in winter sowings. Yield losses range from 20–30% in spring and are around 50–80% in winter chickpea. Weeds also interfere with the mechanical harvesting of the crop. Major weeds are *Glycyrriza glabra*, *Laganychium farctum*, *Centaurea pullescens*, *Xanthium stramonium*, and *Polygonum aviculare*. Chemical control is not used to eradicate chickpea weeds in Iraq because herbicides found effective elsewhere have not so far been evaluated in the country and no recommendations have been made.

Mechanical Harvesting

The area under chickpea has declined over the years because of the rising cost of manual harvesting and nonavailability of equipment for mechanical harvesting. Harvesting methods for chickpea, and the economics of the operation were evaluated between 1986 and 1988. Results showed that direct combining was superior to hand harvesting in terms of both technique and cost and further improvements are possible by shortening the width of cut (Abbas and Satar 1992).

Future Prospects

Half of the total land area in the rainfed region is sown to cereal crops (Fig. 2.2.6). The remaining half, which is currently under fallow, can be replaced by legumes including chickpea, when mechanization and improved cultivars become available (Table 2.2.2). It would be possible to add around 30 000 ha to chickpea area, and

Table 2.2.2. Expansion potential for chickpea in Iraq.

Province	Rainfed area (ha)	Fallow area (ha)	20% fallow area replaced with chickpea (ha)
Al Sulaymaniyah	150 000	50 000	10 000
Dahuk	100 000	33 250	6 500
Irbil	15 000	25 000	5 000
Ninawa	175 000	58 250	11 650
Total	440 000	166 500	33 150

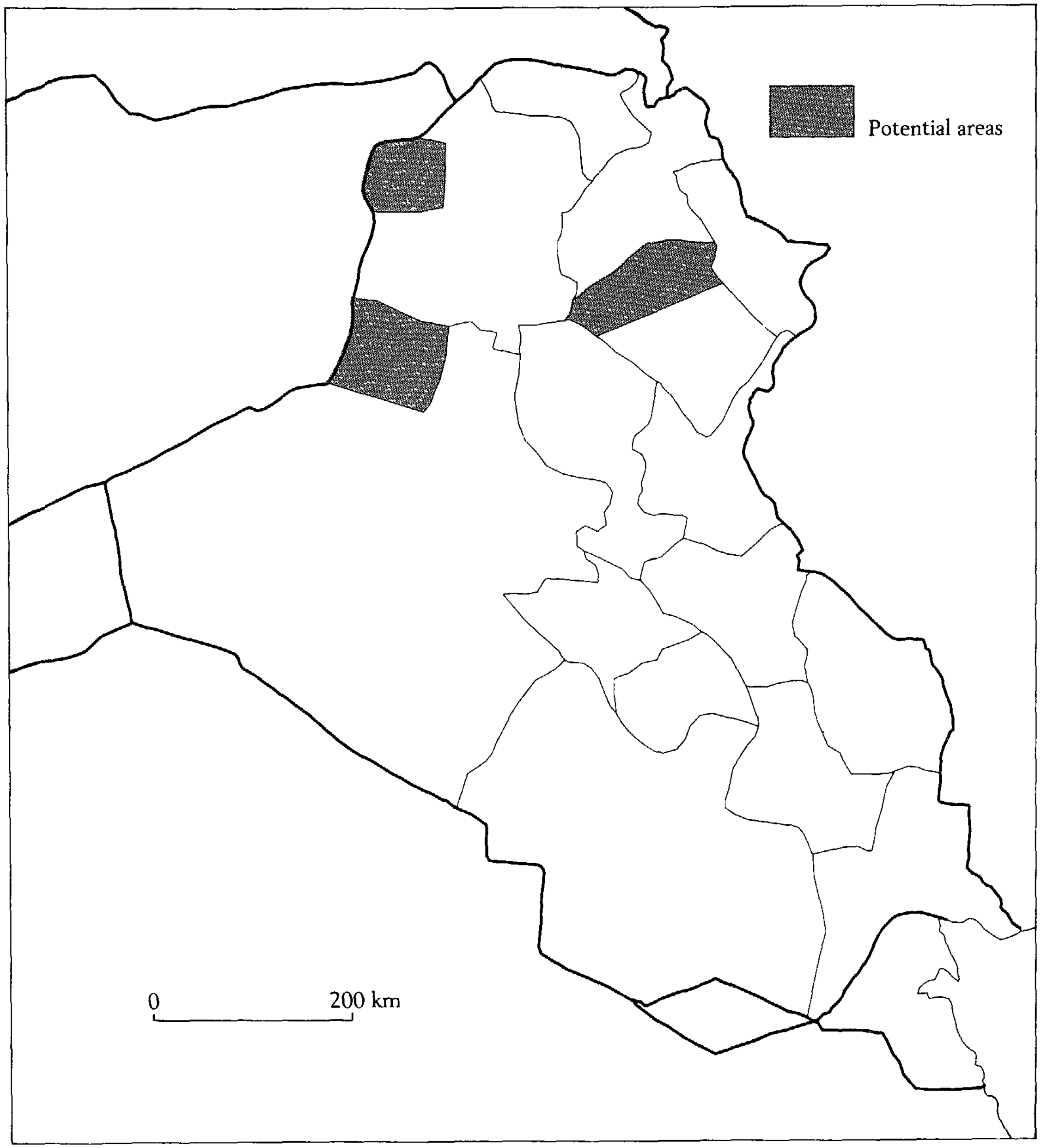


Figure 2.2.9. Potential chickpea areas in Iraq.

increase production by 25 000 t in the country. If this target is realized, around 65–70% of the demand for the crop can be met (Abbas 1990). The current area under winter chickpea is small (about 73 ha) but the government plans to expand this area to 1000 ha for which seeds of appropriate cultivars have already been multiplied.

Expansion of chickpea area is also planned on Calcic Xerosols (Fig. 2.2.4) with supplemental irrigation (Fig. 2.2.9) in the Karbouk region. Problems of salinity are likely to increase in these areas because the soils are shallow and gypsiferous. All precautions should be taken to avoid cultivation of chickpea on such soils.

In 1991, the Center for Excellence in Agricultural Research (IBA) initiated a program on food legumes development focusing on on-farm research and release of varieties. The major objectives of this program are:

- Seed multiplication of promising released varieties;
- Evaluation of promising chickpea genotypes from such international centers as ICARDA, ICRISAT, and from the national program;
- A vigorous extension program to popularize cultivation of legume crops; and
- Identification of new areas for chickpea cultivation.

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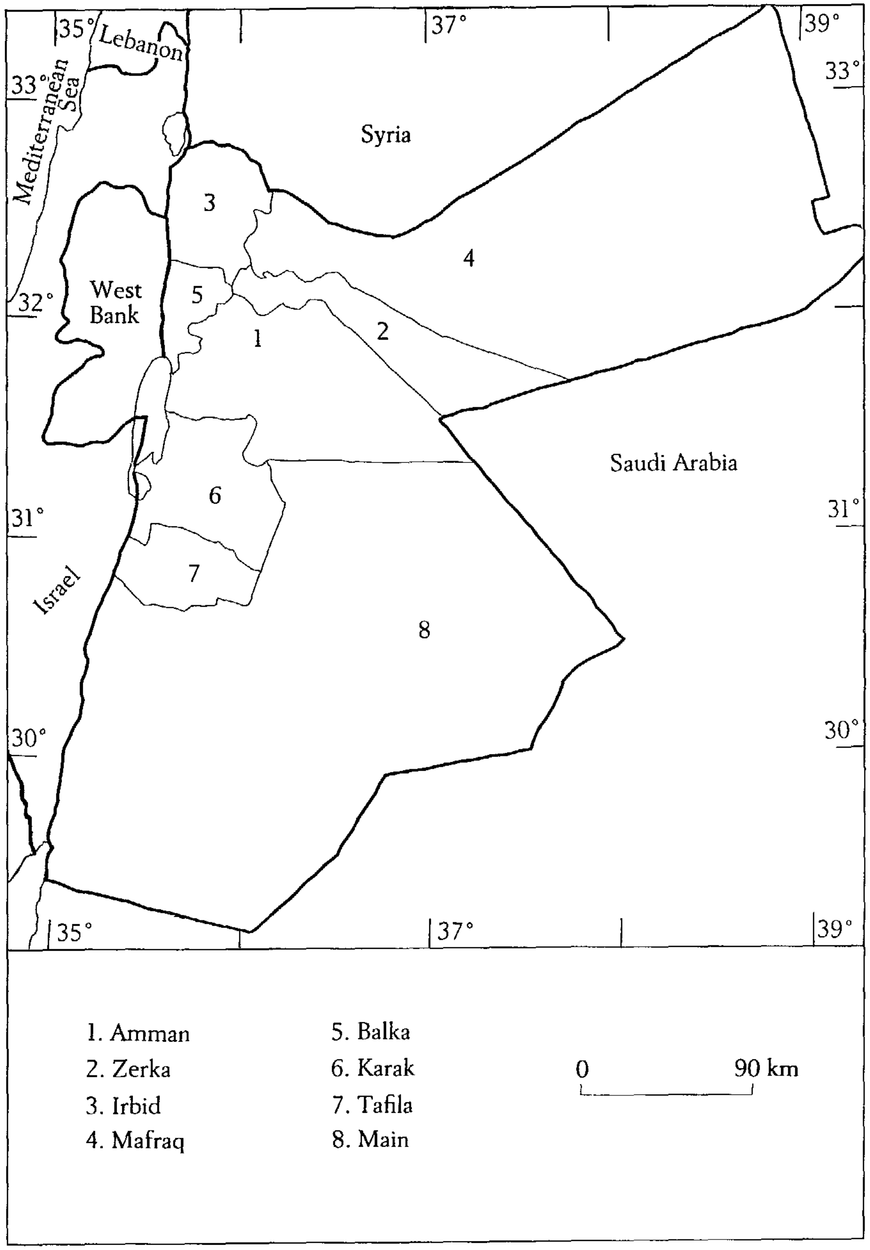

Figure 2.3.1. Administrative boundaries of Jordan.

2.3. Chickpea in Jordan

A Masadeh[1], I Hawash[2], and N Al-Majali[3]

Latitude	29–33° N
Longitude	35–39° E
Altitude	500–1000 m
Total population	4.1 million
Economically active	1 million
Economically active in agriculture	0.05 million
Total area	8.9 million ha
Cultivated area	0.3 million ha
Rainfed area	0.2 million ha
Annual rainfall	200–600 mm
Chickpea rank among legumes	Second
Crop season	Spring (traditional) Winter (recent)

Introduction

Jordan is largely an upland plateau with about 90% of its area above an altitude of 500 m, although only 7% is higher than 1000 m. Less than 5% of its cultivated area is irrigated (Haddad and Snobar 1990). Lentil (*Lens culinaris*) and chickpea (*Cicer arietinum*) are the major food legumes in the rainfed areas of the country. The administrative boundaries of the country are shown in Figure 2.3.1 and the chickpea distribution in Figure 2.3.2.

1. Ministry of Agriculture, PO Box 226, Amman, Jordan.
2. Maru Research Station, PO Box 200, Irbid, Jordan.
3. Regional Center, Raba, Karak, Jordan

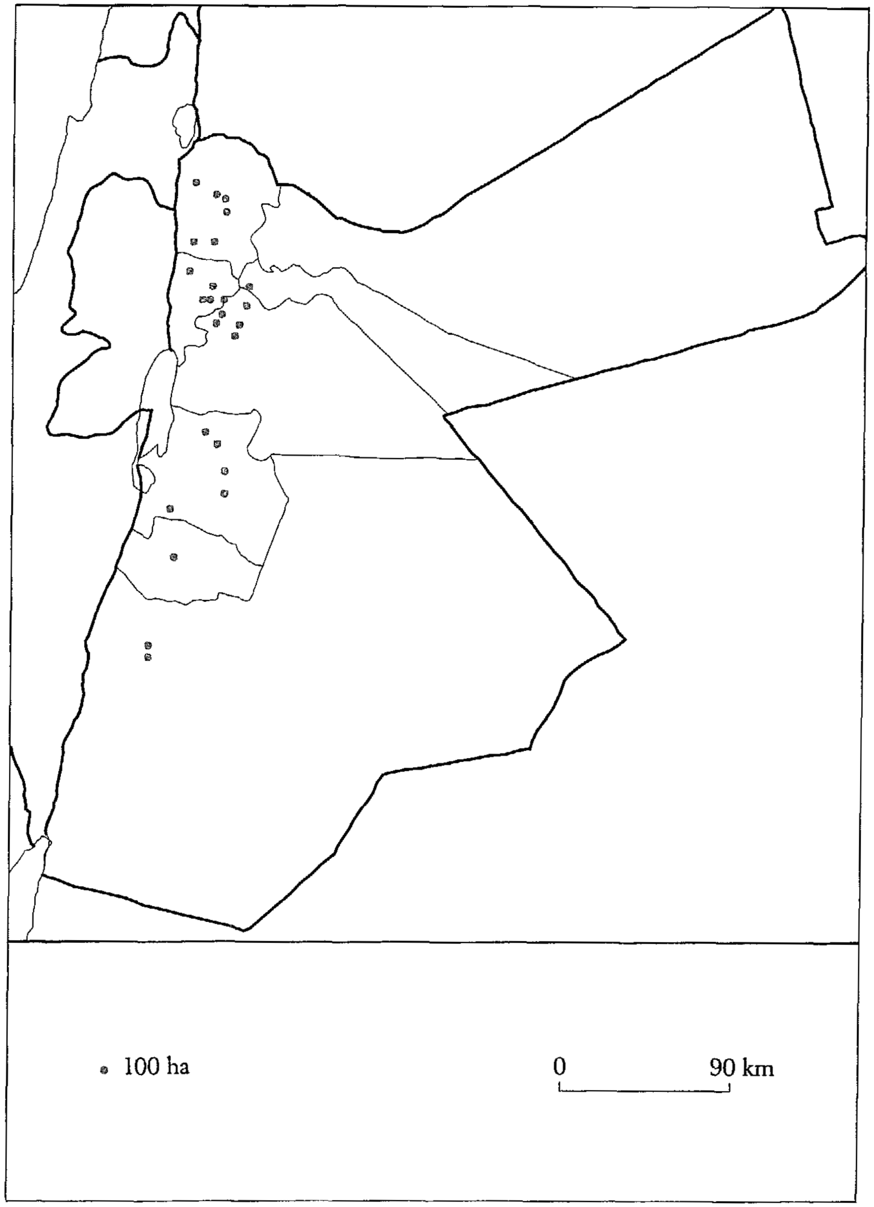

Figure 2.3.2. Chickpea distribution in Jordan. (Source: Snobar et al. 1991.)

Uses

Chickpea is an important source of protein in the Jordanian diet. Dry seeds are soaked, cooked, and used in many preparations, the most popular being *homos bethenah* which is commonly served in most homes and restaurants, it is eaten as an appetizer or used as a sauce with other dishes. Small quantities of seed are consumed as green peas or ground into flour and used in making snack foods. Chickpea has also been introduced in small-scale processed food industries.

Area, Production, and Productivity

The three main governorates in which chickpea is an important crop are Irbid, Amman, and Karak (Fig. 2.3.2) (Snobar et al. 1991). The crop is also grown in Balka, Main, and Tafila. Trends in area, production, and yield of chickpea are presented in Figure 2.3.3. The area under chickpea decreased considerably after 1974, although it increased slightly in 1990. Production has been unstable but an upward trend in productivity has been observed over the last 10 years. Yields fluctuate from year to year and are closely associated with seasonal variation in rainfall.

The overall decline in area appears to be the result of increasing production costs, especially the labor cost for harvesting the crop. Yields are low because traditional methods of production are followed and seeds of unimproved landraces are commonly used throughout the country.

Production is not sufficient to meet the country's demand. Substantial imports are therefore made to bridge the gap (Table 2.3.1) (Anonymous 1973–90). Chickpea imports have increased in the last few years to a maximum of 18 000 t in 1987. The net value of imports in 1990 exceeded 4 million Jordanian Dinars (JD) (US$ 1 = JD 0.69 approximately).

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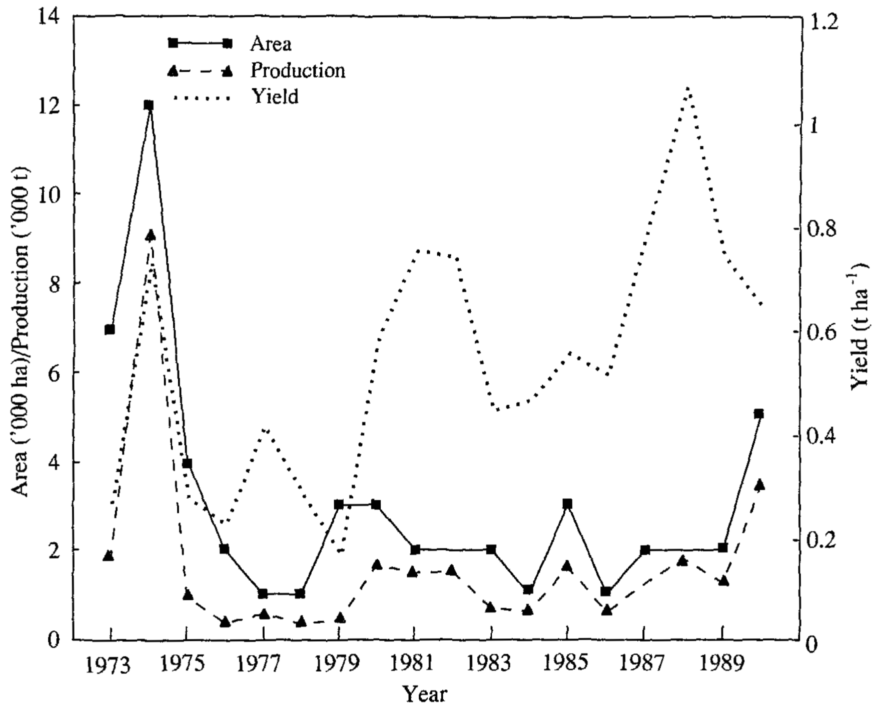


Figure 2.3.3. Trends in chickpea area, production, and yield in Jordan, 1972–90.

Table 2.3.1. Import of chickpea into Jordan, 1986–90.

Year	Quantity (t)	Approx. value ('000 US$)
1986	9 972	2430
1987	18 114	3542
1988	7 517	1430
1989	13 111	5030
1990	10 849	6023

Climate, Soil, and Crop Distribution

The climate of Jordan is semi-arid Mediterranean to subtropical (Fig. 2.3.4). It is characterized by low annual rainfall which is highly seasonal and unreliable from year to year. The summer is hot and dry and the winter mild (Azer 1973). The rainy period extends from Oct to May, but most of the rainfall occurs between Dec and Mar. Four major agroecological zones are recognized (Table 2.3.2).

Table 2.3.2. Agroecological zones of Jordan.

Zone	Annual rainfall
1. Desert (91.5%)	<200 mm
2. Marginal (6%)	200–350 mm
3. Semi-arid (about 1.5%)	350–500 mm
4. Semi-humid (1%)	500–800 mm

Chickpea is sown mainly in the marginal and semi-humid areas on red Mediterranean soils (Fig. 2.3.5), some of which are deep, with a good water-holding capacity (exceeding 100 mm m^{-1} soil depth).

Cropping Systems

Chickpea is grown as a spring or a summer season crop in the wetter rainfed areas (rainfall around 300–500 mm). The crop is sown in Mar and harvested in Jul. It grows mostly on moisture stored in the soil profile from the preceding winter rains. Climatic conditions during the chickpea-growing seasons are shown in Figure 2.3.6. The crop is

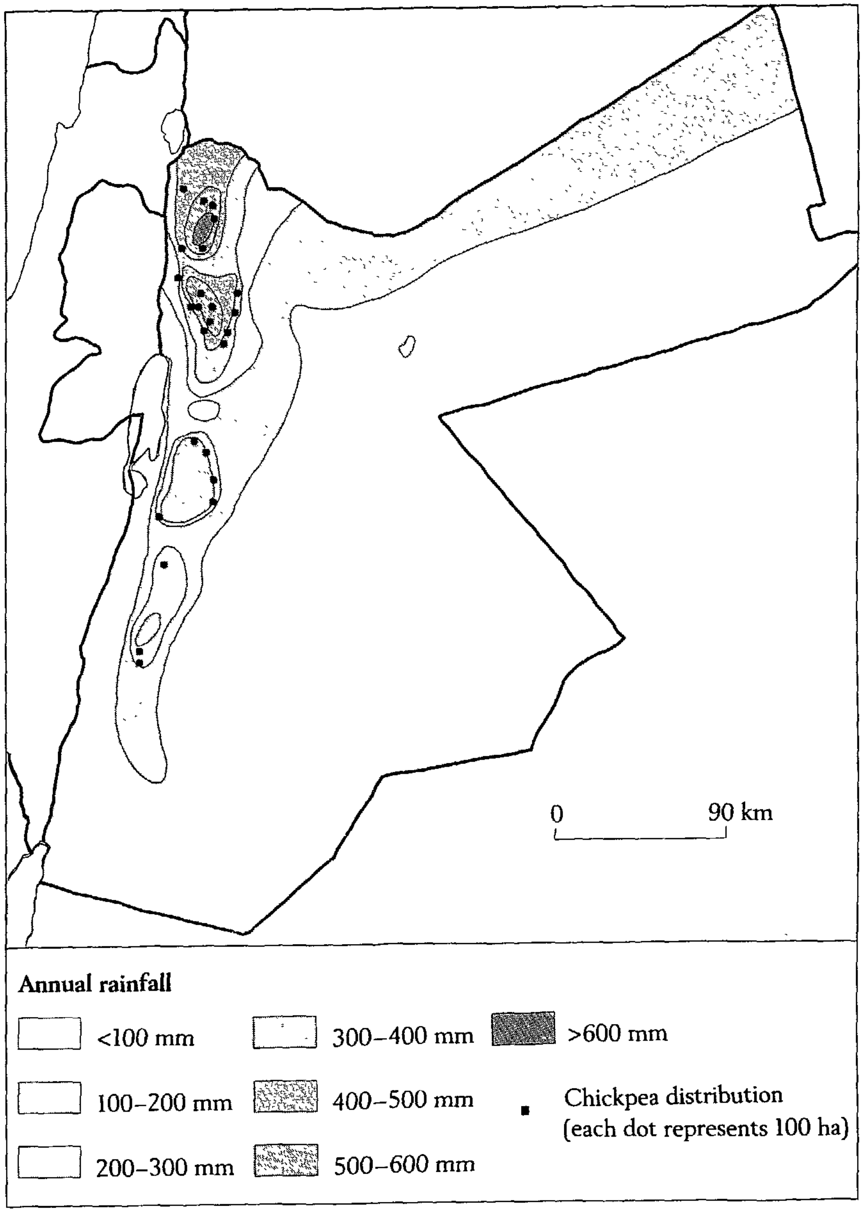


Figure 2.3.4. Average annual rainfall in relation to chickpea distribution in Jordan.

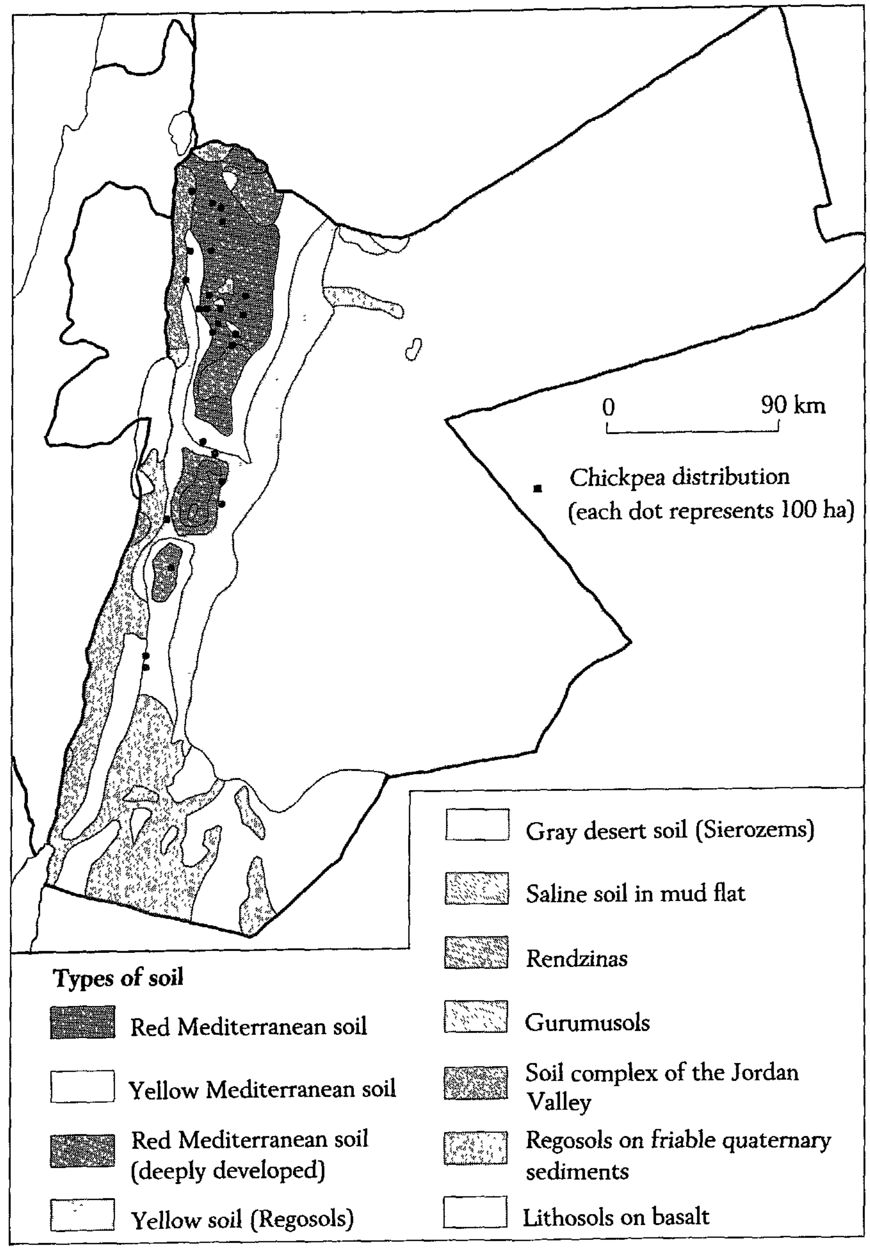


Figure 2.3.5. Soil types in relation to chickpea distribution in Jordan.

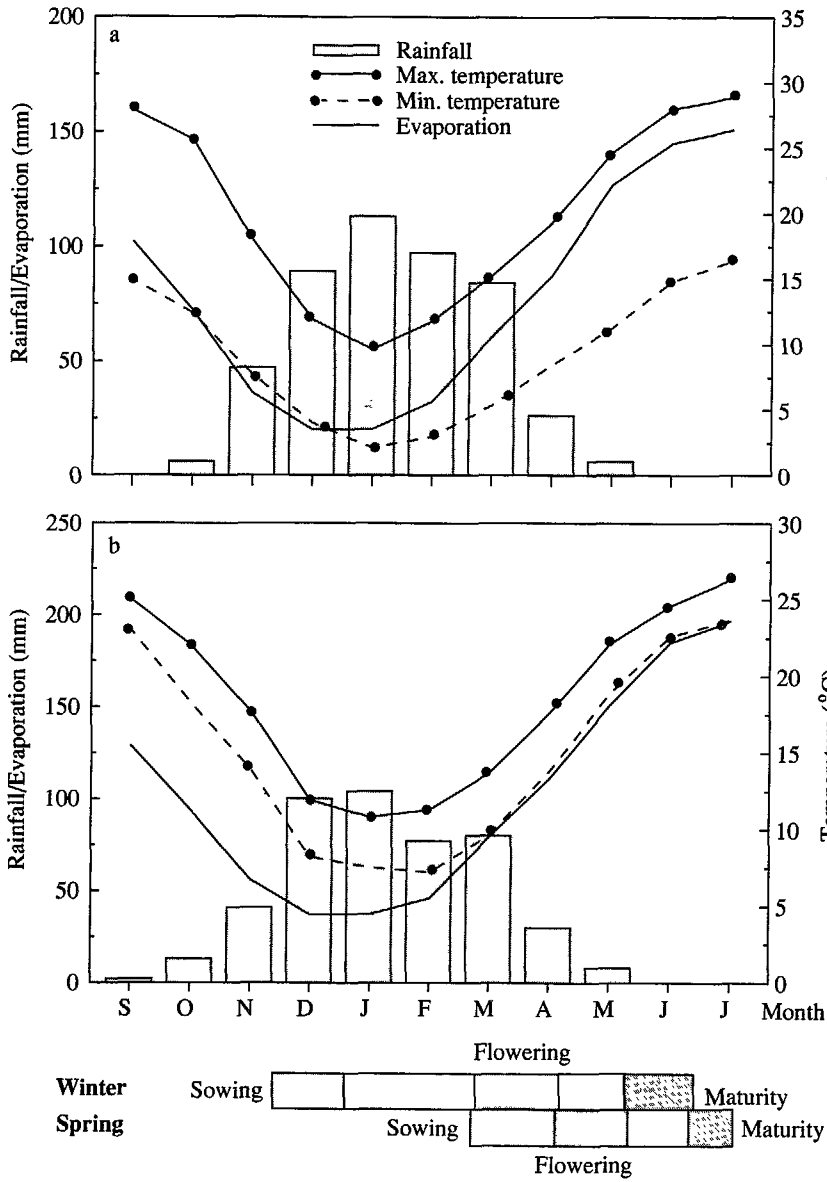


Figure 2.3.6. Crop phenology of spring- and winter-sown chickpea in relation to climatic conditions in two regions of Jordan: (a) Jubeiha; and (b) Irbid, 1931–60.

included in a 3-year crop rotation with cereals and other such summer crops as melons, vegetables, and tobacco (Haddad 1981). In recent years, forage legumes have been introduced in rotation with wheat. This system has become popular in the central regions of Jordan where livestock is an important component of production systems.

Preparatory seedbed cultivation is minimal for growing chickpea. After the cereal crop is harvested and the stubble grazed by animals, fields are disc-plowed to smother weeds. Seeds are sown every 10–15 cm at a rate of 80–100 kg ha^{-1} in furrows, 30–40 cm apart.

Generally animal-drawn plows are used, but in those places where tractors are used for sowing operations, seeds are hand-broadcast and covered by a disc-harrow. The seed used for sowing is usually a part of the produce saved from the previous crop. The crop is mainly hand-harvested.

The release of two new high-yielding cultivars for winter sowing—Jubeiha 2 and Jubeiha 3—selected from the enhanced germplasm jointly developed by the Jordanian national program and ICARDA and the identification of a promising cultivar for spring sowing, will help to usher in rapid developments in chickpea cultivation technology in Jordan. With the availability of these new varieties, winter chickpea technology was introduced in the country (Snobar et al. 1991).

Winter sowing is done in Nov/Dec, and the crop flowers during early Apr and matures by mid-Jun (Fig. 2.3.6). Benefits of winter sowing of chickpea have been demonstrated to farmers in recent years in trials conducted by the Faculty of Agriculture and the Ministry of Agriculture. The results of these trials have shown that the grain yield of winter chickpea is almost double that of spring-sown chickpea.

Mechanized cultivation practices have also been introduced and its benefits demonstrated to farmers. Farmers, although recommended to apply 100 kg diammonium phosphate (20 kg N, 46 kg P_2O_5) ha^{-1} to their chickpea crop, do not use fertilizers or any other chemical inputs.

Production Constraints

Abiotic Constraints

Chickpea yield has remained low, owing to several abiotic constraints. Drought is the major constraint to spring chickpea, and frost to winter chickpea. Research is focused on the evaluation of promising genotypes tolerant of these stresses.

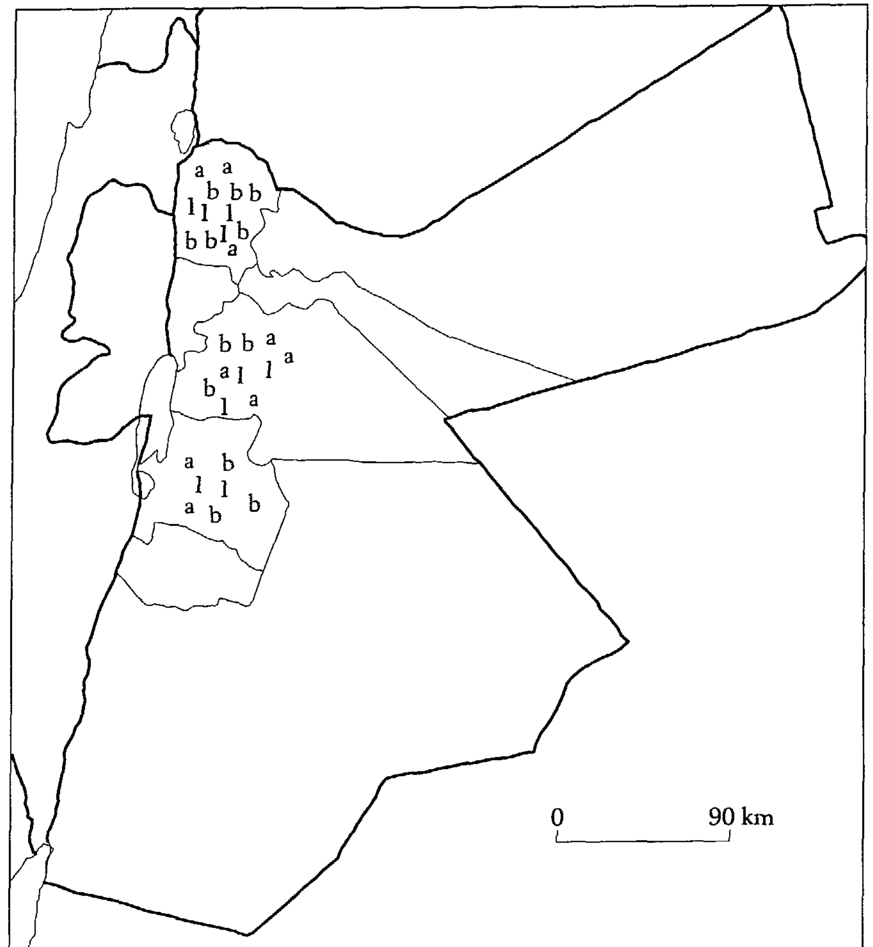
Biotic Constraints

Diseases

Ascochyta blight (*Ascochyta rabiei*) is the most important disease, particularly of winter chickpea, although yield losses due to it have not been estimated and its occurrence in the country has not been properly documented. Pathologists believe that it has been present in the country for a long time. However, no epidemic occurrence has been reported. Spring-sown chickpea is popular mainly because it escapes from ascochyta blight. The distribution of the disease is shown in Figure 2.3.7.

Insect pests

Figure 2.3.7 shows the distribution of the two most important chickpea pests in Jordan. Insect pests on chickpea are, however, relatively fewer than on other crops in the country. Yield losses have not yet been quantified. Most of the damage is due to chickpea leafminer (*Liriomyza cicerina*) and pod borer (*Helicoverpa* sp). Pod borers are common on chickpea in almost all parts of Jordan and the infestation varies from 0 to 20%. Chemical control measures are effective and are used when infestation is high.



	Severe	Moderate	Low
Ascochyta blight	l		l
Pod borer			a
Leafminer		b	

Figure 2.3.7. Disease and insect pest incidence on chickpea in Jordan.

Nematodes

Nematodes have not been identified as a major constraint to chickpea production.

Weeds

Weeds are generally not a problem in the spring-sown crop but are a major constraint to winter chickpea. The highest yield loss due to weeds recorded in experiments was 82%. Herbicides that can effectively control both broad- and narrow-leaf weeds are available (Yasin 1991). Hand weeding, although expensive, is done for both spring and winter chickpea.

Mechanical Harvesting

Traditionally, chickpea is hand-harvested. At maturity, the crop is pulled out from the ground and heaped for sun-drying in the field. It is then hauled by tractors to farmers' yards and threshing ground in the village. Threshing is done by animals, tractors or local threshers. Yield losses are high in manual threshing operations. Mechanical harvesting using combines has been shown to be successful. The availability of cheaper methods of mechanical harvesting of the crop would help in stabilizing and increasing the area under spring-sown chickpea.

Future Prospects

There is considerable scope for expanding chickpea production in Jordan (Fig. 2.3.8). High price is a strong incentive for farmers to increase chickpea area and production. It is realistic to expect self-sufficiency in chickpea production in Jordan because the gap between indigenous production and imports is small and should be easy to bridge. Around 11 000 t of chickpea were imported in 1990; this

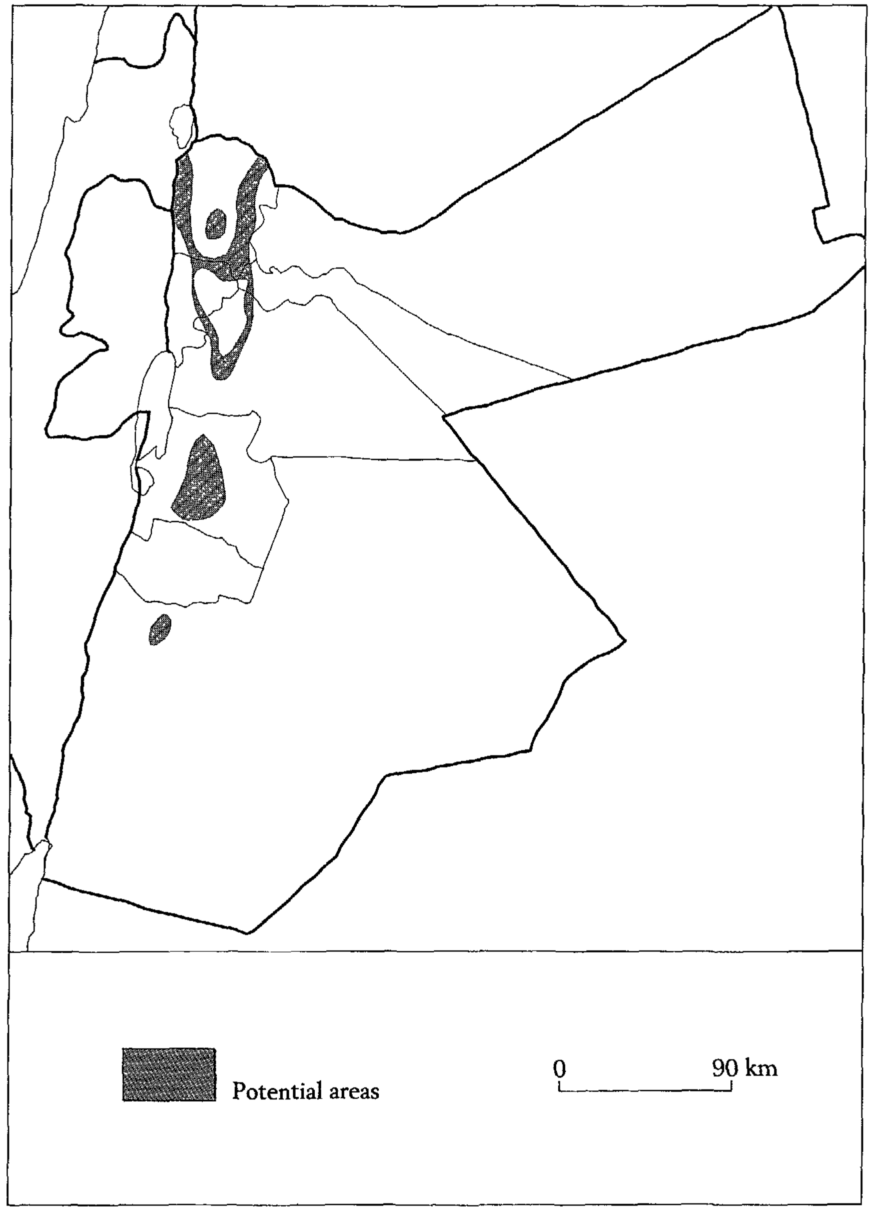


Figure 2.3.8. Potential areas for expansion and/or intensification of chickpea cultivation in Jordan.

amount can be easily produced in the country by increasing the area under chickpea through fallow replacement in the wheat-fallow rotation system. The introduction of winter sowing with the newly released cultivars that have a high yield potential, seems attractive to farmers as grain yield can be doubled by using these cultivars. Follow-up action and demonstration trials to popularize winter sowing of chickpea with a vigorous extension campaign consisting of integrated management of diseases, insect pests, and weeds are being pursued. But more work needs to be done to improve the resistance of varieties to cold and ascochyta blight and to increase seed size. Weed control practices should also be further improved. Efforts should be made to popularize complete mechanization of chickpea production, from sowing to harvesting, as this is now possible.

Potential chickpea areas in Jordan are those with around 300 mm rainfall and a moderate slope of 0–15%. In the semi-arid and semi-humid zones (total land area of around 234 800 ha), about 26 900 ha have a moderate slope (0–9%) and are suitable for chickpea production (Fig. 2.3.8). Further expansion of area is possible in the marginal zone where rainfall is between 300–350 mm.

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2.4. Chickpea in Syria

H El-Ahmed[1], W Tawil[1], M El-Ahmed[1], A Al-Seoud[2], and A M Nassif[1]

Latitude	35–37° N
Longitude	36–43° E
Altitude	15–940 m
Total population	13.8 million
Economically active	3.4 million
Economically active in agriculture	0.7 million
Total area	18.5 million ha
Cultivated area	5 million ha
Rainfed area	4.3 million ha
Annual rainfall	100–1360 mm
Chickpea rank among legumes	Second
Crop season	Spring (traditional) Winter (recent)

Introduction

Syria is the most important chickpea producer in the Arab world, accounting for 12% of the total chickpea area in the region (but only 0.4% of the world chickpea area) (El-Mott 1984). Chickpea (*Cicer arietinum*) is the second most important legume in Syria after lentil (*Lens culinaris*) (FAO 1991). It is predominantly a rainfed crop and accounts for 0.87% of the total rainfed cultivated area in Syria. The administrative boundaries of the country are shown in Figure 2.4.1 and chickpea distribution in Figure 2.4.2.

1. Directorate of Agriculture and Scientific Research (DASR), Douma, PO Box 113, Damascus, Syria.
2. Ezraa Agricultural Research Centre, Ezraa, Daraa, Syria.

Uses

Chickpea is an important ingredient in the Syrian diet. Popular preparations are *hommos* (puree), *falafel* (fried spicy cakes), and *tisqieh* (soaked and boiled chickpea, eaten with *qubz* or flat bread).

Area, Production, and Productivity

Chickpea production is sufficient to meet the country's demand (El-Mott 1984). Exports for 1976–88 averaged around 8700 t per year. Cropping area and production vary widely between years, e.g.,

Table 2.4.1. Area, production, and yield of chickpea, and rainfall in Syria, 1981–87.

	Area ('000 ha)		Production ('000 t)		Yield (t ha^{-1})		Rainfall (mm)	
Province	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Southern Syria								
Daraa	22.4	±12.4	16.4	±11.5	0.68	±0.14	229	±50.6
El-Sweda	15.0	±8.2	4.3	±3.9	0.25	±0.15	336	±63.4
Central Syria								
Homs	0.5	±0.29	0.8	±0.36	0.94	±0.12	400	±87.2
Hama	1.3	±0.45	1.2	±0.49	0.91	±0.12	351	±32.0
El-Ghab	1.1	±0.47	1.6	±0.69	1.57	±0.39	727	±144.4
Northern Syria								
Idleb	7.8	±1.8	7.4	±2.5	0.95	±0.20	527	±108.0
Aleppo	12.8	±2.7	9.1	±2.5	0.72	±0.14	317	±57.3
Northeastern Syria								
El-Hasakeh	1.9	±2.6	1.4	±1.9	0.78	±0.16	262	±60.0
Total country[1]								
Mean	65.8	±22.3	43.6	±18.7	0.66	±0.1		
Maximum	94		75		0.80			
Minimum	25		15		0.48			

1. Based on data for 13 years.
Source. Anonymous (1981–90).

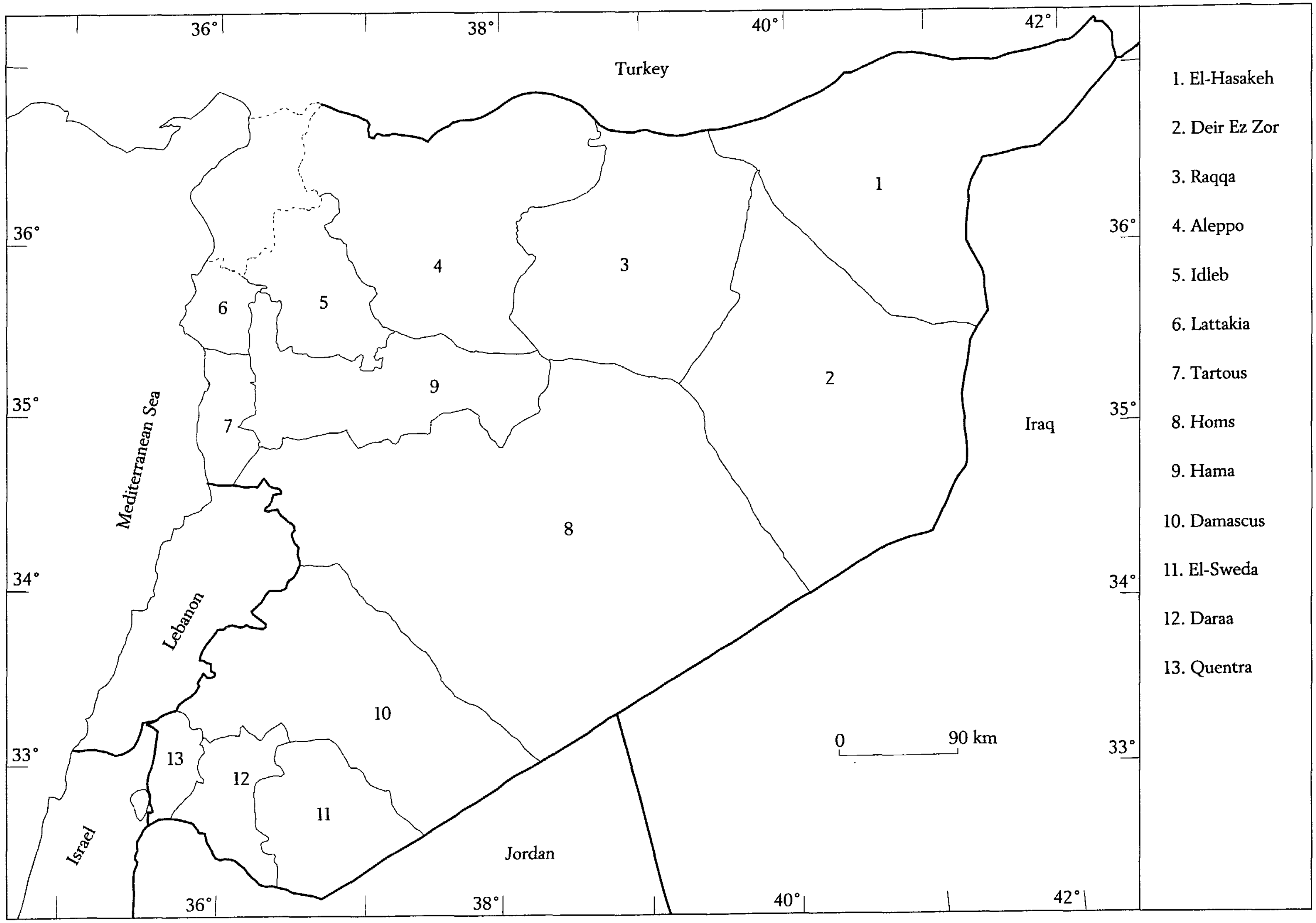

Figure 2.4.1. Administrative boundaries of Syria.

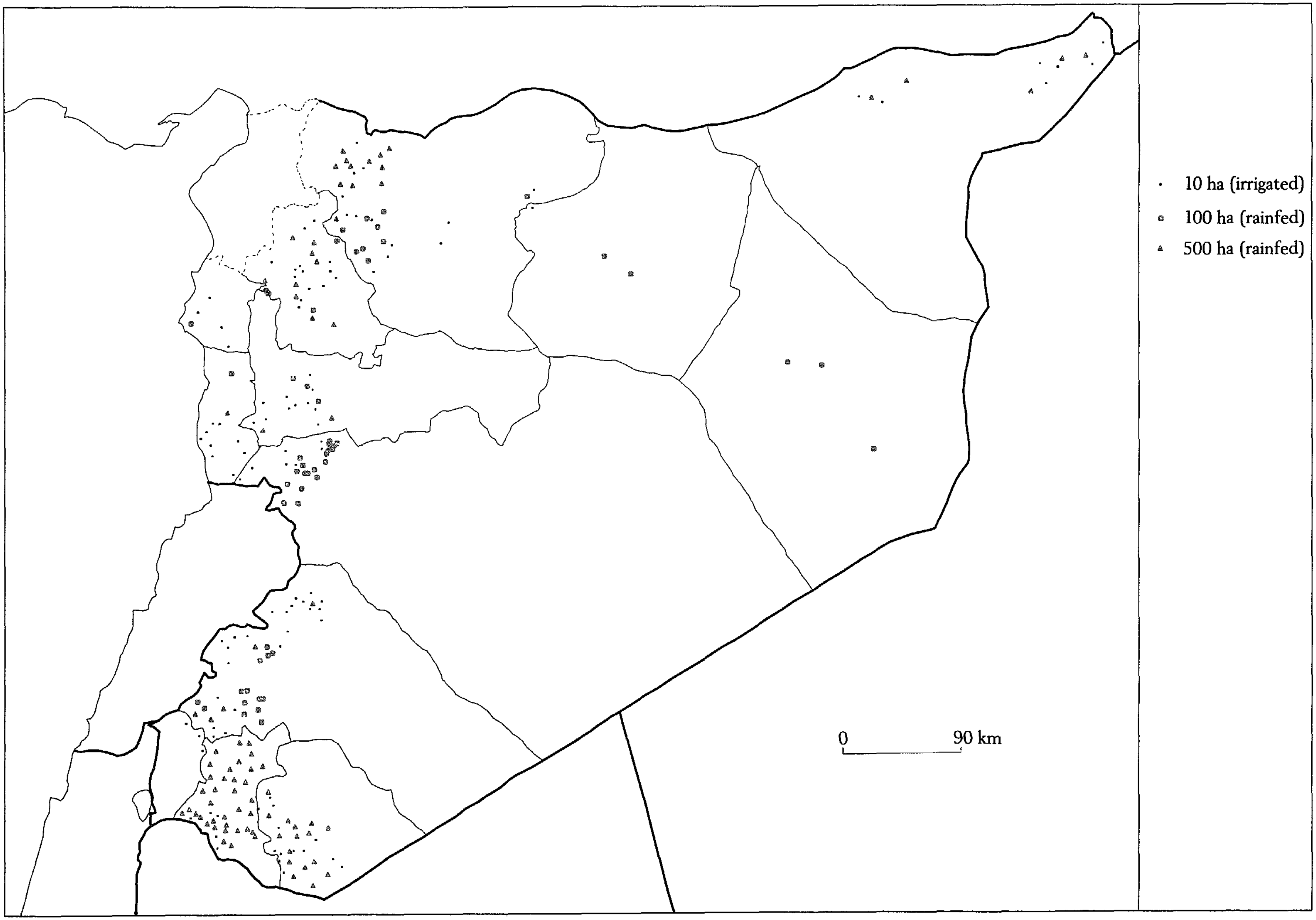

Figure 2.4.2. Chickpea distribution in Syria.

the cropping area ranged from 25 000 to 94 000 ha between 1970 and 1991 (Table 2.4.1; Figure 2.4.3). Average yields are around 0.65 t ha^{-1}; higher in the high-rainfall locations of El-Ghab and Idleb, and lower in El-Sweda (Table 2.4.1). Most of the variability in yield is due to rainfall distribution. Winter-sown chickpea has a distinct yield advantage of 60 to 220% over spring-sown chickpea (Table 2.4.2).

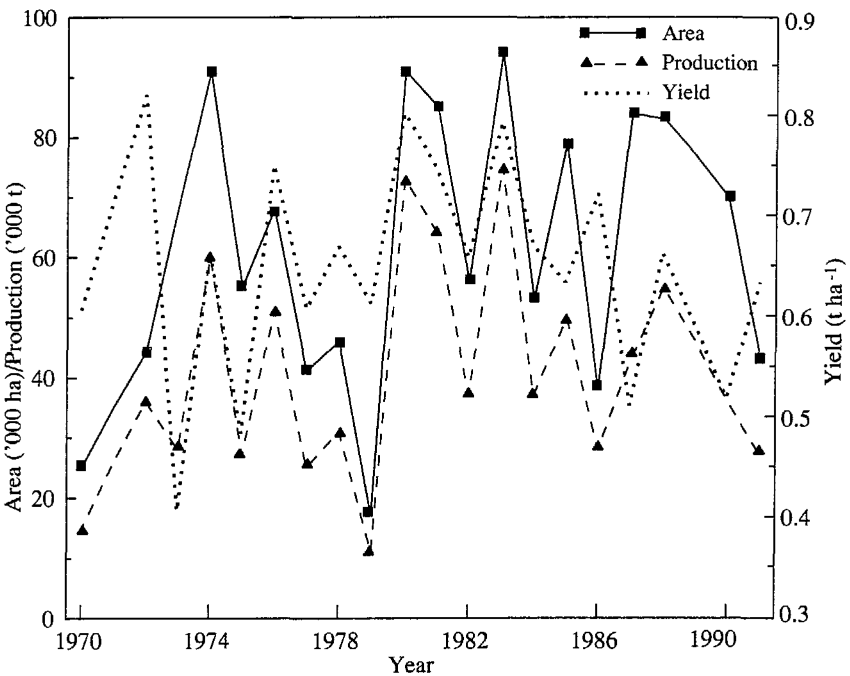

Figure 2.4.3. Trends in area, production, and yield of chickpea in Syria, 1970–91.

Climate, Soil, and Crop Distribution

Detailed climatic data (Anonymous 1977) and soil maps (Ilaiwi 1985) for Syria are available. The country has been divided into five agroclimatic zones based on annual precipitation (FAO 1982) (Fig. 2.4.4). Chickpea cultivation is spread across Zones 1 (350–600 mm rainfall) and 2 (250–350 mm rainfall), but is more intensive in central and southern areas of Zone 2. The two zones together, have nearly 5.2 million ha (28% of the total area). Chickpea cultivation has expanded in recent years to Kamishly, Malkiya, and El-Hasakeh provinces in the north-eastern region.

The minimum temperature isotherms for Dec and Jan suggest that frost is an important constraint of winter chickpea but may not be a severe limitation in the coastal and southern regions (e.g., Houran in Daraa province is an important production region).

Table 2.4.2. Comparison between Ghab 1, a winter chickpea variety and a local spring chickpea variety on experimental stations in Syria, 1986/87 to 1990/91 average.

	Grain yield (t ha^{-1})			Yield increase of Ghab 1 over	Crop duration (d)	
Location	Winter Ghab 1	Spring Local	SE	Local (%)	Winter	Spring
Hama	1.54	0.94	±0.12	64	174	104
Jellin	1.04	0.27	±0.12	219	155	-
Ezraa	0.83	0.51	±0.3	62	164	108
Idleb	1.39	0.83	±0.11	68	152	85
Aleppo	0.58	0.33	±0.57	77	157	82
Kamishly[1]	1.53	0.49	-	210	166	83
El-Ghab[1]	3.49	1.21	-	189	171	97
Mean	1.25	0.66	±0.57	89	160	93

1 Based on 2-year data, excluded from analysis and mean (SE computed from error variance of variety × year)

Source: Directorate of Agriculture and Scientific Research, Damascus, Syria.

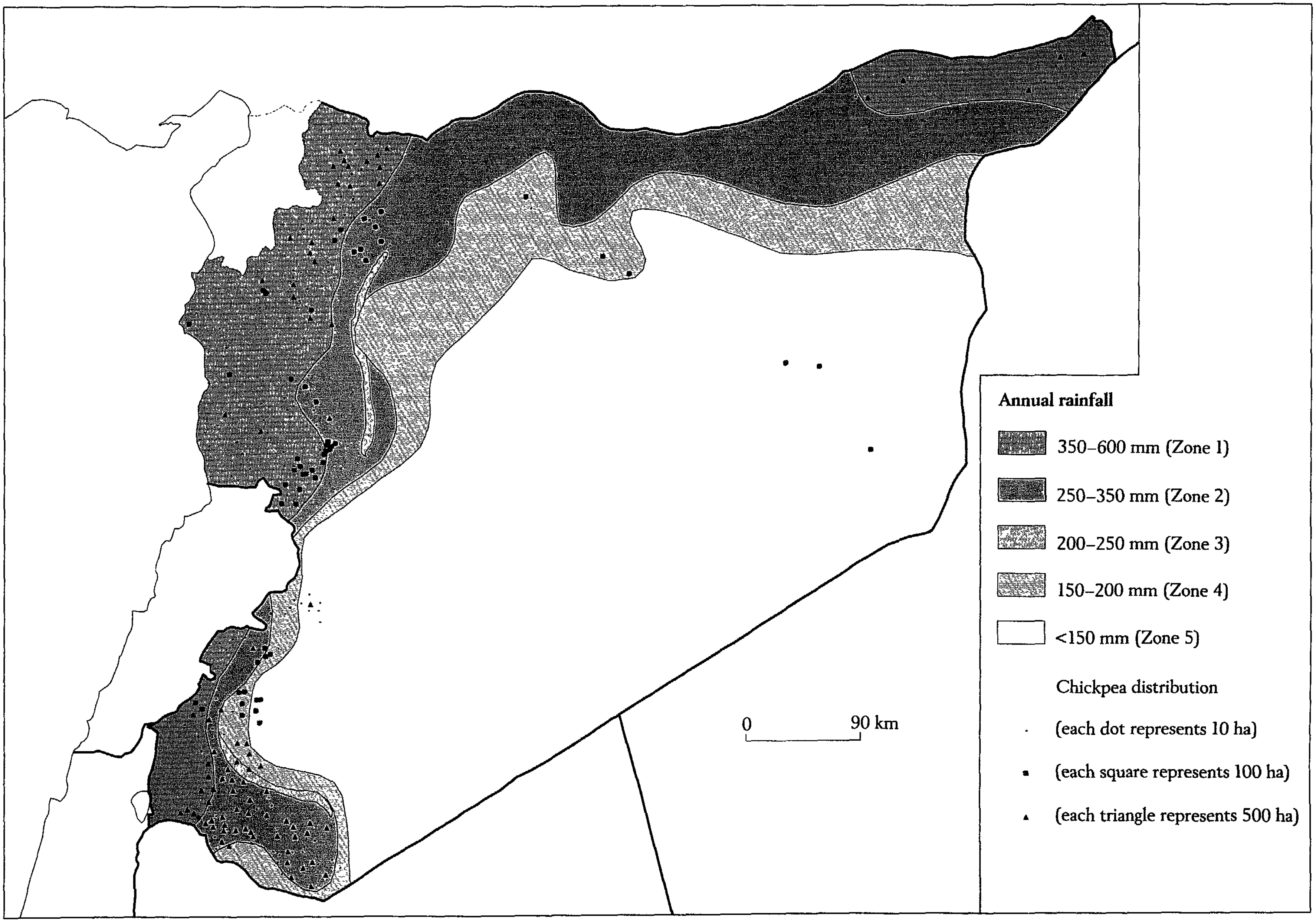

Figure 2.4.4. Mean annual rainfall in relation to chickpea distribution in Syria. (Source: Ilaiwi 1985.)

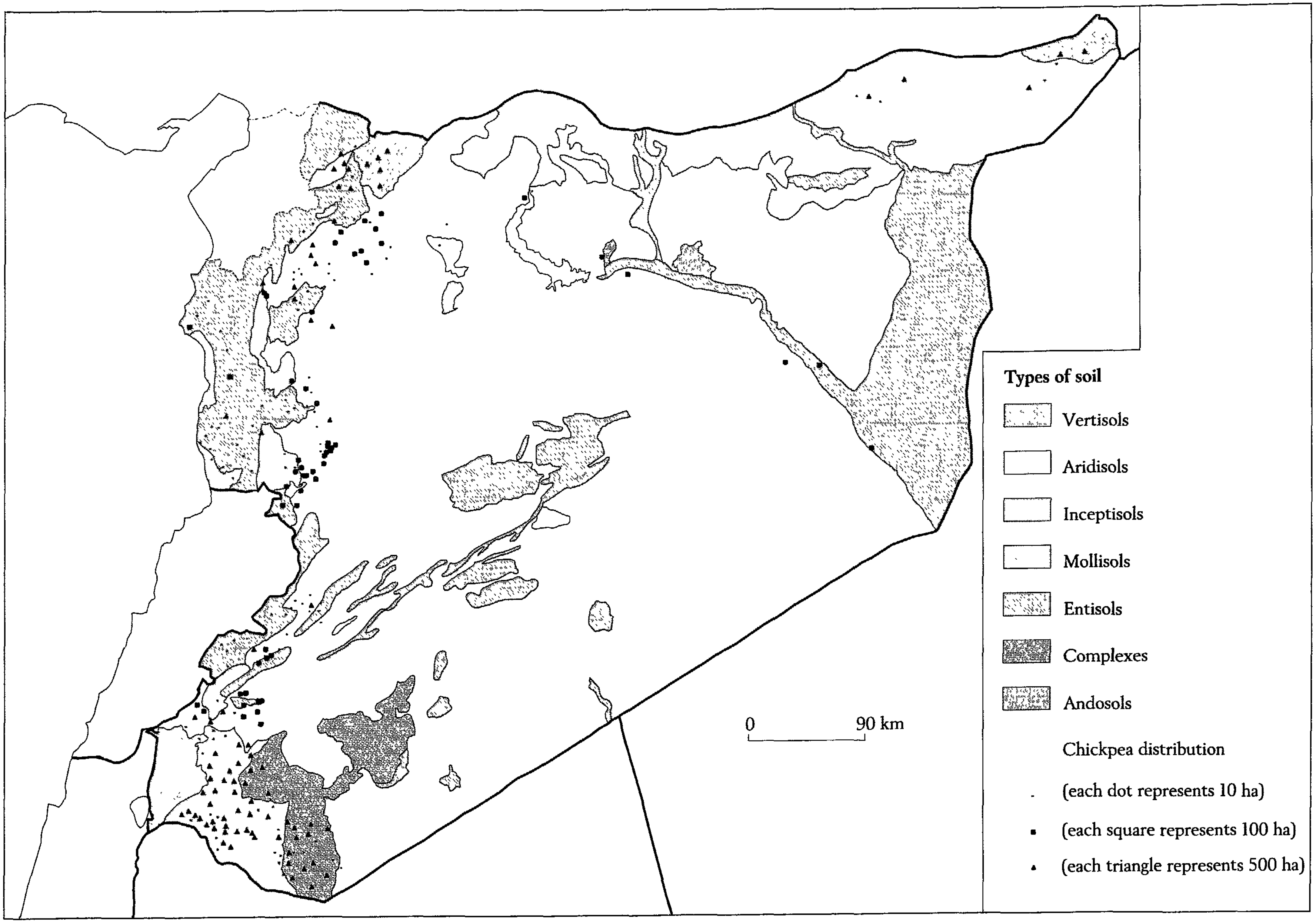

Figure 2.4.5. Soil types in relation to chickpea distribution in Syria.

Chickpea is mostly grown on Inceptisols, which can supply 100 mm of plant extractable soil moisture per meter of soil depth. It is also grown on Entisols, Aridisols, and Vertisols (Fig. 2.4.5).

Cropping Systems

Chickpea is most commonly grown in rotation with wheat. Unlike such cool-season food legumes as lentil, faba bean, and peas, which are sown at the beginning of winter (Nov/Dec), chickpea is traditionally grown as a spring crop. It is sown in mid Feb/Mar (sometimes even in Apr), and harvested in Jun. Most of the rainfall (75% of the seasonal total) is received in winter (Nov to Feb) and the remaining during spring, a characteristic feature of the Mediterranean climate (Fig. 2.4.6). Spring sowing is taken up only when there is sufficient rainfall. Local varieties are preferred because they are large-seeded and better adapted to yearly fluctuations in rainfall. The average growth duration of spring chickpea ranges from 80 to 110 days (Table 2.4.2). Sowing is mainly done by broadcasting seed after applying 50 kg ha^{-1} phosphorus.

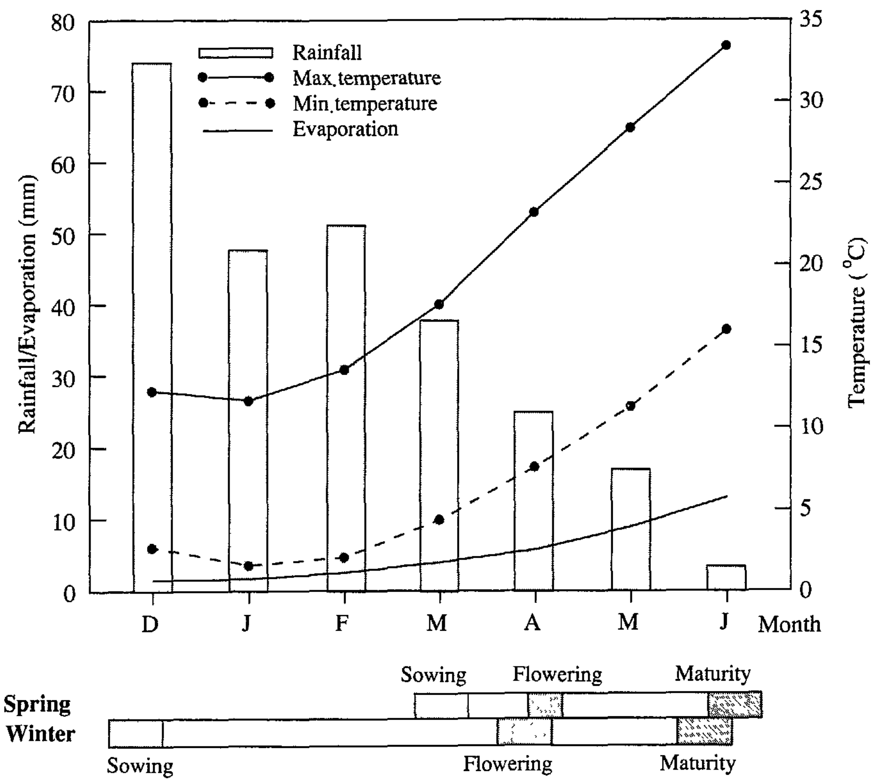

Figure 2.4.6. Crop phenology of winter- and spring-sown chickpea in relation to climatic conditions, Tel Hadya, Syria, 1986–92.

A major breakthrough in chickpea research has been the identification of varieties tolerant of ascochyta blight disease and frost (e.g., Ghab 1, Ghab 2, and Ghab 3) by the Directorate of Agriculture and Scientific Research (DASR) and ICARDA. This has enabled a better matching of the growth period to favorable climatic conditions (Saxena 1984), which was previously not possible, and has helped to increase yield by extending the crop duration from 90 days in spring to 160 days in winter. With the availability of these cultivars, it is expected that winter sowing of chickpea will spread in Syria. They will also help to increase chickpea productivity and stabilize its production in the country. Winter chickpea is sown in Nov/Dec; it flowers in Apr, and is harvested in Jun.

Production Constraints

The constraints to chickpea production have been summarized by El-Mott (1984). For spring chickpea, the constraints in order of priority are: drought and heat; wilt (*Fusarium oxysporum*) and ascochyta blight (*Ascochyta rabiei*); pod borers (*Helicoverpa* spp); poor plant stands; and weeds. In winter, the constraints are: aschochyta blight; frost; weeds; nonavailability of appropriate machines for harvesting; pod borers; and nematodes.

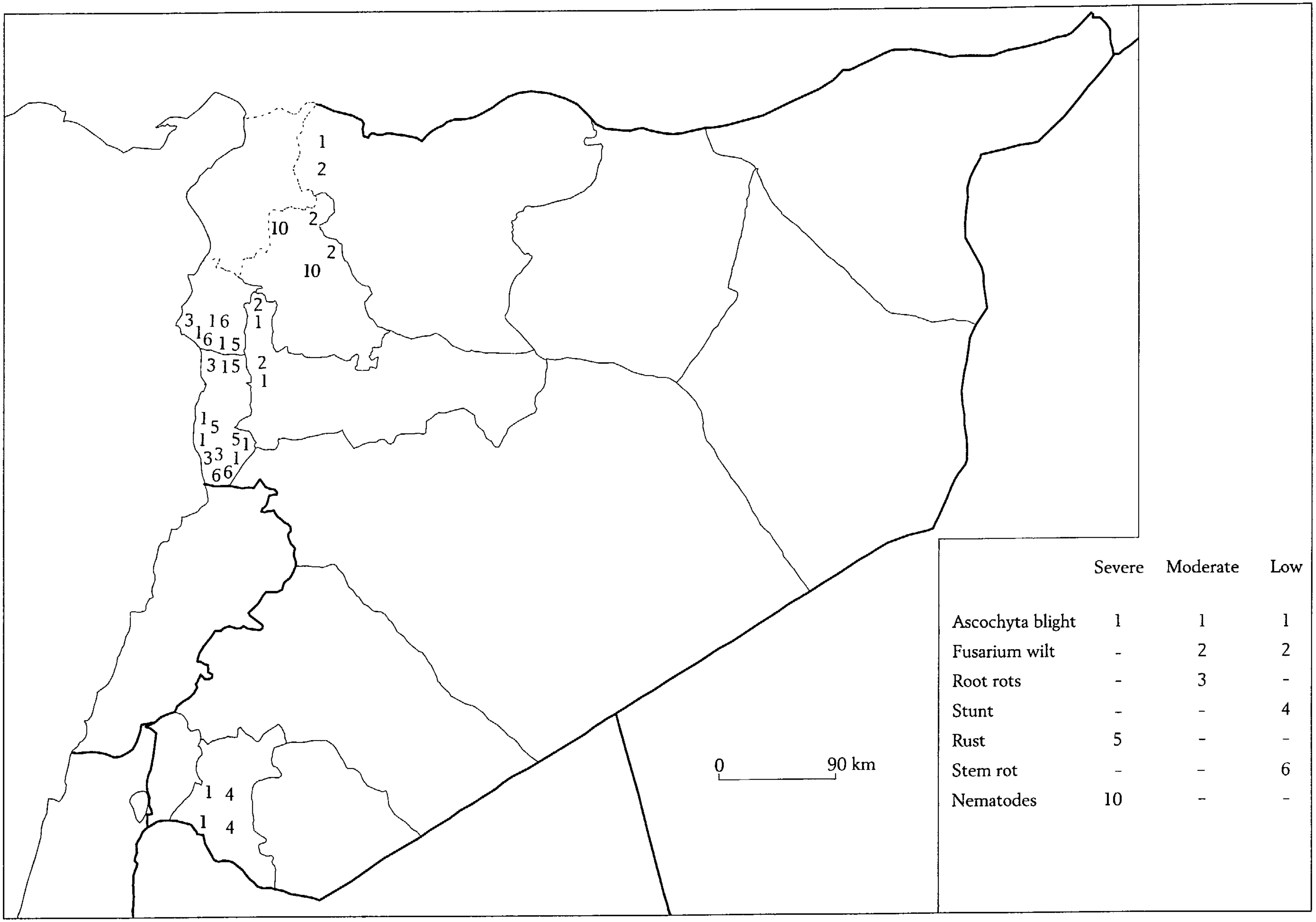

Figure 2.4.7. Disease incidence on chickpea in Syria.

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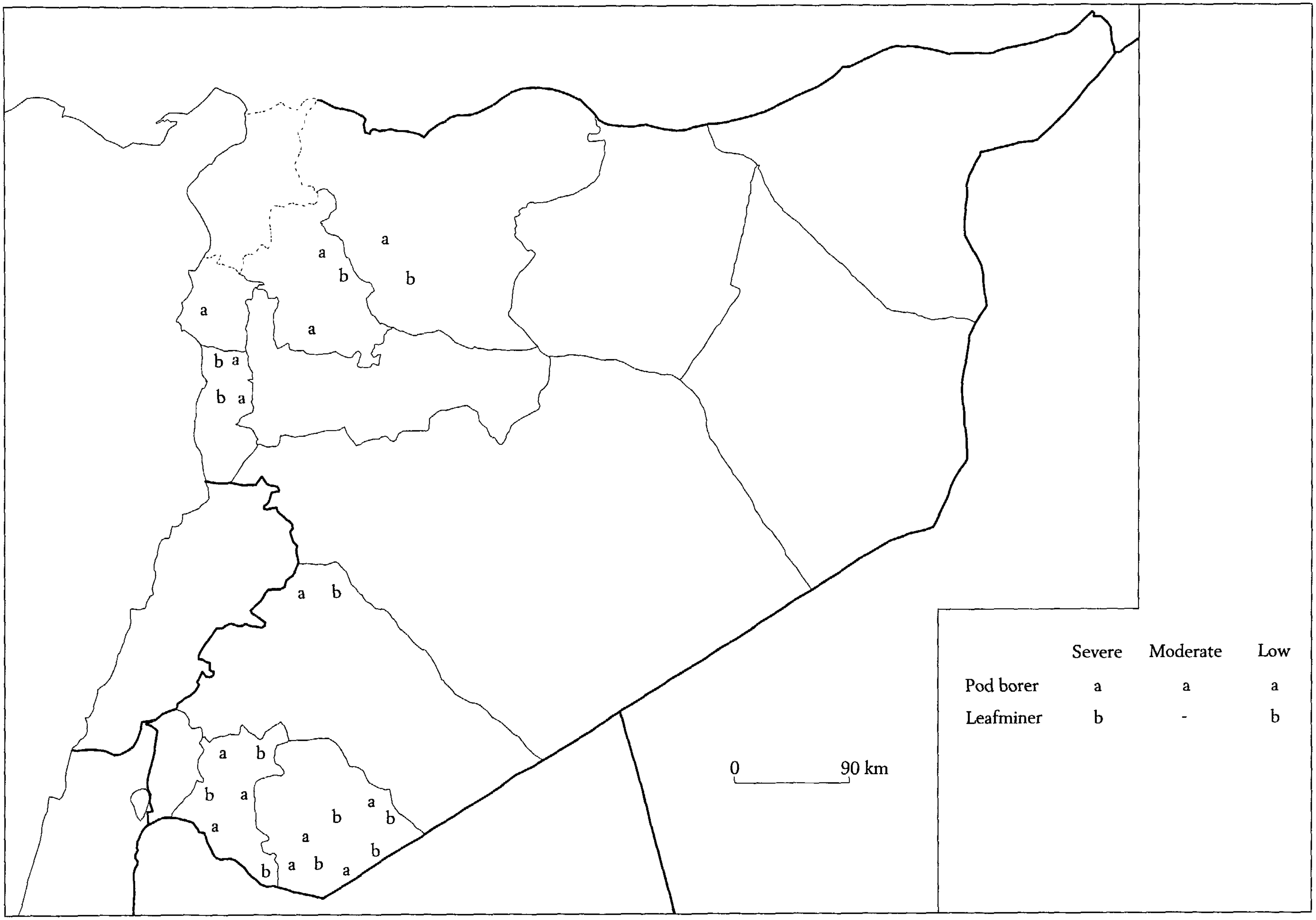

Figure 2.4.8. Insect pest incidence on chickpea in Syria.

Abiotic Constraints

Drought is the most important constraint of spring chickpea. Yield losses due to drought are around 40 to 50%. A single presowing irrigation has doubled yields in experiments (Saxena et al. 1993). Poor plant stands, another limiting factor, are primarily due to broadcast sowing whereby seeds are placed at uneven depths; some seeds fall on dry soil and therefore do not germinate. Other such factors as loss of plant stand due to early failure of rains (Brown et al. 1989), diseases, insect pests, and birds may also contribute to poor plant stands. Frost is an important constraint, particularly in winter-sown chickpea.

Biotic Constraints

Diseases

Yield losses due to diseases are not yet quantified. All major documented fungal and virus diseases of chickpea have been found in the country (Fig. 2.4.7). Ascochyta blight, a foliar disease, is most important on winter chickpea, particularly in coastal (Jableh), southern (Ezraa), and northern (Jinderis) Syria. Fusarium wilt is important on spring chickpea, especially in the northern parts (Afrin and Jinderis). Local varieties from the southern zone are tolerant of this disease. Chickpea root rot (*Rhizoctonia bataticola*), stem rot (*Sclerotinia sclerotiorum*) rust (*Uromyces ciceris-arietini*), and stunt (bean leafroll virus) are of local significance in some areas.

Insect pests

Insect pests on chickpea are relatively few, compared with those on other crops (Fig. 2.4.8). Yield losses have not yet been quantified. Most of the pest damage is due to chickpea pod borers. Common species are *Helicoverpa armigera* and *Heliothis viriplaca*. Damage due to *H. viriplaca* is restricted to the first 6–7 weeks, but damage due to *H. armigera* continues until harvest. Pod borer infestation is relatively high in the southern provinces. Leafminer (*Liriomyza cicerina*) which was not an important insect pest in the past, has gained greater economic significance recently, especially in coastal, northern, and southern Syria. It threatens to become the main insect pest of chickpea in future. The introduction of winter chickpea might increase the pod borer and leafminer populations. Aphids (*Aphis craccivora*) are not important, except as a vector of bean leafroll virus that causes stunt disease.

Nematodes

Nematode is not a major constraint, but some damage is caused by cyst (*Heterodera ciceri*) and root lesion (*Pratylenchus thornei*) in the Idleb and Aleppo provinces (Al-Ahmed 1988). Root-knot nematode (*Meloidogyne artiellia*) is found sporadically on winter-sown chickpea (Al-Ahmed 1988).

Weeds

Weeds are a major constraint, particularly for winter chickpea. Up to 40% yield losses due to weeds have been recorded. Herbicides are available for effective control of both broad- and narrow-leaf weeds (Saxena 1984; Pala and Mazid 1991). Hand weeding, although costly, is practiced to some extent in winter chickpea.

Mechanical Harvesting

Most of the chickpea grown in Syria is currently hand-harvested. Options for mechanical harvesting would help stabilize, or even increase, the current area under the crop. In recent years combines have been used by some farmers to harvest chickpea. More farmers would use combines if the following problems are overcome:

- Yield losses which are currently estimated at 10–15%;
- Shattering leading to the growth of chickpea volunteers in the subsequent crop;
- Difficulties in rapid calibration of machinery after use on other crops.

Future Prospects

There is good scope to increase chickpea area, production, and productivity. Farmers began growing winter chickpea in 1987/88, and it is now popular in Al-Hasakeh, Aleppo, and El-Ghab provinces. Surveys have shown that the winter chickpea area in 1991/92 was around 15 000 ha (unofficial estimates).

Constraints to chickpea yield should be analyzed. Immediate short-term (5 years) priorities for expanding and stabilizing chickpea area and production are:

- Extending the winter-sowing technology with integrated management of diseases, insect pests, and weeds, and increasing the availability of options for mechanical harvesting;
- Stabilizing the spring chickpea yield by using varieties that can better escape/tolerate drought.

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2.5. Chickpea in Turkey

I Kusmenoglu and K Meyveci[1]

Latitude	30–42° N
Longitude	25–44° E
Altitude	0–2500 m
Total population	59.6 million
Economically active	25.6 million
Economically active in agriculture	11.7 million
Total area	77.9 million ha
Cultivated area	24.7 million ha
Rainfed area	22.3 million ha
Annual rainfall	400–1000 mm
Chickpea rank among legumes	Second
Crop season	Spring

Introduction

Turkey accounts for 12% of the total world chickpea (*Cicer arietinum*) production. It is the second largest producer of the crop in the world (FAO 1992) and the largest in WANA. Chickpea is grown on approximately 3% of the total cultivated area and is the second most important food legume after lentil (*Lens culinaris*) in the country. The administrative boundaries of Turkey are shown in Figure 2.5.1 and the chickpea distribution in Figure 2.5.2.

Annually, 19 million ha are used for the production of various field crops and 5.2 million ha (21% of the total agricultural land) are left fallow (SIS 1989). Chickpea has been a traditional crop in Turkey for centuries. In the late 1970s, the crop was grown in rotation with cereals in the transition zones of central Anatolia (Fig. 2.5.3). It is one of the three crops included in the Utilization of Fallow Area Project (UFAP) and has, therefore, received special attention. Large new areas on the fallow land are sown to the crop every year.

Exports of chickpea increased steadily from the 1980s, and reached 367 000 t in 1991, which earned US$ 139 million in foreign exchange for the country (Akova 1992, SIS 1990) (Fig. 2.5.4). In 1990, chickpea was the third most important export crop and foreign exchange earner after raisins and hazelnuts (Uzunlu and Bayaner 1991).

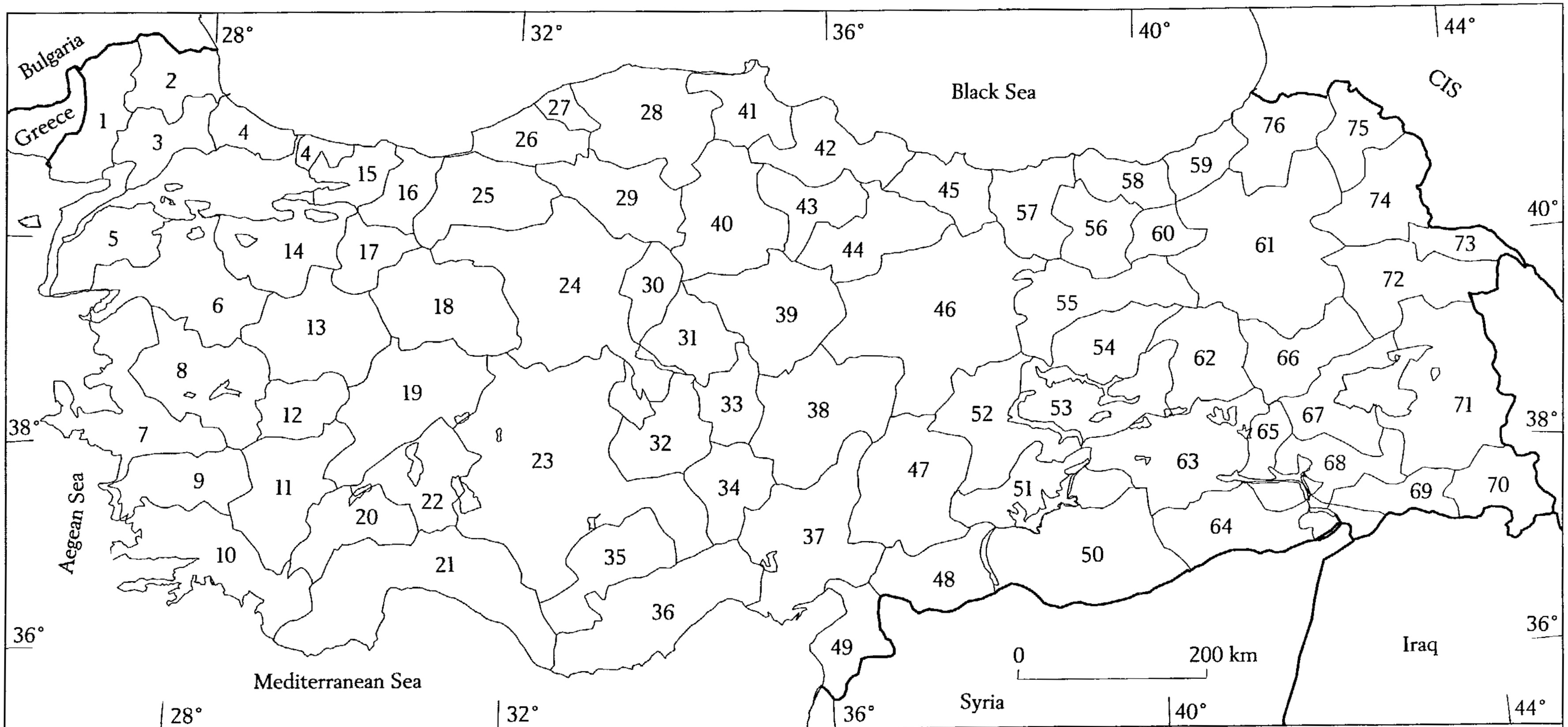
Uses

Chickpea is one of the main sources of protein in the diet of the Turkish people, particularly in rural areas. Cultivation of large-seeded kabuli chickpea is preferred in almost all the regions of the country. It is used in various preparations in the Turkish cuisine. *Nohut yemegi* (chickpea soaked and boiled with meat and dressed with vegetables and spices) is a popular meal throughout the country. *Hommos* (puree) is common in southern Turkey. Chickpea is also used in different kinds of *leblebi* (roasted chickpea, mixed with salt, spices, or sugar and eaten as a snack). Its flour is used in making pastries.

Area, Production, and Productivity

A major breakthrough in chickpea cultivation occurred after 1982 because of the efforts made by UFAP in research and extension and rapid increases in chickpea area (Fig. 2.5.5). By 1988, 37% (estimated at around 3 million ha) of the fallow area existing in 1981 was sown to various crops, including chickpea. The increase in the field crop area was 2.3 million ha, of which 34.1% was under chickpea

1. Field Crop Improvement Centre, PO Box 226, Ankara, Turkey.



1. Edirne
2. Kirklareli
3. Tekirdag
4. Istanbul
5. Canakkale
6. Balikesir
7. Izmir
8. Manisa
9. Aydin
10. Mugla
11. Denizli
12. Usak
13. Kutahya
14. Bursa
15. Kocaeli
16. Sakarya
17. Bilecik
18. Eskisehir
19. Afyon
20. Burdur
21. Antalya
22. Isparta
23. Konya
24. Ankara
25. Bolu
26. Zonguldak
27. Bartin
28. Kastamonu
29. Cankiri
30. Kirikkale
31. Kirsehir
32. Aksaray
33. Nevsehir
34. Nigde
35. Karaman
36. Icel
37. Adana
38. Kayseri
39. Yozgat
40. Corum
41. Sinop
42. Samsun
43. Amasya
44. Tokat
45. Ordu
46. Sivas
47. K Maras
48. Gaziantep
49. Hatay
50. Sanliurfa
51. Adiyaman
52. Malatya
53. Elazig
54. Tunceli
55. Erzincan
56. Gumushane
57. Giresun
58. Trabzon
59. Rize
60. Bayburt
61. Erzurum
62. Bingol
63. Diyarbakir
64. Mardin
65. Batman
66. Mus
67. Bitlis
68. Siirt
69. Sirnak
70. Hakkari
71. Van
72. Agri
73. Igdir
74. Kars
75. Ardahan
76. Artvin

Figure 2.5.1. Administrative boundaries of Turkey.

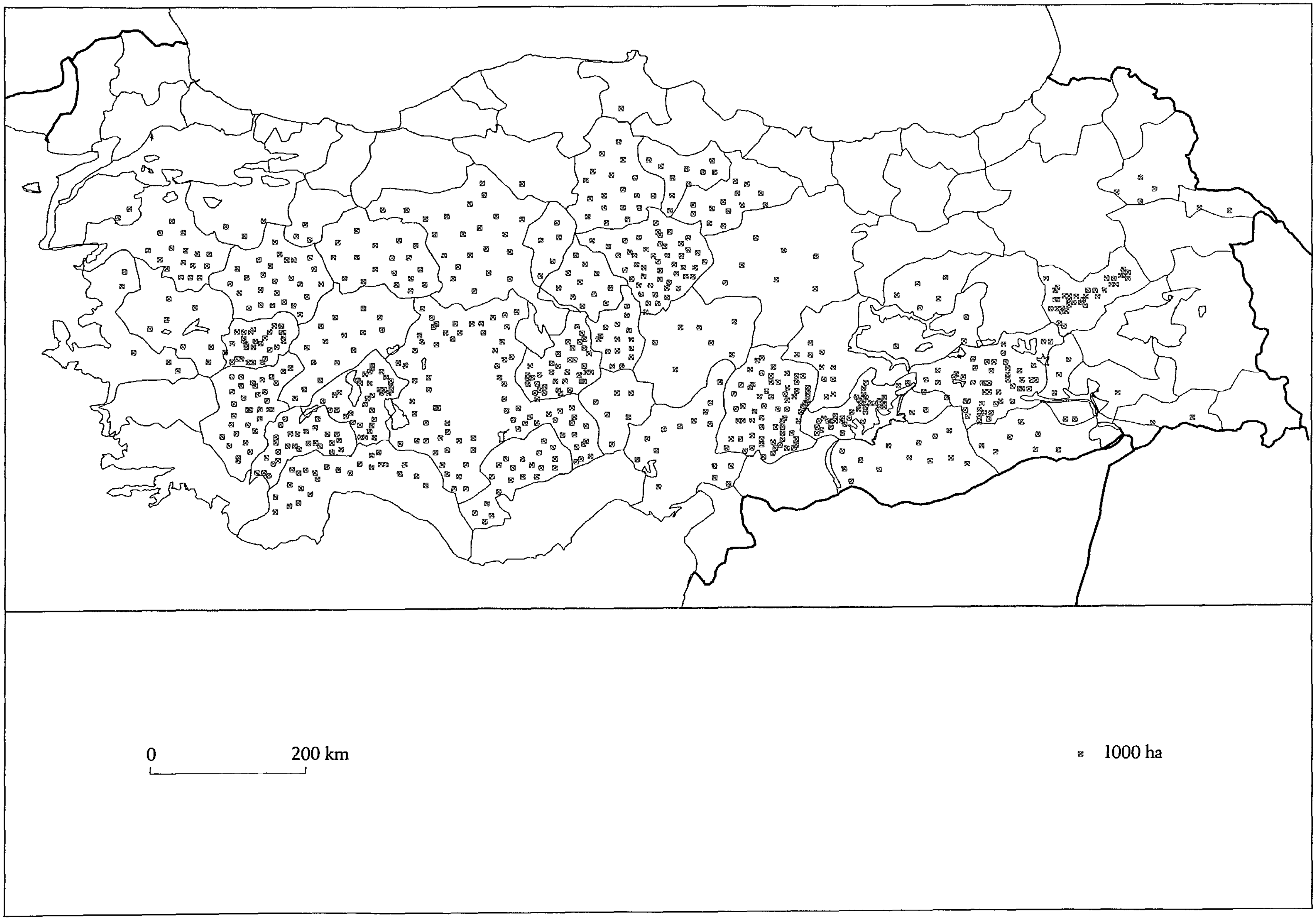


Figure 2.5.2. Chickpea distribution in Turkey.

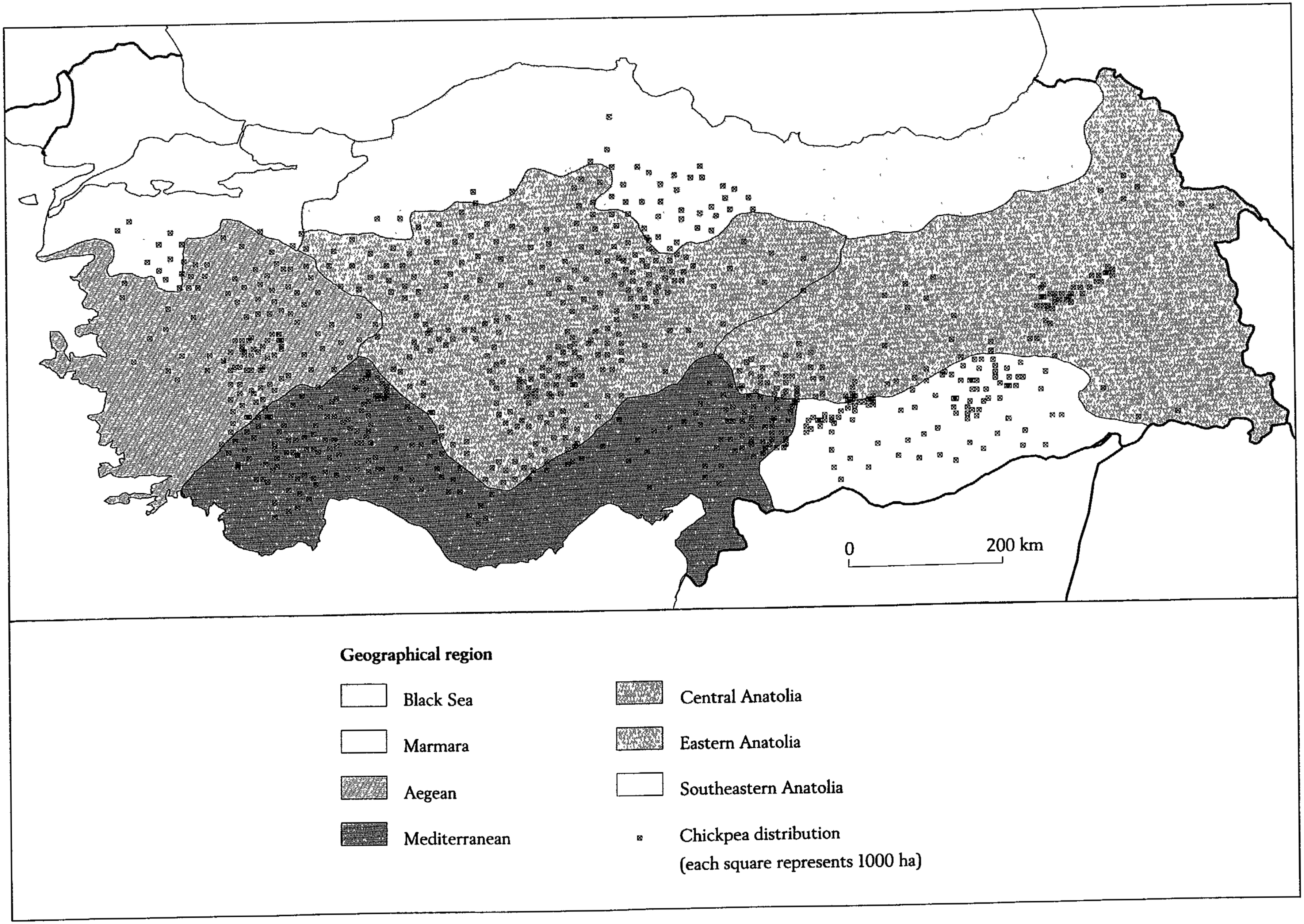


Figure 2.5.3. Geographical regions in relation to chickpea distribution in Turkey.

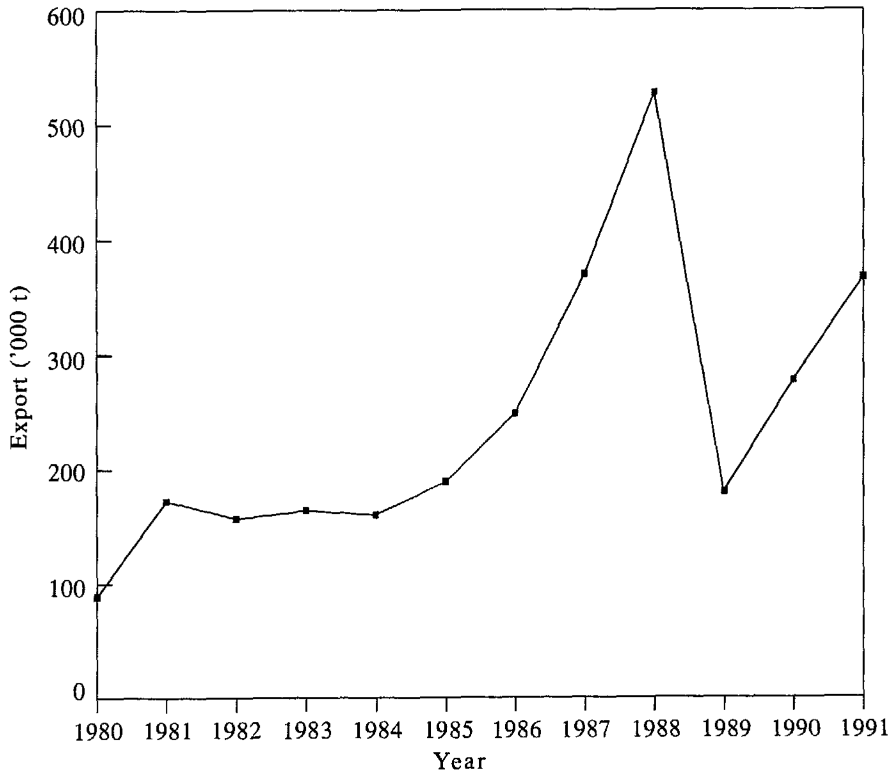


Figure 2.5.4. Chickpea exports from Turkey, 1980–91.

Table 2.5.1. Chickpea area and yield in Turkey, 1991.

Region		Area (ha)		Yield (t ha^{-1})
1. Central north		180 347		1.07
2. Aegean		126 103		1.02
3. Marmara		4 715		1.08
4. Mediterranean		172 587		0.89
5. Northeast		6 979		0.65
6. Southeast		121 577		1.01
7. Black Sea		2 570		0.77
8. Central east		88 446		1.16
9. Central south		179 982		1.01
	Total	883 306	Average	0.96

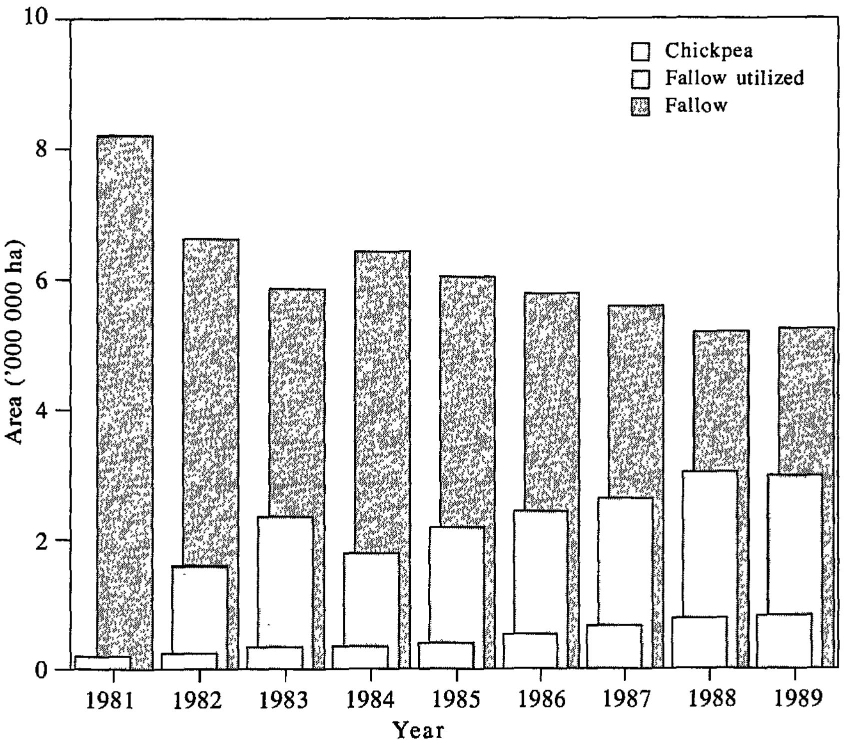


Figure 2.5.5. Fallow utilization and increase in chickpea area.

(Acikgoz et al. 1993). Substantial increases in chickpea area and production are projected in the sixth 5-year State Plan for 1990–94 by extending further its cultivation in the remaining fallow area (DPT 1990).

Although there has been more than a threefold increase in the country's chickpea area in the 1980s, yield has decreased over the last 20 years due the expansion of cultivation into marginal lands and to late sowing in order to escape ascochyta blight (*Ascochyta rabiei*) (Fig. 2.5.6). However, the national average yield of 0.96 t ha^{-1} recorded in 1991 is well above the world average (Table 2.5.1).

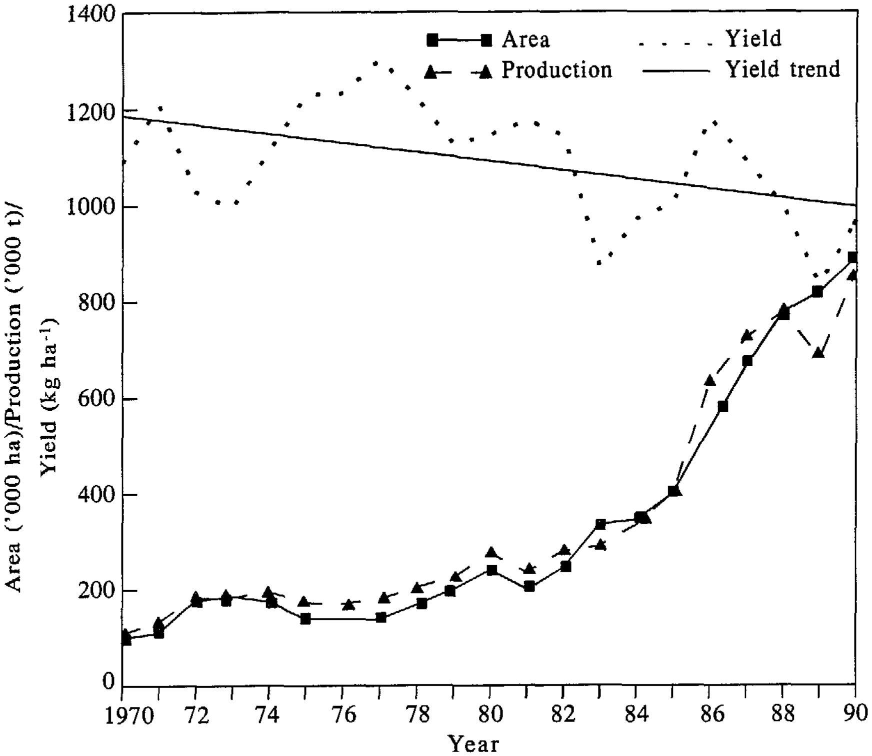


Figure 2.5.6. Trends in area, production, and yield of chickpea, 1970–90.

Climate, Soil, and Crop Distribution

The Turkish State Institute of Statistics has identified and characterized nine agricultural regions on the basis of topography, climate, and dominant farming systems (Table 2.5.2; Fig. 2.5.7). Although chickpea is cultivated throughout the country, it is more intensively cultivated in Region 1, followed in decreasing order by Regions 9, 4, 2, 6, 8, 5, 3, and 7. Regional rankings for productivity differ from those for area and production. Region 8 is the highest-yielding, followed by Regions 3, 1, 2, 6, 9, 4, 7, and 5 (SIS 1990) (Table 2.5.1).

The climate of Turkey has been described in detail (Mizrak 1983, Guler et al. 1990). A Mediterranean type of climate prevails throughout the country. Although Turkey lies in the temperate zone, climate is determined more by altitute and distance from the sea than by geographical position. More than 65% of the annual precipitation is received during winter and spring. Apart from central Anatolia and some parts of the southeastern region (annual rainfall 300–500 mm), the rest of the country receives precipitation well above 500 mm (Fig. 2.5.8). Temperature rises from Feb to Jul and decreases from Aug to Dec. The dry season begins in Jun and lasts until the end of Oct in most regions.

Table 2.5.2. Main characteristics of agricultural regions in Turkey.

Region	Annual rainfall (mm)	Frost (d)	Topography and soil	Main farming system
1. Central north	375	80–100	Central Anatolia plateau with fertile soil	Cereals, livestock
2. Aegean	800	5–15	Hills interposed with valleys and plains. Calcareous soil	Cereals, olive, cotton
3. Marmara	700	20–30	Similar to the Aegean region with soils of moderate fertility	Cereals, olive, cotton
4. Mediterranean	700	5–10	Alluvial plains with good agricultural potential	Cereals, cotton, citrus
5. Northeast	400	100–180	Hilly to mountainous. Altitude major determinant of climate	Livestock, cereals
6. Southeast	450	30–130	Treeless plains to mountainous terrain. Good to rocky soil	Livestock, cereals
7. Black Sea	1500	5–15	Low altitude; other traits similar to the northeastern region	Cereals, hazelnuts, tea
8. Central east	400	80–120	More hilly and mountainous than Central north	Livestock, cereals
9. Central south	350	80–100	Similar to Central north	Cereals, livestock

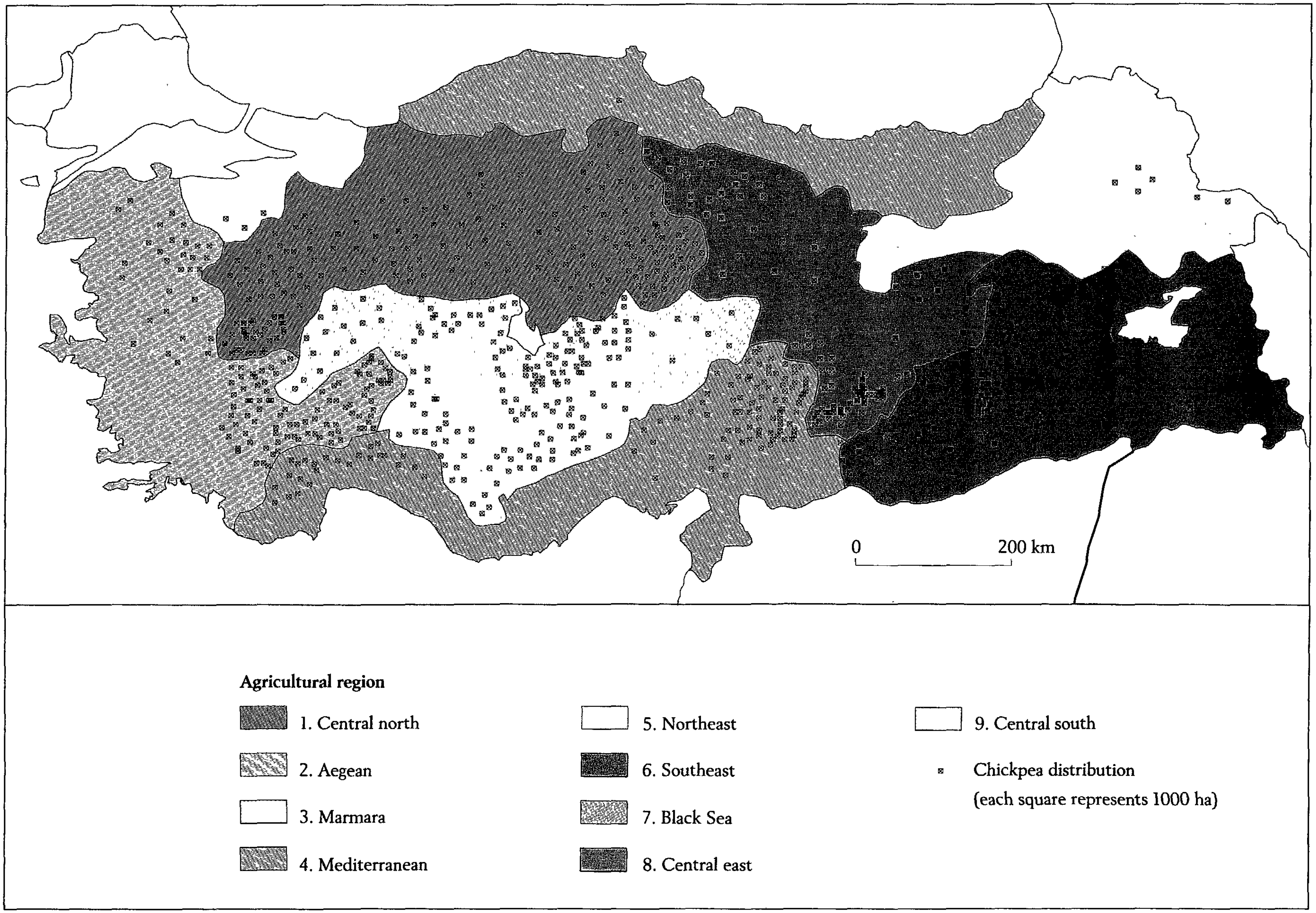


Figure 2.5.7. Agricultural regions in relation to chickpea distribution in Turkey.

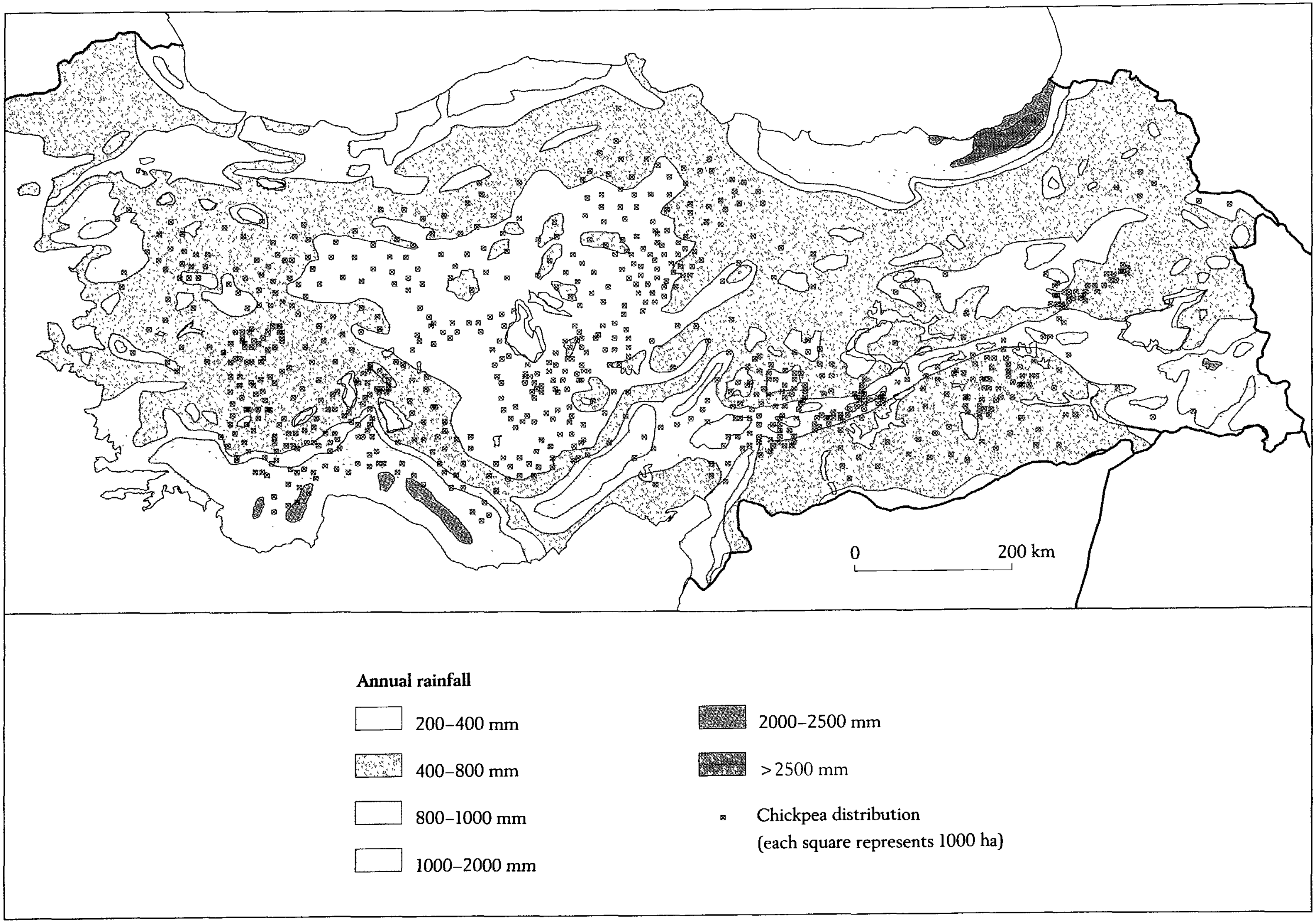


Figure 2.5.8. Mean annual rainfall in relation to chickpea distribution in Turkey.

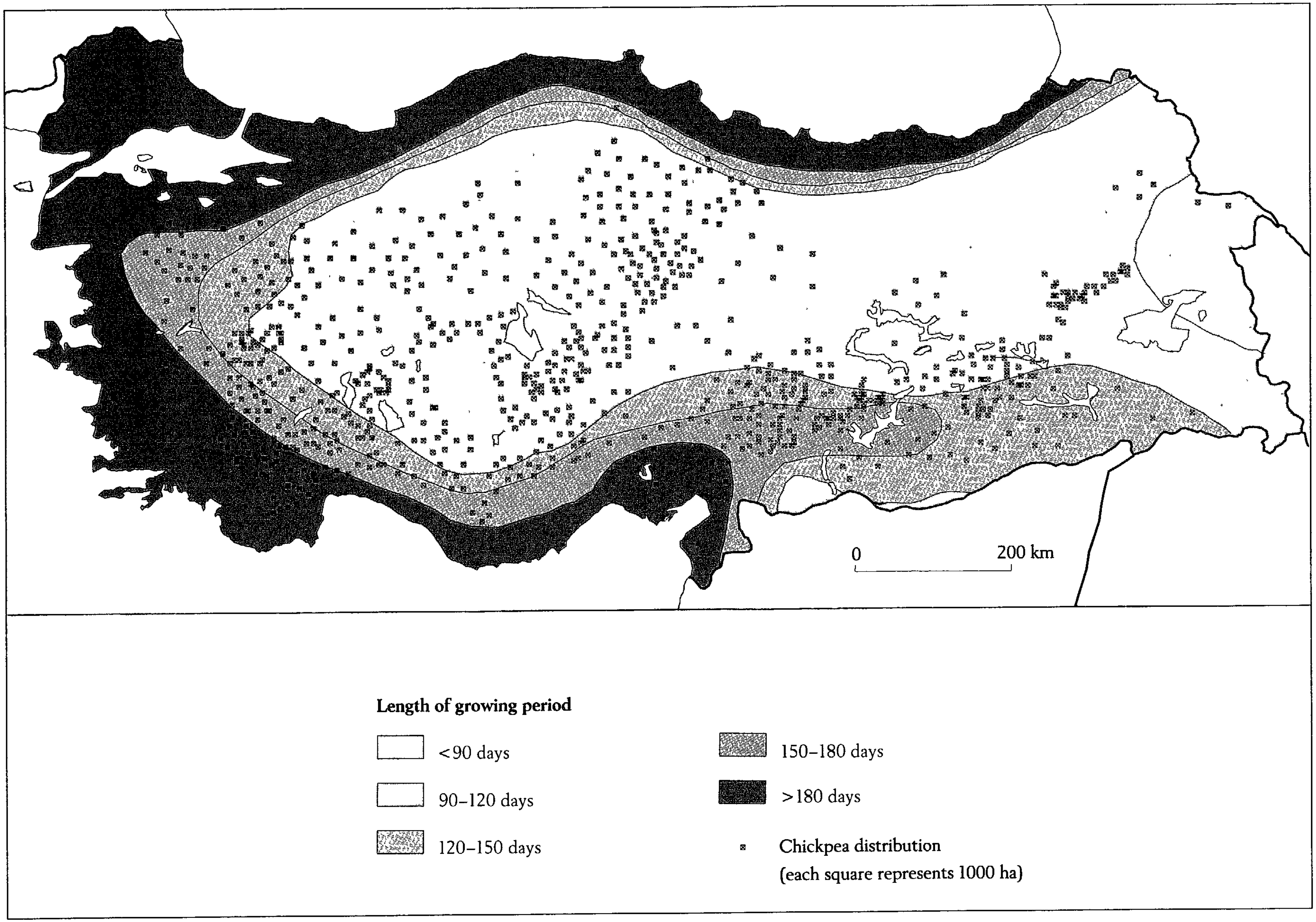


Figure 2.5.9. Length of growing period in relation to chickpea distribution in Turkey.

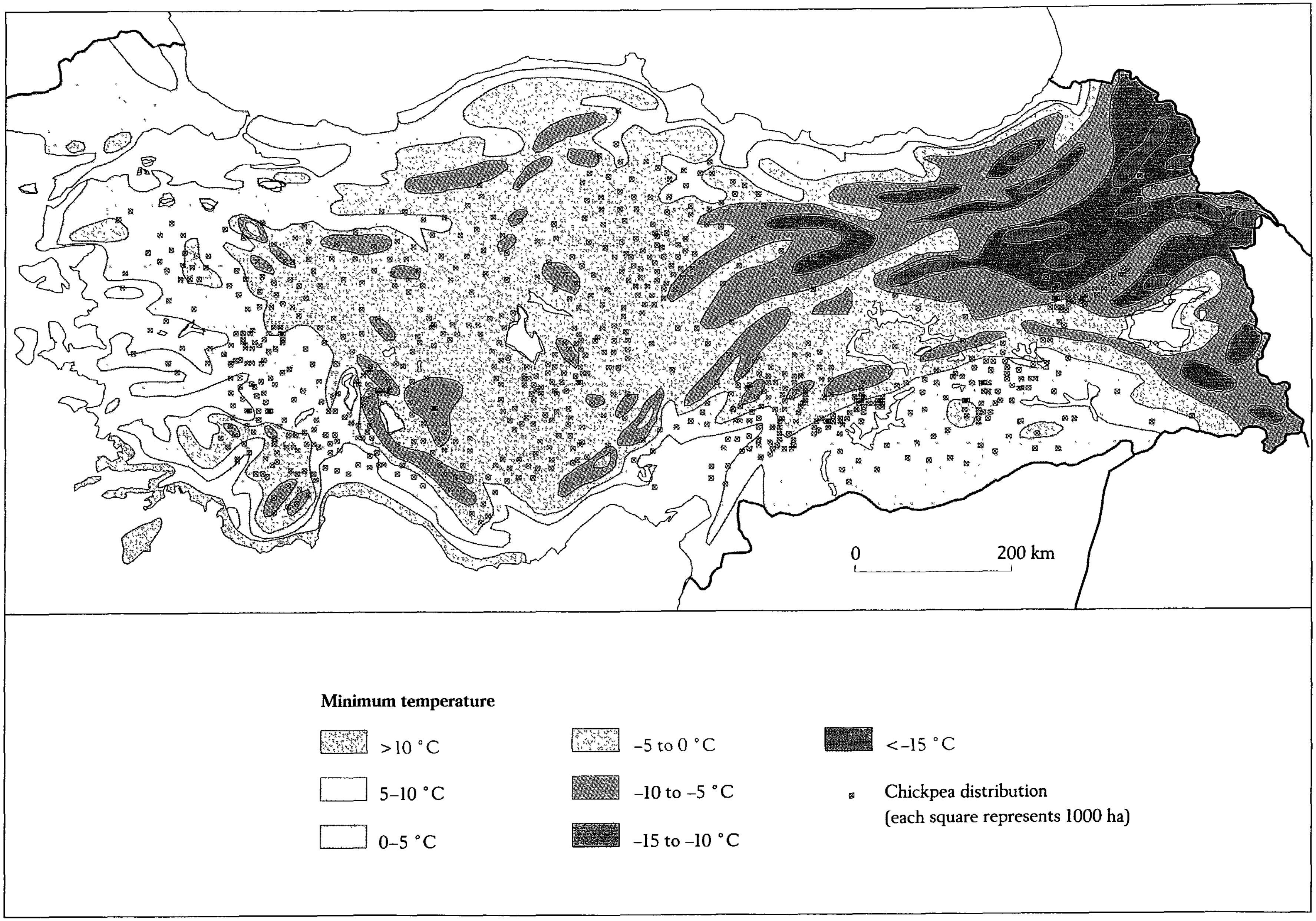


Figure 2.5.10. Mean minimum temperature in January in relation to chickpea distribution in Turkey.

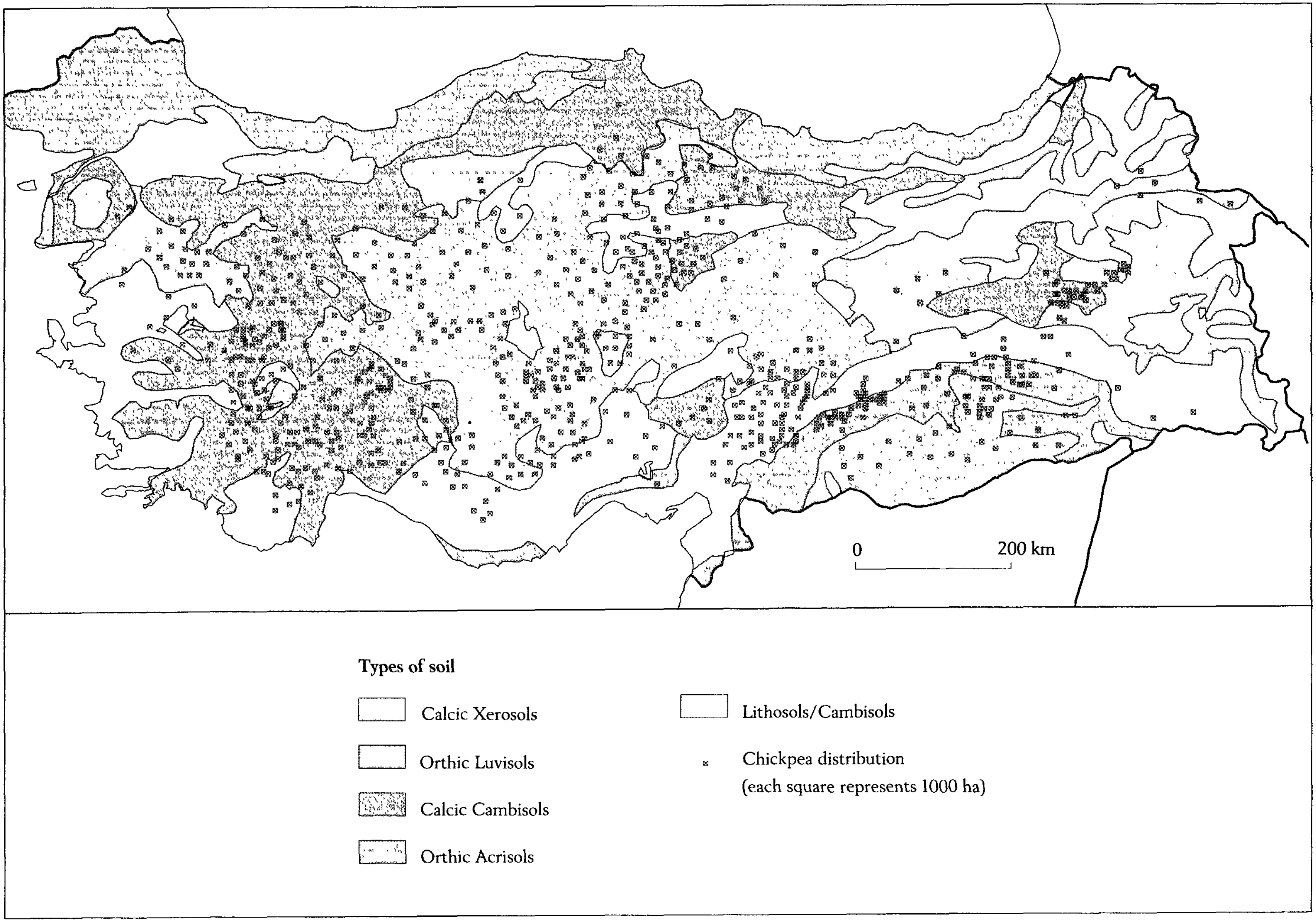


Figure 2.5.11. Soil types in relation to chickpea distribution in Turkey.

Chickpea is confined mostly to dry areas. The chickpea-growing areas of Turkey can be divided into five regions based on average temperature (Guler 1990) (Table 2.5.3). In central and eastern Anatolia, where altitude varies between 800 and 1900 m, frost and low air temperature are the main constraints hindering winter or early spring sowing of chickpea. As a result, the growing period is less than 120 days (Fig. 2.5.9). However, in the coastal regions and southeastern Anatolia, where frost is less severe (Fig. 2.5.10), the growing period is long (180 days) (Fig. 2.5.9) and winter chickpea production holds great promise.

Chickpea in Turkey is cultivated mostly on Calcic Xerosols, Calcic Cambisols, and Lithosols/Cambisols (Fig. 2.5.11).

Table 2.5.3. Air temperature and elevation of important chickpea production regions in Turkey.

Region	Temperature (°C) January	July	Elevation (m)
South coast	7–10	27–28	1– 100
Southeast	1.5–6	27–31	400– 900
Marmara	1.5–6	22–34	1–1000
Central	0–4	19–23	800–1500
East	–8 to 12	17–20	1300–1900

Source: Guler 1990.

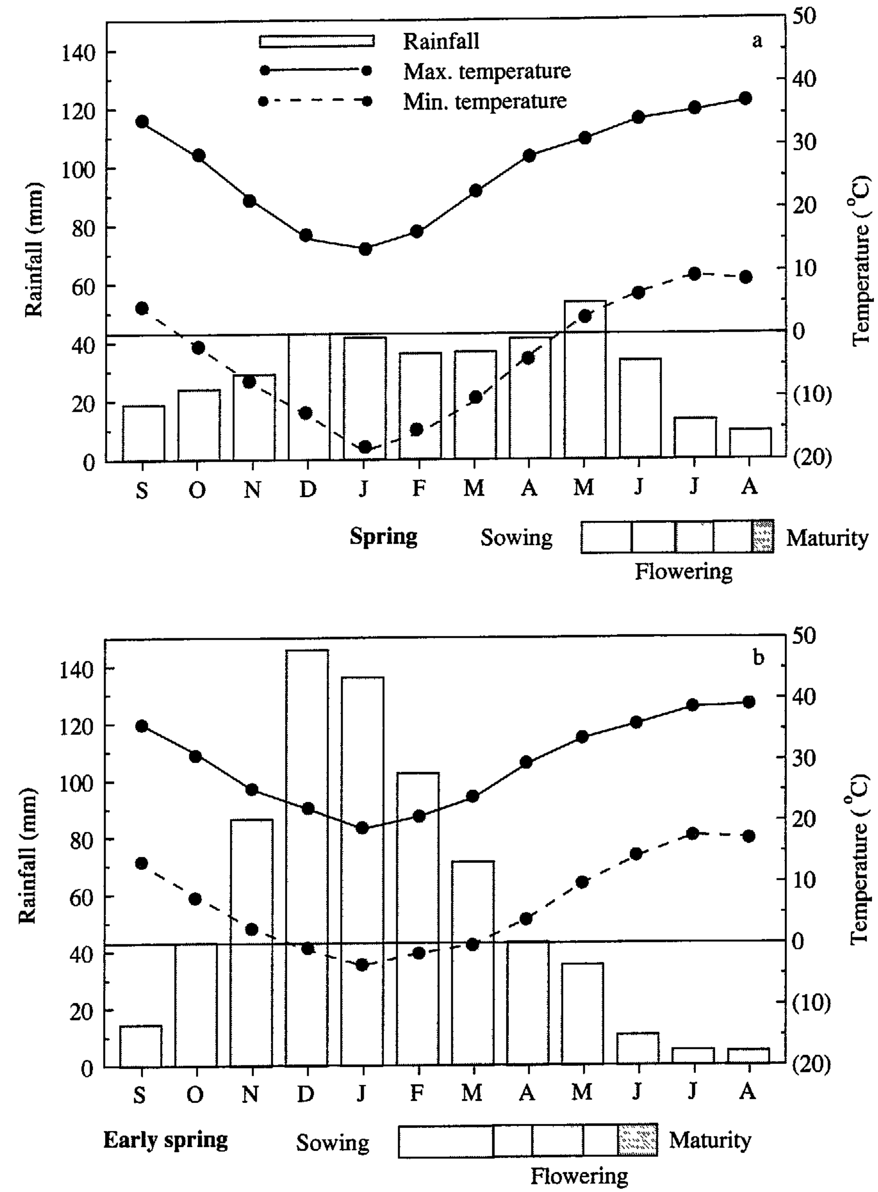


Figure 2.5.12. Crop phenology of chickpea in relation to climatic conditions in (a) Central Anatolia; and (b) West Anatolia, 1984.

Cropping Systems

Chickpea is one of the major components in cereal-based farming systems in Turkey. The results of experiments conducted in the 1980s showed that chickpea is one of the most profitable crops to replace fallow areas.

Traditionally, it is grown as a rainfed spring-season crop. Small areas are irrigated. Chickpea is not sown in winter but the prospects of introducing it as a winter crop are promising. In south-eastern Anatolia and in coastal regions, it is sown in early spring (Feb and Mar) and harvested in Jun (Fig. 2.5.12). In highland areas, it is sown late to escape from ascochyta blight. Several cultivars resistant to ascochyta blight and cold were recently released in the country (Table 2.5.4). These are dual-purpose cultivars as they are equally well-adapted to a short growing season of around 120 days.

Table 2.5.4. Seed size, plant height, and reaction to ascochyta blight and cold of released chickpea cultivars in Turkey.

	Reaction to			
Cultivar	Ascochyta blight	Cold	Seed size	Plant height
Canitez 87	Susceptible	Susceptible	Large	Tall
Eser 87	Tolerant	Susceptible	Small	Short
ILC 482	Tolerant	Tolerant	Small	Short
Akcin 91	Tolerant	Susceptible	Medium	Tall
Aydin 92	Resistant	-[2]	Small	Tall
Menemen 92	Tolerant	-	Medium	Tall
Izmir 92	Tolerant	-	Medium	Tall
ILC 195-2[1]	Resistant	-	Small	Tall
87 AK 71112[1]	Resistant	-	Small	Tall

1 Licensed for seed multiplication.
2. Reaction not noted.

Production Constraints

As chickpea is increasingly being grown across a wide range of soil and environmental conditions, it is exposed to severe climatic and biotic stress. Constraints to chickpea production in Turkey have been examined by Sakar et al. (1988), Durutan et al. (1988), Guler (1990), Acikgoz (1990), and Acikgoz et al. (1993).

Abiotic Constraints

Drought and heat are the major constraints of chickpea if it is sown late in spring as late sowing coincides with the beginning of the dry period.
The crop is then forced to grow on the moisture stored in the soil profile, which is often insufficient, and yield losses range from 25 to 30%. Yields can be increased if late winter to early spring sowings are made popular. Frost is not a constraint in late spring-sown chickpea, but is a serious limitation to the introduction of winter or early spring-sown chickpea.

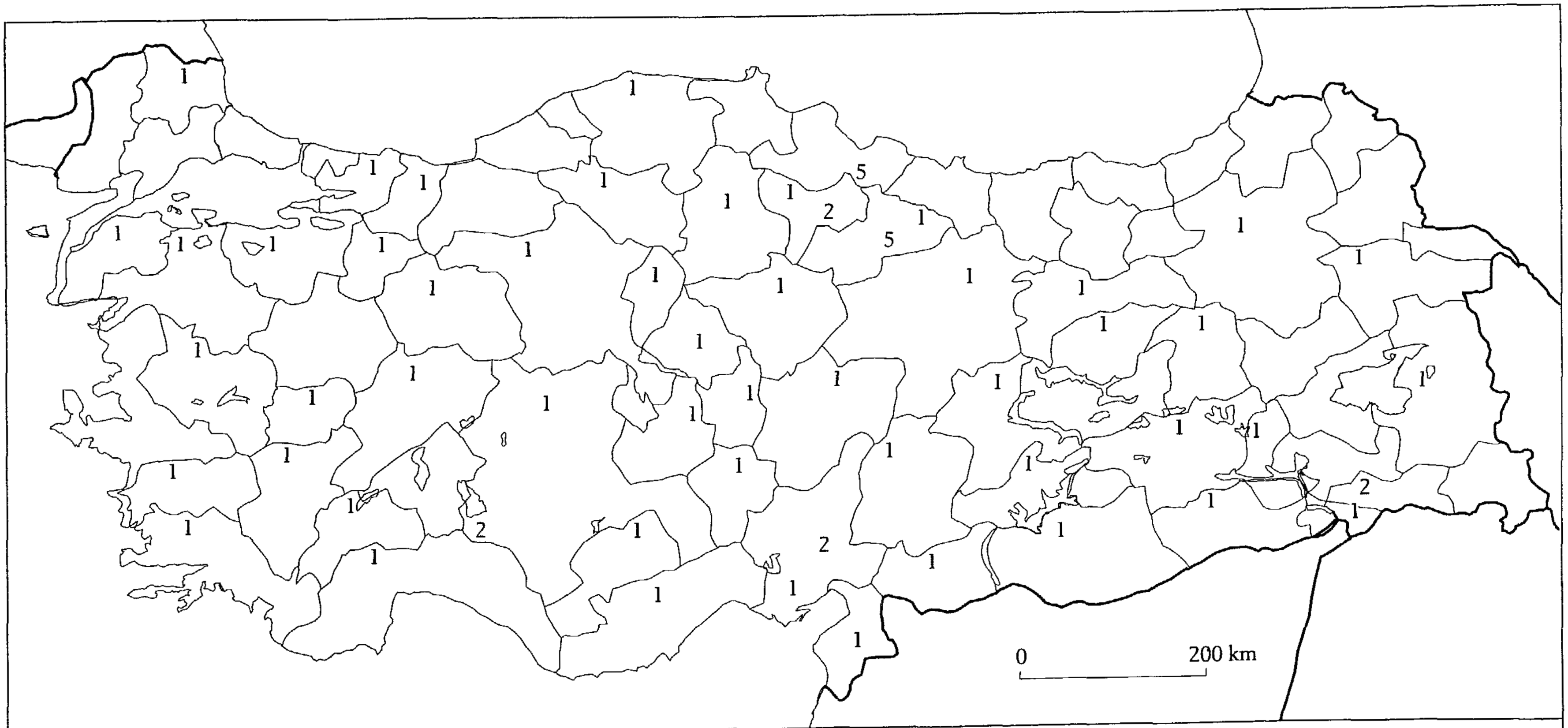
Biotic Constraints

Diseases

Ascochyta blight is the most serious disease of chickpea, causing damage in all chickpea-growing areas (Fig. 2.5.13). Localized epidemics are quite common but large-scale ones are rare. The worst epidemic occurred in 1983 and caused a sharp decrease in yield (Fig. 2.5.6). Fusarium wilt (*Fusarium oxysporum*) and rust (*Uromyces ciceris-arietini*) diseases have been observed occasionally in some regions but neither of them is a serious constraint to yield.

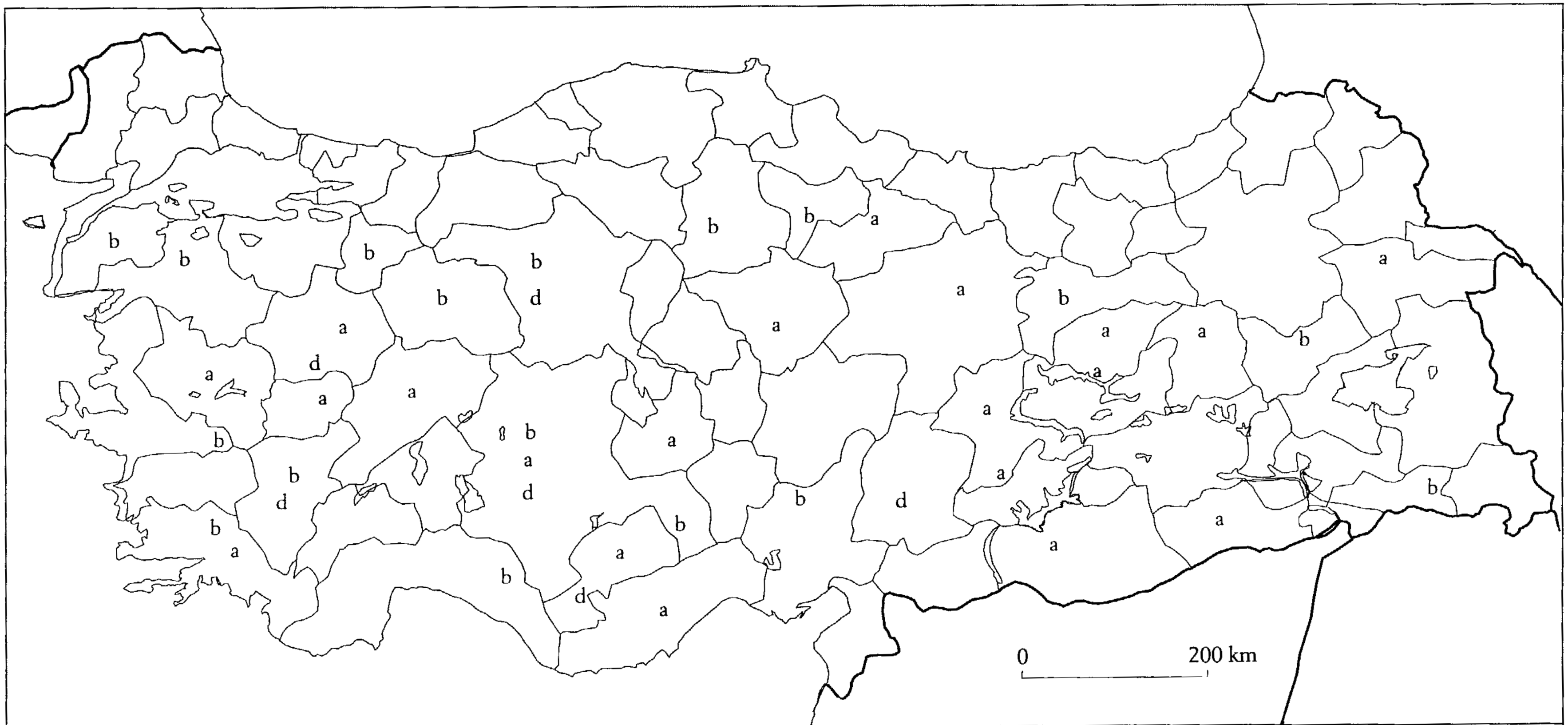
Insect Pests

Leafminer (*Liriomyza* spp), pod borer (*Helicoverpa* spp), cutworms (*Agrotis* spp), and seed beetle (*Bruchus* spp) are common pests of chickpea (Fig. 2.5.14). Yield losses due to insect pests range from 10 to 15%.



	Severe	Moderate	Low
Ascochyta blight	1	1	1
Fusarium wilt	-	2	2
Rust	-	-	5

Figure 2.5.13. Disease incidence on chickpea in Turkey.



	Severe	Moderate	Low
Pod borer	a	a	a
Leafminer	-	b	b
Cutworm	-	d	d

Figure 2.5.14. Insect pest incidence on chickpea in Turkey.

Nematodes

Systematic studies on nematodes of chickpea in Turkey have not been made. Field surveys show the presence of different types of nematodes in chickpea-growing areas. The root-lesion nematode (*Pratylenchus* sp) is a cause for concern, particularly in southeastern Anatolia where the symptoms of nematode damage are often confused with those of drought stress.

Weeds

Weeds are another major constraint to chickpea (Durutan et al. 1989). Herbicides are used to control broad-leaf weeds. On small farms, family labor is used for weeding, but weeding is not done on large farms because of prohibitive labor costs. In the central and eastern regions, farmers delay sowing until the end of May to reduce the weed problem.

Cultural Constraints

Farmers believe that chickpea is a crop adapted to poor and marginal soils. They need to be convinced through extension services that the crop can be highly productive on fertile soils. Chickpea is often sown on stony and steep fields where forage crops would perhaps be a better choice. Farmers apply the best type of inputs and adopt modern management practices to increase wheat yields but apply minimum inputs (in terms of economic or technological resources) to the chickpea crop and appear to accept the low yields. Chickpea is seen only as an alternative to keeping the land fallow.

Soil tillage is the most neglected aspect of chickpea cultivation. Seedbeds are usually very poorly prepared. Seeds are broadcast in stubble of previous crops and incorporated by mold-board plowing which places the seed at uneven depths in the soil, and results in suboptimum and uneven plant stands. Generally, high seed rates are used to overcome the problem of poor plant stand. Shallow sowing and rooting aggravate the effects of terminal drought during the pod-filling stage. Seed drills are rarely used for chickpea.

Vigorous extension campaigns will be necessary to bring about an effective transfer of technology. Although high-yielding cultivars have been introduced and released, farmers are reluctant to change over to new varieties. They readily agreed to replace fallow lands with chickpea because of free distribution of seed. However, they stuck to their traditional practices instead of using improved technology recommended with the supply of seed.

Fertilizers, herbicides or insecticides are rarely used on chickpea. While wheat harvesting is totally mechanized, chickpea continues to be hand-harvested. Manual harvesting is a major constraint to the expansion of chickpea area.

Future Prospects

There is scope for expansion of spring chickpea by replacing fallow lands (Fig. 2.5.3). Ascochyta blight resistant and large-seeded cultivars that are being developed will encourage farmers to expand the area under winter chickpea. Such cultivars can be sown in early spring without the risk of getting affected by ascochyta blight and frost in the highlands (FLRP 1991). They can also be grown from spring to fall in the southeastern and Mediterranean regions of Turkey (Orhan and Ozkan 1989). A greater degree of cold tolerance is required for these regions and attempts to incorporate cold tolerance in acceptable cultivars are being made.

Manual harvesting is expensive and time-consuming, and labor is scarce in the country. Options for mechanized harvesting of the crop should be made available and chickpea cultivars (tall and upright) suited to combine harvesting should be developed.

Since chickpea is grown in rotation with cereals, research in this area is receiving special attention under UFAP in relation to crop yield, soil health, and sustainability. Research on optimum cultural practices (sowing date, seed rate, row spacing, method and rate of fertilizer application, and weed control) to maximize economic returns is also being conducted to formulate and recommend package of practices to the farmers.

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2.6. Regional Summary: West Asia

M Jones[1], N Haddad[2], and H Harris[1]

The area under chickpea is still expanding in Turkey through replacement of fallow land. But in Iraq, the area has decreased due to very attractive—possibly even distorted—prices for cereals which have discouraged the farmers from growing other crops. However, this trend is expected to reverse. The area under chickpea in the other countries of the region appears to have been stable over time, and there is scope for further expansion through fallow replacement.

Turkey, and to a much lesser extent Syria, are exporters of chickpea, whereas Iraq, Jordan, and Iran are importers. Jordan sees self-sufficiency in chickpea production as a goal that can be attained if chickpea prices remain high. Iraq expects to meet 60–70% of its demand but such information is not available for Iran.

Apart from Syria, most chickpea that is grown in West Asia is sown in spring. But all the chickpea-growing countries in the region are seriously considering the introduction of winter chickpea, or at least, sowing earlier in spring than they are traditionally used to. In Syria, winter sowing is increasingly being adopted wherever the climate is favorable, but spring sowing will probably continue to predominate. There is a large potential for a new group of growers in the region who had never grown winter chickpea before; examples are cited in some of the country reports.

The issue of spring versus winter chickpea is more complex than is sometimes portrayed. It should be noted that chickpea is sown in spring primarily to escape from ascochyta blight (*Ascochyta rabiei*) and frost. Winter sowing should not be seen as a mere replacement or an improvement over spring sowing. Between the two extremes, there is obviously a continuum of options, depending on location, from early winter to late spring sowing. Attempts at dividing these options into just two groups would lead to an oversimplification of the situation.

It has been found that if chickpea is sown early in spring, higher yields can be obtained than in the traditional method. However, its potential depends on the development and availability of improved sowing techniques. The improvement of spring-sown chickpea has received low priority and should be given greater attention in a future research agenda.

Chickpea is essentially rainfed except in Iran, where 10% of the crop is irrigated. Some expansion of irrigated chickpea is expected in Iraq. Weed control is a more serious problem with winter sowing than with spring sowing and this is another reason why most farmers in the region will continue to grow spring chickpea.

Mechanization seems to be a key issue in the cultivation of chickpea in West Asia. At this stage, it does not seem necessary to develop new varieties and machines to effectively market the high-yielding management technology. Extension work, primarily directed towards popularizing machines that could assist in early sowing in spring, needs greater attention. Another major concern in all the countries of the region is a need for mechanized harvesting of the crop.

The importance of such constraints as weeds and diseases including ascochyta blight, fusarium wilt (*Fusarium oxysporum*), and root rots (*Rhizoctonia bataticola*, *R. solani*, and *F. solani*) differ between countries. Insect pests of importance are pod borer (*Helicoverpa armigera*) and leafminer (*Liriomyza cicerina*). Although bruchid (*Callosobruchus chinensis*) is a major storage pest in all the countries, it has received very little attention. Yield losses due to major diseases and insect pests, and the frequency of their occurrence, need to be better quantified. The status of *Rhizobium* is not well documented in the

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region and we need more studies of the type that is recently being conducted in Turkey.

Among the abiotic stresses, drought is seen as the most important constraint throughout the region. Cold imposes production limits in Turkey, Iran, and Iraq. High temperatures are a constraint in Iraq. Salinity is a problem in Iran and potentially a problem in Iraq if the area under chickpea is going to be expanded.

In Iraq, and perhaps in several other countries, if farmers wish to add phosphorus (P) to the crop they have to add nitrogen (N) also, because the only fertilizers locally available are compounds of N and P. This interferes with the efficiency of biological N_2 fixation.

Chickpea has not been adequately examined in the context of rotations and farming systems. For example, it seems feasible that P fertilizer added to a preceding cereal crop would also benefit the chickpea crop that is grown subsequently. In addition, due to the particular ability of chickpea to obtain P from calcareous soils (Section 5.5), no fertilizers will perhaps be required for the chickpea crop, in most circumstances, provided the fertility of the rotation is maintained.

Future Prospects

Fallow land will continue to be replaced in the region with either spring or winter-sown chickpea, so an increase in area under chickpea can be expected. Increased use of supplemental irrigation may raise the risk of diseases and other dangers associated with it (Section 2.2), therefore, further research on disease resistance would be necessary. The type of supplemental irrigation that could be used in the region and its overhead costs will need to be closely examined.

Integrated control methods should be developed for both insects and weeds. There is also a need to look at the management of the crop in rotations and not in isolation, in relation to pest control.

Postharvest technology, particularly relating to storage pests and marketing, which has largely been neglected until now, should receive greater attention. The other issues that should be given more importance in future are the seed size, especially important for marketing in all the countries; seed production systems, including seed dressing; improvement of harvest technology through breeding (reshaping the plant) and through development of machinery for mechanization.

The scientists of the national programs have described well the environments in which chickpea is grown in their countries, but this is not quite the same thing as describing the environments best suited for the crop. The environments most favorable to chickpea need to be clearly delineated.

There is a need to identify situations where chickpea has a comparative advantage in fallow replacement over lentil, oilseeds, or other crops and situations where it has not. To do so, requires an understanding of the agronomy as well as the physical and economic conditions under which chickpea is grown.

It is necessary to collect and disseminate information as to what conditions favor ascochyta blight in terms of such factors as humidity, temperature, duration of leaf wetness, etc. This is a prerequisite to planning for supplemental irrigation and for extending chickpea cultivation into new zones.

3. Country Case Studies—North Africa

3.1. Chickpea in Algeria

E H Maatougui[1], Z Bouznad[2], and M Labdi[1]

Latitude	19–36° N
Longitude	9° W–12° E
Altitude	0–1200 m
Total population	27.1 million
Economically active	6.44 million
Economically active in agriculture	1.47 million
Total area	238 million ha
Cultivated area	7 million ha
Rainfed area	6.9 million ha
Annual rainfall	0–600 mm
Chickpea rank among legumes	First (shared with faba bean)
Crop season	Spring (traditional) Winter (recent)

Introduction

In Algeria, most of the cultivated land is found in the northern part of the country within 100–150 km of the Mediterranean coast. The northern region predominantly influences the economy of the country. Although it covers only 16.8% of the country's territory, the region possesses 99.8% of Algeria's arable land (Cabot 1976). Chickpea (*Cicer arietinum*) in Algeria is cultivated mostly in regions with altitude of 400–500 m. The traditional food legumes are faba bean (*Vicia faba*), chickpea, dry pea (*Pisum sativum*), lentil (*Lens culinaris*), dry bean (*Phaseolus vulgaris*), and lathyrus (*Lathyrus sativum*) (for food and feed). During 1985–88, the average area under food legumes was around 151 000 ha, of which chickpea accounted for 56 000 ha (37%). The administrative divisions of Algeria are shown in Figure 3.1.1 and the chickpea distribution in Figure 3.1.2.

Uses

Chickpea is used for making soups (*chorba* and *harira*), sauces (*couscous*), snacks (*tadjines*), and sandwiches (*karentika*) (Labdi 1990).

Area, Production, and Productivity

The status of chickpea cultivation in Algeria has been reviewed by Labdi (1990), Benelkacem (1990), and Maatougui (1991). As indigenous production does not meet the demand for chickpea, an average of 35 000 t of chickpea per year was imported during 1981–85, costing around 35 million Algerian dinars (approximately US$ 7 million). The area, production, and yield of chickpea have been variable in the past 2 decades (Fig. 3.1.3a). The area under chickpea increased up to 1987, reaching a record 69 620 ha which then dropped steeply, coinciding with the privatization of the agricultural sector. This decline in area persisted in spite of a consistent increase in chickpea price (Fig. 3.1.3b). Subsequently, the area expanded from 29 120 ha in 1990 to 39 945 ha in 1991.

A large area is sown to chickpea in northwestern Algeria (around 25 030 ha) followed by northeastern (18 720 ha), and north central Algeria (13 068 ha) (Table 3.1.1). Nearly 50% of the total chickpea area and production comes from five out of the 30 provinces in the country (Table 3.1.2). On the basis of topography, three main agroecological

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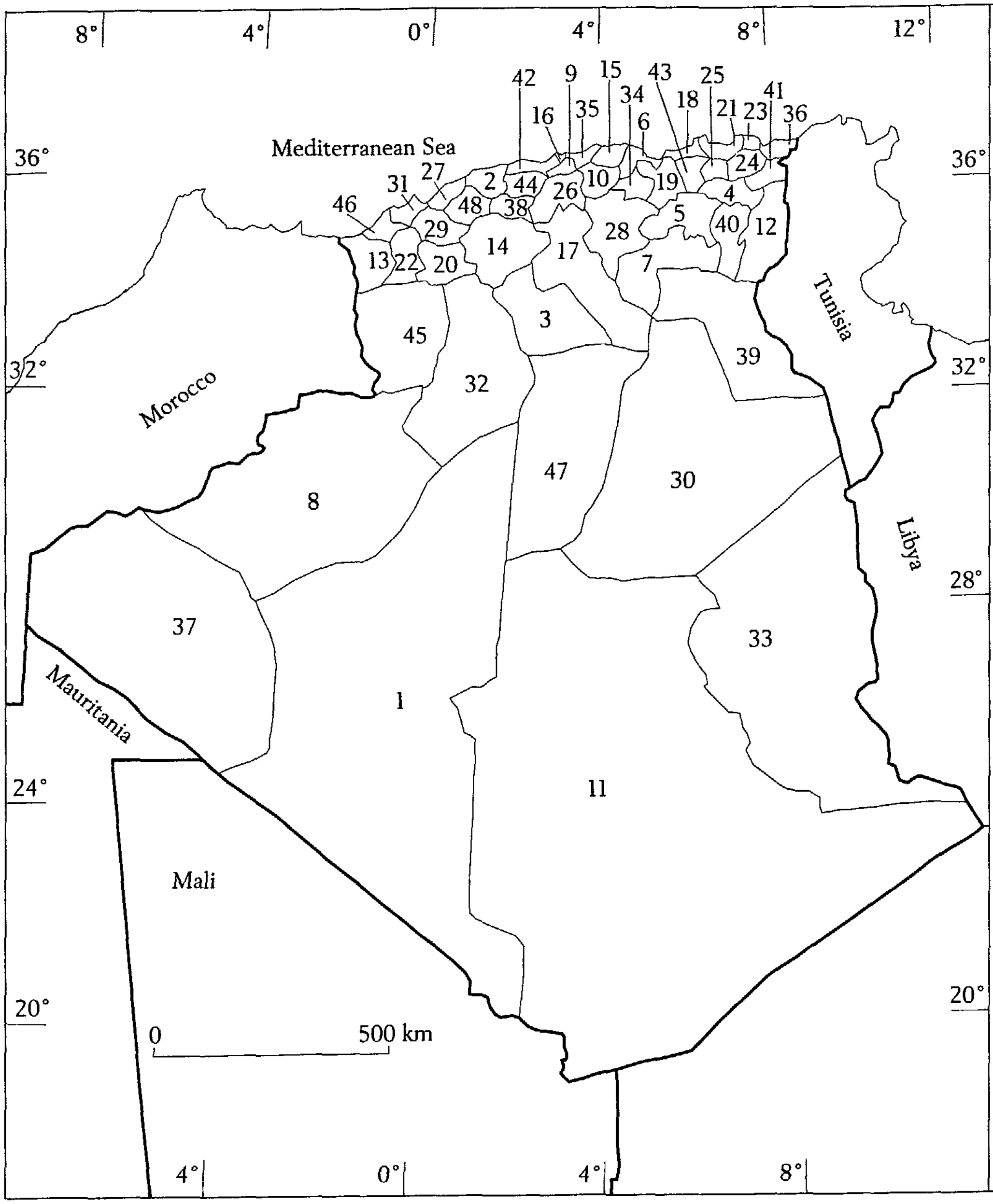

1. Adrar
2. Chlef
3. Laghouat
4. Oum-el Bouaghi
5. Batna
6. Bejaia
7. Biskra
8. Bechar
9. Blida
10. Bouira
11. Tamanrasset
12. Tebessa
13. Tlemcen
14. Tiaret
15. Tizi-Ouzou
16. Alger
17. Djelfa
18. Jijel
19. Setif
20. Saida
21. Skikda
22. Sidi-Bel-Abbes
23. Annaba
24. Guelma
25. Constantine
26. Medea
27. Mostaganem
28. M'Sila
29. Mascara
30. Ouargla
31. Oran
32. El Bayadh
33. Illizi
34. Bordj-Bou-Arreridj
35. Boumerdes
36. El Tarf
37. Tindouf
38. Tissemsilt
39. El Oued
40. Khenchela
41. Souk Ahras
42. Tipaza
43. Mila
44. Ain Defla
45. Naama
46. Ain Temouchent
47. Ghardaia
48. Relizane

Figure 3.1.1. Administrative boundaries of Algeria.

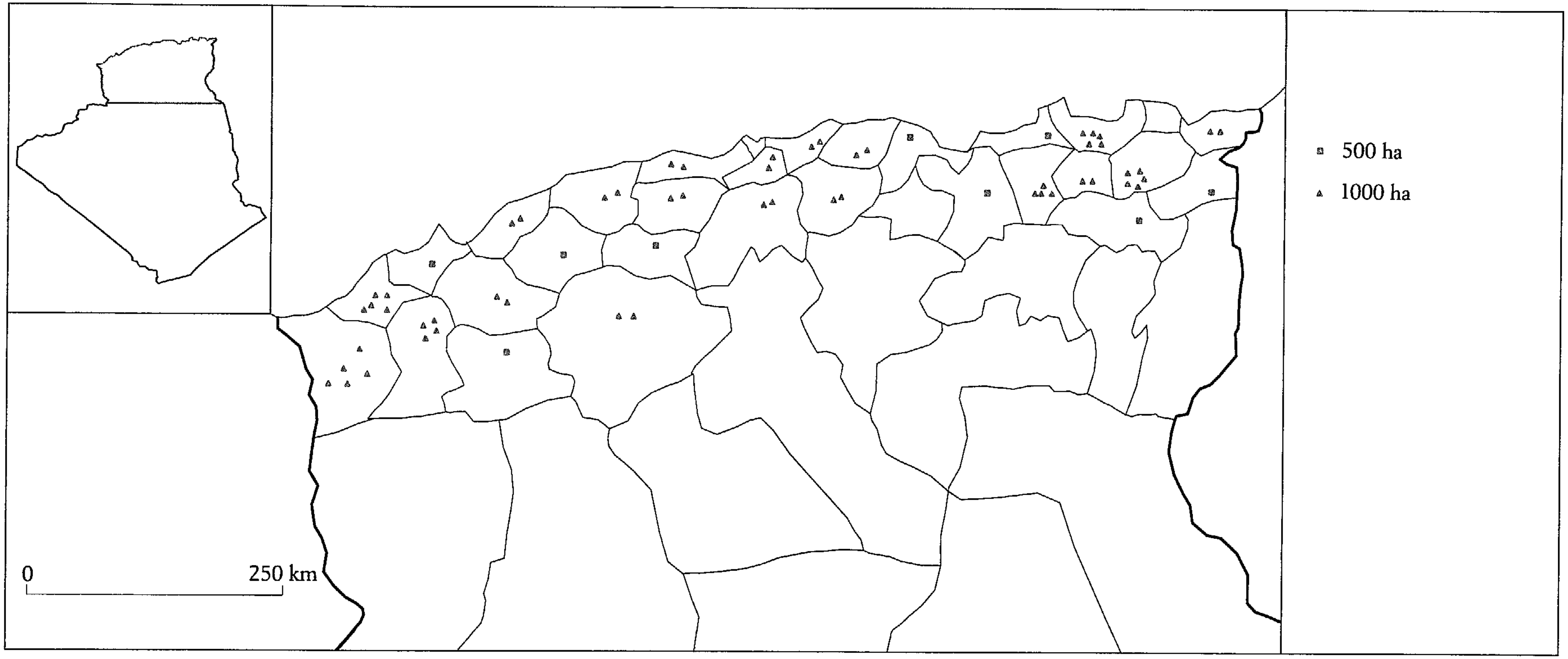

Figure 3.1.2. Chickpea distribution in Algeria.

zones are recognized in the country: the coastal plains, the interior plains, and the high plateaux. Chickpea is grown mostly in the coastal and interior plains (Table 3.1.1). Its cultivation is less common in the high plateaux where even spring-sown chickpea is affected by frost and drought and farmers are, therefore, reluctant to take risks. An analysis of the effects of variation in area and yield on variation in production showed that area accounts for around 11.5% and yield, 45% of yearly variation in chickpea production in the country, and the two together around 98% variation. However, multiple regression analysis showed a dominant effect of yield (82.6% of variation) and a relatively small effect of area (15.7%). In 1990 and 1991, chickpea productivity increased to an average of 0.50 t ha^{-1}, compared with the long-term average of 0.44 t ha^{-1}.

Yield in the coastal and interior plains in north central and northeastern Algeria is high (0.42 t ha^{-1}), compared with 0.25 t ha^{-1} in northwestern Algeria. The provinces with high average yields, such as Bejaia (0.95 t ha^{-1}), Jijel (0.84 t ha^{-1}), Tarf (0.56 t ha^{-1}), and Constantine (0.51 t ha^{-1}), represent only 13.2% of the total chickpea area. In these provinces located in mountainous areas with high rainfall, chickpea fields are small and well-managed.

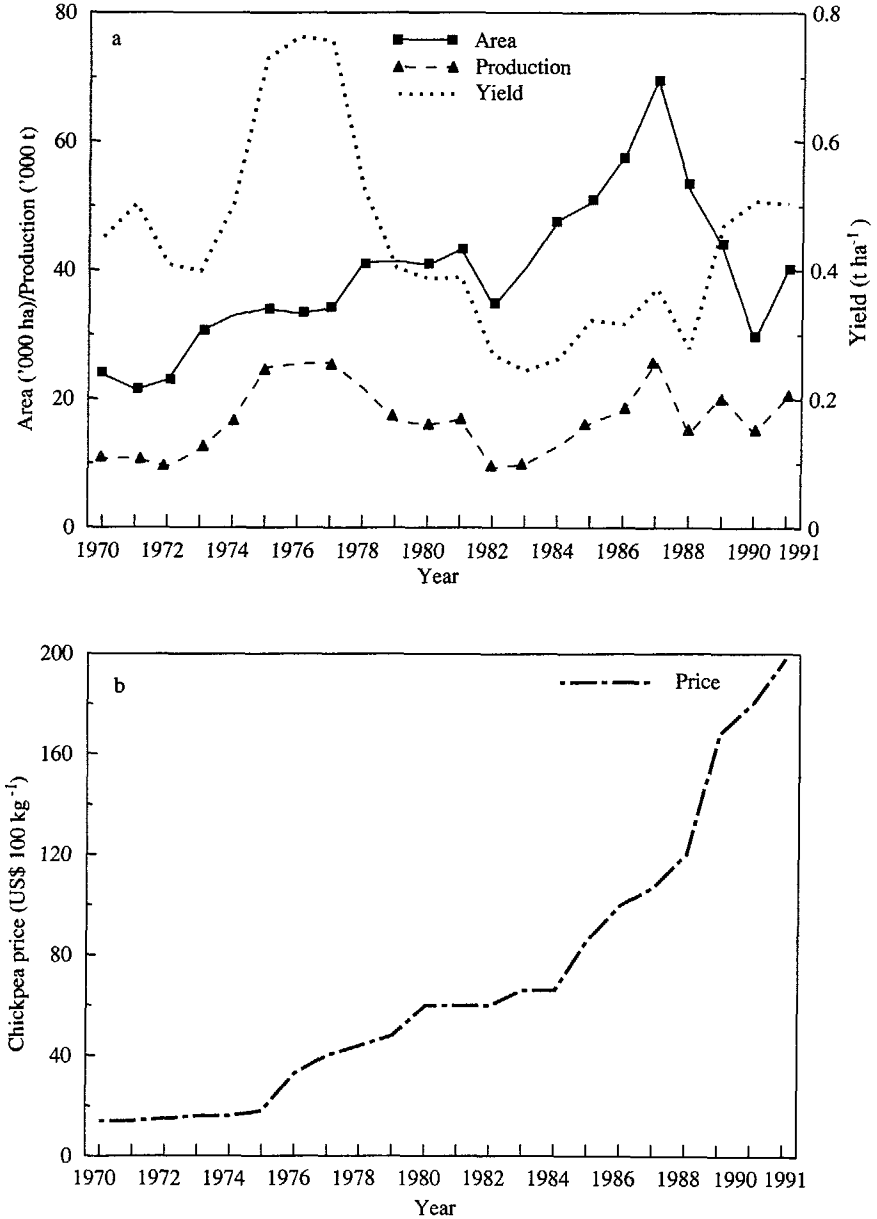

Figure 3.1.3. Trends in: (a) area, yield, and production; and (b) price of chickpea in Algeria, 1970–91.

Table 3.1.1. Area, production, and yield of chickpea, in northwestern, north central, and northeastern Algeria, 1985–88.

Agroecological zones	Northwest	North Central	Northeast	Total
Area (ha)				
Coastal plains	10 730	4 901	8 005	23 636
Interior plains	12 451	3 936	9 936	26 323
High plateaux	1 850	4 231	780	6 861
Total	25 031 (44.1)[1]	13 068 (23.0)	18 721 (32.9)	56 820
Production (t)				
Coastal plains	2 584	2 534	3 907	9 025
Interior plains	3 361	1 629	3 720	8 710
High plateaux	240	1 315	146	1 701
Total	6 185 (31.8)[2]	5 478 (28.2)	7 773 (40.2)	19 436
Mean yield (t ha^{-1})				
Coastal plains	0.24	0.52	0.49	
Interior plains	0.27	0.41	0.37	
High plateaux	0.13	0.31	0.19	
Region mean	0.25	0.42	0.42	

1. Figures within parentheses in this row indicate percentage of total area.
2. Figures within parentheses in this row indicate percentage of total production.

Table 3.1.2. Area, production, and yield in some important chickpea-growing provinces of Algeria (1986–88).

Province	Area (ha)	Production (t)	Yield (t ha^{-1})
Ain Temouchent	8800 (15.3)[1]	2099 (10.8)[2]	0.24
Tlemcen	6875 (11.3)	2246 (11.6)	0.33
Sidi-Bel-Abbes	3608 (6.3)	543 (2.8)	0.15
Skikda	4363 (7.6)	1795 (9.2)	0.41
Guelma	4470 (7.8)	1673 (8.6)	0.38

1. Figures within parentheses in this column indicate percentage of total area.
2. Figures within parentheses in this column indicate percentage of total production.

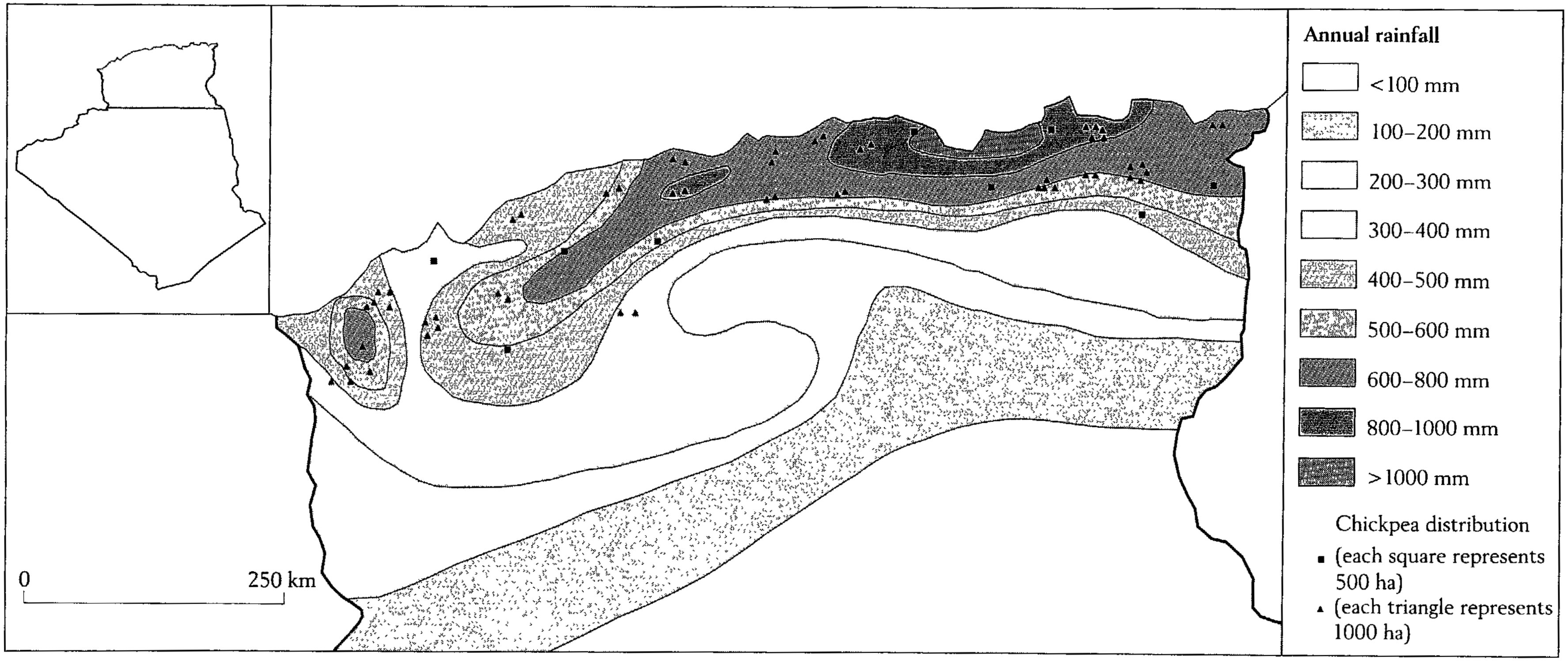

Figure 3.1.4. Mean annual rainfall in relation to chickpea distribution in Algeria.

Table 3.1.3. Characteristics of agroecological zones in Algeria (tentatively defined by the Ministry of Agriculture).

Zone	Total area ('000 000 ha)	Average annual rainfall (mm)	Types of soil	Main cropping system	Area under cereals and fallow (ha)
A	0.3	>600	Clay loams to heavy clay, poorly drained soil	Cereals + Fallow	6 400 + 38 000
B	1.7	450–600	Clay to calcareous clay loams of variable depth	Cereals + Fallow	850 000 + 380 000
C	2.7	350–450	Calcareous loams, sandy, stony, and shallow	Cereals + Fallow	1410 000 + 780 000
M	1.1	300–600	Variable types of soil	Cereals + Fallow	330 000 + 300 000

Climate, Soil, and Crop Distribution

The annual rainfall distribution map is shown in Figure 3.1.4. A tentative zoning of the country, on the basis of agroecological classification has been done by the Ministry of Agriculture (Table 3.1.3). Chickpea is an important crop primarily in Zones B and C (Table 3.1.4), where rainfall ranges between 350 and 600 mm and the crop is grown on calcareous loam to clay loam soils.

Table 3.1.4. Mean annual rainfall and temperatures (maximum and minimum) for some important chickpea-growing provinces in Algeria.

	Zone[1] (%)				Mean annual	Temperature (°C)	
Province	A	B	C	M	rainfall (mm)	Maximum	Minimum
Coastal plains							
Ain Temouchent	12	35	53	-	473	22.6	13.0
Skikda	32	-	-	68	729	21.9	13.0
Interior plains							
Tlemcen	-	32	27	35	371	24.0	11.7
Sidi-Bel-Abbes	-	34	57	-	393	23.8	9.6
Guelma	-	53	36	11	652	23.6	12.1
Souk Ahras	-	60	30	10	633	23.4	9.0

1 See Table 3.1.3 for definition.

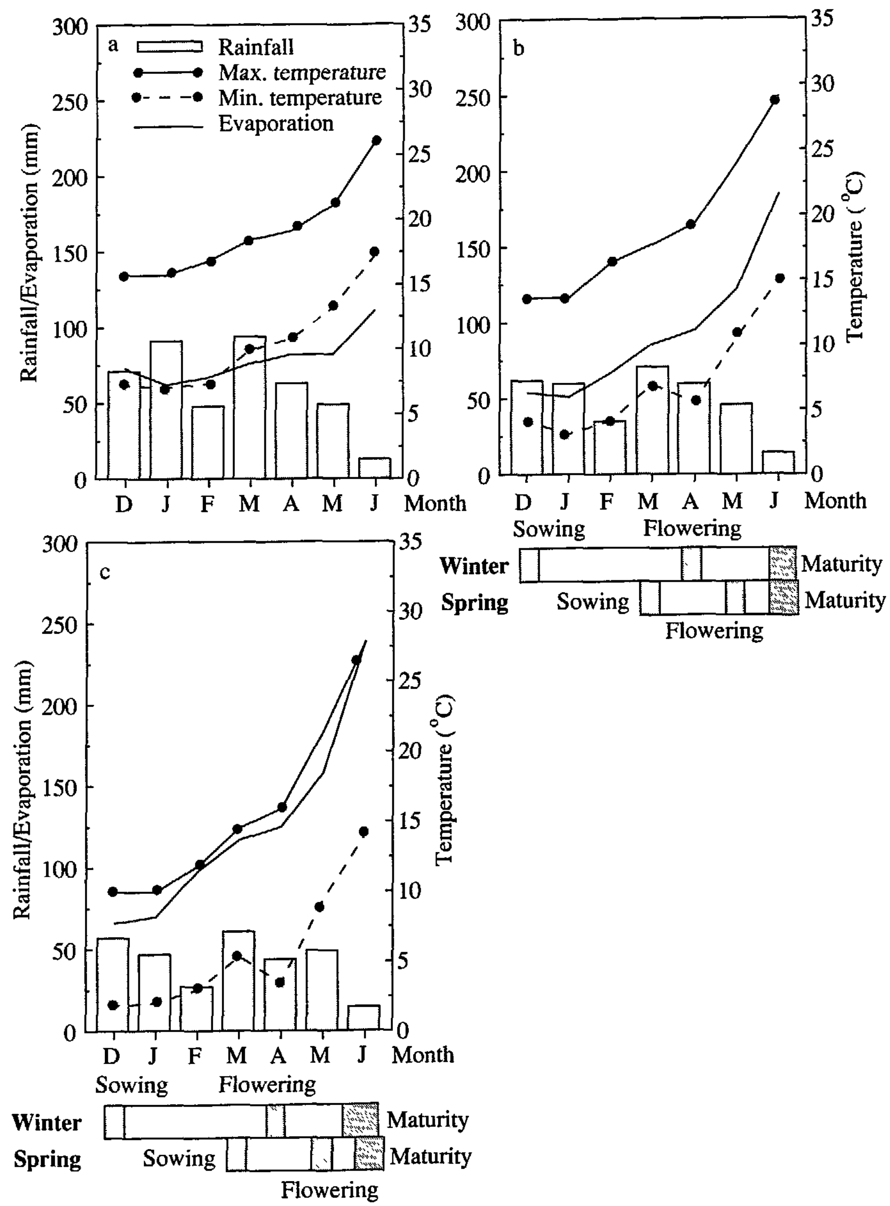

Figure 3.1.5. Crop phenology of spring-and winter-sown chickpea in relation to climatic conditions in three regions of Algeria: (a) coastal plains; (b) interior plains; and (c) high plateaux, 1985–89.

Cropping Systems

Chickpea is primarily a spring crop, sown from mid-Feb to end Mar. In areas with high rainfall in winter, sowing is delayed to early Apr. Flowering occurs from mid- to end May. The crop is harvested in end Jun or early Jul (Fig. 3.1.5.). Yield of spring-sown chickpea is highly dependent on rainfall received from mid-Mar to end May. Chickpea seeds are usually sown by hand or by using drills in rows widely spaced (0.5–3 m) to control weed through interrow cultivation, as weeds are one of the most important constraints of the crop. However, this practice leads to a loss of soil moisture which aggravates the effects of drought on shallow soils. Seed rate rarely exceeds 0.10 t ha^{-1}. No particular care is taken to achieve optimum plant density within a row. The plants are hand-harvested and then sun-dried in the field. Threshing is generally done using a combine but also by animal traction. Recently farmers have shown interest in growing winter chickpea in almost all the agroecological zones, because the potential for high yields is greater and the prospects for mechanization better than those of spring chickpea. However, its adoption is hindered by lack of seed of improved cultivars and the need to invest in machinery (drill, sprayer, etc.) and in herbicides. At present winter chickpea occupies less than 500 ha, although it seems to be the best option for the high plateaux of the country.

Production Constraints

Abiotic Constraints

Drought and heat

Terminal drought is by far the most serious limitation to chickpea cultivation, particularly on shallow soils. It is a problem that affects the entire chickpea area, from the cold interior plains to the high plateaux. The effects of drought are accentuated by heat stress, caused by sirocco, the hot winds from the Sahara Desert. In the interior plains, heavy weed infestations aggravate the effect of drought by competing for soil moisture, and also for nutrients. In many chickpea areas, where rainfall is not received in May and hot winds prevail in Jun, drought drastically reduces yield, and in some years even causes the crop to fail.

Temperatures above the optimal are quite common in chickpea-growing areas in Algeria; they can cause severe yield loss in spring-sown chickpea. Breeding for resistance to heat, therefore, needs urgent attention.

Cold and frost

Low temperature plays a key role in parts of the interior plains and mainly in the high plateaux. The effects of cold are delayed emergence, slow crop development, reduced plant stand, and aborted flowers in spring chickpea, often caused by late frost in Apr. Minimum temperature isotherms for the coldest months are shown in Figure 3.1.6. In winter chickpea, cold affects nodulation, and late frosts cause flower and pod abortion. Effects on plant stand vary with variety, for example, ILC 3279 withstands cold better than ILC 482.

Salinity

Salinity is not a serious constraint in the chickpea-producing areas.

Poor plant stand

As rows are very widely spaced in chickpea cultivation, plant stands cannot be properly assessed. A survey conducted on 39 farmers' fields in the Sidi-Bel-Abbes region in northwestern Algeria showed that plant stands ranged from 13 to 41 plants m^{-2} with an average of 27 plants m^{-2}. No recommendation for optimum plant stand for hand-sown spring chickpea has been made. However, for winter chickpea sown with drills, the recommended plant density is 50 to 70 plants m^{-2} (equivalent to a seed rate of 0.13–0.15 t ha^{-1}), with 30-cm row spacing. For spring chickpea sown with drills, the recommended density is 30 plants m^{-2} with a 50-cm row spacing (equivalent to a seed rate of 0.9 to 0.10 t ha^{-1}).

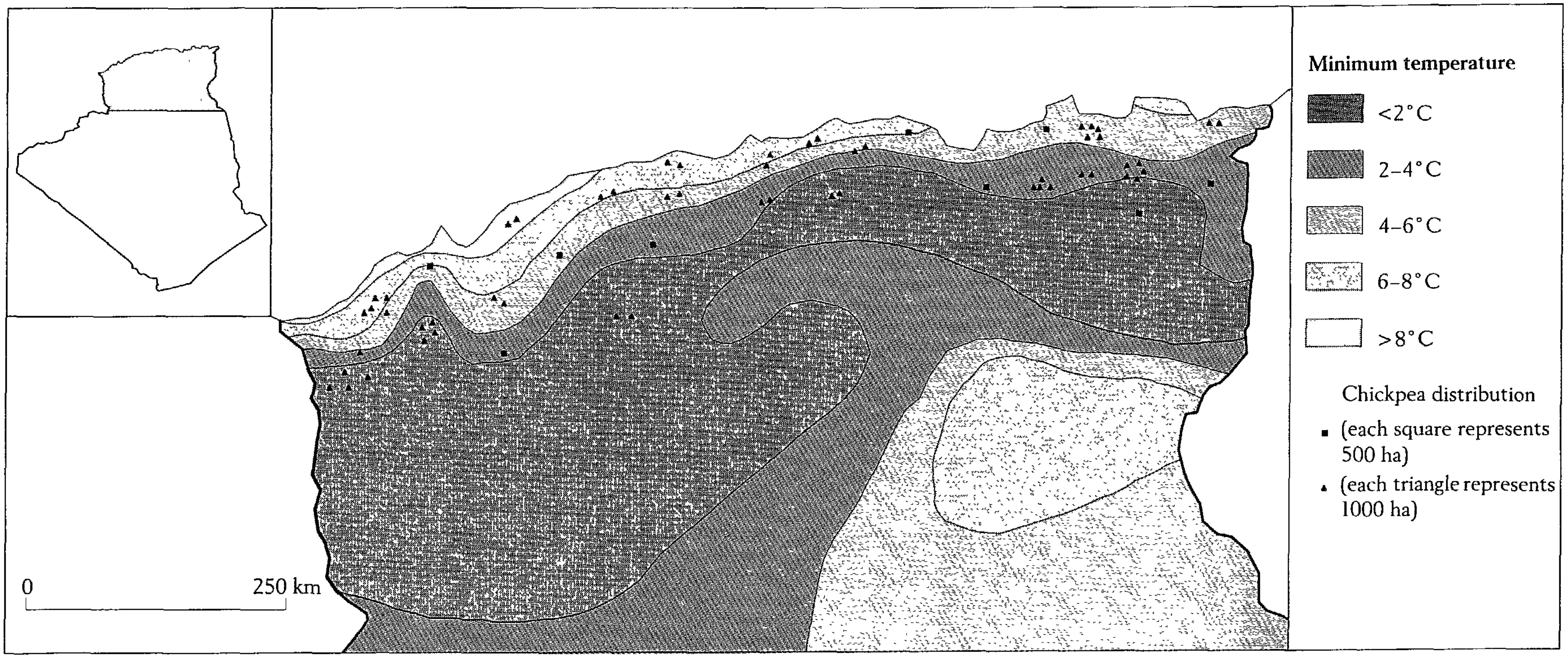

Figure 3.1.6. Mean minimum temperature in the coldest months in relation to chickpea distribution in Algeria.

Biotic Constraints

Diseases

The major diseases (Figure 3.1.7) that affect spring chickpea are fusarium wilt (*Fusarium oxysporum*), phoma blight (*Phoma medicaginis*), ascochyta blight (*Ascochyta rabiei*), and stunt (bean leaf roll virus) (ICARDA 1989; Bouznad et al. 1990). Fusarium wilt, ascochyta blight, and phoma blight are economically important and more widespread in the country than the other diseases. Ascochyta blight is the most important disease that affects winter chickpea.

Systematic surveys to study disease severity and yield losses have not been carried out in all the chickpea-growing areas. In a survey conducted in northwestern Algeria, 20–45% of the fields surveyed were affected by fusarium wilt (ICARDA 1989; Bouznad et al. 1990). Phoma blight affected 20–80% of fields surveyed in north central Algeria and 55–65% in northwestern Algeria. Local cultivars are highly susceptible to ascochyta blight.

Work on pathogen variability and screening for resistance sources of the major diseases in field and laboratory conditions has been initiated. Considerable pathogenic diversity was found in ascochyta blight.

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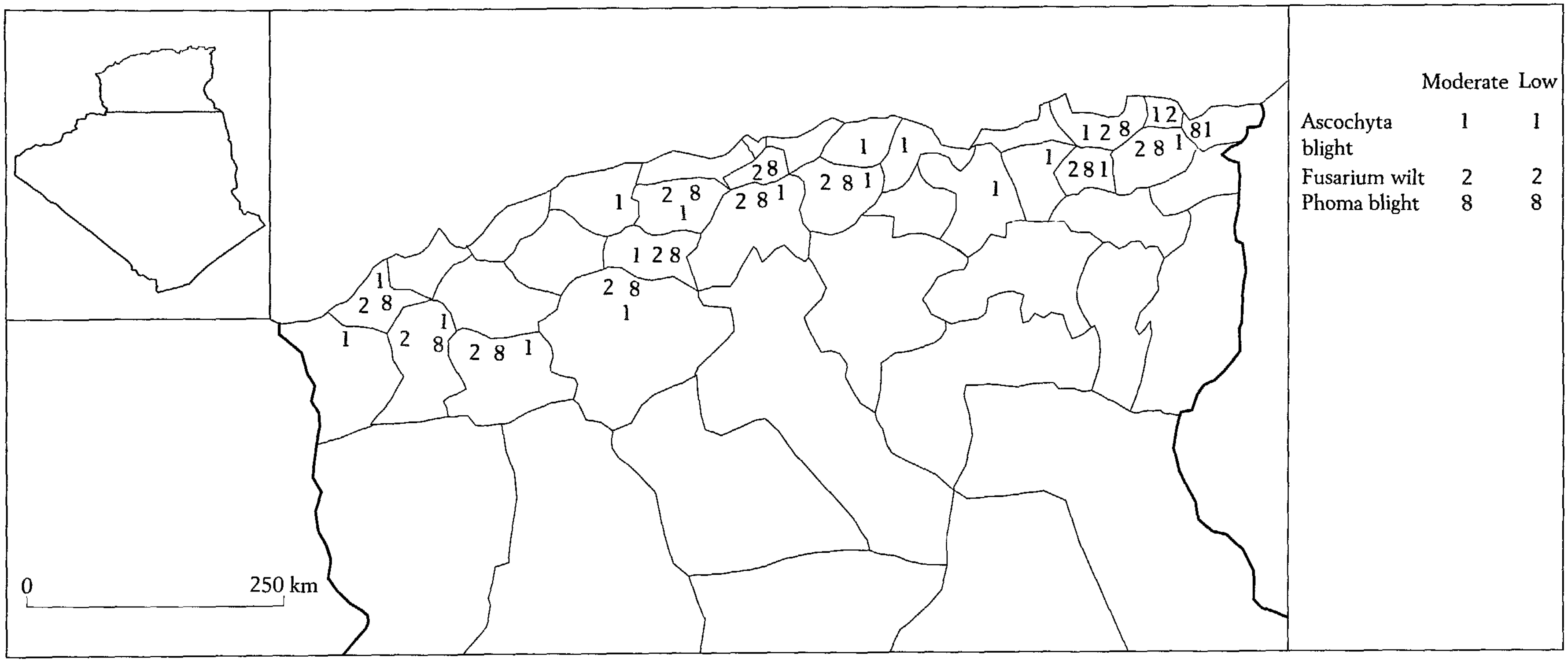

Figure 3.1.7. Disease incidence on chickpea in Algeria.

Good sources of tolerance for the disease have been identified in collaboration with ICARDA (Bouznad et al. 1992).

Insects

Leafminer (*Liriomyza cicerina*) is the only important insect pest of chickpea in Algeria. It causes severe damage on spring-sown chickpea in areas where the crop growth is good. Heavy attacks by leafminers can cause severe defoliation and yield loss. However, the information available is not adequate to show its distribution and estimate the yield loss it causes.

Nematodes

Spring-sown chickpea is affected by root lesion nematode (*Pratylenchus thornei*) (ICARDA 1989; Bouznad et al. 1990).

Weeds

Weeds are one of the major constraints to spring and winter chickpea production and are particularly severe in areas of high rainfall. They often cause greater losses to chickpea than diseases. Weeds that germinate late in the season compete with the crop for water.

Hand-weeding is costly and generally not very effective. The use of herbicides is not common, because sprayers and effective herbicides are not available.

Future Prospects

To meet the country's demand for chickpea, it is estimated that the area under spring chickpea needs to be expanded to around 70 000 ha with an average yield of 0.80 t ha^{-1} (Maatougui 1991). It will be difficult to achieve this target without adopting improved cultivation practices in traditional spring chickpea-growing areas. The prospects for expanding winter chickpea cultivation in Algeria are very promising (Fig. 3.1.8). The coastal and the interior plains, with suitable soil and favorable climatic conditions have high potential for growing winter chickpea. Varieties resistant to ascochyta blight should be introduced and effective weed control practices popularized.

Estimates of area for potential chickpea expansion (both for spring and winter sowing) made in 1991 were around 39 900 ha. Suitable cultivars have been identified for release and measures to provide sufficient quantities of seed have been taken. New cultivars, although

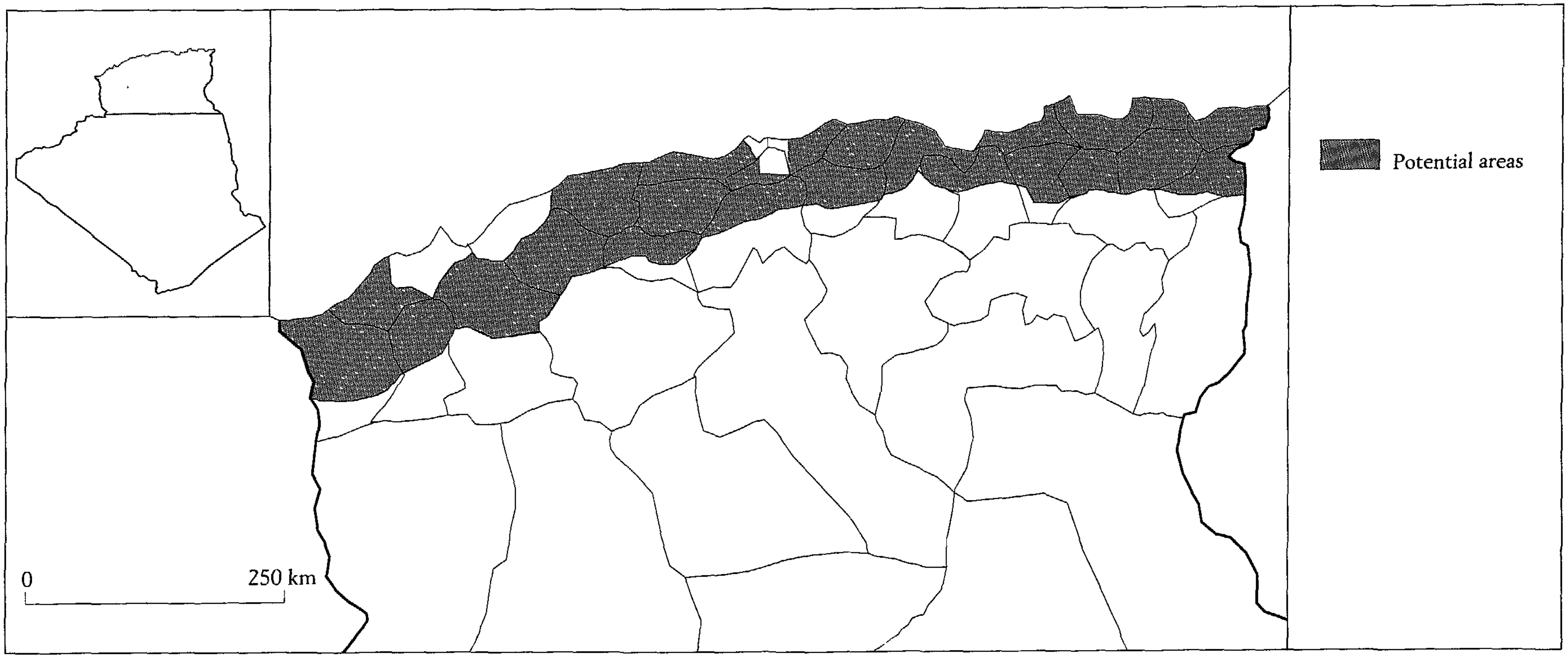

Figure 3.1.8. Potential areas for expansion and/or intensification of chickpea cultivation in Algeria.

smaller in seed size than the local varieties, have been accepted by farmers because of their higher productivity. The major bottleneck in expanding winter chickpea areas is lack of effective weed control measures.

In the high plateaux particularly, fallow areas could be replaced by winter chickpea. Winter-sowing technology is well-developed, but needs to be popularized through on-farm demonstration trials. The availability of technological support, such as appropriate machinery, herbicides, and seeds of newly recommended varieties should be ensured. Incentives such as high price for chickpea should also help in reaching the national target.

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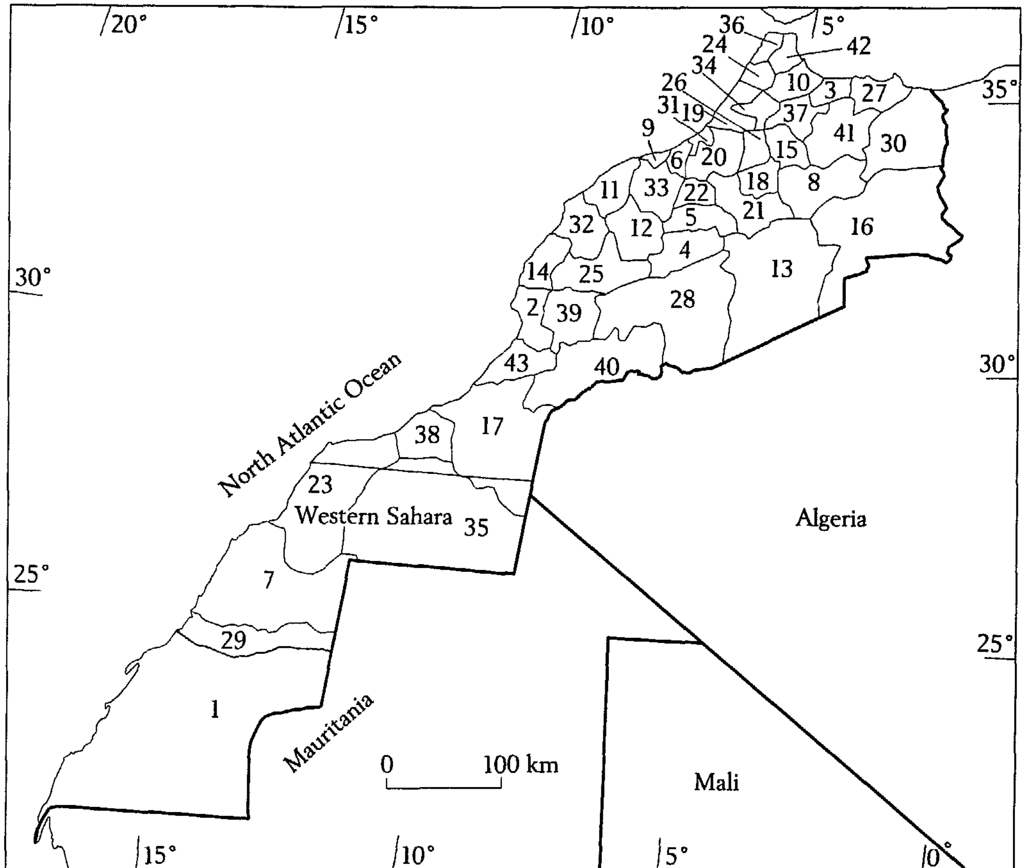

1. Addakhla
2. Agadir
3. Al Hoceima
4. Azilal
5. Beni Mellal
6. Ben Slimane
7. Boujdour
8. Boulemane
9. Casablanca
10. Chef Chaouen
11. El Jadida
12. El Kelaa
13. Er Rachidia
14. Essaouira
15. Fes
16. Figuig
17. Guelmima
18. Ifrane
19. Kenitra
20. Khemisset
21. Khenifra
22. Khouribga
23. Laayoune
24. Larache
25. Marrakech
26. Meknes
27. Nador
28. Ouarzazate
29. Oued Eddahab
30. Oujda
31. Rabat
32. Safi
33. Settat
34. Sidi Kacem
35. Smara
36. Tangier
37. Taounate
38. Tan Tan
39. Taroudant
40. Tata
41. Taza
42. Tetouan
43. Tiznit

Figure 3.2.1. Administrative boundaries of Morocco.

3.2. Chickpea in Morocco

M Amine[1], M Boulif[2], and S P S Beniwal[3]

Latitude	21–36° N
Longitude	1–17° E
Altitude	0–4165 m
Total population	27 million
Economically active	8.4 million
Economically active in agriculture	2.9 million
Total area	44.6 million ha
Cultivated area	9.2 million ha
Rainfed area	7.9 million ha
Annual rainfall	50–1000 mm
Chickpea rank among legumes	Second
Crop season	Spring (traditional) Winter (recent)

Introduction

In Morocco, around 20% of the total area is cultivated. Food legumes occupy 4.8% of the total cropped area (445 000 ha) and are ranked second after cereals in terms of area in the rainfed cropping systems. They are usually cultivated in regions with a favorable climate. Faba bean (*Vicia faba*) is the most important food legume (40% of the total legume area), followed by chick-

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pea (*Cicer arietinum*) (18.9%), dry pea (*Pisum sativum*) (13.9%), and lentil (*Lens culinaris*) (10.7%).

The administrative divisions of the country are shown in Figure 3.2.1 and the chickpea distribution in Figure 3.2.2. The status of chickpea production in the country has been reviewed by Kamal (1984). Chickpea is consumed either at the farm level (in the Prerif region) or used as a trade commodity at the local and regional levels. Chickpea exports constitute 21% of the total export of food legumes (Fig. 3.2.3).

Uses

Legumes are important in the traditional diet of Moroccans in many parts of the country. Chickpea is mostly used in the form of dry seed, although green seeds are also consumed as fresh snacks. Seed size and appearance are important quality traits, as dry seeds are mostly soaked and boiled and seldom crushed. Common chickpea preparations are *homos maslou*, *couscous be homos*, *grain be homos*, and *taajin be homos*.

Area, Production, and Productivity

The total area under food legumes fluctuated around 457 000 ha in the last 3 decades (1960–91). The mean area under chickpea during that period has been about 97 000 ha with large yearly fluctuations, as indicated by a high coefficient of variation (Table 3.2.1). Chickpea area decreased from around 130 000 ha, or 33% of the total pulse area in 1960–75 to around 71 200 ha, or 16.6% of the total pulse area in 1976–90. Around 85% of the

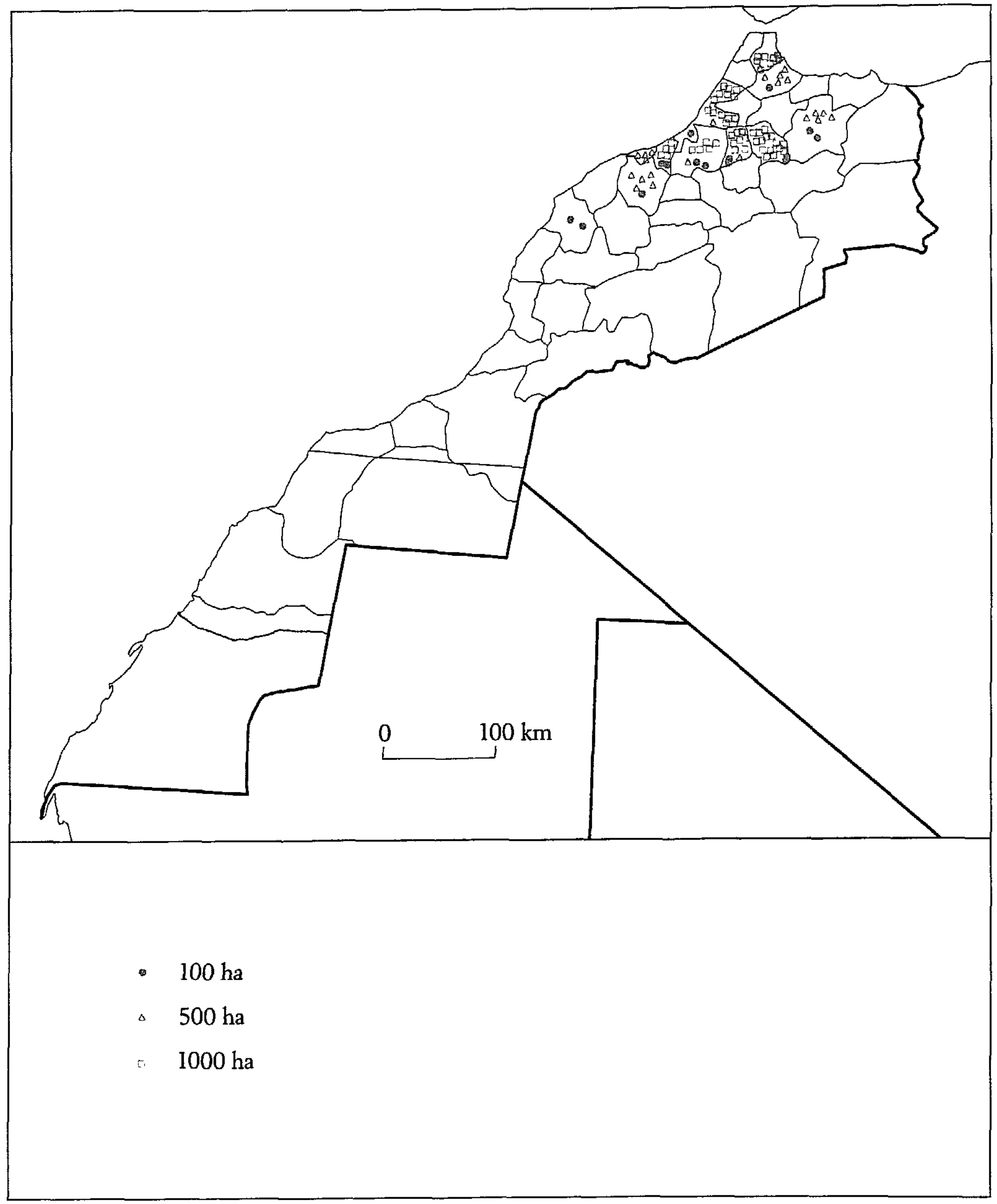

Figure 3.2.2. Chickpea distribution in Morocco.

total chickpea area is found in eight provinces: Kenitra, Ben Slimane, Fes, Meknes, Khemisset, Taza, Chef Chaouen, and Settat. Kenitra has 21% of the chickpea area, and Fes and Meknes together have 14% of the chickpea area.

During 1961–91, chickpea production averaged around 60 000 t per year and ranged from a minimum of 2.2 t in 1971 due to an ascochyta blight (*Ascochyta rabiei*) epidemic to a maximum of 164 000 t in 1974 (Fig. 3.2.3a and Table 3.2.1). The average yield during 1961–91 was around 0.64 t ha^{-1} with a minimum of 0.02 t ha^{-1} in 1971 to a maximum of over 1 t ha^{-1} in 1974 and 1979 (Fig. 3.2.3a). Although the long-term average shows that around 60% of the production is consumed in the country and the rest is exported (Table 3.2.2),

Table 3.2.1. Chickpea area, yield, and production in Morocco (1961–91).

	Area (ha)	Yield (t ha^{-1})	Production (t)
Mean	96 881 ±39 844	0.64±0.25	59 984 ±35 623
CV (%)	41.1	38.8	55.3
Maximum	158 100	1.04	164 420
Minimum	32 100	0.02	2 160

Table 3.2.2. Chickpea production, consumption, and exports in Morocco (1968–89).

	Production (t)	Consumption (t)	Exports (t)
Mean	59 000 ±37 300	36 000 ±17 800	17 000 ±19 900
CV (%)	65.6	54.9	127.1
Maximum	164 420	62 500	80 500
Minimum	2 160	0	0

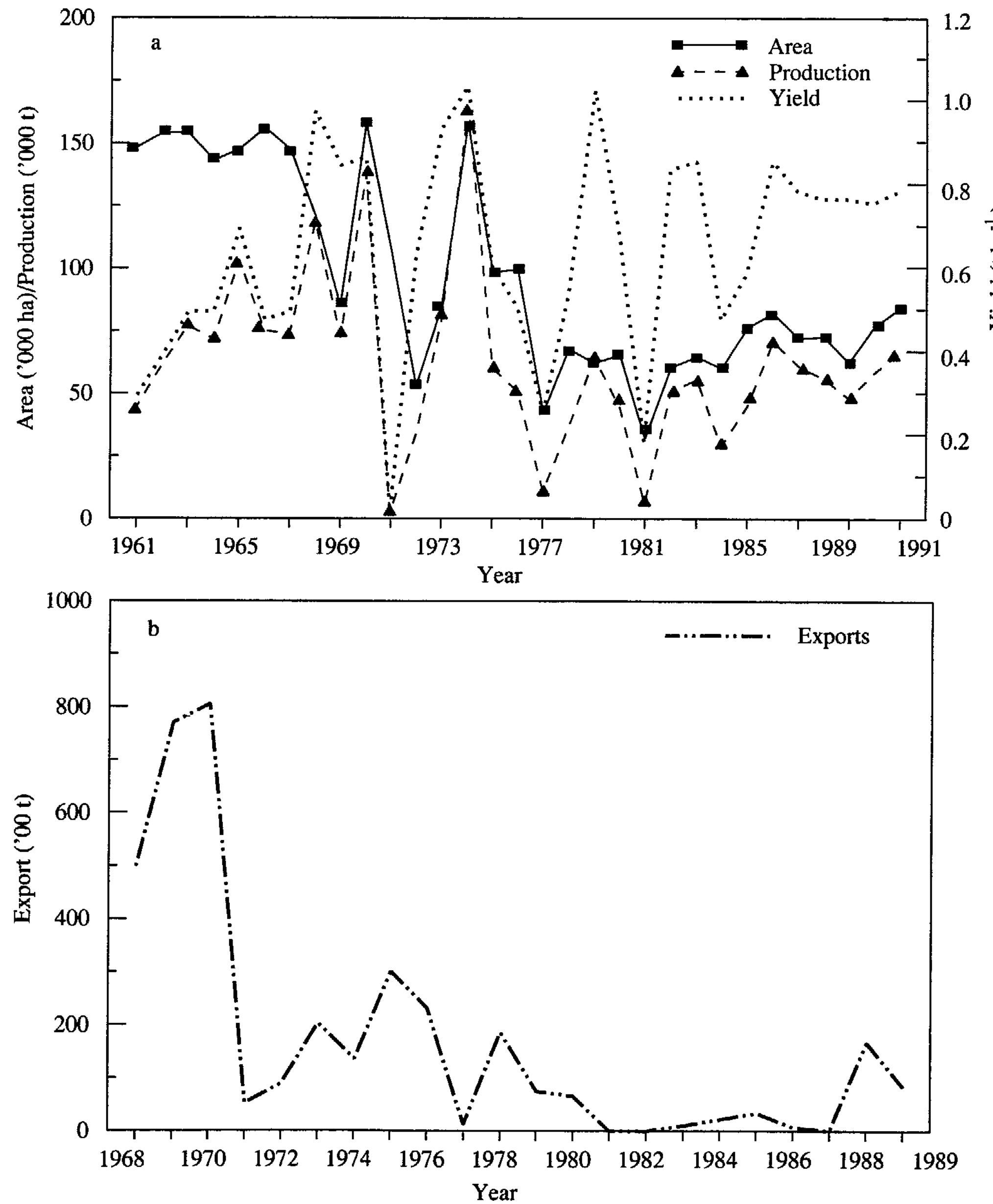

Figure 3.2.3. Trends in: (a) area, production, yield; and (b) export of chickpea in Morocco.

exports dropped steeply after 1970 and have been decreasing consistently since then. In fact, in the dry years, as for instance in the early 1980s, export of chickpea practically stopped (Fig. 3.2.3b). However, small quantities are still exported, mainly to France and Italy.

Climate, Soil, and Crop Distribution

The physiography and climate of Morocco have been described in detail by Noin (1976). The climate across the country is Mediterranean, hot and dry in summer, and wet and cool in winter. The country receives the maximum amount of rainfall from Dec to Feb, which varies from less than 50 mm in the south (desert) to more than 1000 mm in some areas (Rif mountains in the north).

There is a progressive decrease of precipitation from north to south and from west to east (Fig. 3.2.4). Average annual rainfall in the chickpea-growing areas is 350 to 400 mm, with large variations from year to year.

Six agroclimatic zones are recognized on the basis of rainfall (Fig. 3.2.5 and Table 3.2.3). Chickpea is grown mostly in areas where annual rainfall exceeds 300 mm. Its cultivation is considered to be free of risk in the northwestern parts of the country where rainfall—both in terms of quantity and distribution—is dependable from year to year. In areas with rainfall less than 300 mm, its production is uncertain.

Chickpea is mostly grown on Vertisols in the northwest as well as in the middle plateaux of the Meknes and Fes regions (Fig. 3.2.6).

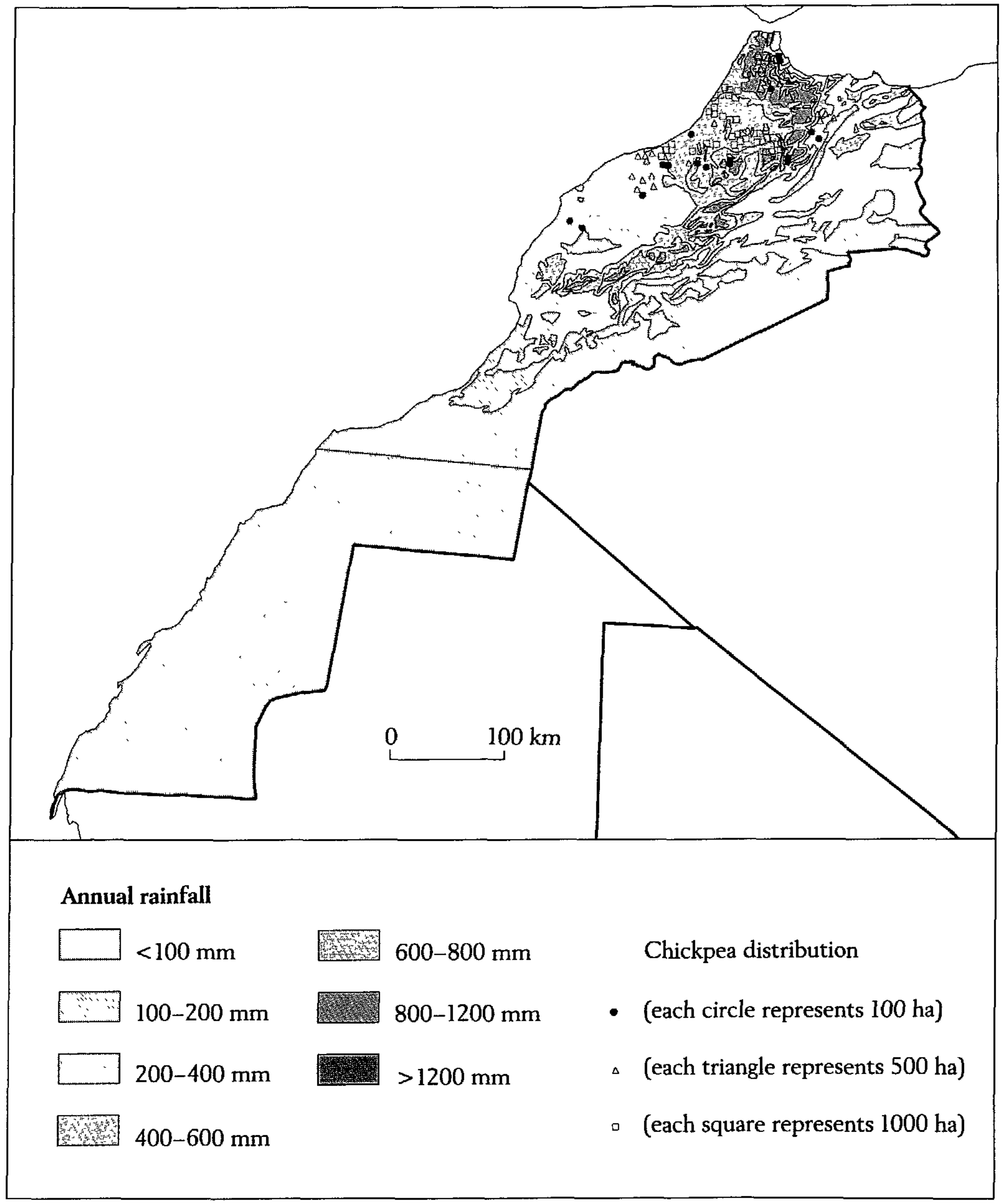

Figure 3.2.4 Mean annual rainfall in relation to chickpea distribution in Morocco.

Table 3.2.3. Characteristics of the main agroclimatic zones of Morocco.

Zone	Type	Rainfall (mm)	Main crops
1	Very favorable zone for cultivation	>400	Cereals, especially wheat. Food legumes: faba bean, chickpea, and lentil
2	Moderately favorable zone	300–400	Cereals. Food legumes: lentil, chickpea, and dry pea
3	Southern unfavorable zone	150–300	Mainly barley. Biannual rotation of cereals-fallow. Food legumes in a few areas
4	Eastern unfavorable zone	<250	Mainly barley. Large areas used for rangeland
5	High elevation zone	>600	Mainly forest or rangeland. Limited cultivation of cereals and food legumes
6	Sahara zone	<150	Desert or rangeland. Limited cultivation of vegetables and forages with irrigation.

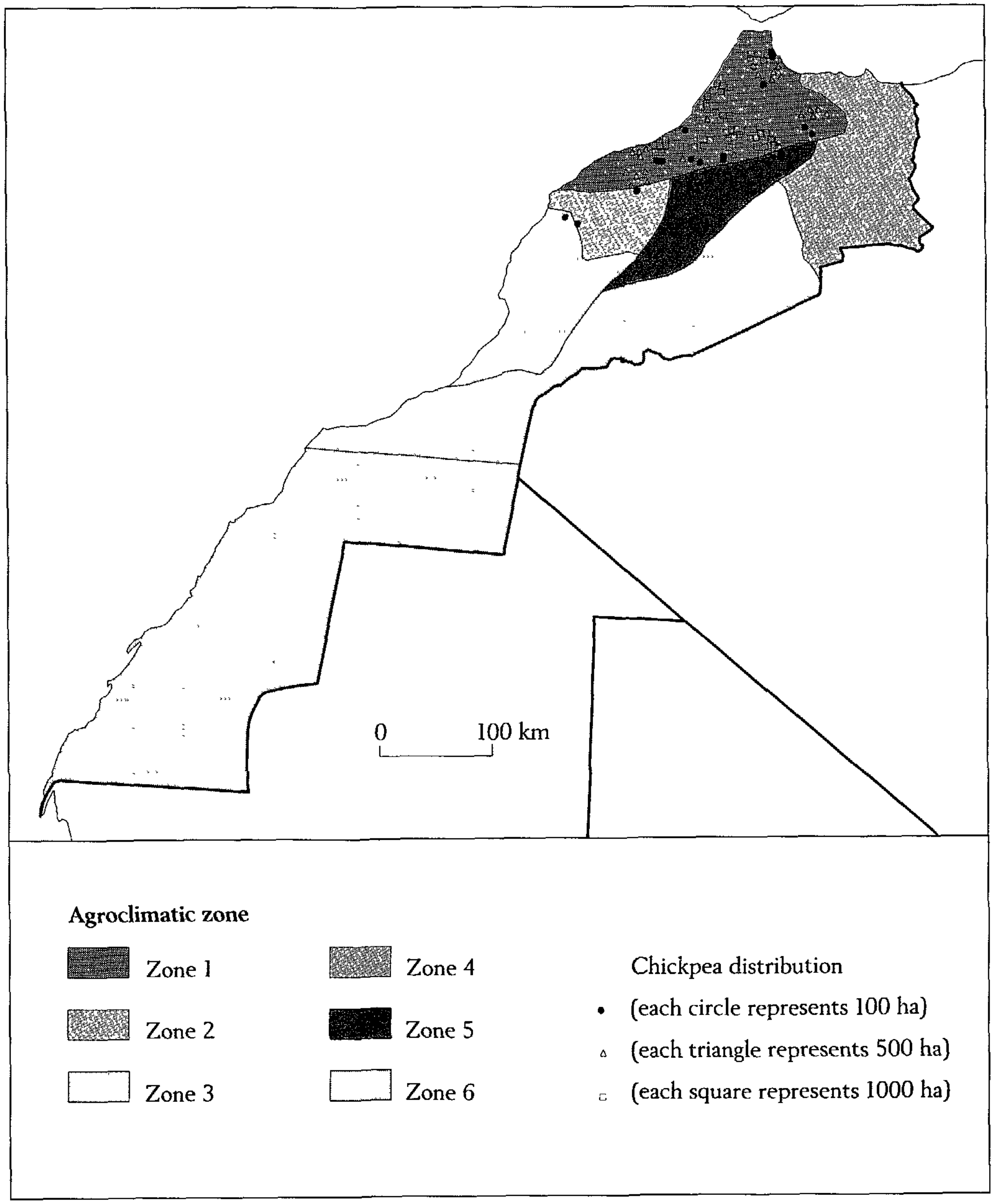

Figure 3.2.5. Agroclimatic zones in relation to chickpea distribution in Morocco.

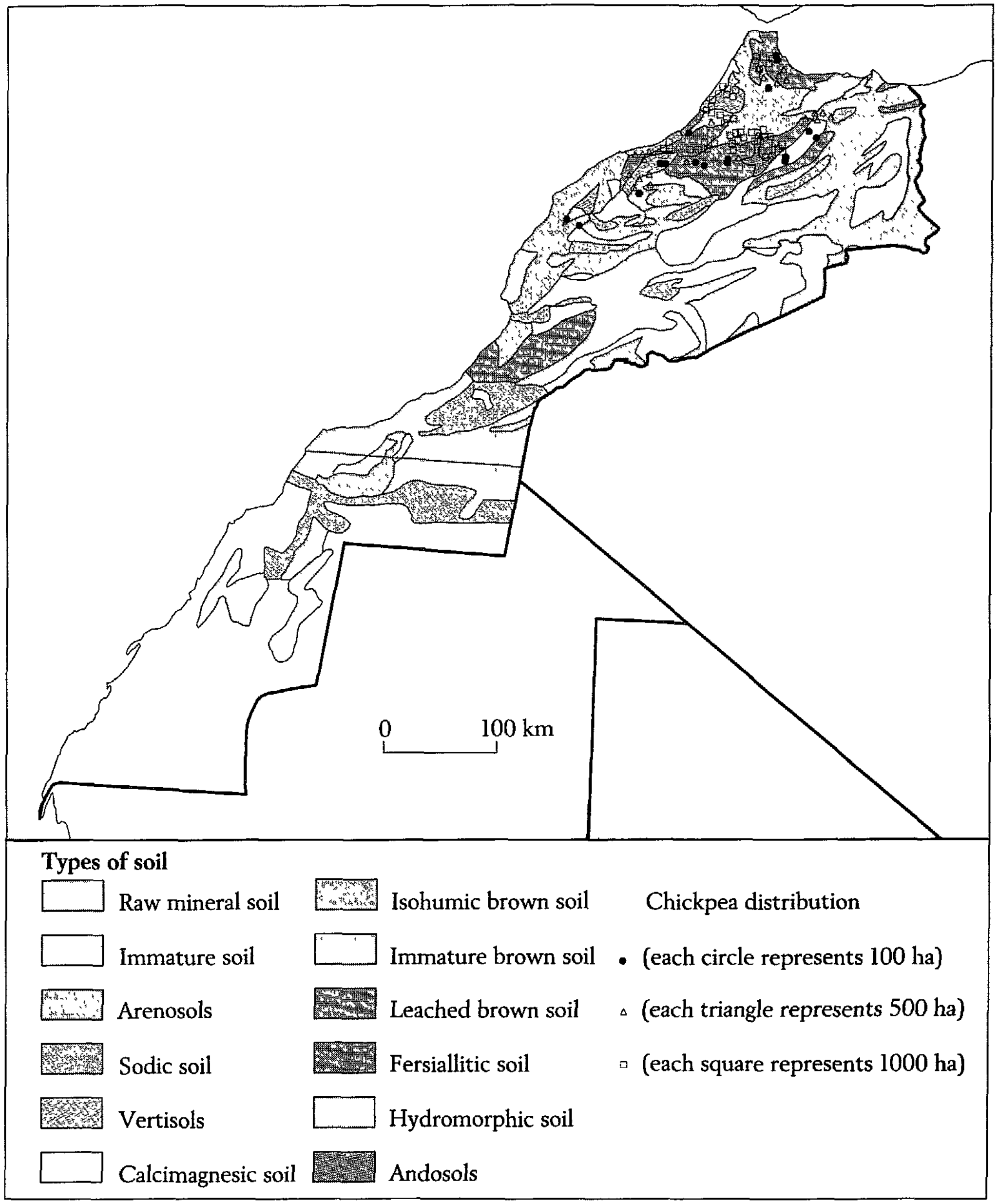

Figure 3.2.6. Soil types in relation to chickpea distribution in Morocco.

Cropping Systems

Traditionally, chickpea is cultivated as a spring season crop. It is sown from mid-Feb to mid-Mar, depending upon the region, and flowering occurs during Apr and May. The area under winter chickpea is small; the variety ILC 195 is grown on around 500 ha. Climatic conditions during the growing periods of spring- and winter-sown chickpea range from moderately favorable (Fig. 3.2.7a) to favorable (Fig. 3.2.7b). On-farm demonstration trials comparing yields of spring and winter chickpea have shown in general, large and consistent gains in yield with winter sowing (Fig. 3.2.8). A large number of chickpea varieties tolerant of ascochyta blight have been evaluated in yield trials and several high-yielding varieties suitable for sowing in winter have been identified. These have now been entered in national yield demonstration trials.

Soil is tilled using either animal-drawn implements or tractors. The crop is sown in rows, spaced 40 to 70 cm apart or in paired rows (15–17cm) with 60–70 cm row spacing. In some areas (the Prerif region) seed is broadcast and then covered by light harrowing. Seed drills are used on farms that are larger than 15 ha.

Seed rates vary from 0.08 to 0.12 t ha^{-1}. Large-seeded local varieties are widely grown and preferred. Registered varieties include two large-seeded spring varieties, PCH 37 and PCH 46 (40 g 100 $seed^{-1}$), and three winter chickpea varieties, ILC 195 (27 g 100 $seed^{-1}$), FLIP 83-48C, and FLIP 84-92C (35 g 100 $seed^{-1}$).

Chickpea is manually harvested during Jun and Jul. On large farms, combines are used for harvesting and threshing.

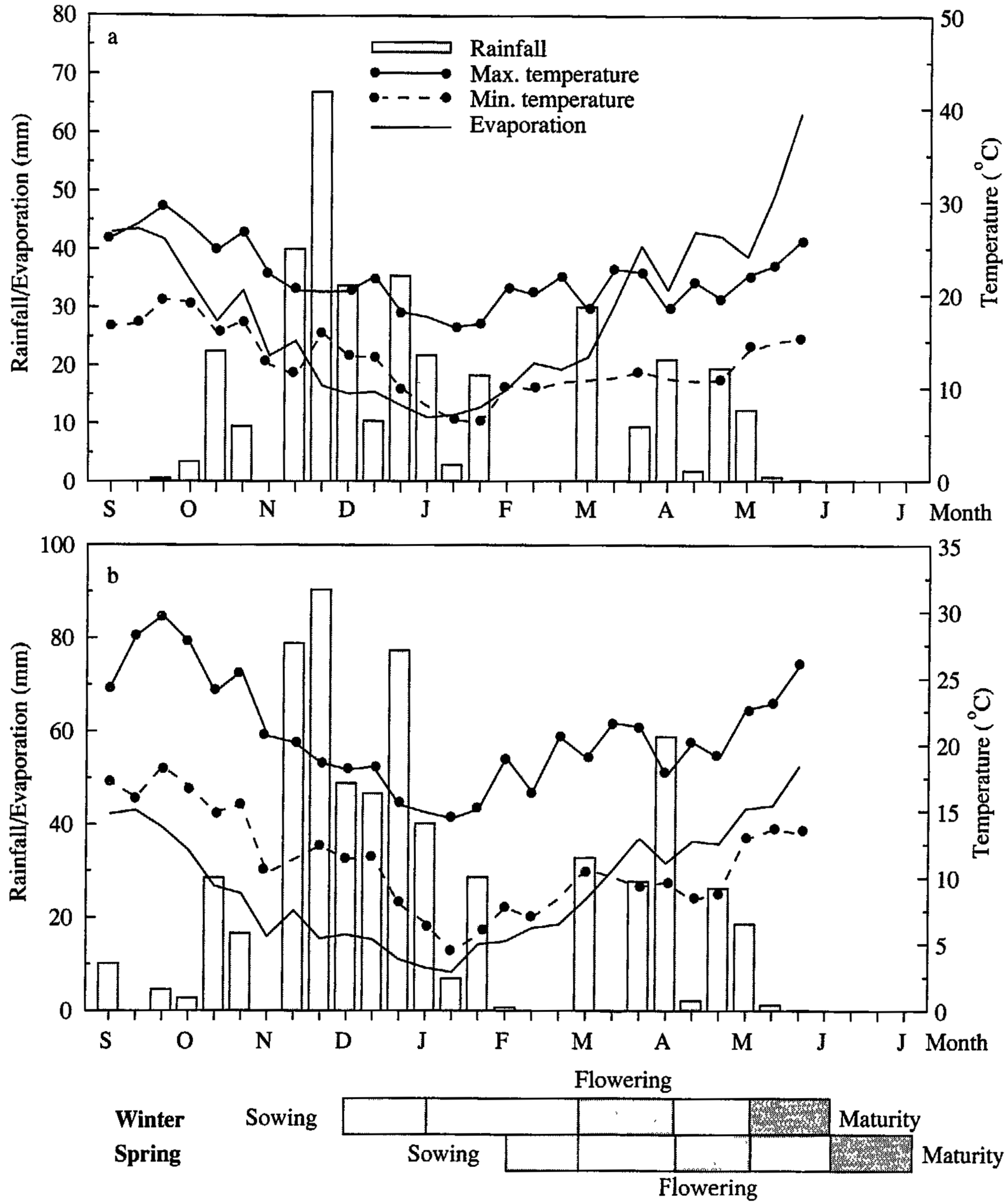

Figure 3.2.7. Crop phenology of spring- and winter-sown chickpea in relation to climatic conditions in two types of growing environments in Morocco: (a) moderately favorable; and (b) favorable.

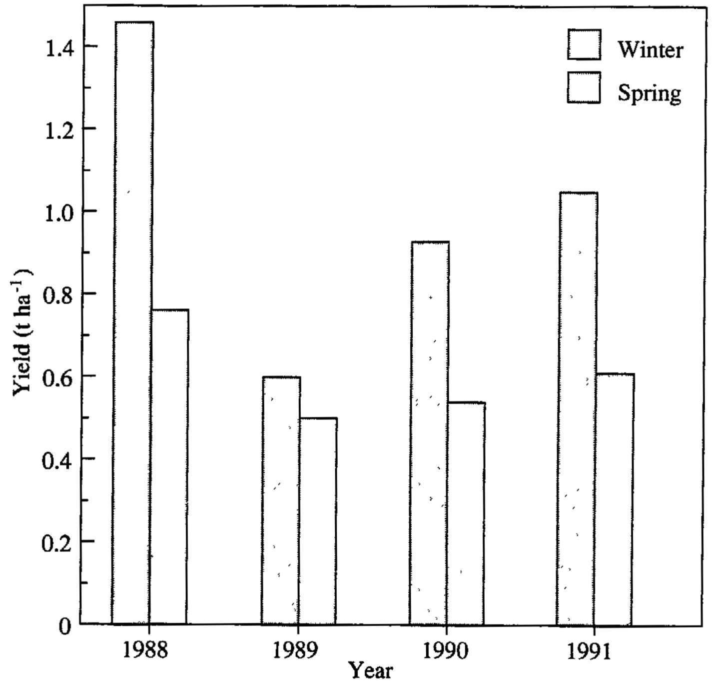

Figure 3.2.8. Yield advantage of winter- over spring-sown chickpea in Morocco, 1988–91.

Production Constraints

Abiotic Constraints

Drought

In the rainfed areas, particularly in the semi-arid zone, yields of spring chickpea are low due to terminal drought during the flowering and pod-filling stages. Advancing the sowing date to winter (Nov/Dec) increases yield (Fig. 3.2.8). Estimates of yield losses due to drought are not available but studies have been initiated.

Frost

Frost, a constraint of winter chickpea, is not a major problem in Morocco because most of the chickpea is at present sown in spring.

Heat

Heat is a constraint to late-sown spring chickpea in areas where the crop is exposed to the risk of hot summer winds blowing from the east (*Chergui*). It is a common constraint in most chickpea-growing areas both in the favorable and semi-arid zones.

Biotic Constraints

Several pests and diseases affect chickpea in Morocco. Ascochyta blight (Fig. 3.2.9) is the most important disease followed by wilt (*Fusarium oxysporum*). Yield losses due to these diseases range from 10% to complete crop failure.

The severity of seedling diseases (*Rhizoctonia solani, Sclerotium rolfsii*, and *F. solani*) and stunt varies from year to year, depending upon the weather.

Leafminer (*Liriomyza cicerina*) is the most important insect pest on chickpea in the country (Fig. 3.2.10). During storage, bruchids (*Callosobruchus* spp) cause significant economic losses.

Weeds

Weed infestation in spring-sown chickpea ranges from low to moderate. But, in winter-sown chickpea, they are a major problem and can cause heavy yield losses.

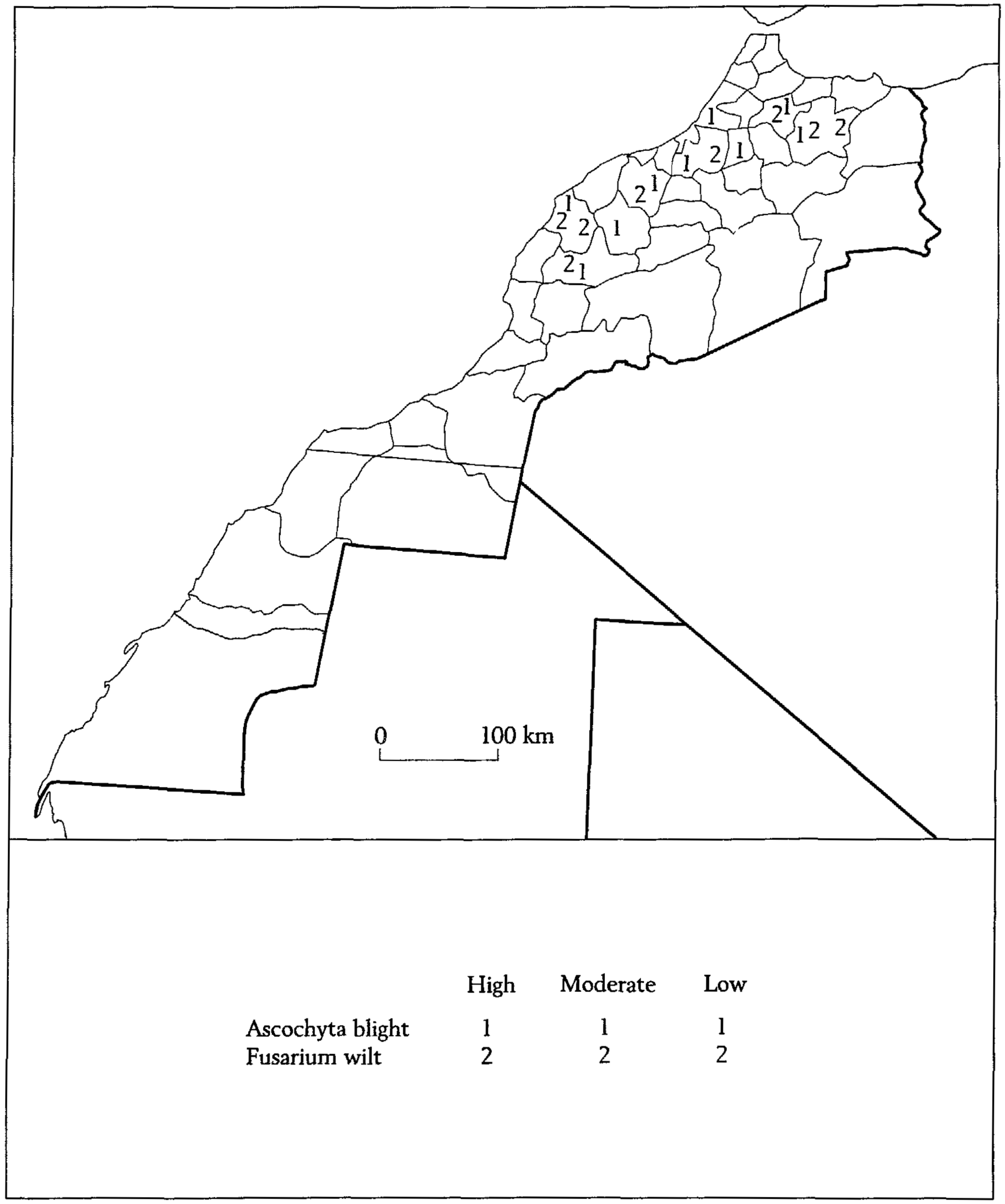

Figure 3.2.9. Disease incidence on chickpea in Morocco.

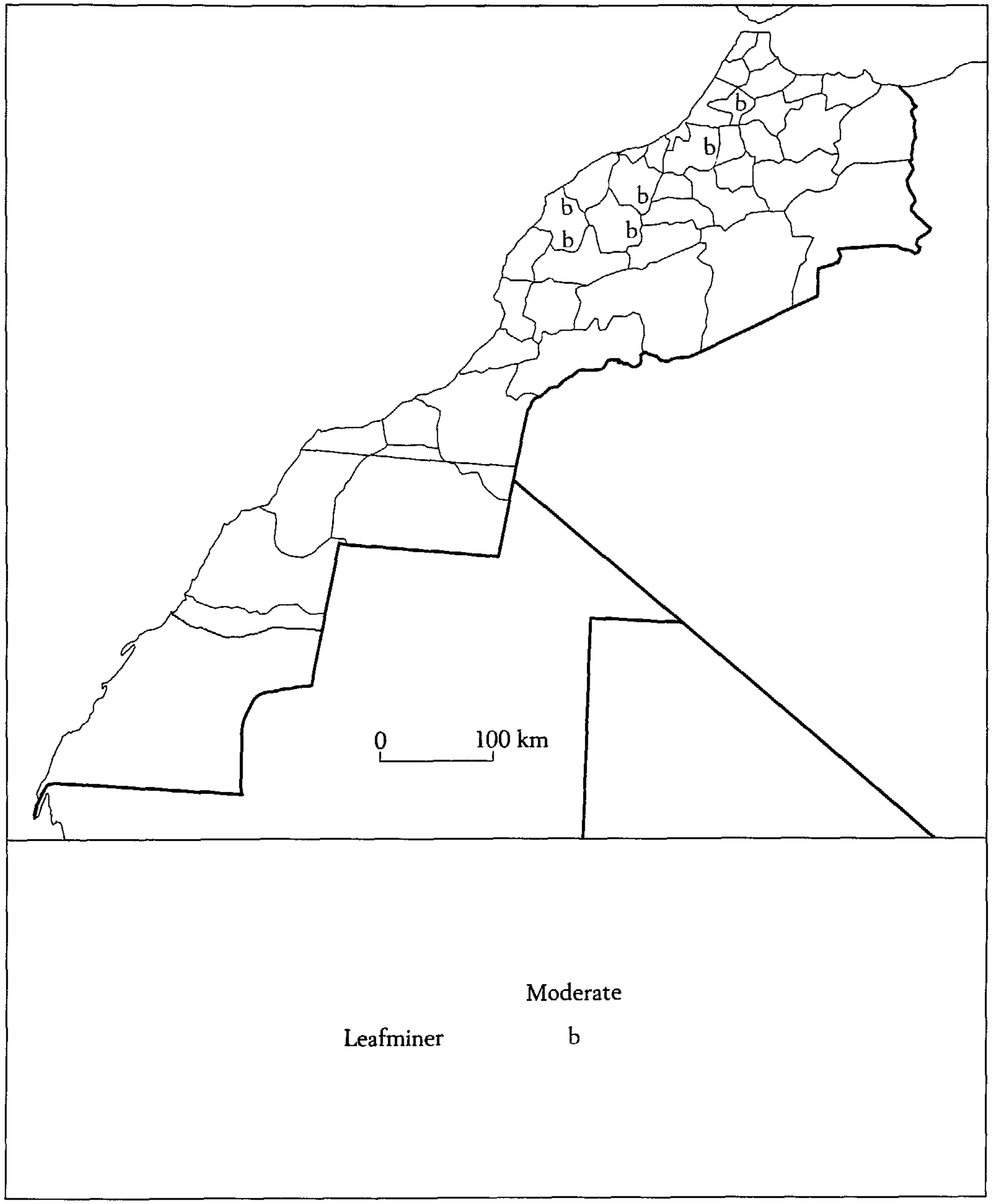

Figure 3.2.10. Leafminer incidence on chickpea in Morocco.

Future Prospects

Although chickpea has a special importance in the farming systems of the northwest region of Morocco, it remains confined to only a few agricultural zones within the country. Yields are generally low due to several biotic and abiotic constraints and to poor management by farmers. Such economic constraints as variability in price and demand, difficulties of storage, etc., do not make the crop very profitable.

Chickpea, however, has tremendous potential, both as a spring- and a winter-sown crop in the cereal-based cropping systems (Figure 3.2.11), especially since ascochyta blight resistant and high-yielding winter chickpea varieties that are also adapted to spring-sowing conditions have become popular with farmers. The average yield of spring chickpea reached 1.6 t ha^{-1} in some provinces e.g., in the Taza Province in 1979. On large demonstration trials in farmers' fields, winter chickpea yields reached 3 t ha^{-1}.

The cultivation of spring chickpea could be expanded within the traditional chickpea areas of Kenitra, Meknes, Fes, Taza, Khemisset, and Ben Slimane. In these areas, winter sowing could also be introduced to increase yield and production. New areas, such as Safi and Essaouira in the semi-arid zone and certain areas of the Atlas mountains are promising for introduction of winter chickpea. However, in spite of the success of winter-sown chickpea, spring-sown chickpea will continue to have its place in the farming systems of Morocco, especially in areas that are highly prone to ascochyta blight.

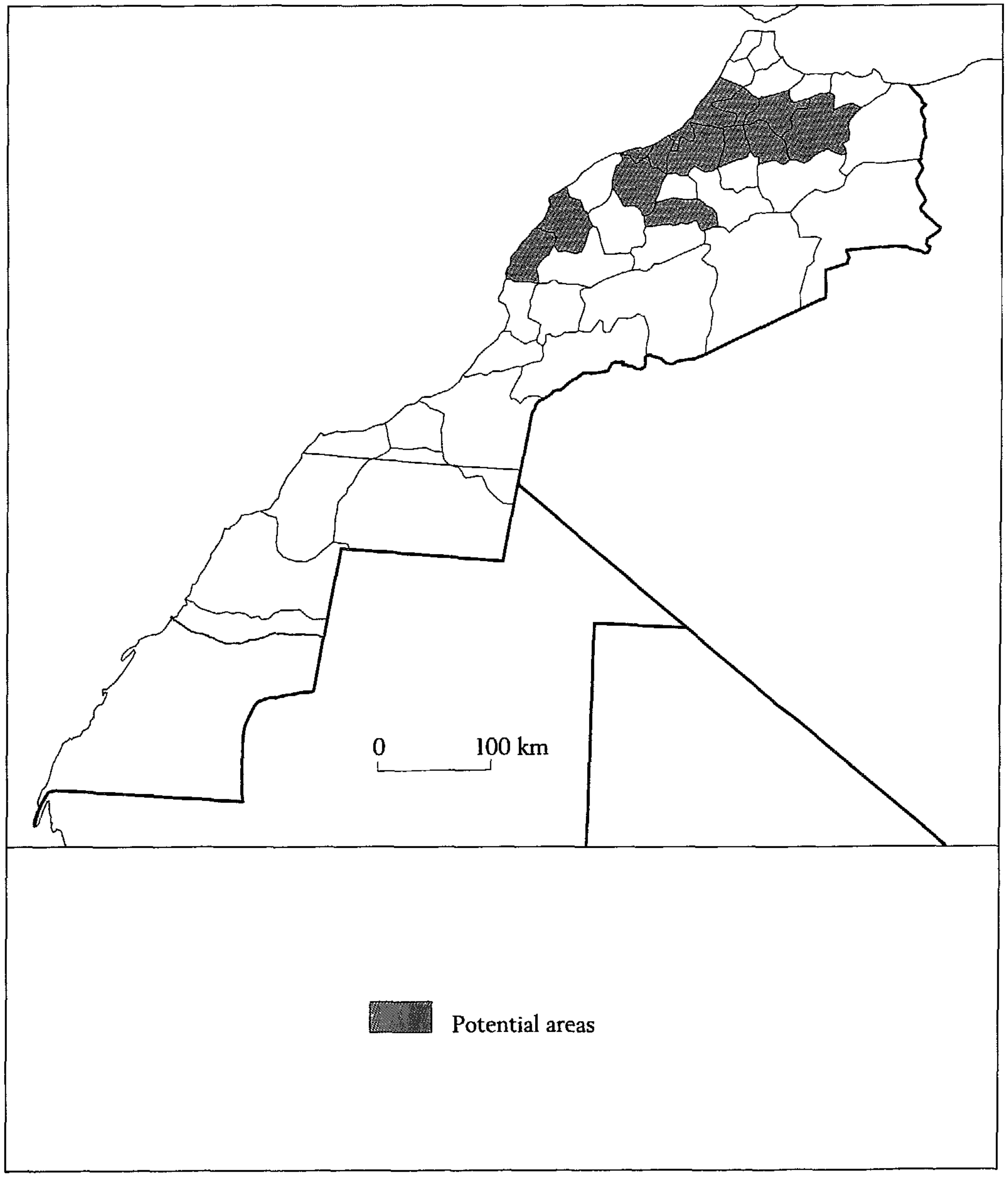

Figure 3.2.11. Potential areas for expansion and/or intensification of chickpea cultivation in Morocco.

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Kamal, M. 1984. The status of chickpea production and research in Morocco. Pages 247–253 *in* Ascochyta blight and winter sowing of chickpea (Saxena, M.C., and Singh, K.B., eds.). The Hague, Netherlands: Martinus Nijhoff/Dr W Junk Publishers.

Noin, D. 1976. Morocco. Pages 377–387 *in* World Atlas of Agriculture. Monograph. Vol 4, Africa. Novara, Italy: Instituto Geografico de Agostini.

Additional Literature

The publication listed here is not cited in the text, but it provides further information on chickpea in Morocco.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1987–93. Morocco/ICARDA Cooperative Program *in* Legume Program Annual Reports 1987 to 1993. Aleppo, Syria: ICARDA.

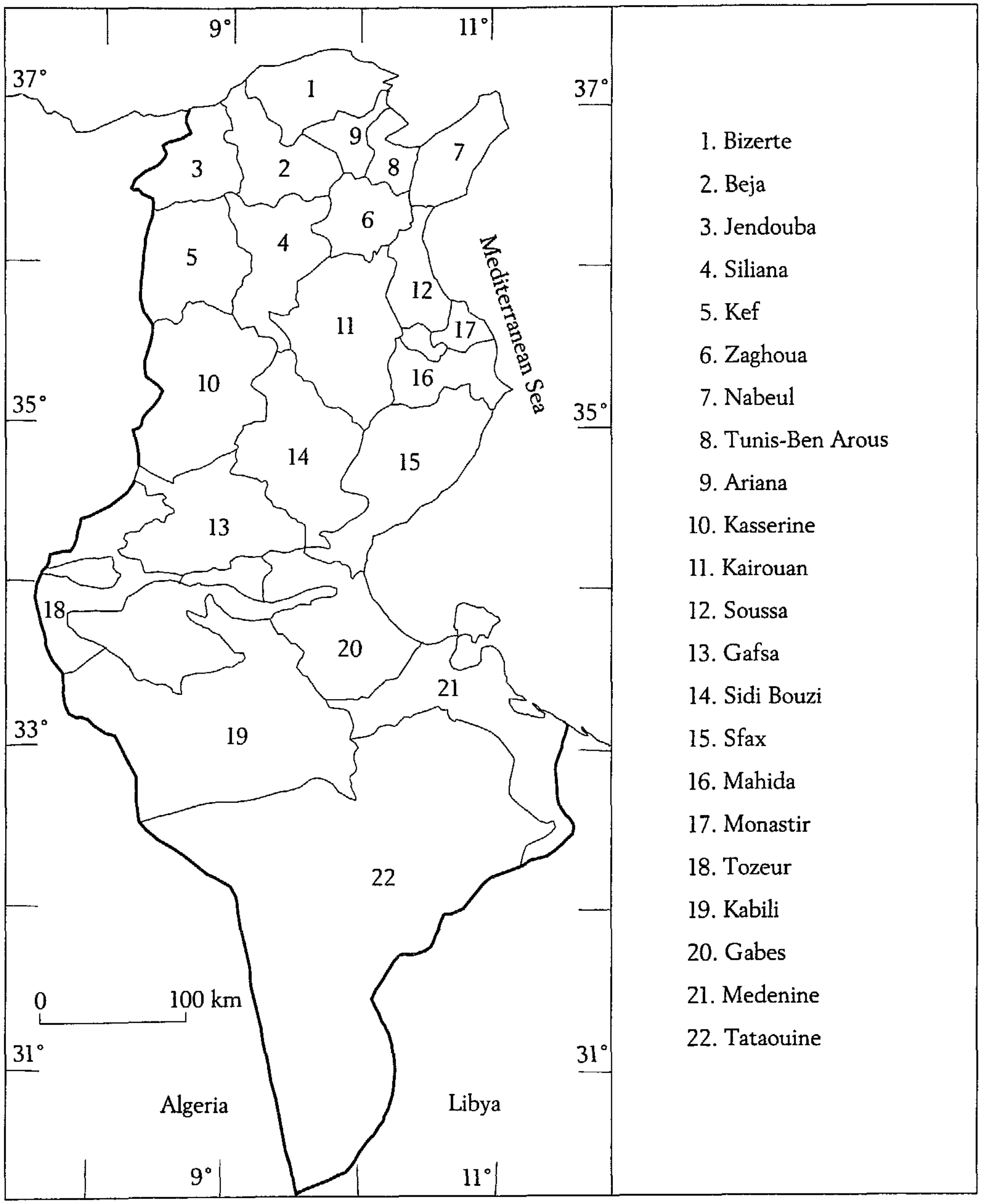

Figure 3.3.1. Administrative boundaries of Tunisia.

3.3. Chickpea in Tunisia

A Haddad[1], M H Halila[2], and M Jendoubi[1]

Latitude	30–37° N
Longitude	12–17° E
Altitude	300–1200 m
Total population	8.6 million
Economically active	2.9 million
Economically active in agriculture	0.63 million
Total area	16.4 million ha
Cultivated area	2.9 million ha
Rainfed area	2.7 million ha
Annual rainfall	150–1500 mm
Chickpea rank among legumes	First (shared with faba bean)
Crop season	Spring (traditional) Winter (recent)

Introduction

Chickpea (*Cicer arietinum*) is among the most important food legumes in Tunisia. It is predominantly a rainfed crop and accounts for 1.5% of the total cropped area. The area under chickpea (36% of the total food legume area) is as large as that under faba bean (*Vicia faba*) (40%). Besides its importance as a source of protein in the daily diet of most Tunisians, chickpea fits well

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into the cropping systems practiced by farmers in the main cereal-producing areas of the country. The administrative boundaries of Tunisia are shown in Figure 3.3.1 and the distribution of chickpea in Figure 3.3.2.

Uses

Chickpea is prepared in various ways in Tunisia. *Homosbiteheneh* (seed soaked, boiled, and dressed with spices) is a popular dish throughout the country. *Lablebi* (seed boiled with salt and pepper) is another common preparation. Chickpea is also used in cakes and coffee blends (Bouslama 1980). Roasted seed are used for snacks.

Area, Production, and Productivity

Table 3.3.1 presents information on the area, production, and yield of chickpea in some important chickpea-growing governorates of Tunisia. Nearly 93% of the total chickpea area lies in the north (Figure 3.3.2), where the average rainfall is above 350 mm. The crop is also grown along the coast between Soussa and Sfax (7% of the area) where the annual rainfall is below 300 mm (Anonymous 1992; Halila et al. 1988).

There are large year-to-year fluctuations in the area and production of chickpea (Fig. 3.3.3) that are closely related to variations in weather conditions, primarily rainfall. The average area sown to chickpea during 1976–92 has been around 33 400 ha, with a minimum of 22 650 ha in 1987/88 and a maximum of 44 500 ha in 1990/91 (Anonymous 1992). The mean annual production during the same period was about 24 900 t and the

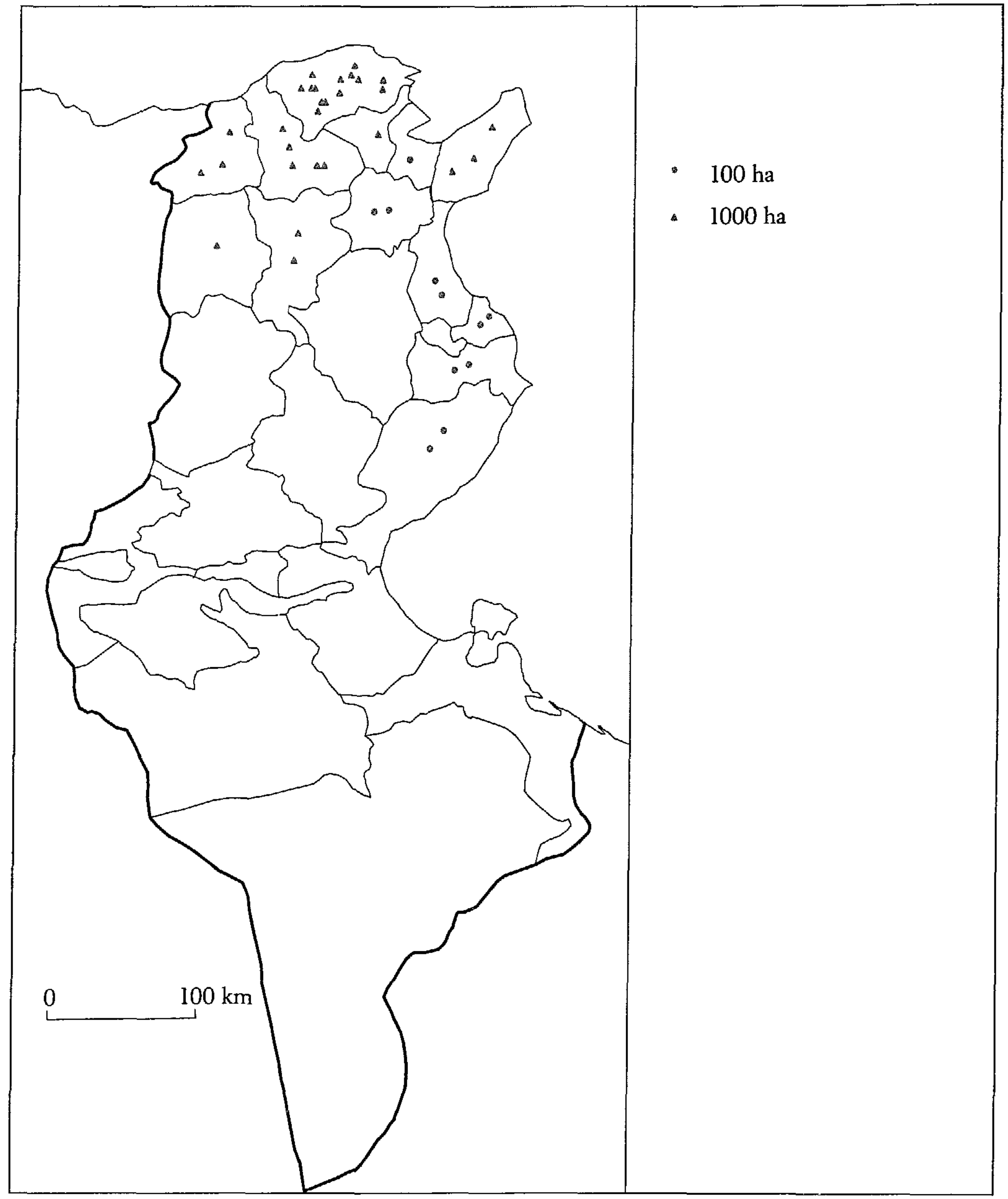


Figure 3.3.2. Chickpea distribution in Tunisia.

Table 3.3.1. Area, production, and yield of chickpea in some important chickpea-growing governorates of Tunisia (mean of 1985–92).

Governorate	Area (ha)	Production (t)	Yield (t ha^{-1})
Bizerte	15 246	14 424	0.95
Beja	4 570	3 399	0.74
Jendouba	2 796	1 898	0.68
Siliana	2 175	1 466	0.67
Kef	800	411	0.51
Zaghoua	218	81	0.37
Nabeul	4 370	2 552	0.56
Tunis-Ben Arous	127	96	0.76
Ariana	1 005	667	0.66

average yield 0.7 t ha^{-1}. Production was lowest in 1987/88 (9570 t with an average yield of 0.4 t ha^{-1}) and highest in 1980/81 (32 024 t with an average yield of 1 t ha^{-1}) (Fig. 3.3.3).

Winter sowing technology was recently introduced in Tunisia. This technology was made possible by developing cultivars showing resistance to low temperature. Two cultivars suitable for winter sowing, Chetoui (ILC 3279) and Kassab (F83-46C), have been developed and their seed multiplied during 1988–92. The advantage of winter-sown chickpea over spring sowing has been shown in demonstrations on experimental stations and in on-farm trials (Halila et al. 1988). The winter-sown crop profits from winter rainfall and has a vigorous growth. The average yield of varieties adapted to winter sowing, was about 53% higher than that of Amdoun 1, a spring-sown variety in experiments conducted from 1989 to 1992 (Table 3.3.2).

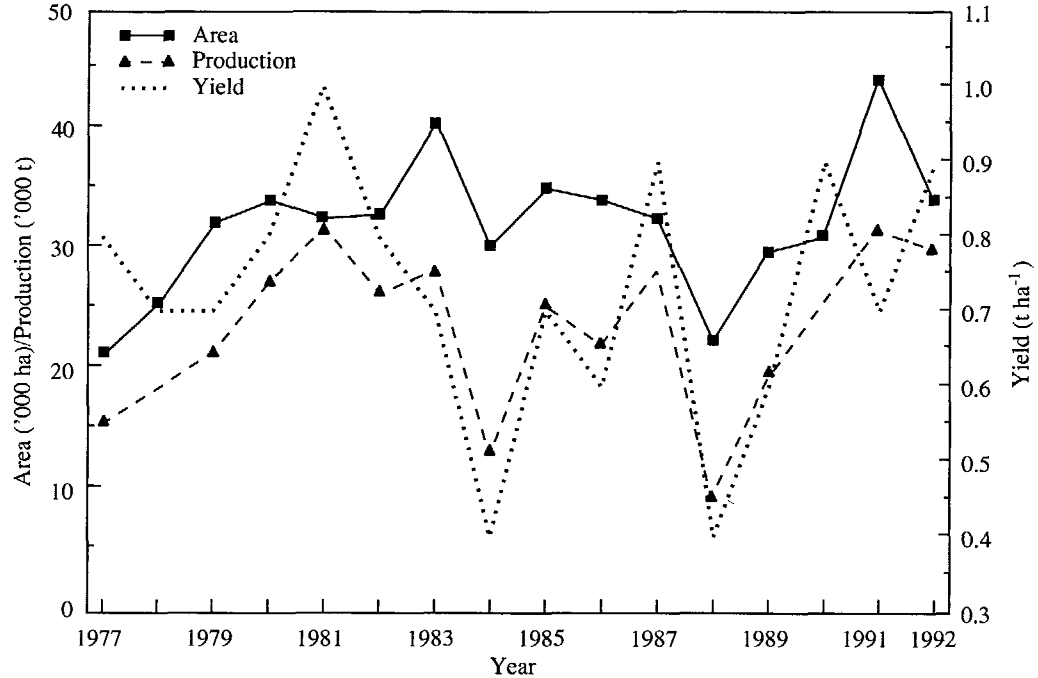


Figure 3.3.3. Trends in area, production, and yield of chickpea in Tunisia, 1977–92.

Table 3.3.2. Comparison of varieties adapted to winter sowing with Amdoun 1, a spring variety (average of Bizerte, Mateur, Beja, and Jendouba on-farm trials, 1989–92).

Year	Yield (t ha^{-1}) Kassab[1]	Chetoui[2]	Mean	Amdoun 1	Yield increase over Amdoun 1 (%)
1988/89	1.51	0.94	1.23	0.83	47.5
1989/90	2.01	1.41	1.71	1.73	–1.3
1990/91	1.37	1.32	1.35	0.19	627.6
1991/92	1.88	1.71	1.80	1.21	48.4
Mean	1.69	1.35	1.52	0.99	53.5[3]

1. F83-46C. 2. ILC 3279. 3. Mean of means.

Soil, Climate, and Crop Distribution

The main chickpea-growing areas are located within a belt extending across the governorates of Bizerte, Beja, Jendouba, and Nabeul (Mlaiki and Ben Salah 1984). Soils in these zones (Fig. 3.3.4) are calcareous (brown) at Mateur and in the Medjerda Valley and deep clay-loamy Vertisols at Beja and Jendouba (Belkhodja et al. 1973).

The mean annual temperature in northern Tunisia is between 18 and 21°C (Fig. 3.3.5). The highest temperatures occur in Jul varying from 28 to 37°C (Belkhodja et al. 1973). Minimum temperature isotherms in Jan (the coldest month of the year) are shown in Figure 3.3.6. Characteristic low temperature zones are:

- A coastal zone shaped as a thin band that widens at Bizerte and Capbon, with an average minimum temperature of 7°C. Frost is not a major constraint to chickpea cultivation in this zone.
- An intermediate zone enclosing Beja, Medjez, and Zaghoua with an average minimum temperature between 2 and 7°. This zone is characterized by a high inter-annual fluctuation in temperature with winters mild in some years and cold in others.
- A continental high plateau zone of Kef-Sers-Maktar with an average minimum temperature below 2°C but rarely down to 0°C in Jan. In this zone, frost is common during 2 to 3 months of the year (Belkhodja et al. 1973; Bouslama 1980).

Chickpea is mostly cultivated in the first two zones where problems of frost rarely occur. The rainfall distribution in Tunisia is shown in Figure 3.3.7. The chickpea-

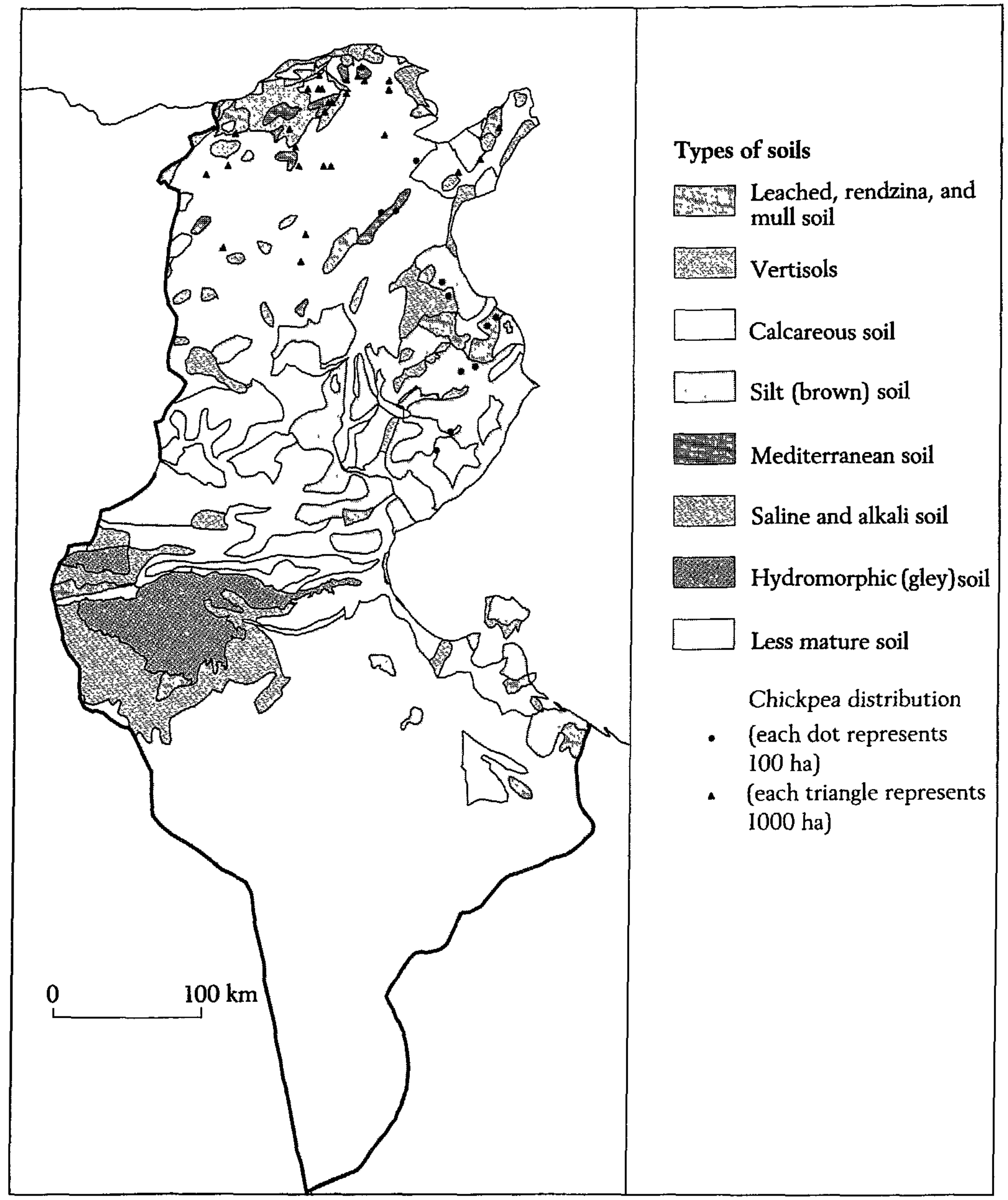


Figure 3.3.4. Soil types in relation to chickpea distribution in Tunisia.

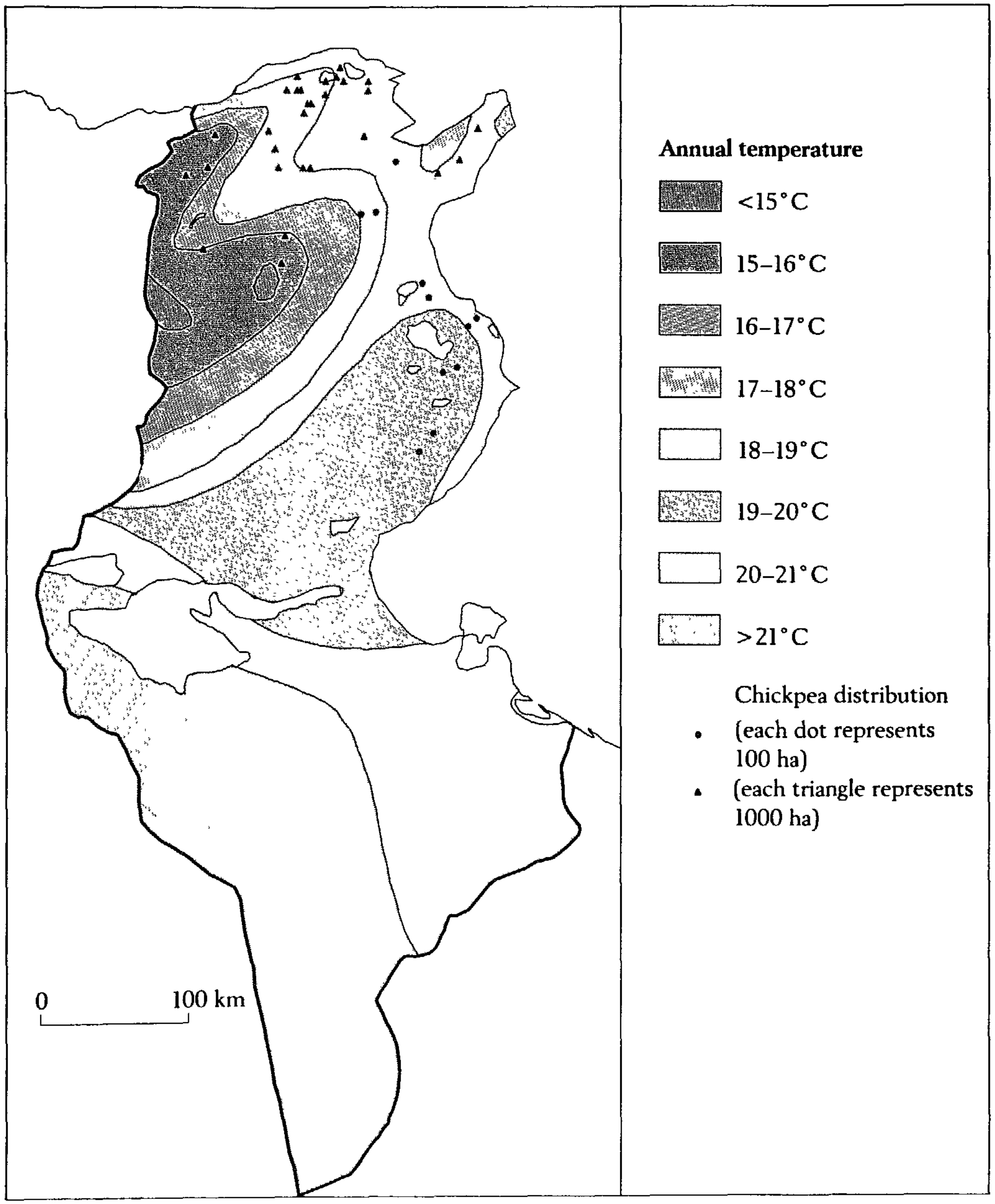


Figure 3.3.5. Mean temperature in relation to chickpea distribution in Tunisia.

producing areas in the north are mainly located in two climatic zones with rainfall varying between 300–800 mm (Fig. 3.3.8):

- The subhumid zone (600–800 mm) extending as a 50-km band across Bizerte, Beja, and Jendouba.
- The semi-arid zone (300–600 mm) which is the main cereal and food legume area of the country, extending to the Sahel (Soussa) and the center (Kairouan). This zone in turn is divided into three subregions characterized by different types of winter: (1) predominantly mild winter; (2) predominantly cool winter; and (3) cold at high altitudes and mild in the coastal areas. Chickpea is grown mainly in the first two subregions (Belkhodja et al. 1973; Bouslama 1980; Halila et al. 1988).

Prevailing winds normally blow from the north-west. Air humidity is quite high throughout the chickpea-producing area during the growing season.

Cropping Systems

Chickpea fits into a 2- to 4-year rotation with cereals, forages, industrial crops (sugar beet, sunflower, etc.), and fallow (Bouslama 1980; Halila et al. 1988; Mlaiki and Salah 1984). The chickpea-wheat rotation is quite common and beneficial to wheat: the weeds that infest the chickpea crop are usually pulled out by hand; the wheat crop which is sown after chickpea benefits from this practice and from the residual effect of nitrogen contributed through symbiotic N_2 fixation. Some farmers grow spring chickpea, mostly during wet years, as a second

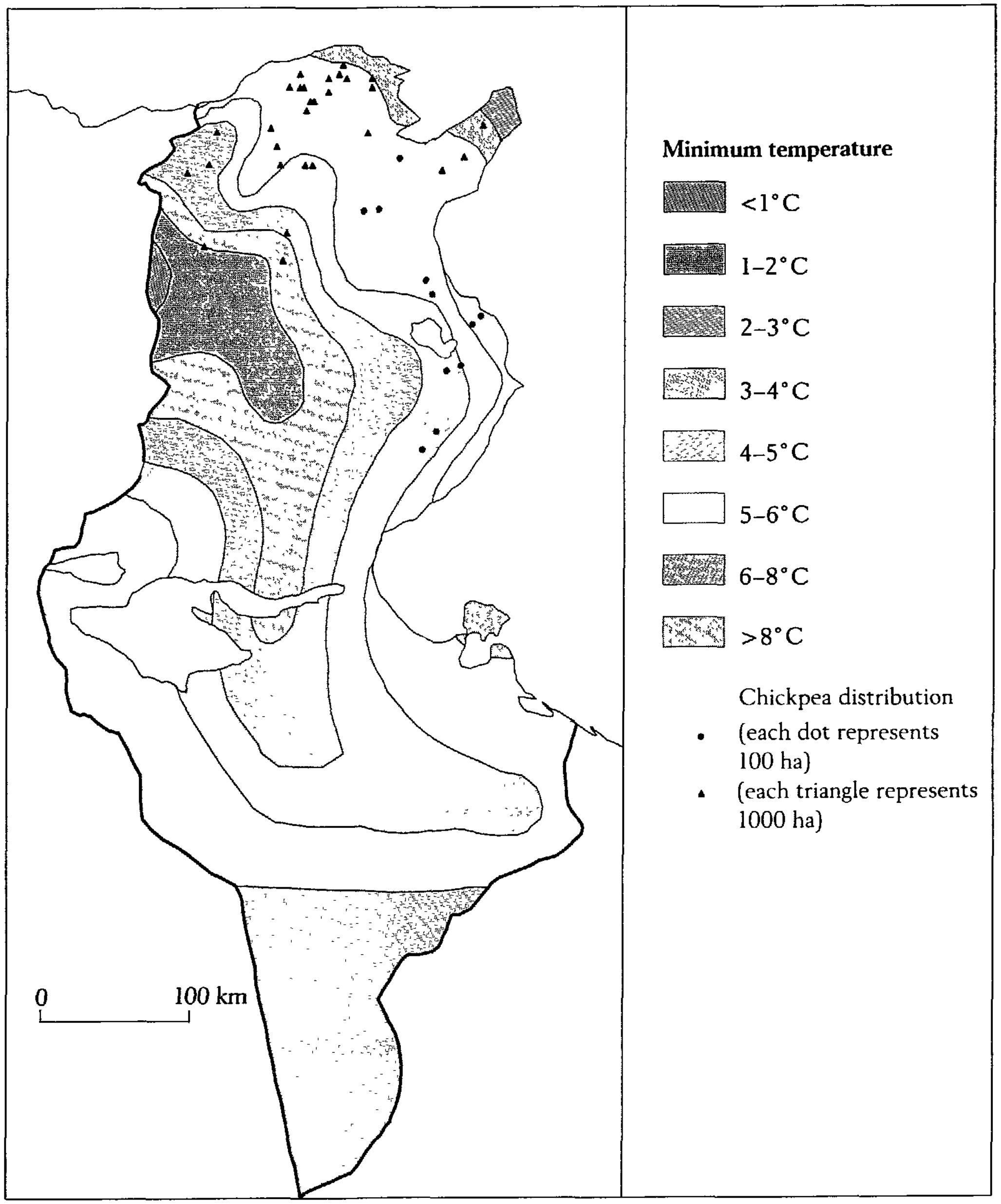


Figure 3.3.6. Minimum temperature in relation to chickpea distribution in Tunisia.

crop after a fodder crop, such as barley used for making hay or silage.

Chickpea is sown mainly in spring, from mid-Mar to mid-Apr. Sowing in winter is still new. The climatic conditions prevailing during crop growth of spring- and winter-sown chickpea are shown in Figure 3.3.9. Seeds are often sown with drills. However, most of the small farmers sow the crop manually, using the broadcast method or in furrows opened with an animal-drawn plow (rows 70–100 cm apart). Plant densities in farmers' fields are often less than optimal (20 plants m^{-2}).

Weeding is done manually or by animal-drawn plows. Preemergence herbicides are sometimes applied (Trifluraline® and Simazine®). But small farmers have difficulty in handling such chemicals, often applying higher doses than recommended which has frequently resulted in a total loss of crops at the emergence stage (Khaldi et al. 1991).

Chickpea is manually harvested. Plants are collected in heaps and threshed by draft animals, tractors or combines. Direct combining is sometimes done by farmers who have large holdings.

Although improved varieties are available, most farmers continue to use local varieties or mixtures of various seeds. They use seed saved from their previous crop, or buy from their neighbors or the local market. The Tunisian Government is making great efforts to introduce certified seed in the country.

Research and Extension

Research on food legumes, including chickpea, began with the launching of the Food Legume Improvement

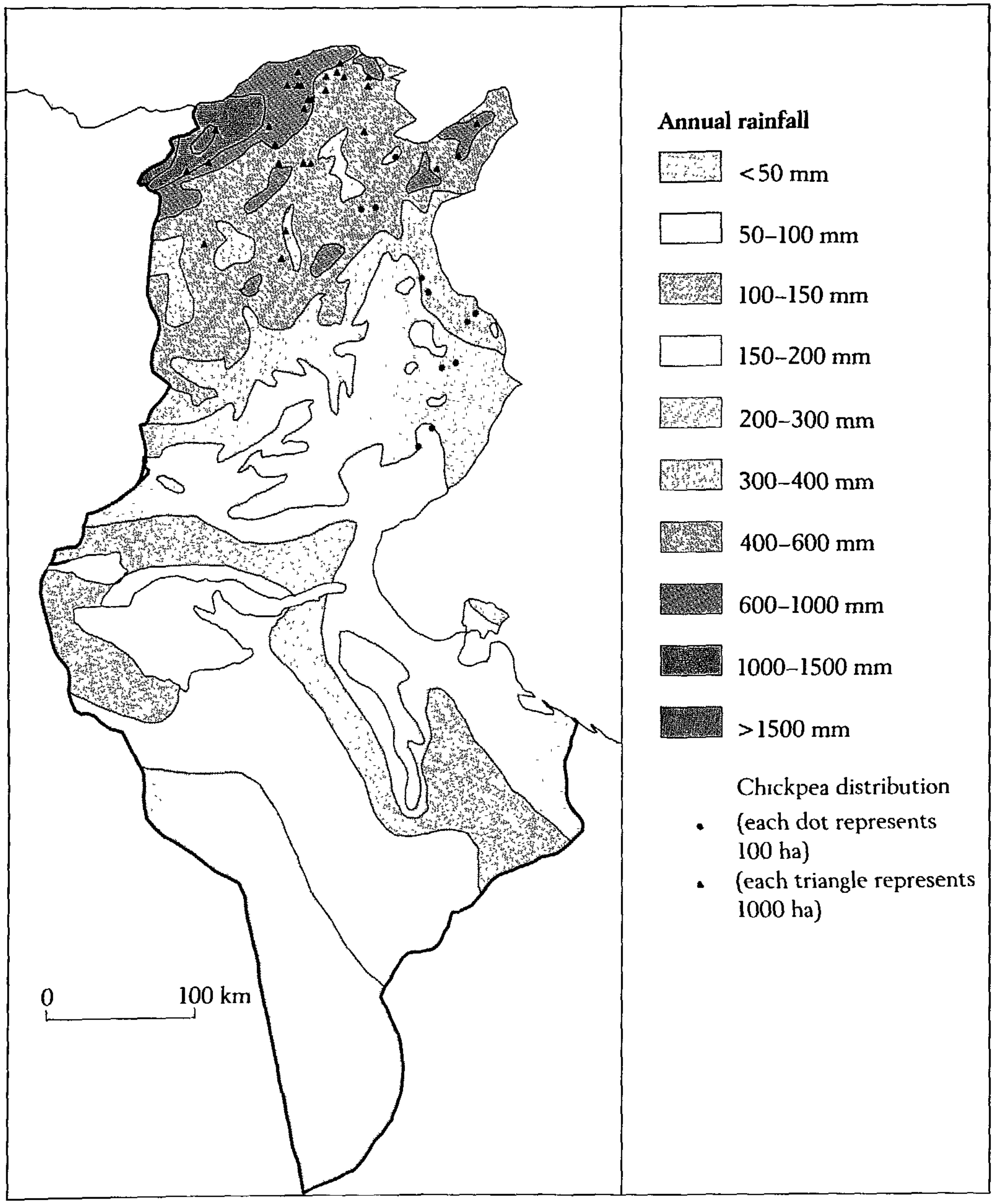


Figure 3.3.7. Mean annual rainfall in relation to chickpea distribution in Tunisia.

Program in 1982 at the Institut national de la recherche agronomique de Tunisie (INRAT) under the ICARDA/Tunisia collaborative project. This project is coordinated by the national research and teaching institutions and extension organizations such as the Office des céréales.

The ICARDA-Tunisia collaborative effort has resulted in the development of a package of practices that has been evaluated in on-farm trials. Three high-yielding varieties have also been released by this joint program. The first variety, Amdoun 1, is totally resistant to wilt caused by *Fusarium* spp (Halila and Harrabi 1990) and is recommended for spring sowing. Amdoun 1 is similar to the local chickpea variety in seed size, color, shape, and cooking quality, but outyields it by 10% and has thus been immediately accepted by farmers and consumers. It is not recommended for winter sowing because of its susceptibility to ascochyta blight (Halila and Harrabi 1990).

The other two varieties, Kassab and Chetoui, were selected from the ICARDA elite selections and have moderate levels of tolerance for ascochyta blight. These have been recommended for winter sowing (Halila and Harrabi 1990; Singh et al. 1992). Results of on-farm trials conducted from 1989 to 1992 show that these varieties consistently produced higher yields than Amdoun 1 when sown on the same date, especially during years when ascochyta blight appeared in epidemic form (Table 3.3.2). Chetoui is suitable for mechanical harvesting (Halila et al. 1988).

The package of practices for cultivation of winter chickpea includes recommendations on the optimum

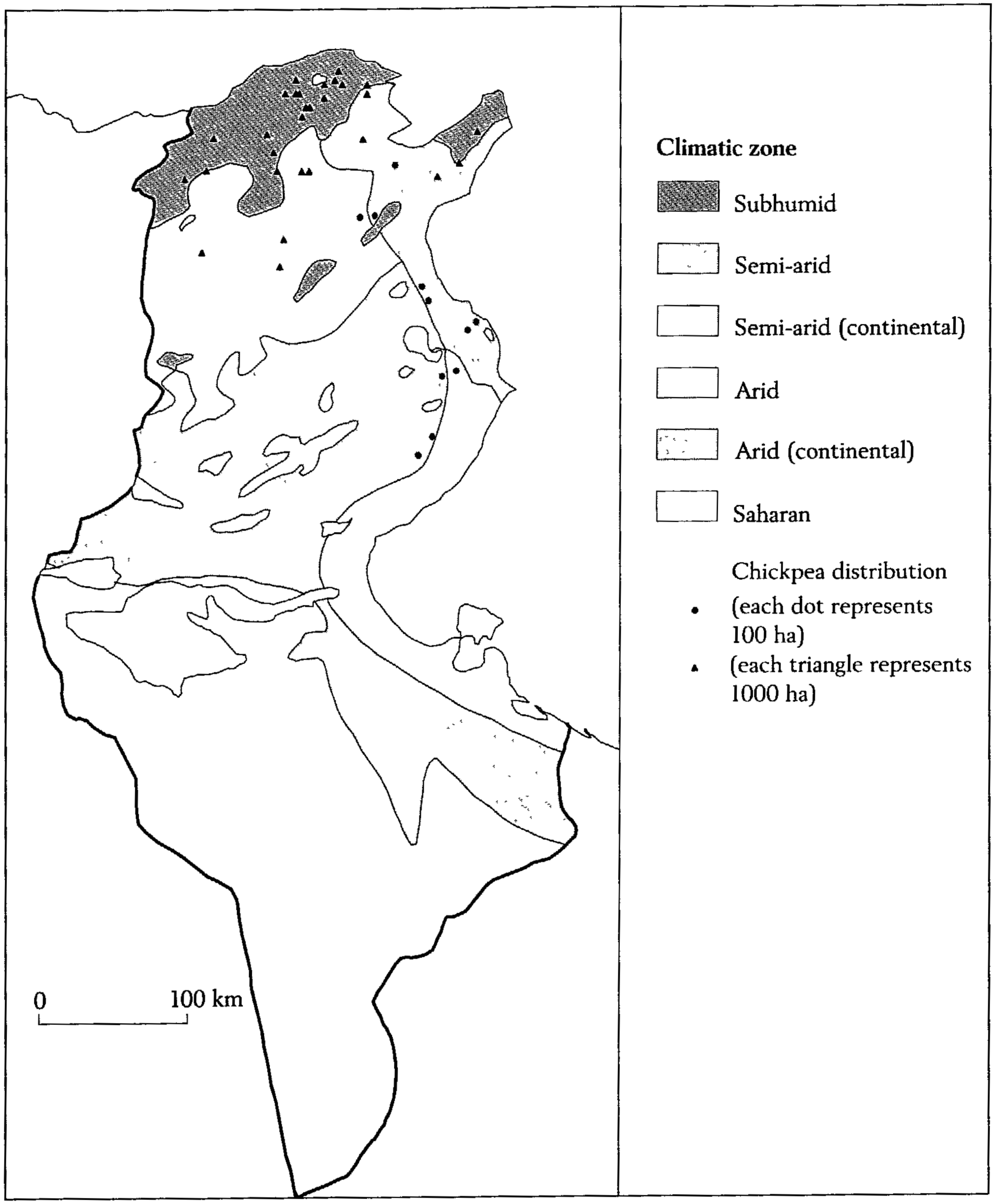


Figure 3.3.8. Climatic zones in relation to chickpea distribution in Tunisia.

sowing date, plant population, and method of weed control. The use of this package has resulted in yield increases ranging from 40 to more than 100% (Table 3.3.3). However, the package needs to be popularized among farmers.

Table 3.3.3. Comparison of a recommended agronomic package with farmers' practice using local varieties (average of Bizerte, Beja, and Jendouba demonstration trials, 1989–91).

	Yield (t ha^{-1})		
Year	Farmers' practice	Recommended agronomic package[1]	Yield advantage over farmers' practice (%)
1988/89	0.96	1.38	42.6
1989/90	0.39	0.87	123.9
1990/91	0.84	1.31	55.8
Mean	0.73	1.19	62.0[2]

1. Optimum date of sowing, plant population, and weed control.
2. Mean of means.

In spite of the advantages of winter chickpea, the adoption rate is slow because farmers are not yet fully aware of the benefits of this technology. The major constraint to the adoption of winter varieties at present is the size of the seeds which are at least 25 to 30% smaller than the local varieties. Seed size is an important quality trait that is linked to the price of chickpea in Tunisia (Scheriebier 1979). Smaller seed would be acceptable only for industrial uses such as in coffee blends and cakes.

A 3-year study (1989–91) of yields in on-farm trials conducted by the Office des céréales at four sites (Beja,

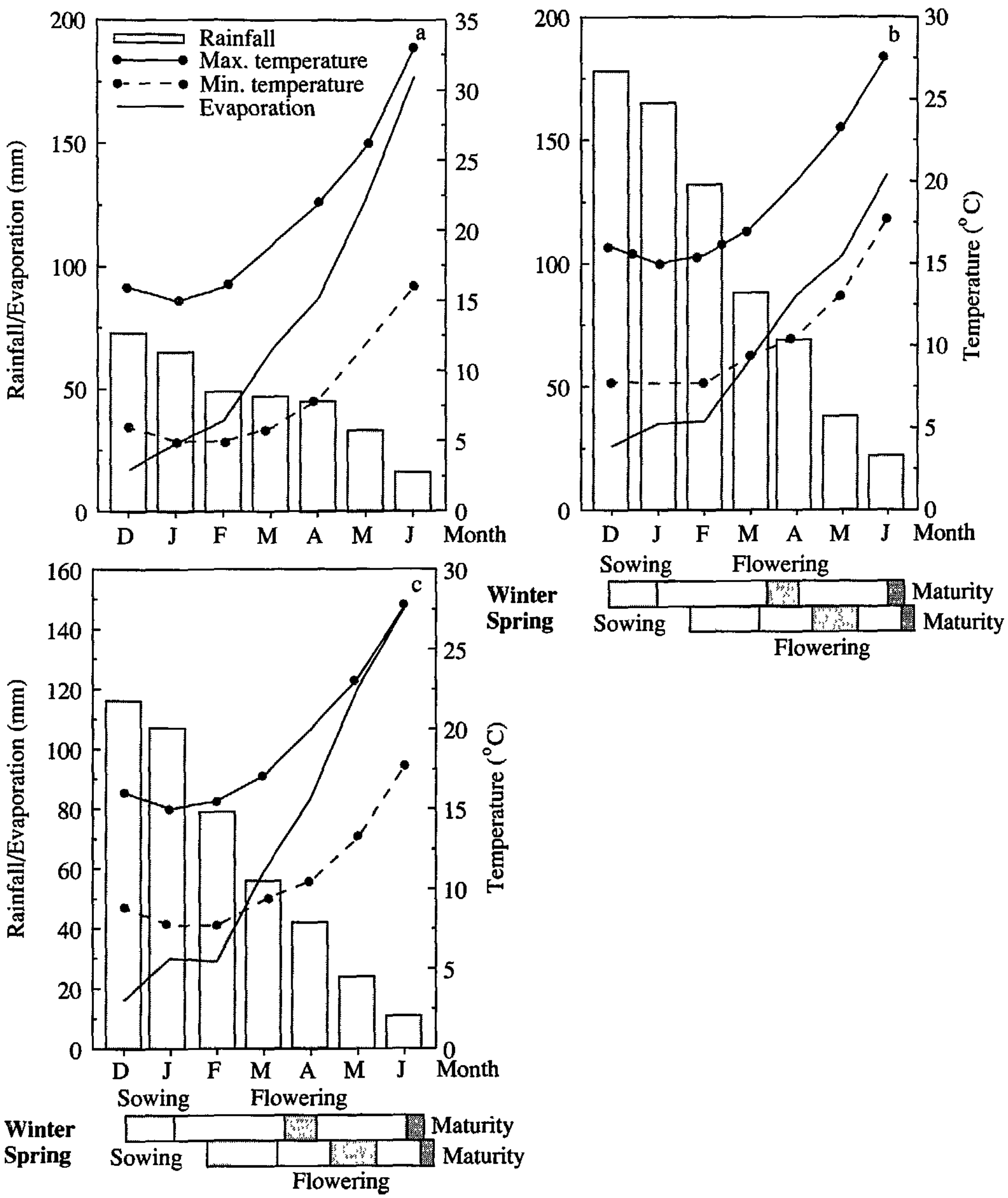


Figure 3.3.9. Crop phenology of spring- and winter-sown chickpea in relation to climatic conditions in three governorates of Tunisia: (a) Jendouba; (b) Tabarka; and (c) Bizerte, 1931–60.

Mateur, Fritissa, and Kef), showed that among the four cultivars studied—Amdoun 1, Kassab, Chetoui, and F84-92C—F84-92C seemed to be the most stable (A Zaghdoudi 1992, unpublished MS thesis). Chetoui came next, followed by Kassab and Amdoun 1. This study showed that Amdoun 1 was better adapted to favorable conditions and Kassab to unfavorable conditions.

Production Constraints

Abiotic Constraints

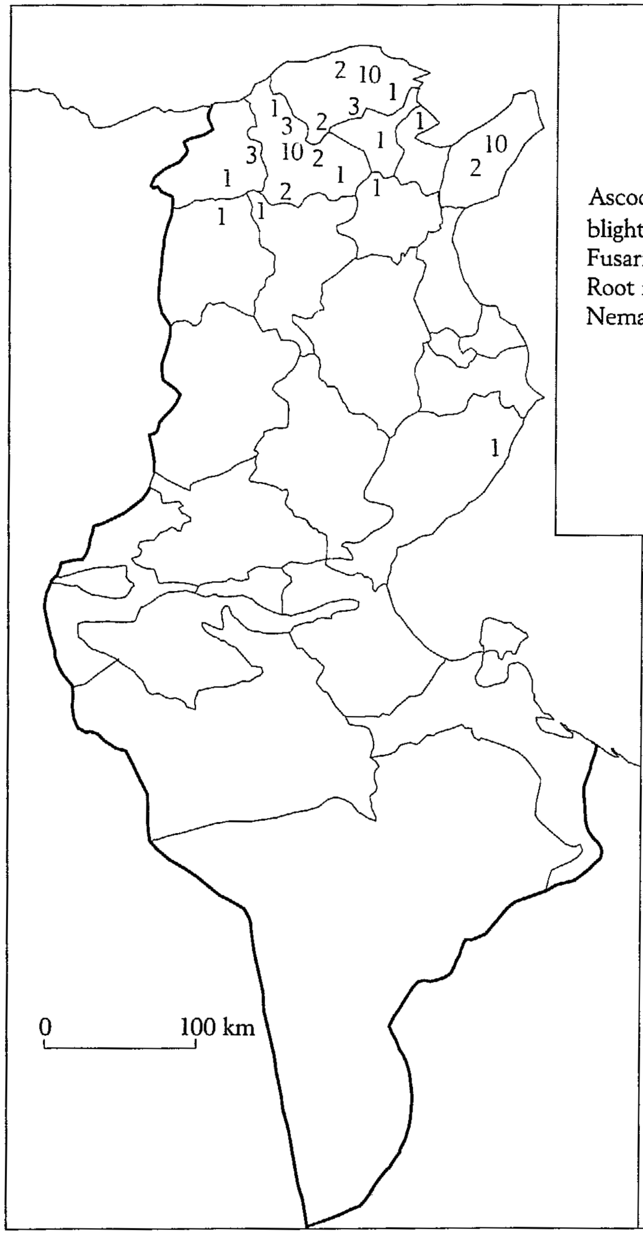
Spring-sown chickpea often suffers from terminal drought associated with heat stress during May and Jun. Traditional chickpea-growing areas are not prone to severe frost. Salinity is not a problem for chickpea in Tunisia, except in rare situations where chickpea is grown in lowland areas.

Biotic Constraints

Diseases

The wilt-root rot complex is found mainly in the south of Bizerte (Mateur) and north of Beja (Sidi Nasir) governorates. These diseases have also been found recently in Nabeul and south of Beja (Fig. 3.3.10).

Severe incidence of dry root rot (*Rhizoctonia bataticola*) was observed in 1992 in Bizerte governorate. In 1992, wilt incidence varied between 20 and 100% and that of root rot from 0 to 50% in different chickpea areas.



	Severe	Moderate	Low
Ascochyta blight	1	1	1
Fusarium wilt	2	2	2
Root rot	3	3	3
Nematodes	-	-	10

Figure 3.3.10. Disease incidence on chickpea in Tunisia.

Ascochyta blight (*Ascochyta rabiei*) is spread across the food legume belt in northern Tunisia. Disease incidence ranges from very low to 100%. In 1992, a high incidence of the disease was noticed in Sfax governorate on early sowings of chickpea. This governorate is a non-traditional chickpea-growing area.

Insect pests

Insects pests on chickpea in Tunisia are mainly leafminer and sometimes pod borer, *Helicoverpa armigera*. Incidence is variable but never serious. Leafminer occurs mainly in Bizerte and Beja governorates (Fig. 3.3.11).

Future Prospects

Potential new areas for expanding chickpea cultivation are mainly in "secondary zones", which could become important chickpea areas, especially with the introduction of early sowing techniques (Fig. 3.3.12).

Although, chickpea in Tunisia is traditionally grown as a spring crop, results of research, on-farm trials, and demonstrations have shown good prospects for winter chickpea in the country. In certain areas, farmers have already adopted winter chickpea. Research is now directed towards improving the seed size in disease-resistant varieties, and farmers' acceptance of these new varieties.

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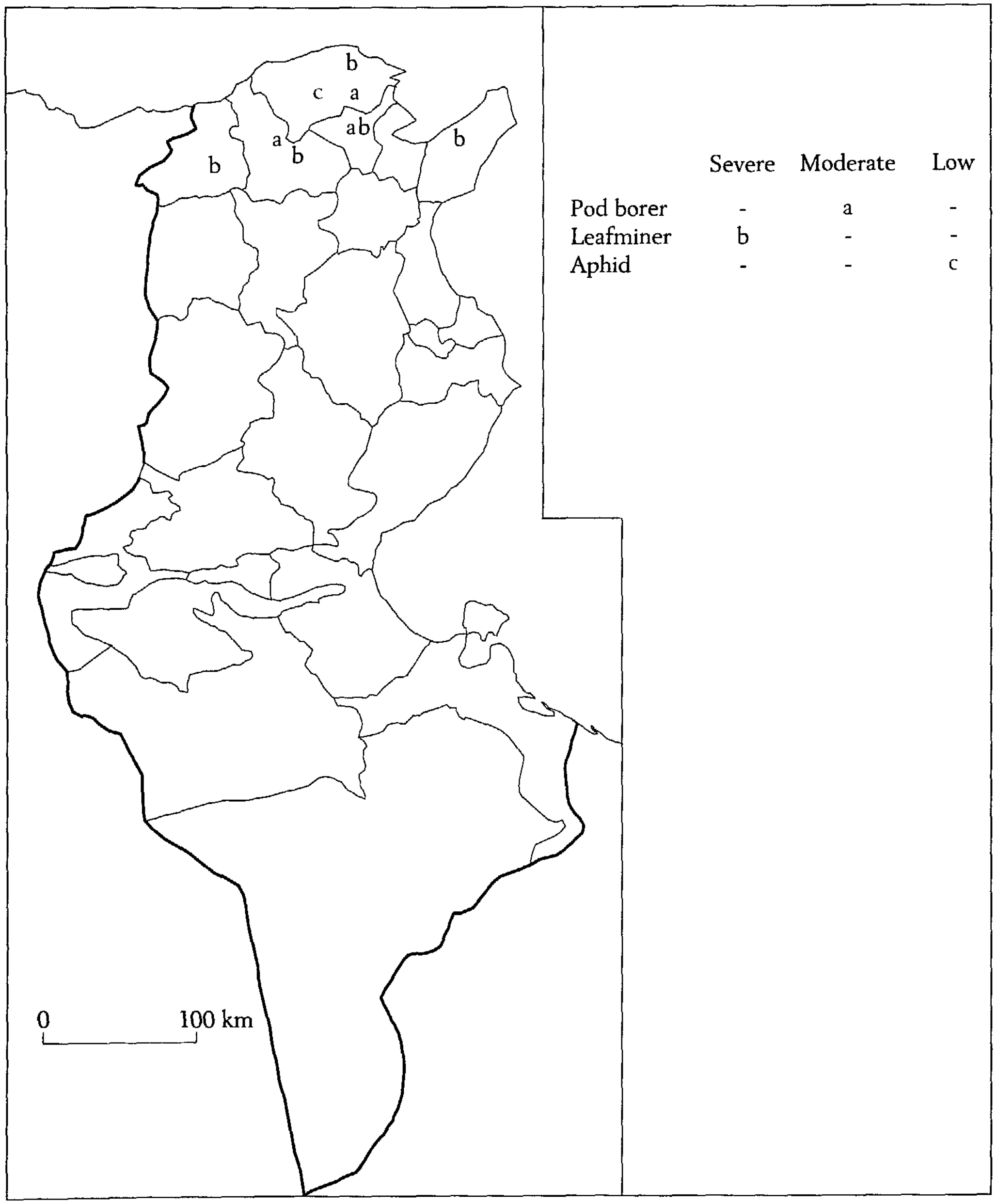

Figure 3.3.11. Insect pest incidence on chickpea in Tunisia.

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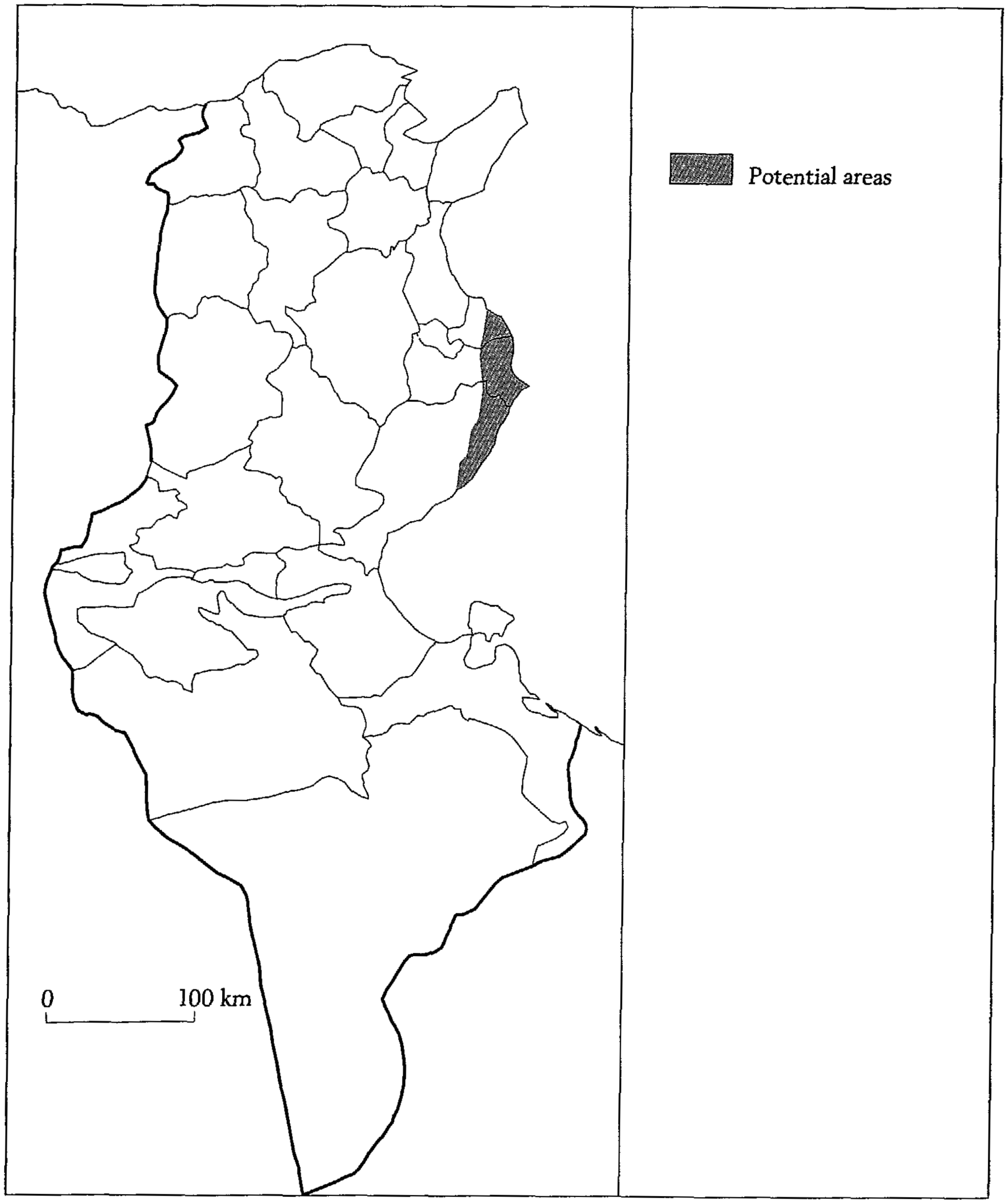

Figure 3.3.12. Potential chickpea areas in Tunisia.

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3.4. Regional Summary: North Africa

D McDonald[1] and A Kamel[2]

Algeria, Morocco, and Tunisia, the three important chickpea-growing countries of North Africa, are located between 21 and 40° N. They have a total chickpea-growing area of around 0.2 million ha, representing 14.9% of the WANA and 1.9% of the world chickpea area. Chickpea is the second most important legume crop after faba bean in Algeria and Morocco, and in Tunisia it is as important as faba bean. There is significant international trade in chickpea in the region. Algeria imports around 30% of its requirement, while Morocco exports variable quantities, depending upon production, local demand, and export prices. A sharp drop in crop area coincided with a policy decision on privatization of land in Algeria, but the area under chickpea has started to increase again over the last 2–3 years. In Morocco and Tunisia, the area sown to the crop has fluctuated widely.

Chickpea is primarily a spring-sown crop in the region, fitting into various cropping sequences. Average yields of spring-sown chickpea in Morocco can be very high (about 1.5 t ha^{-1}). The benefits of winter sowing have been convincingly demonstrated, and the technology is gradually being adopted by farmers. This process can be accelerated by increased extension efforts.

Drought effects are accentuated by high temperatures in spring-sown chickpea in Algeria. Low temperature is mainly a constraint to the winter-sown crop, and is particularly important in the high plateau areas.

In the maps relating to diseases and pests, the data available across the countries are not uniform and consistent. Some areas have been very well surveyed and others have not. As most of the data on diseases and insect pests have been collected over a relatively short period of time, they are more qualitative than quantitative. More work is needed to gather sufficient records so that reliable average figures for incidence and severity of biotic stress, and even more so for yield losses, can be obtained and mapped. In all the three countries, disease surveys have been initiated about 4–5 years ago. Continued surveys will confer greater reliability on the information on disease and pest occurrence, severity of attacks, and crop losses due to biotic stresses.

Although most of the maps prepared were adequate for the preparation of this book, there is much scope for improvement by supplementing and validating the data, as most of these are dynamic and variable. There is a need to encourage recording of occurrence and severity of both biotic and abiotic stresses, and where feasible, these should be linked to evaluate economic losses, both in yield and quality. Such information should also be made available in suitable format for entry into the Geographic Information System (GIS), which by its very nature is a dynamic tool and well-suited to handling information that keeps changing; updates can be easily made at frequent intervals. Organization of regional and in-country training workshops on survey and crop loss assessment methodologies, preparation of instruction manuals, and development of uniform minimum data sets would facilitate the mapping of biotic stresses of chickpea cultivation.

For some highly variable pathogens, there is a need to record the occurrence of different races. Good work has already been done in Algeria, Morocco, and Tunisia in monitoring chickpea crops for the occurrence and incidence of ascochyta races. Similar data on other highly variable pathogens should be collected on a regional basis. Uniform disease nurseries by incorporating differential series, should be organized wherever possible. Genes and gene combinations associated with resistance to diseases should be reported and documented.

It is hoped that good use of the crop adaptation data will be made by those concerned with preparation of research plans and project

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2. North Africa Regional Program, PO Box 84, Ariana 2049, Tunis, Tunisia.

proposals. These will be greatly strengthened by including the types of maps developed in this book.

This exercise on the adaptation of chickpeas in the WANA region has prepared the way for similar work on other crops and it should be a relatively simple matter to extend the adaptation studies to other legumes and possibly to cereal crops. At some stage, it should be possible to utilize the data from the study of component crops to evaluate the sustainability and stability of specific farming systems and better understand how the systems will react to environmental changes.

The data collected should be used to indicate areas in the region that have environments favorable for the establishment and spread of new pests and diseases. This would alert quarantine authorities and prevent them from accepting consignments of infected plant materials. Such information would help to determine the type of diseases and pests to be looked for in future surveys.

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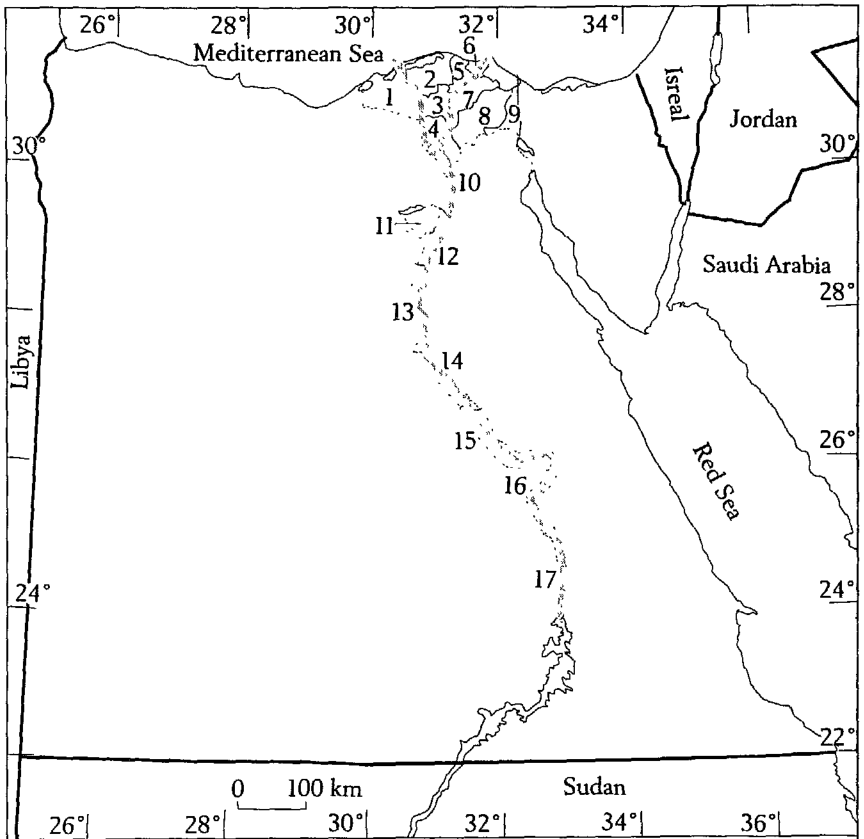
4. Country Case Studies—Nile Valley



1. Beheira
2. Kafr El-Sheikh
3. Gharbia
4. Menufia
5. Dakhalia
6. Domietta
7. Mansura
8. Sharkia
9. Ismailia
10. Gaza
11. Fayoum
12. Beni-Suef
13. Minia
14. Assuit
15. Sohag
16. Qena
17. Aswan

Figure 4.1.1. Administrative boundaries of Egypt.

4.1. Chickpea in Egypt

A M Khattab[1] and M H El-Sherbeeny[1]

Latitude	22–32° N
Longitude	26–34° E
Altitude	0–2637 m
Total population	56.1 million
Economically active	15.7 million
Economically active in agriculture	6.1 million
Total area	100.1 million ha
Cultivated area	2.6 million ha
Rainfed area	Insignificant
Annual rainfall	0–175 mm
Chickpea rank among legumes	Second
Crop season	Winter

Introduction

Cropping in Egypt relies almost exclusively on irrigation, with water drawn from the Nile river. Chickpea (*Cicer arietinum*) is cultivated on around 10 000 ha annually and is the second most important food legume crop after faba bean (*Vicia faba*). The high selling price of around 2400 Egyptian pounds per t of chickpea (1 US$ = 2.6 Egyptian pounds) in recent years makes it a highly profitable crop (Khattab 1990). Production is sufficient to meet the current domestic demand and in some years a surplus is exported to countries in the region. The highest record of chickpea export has been 5000 t per year. The administrative divisions of Egypt are shown in Figure 4.1.1 and chickpea distribution in Figure 4.1.2.

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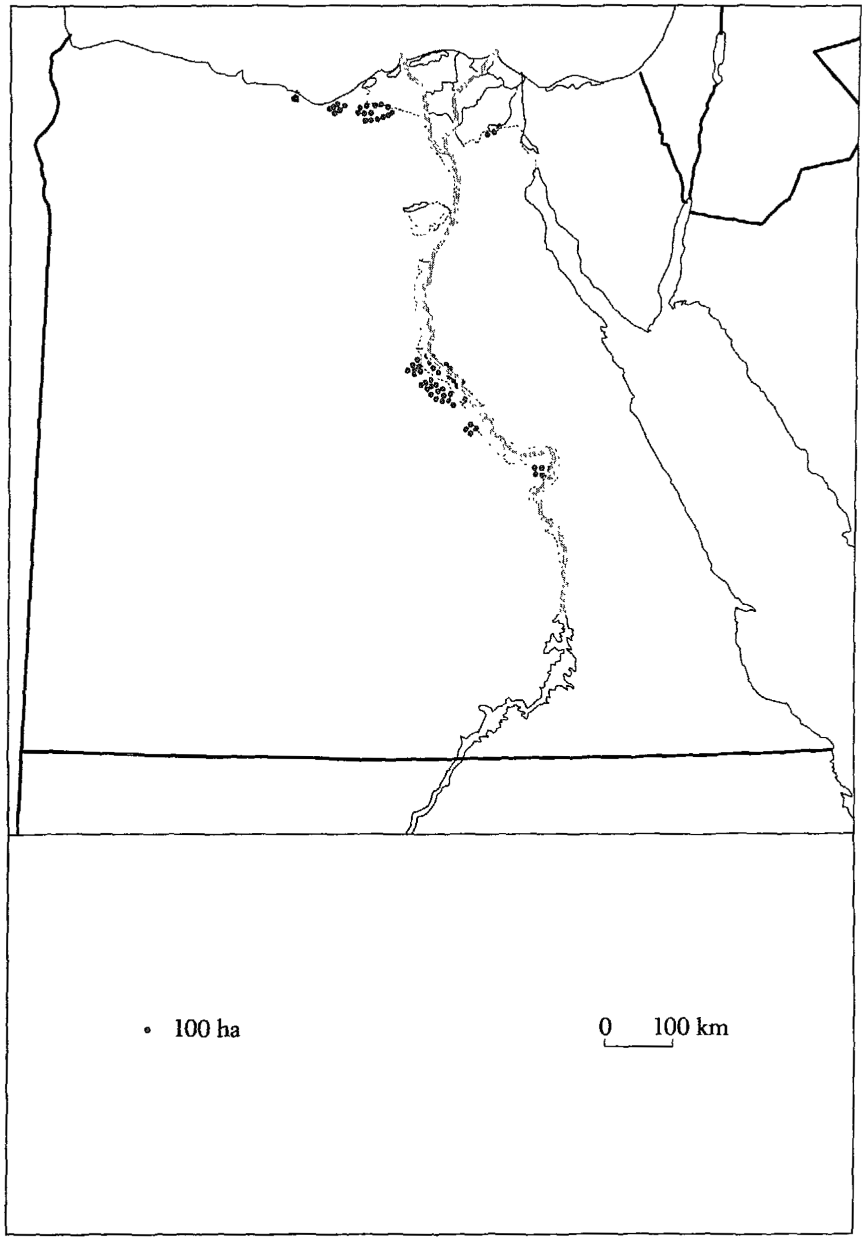


Figure 4.1.2. Chickpea distribution in Egypt.

Uses

Chickpea is prepared and consumed in several ways in Egypt, ranging from nutritious baby food to popular snacks. Its green seeds are used as vegetable (*malianeh*); *awwsa* is a traditional preparation where chickpea is boiled in water with salt, and mixed with chillies, and garlic paste. In *hommos moughar*, wet seeds are treated with lime to remove the seed coat. A wide range of sweets, such as sugar-coated roasted chickpea, are also prepared.

Area, Production, and Productivity

The area under chickpea in Egypt accounts for only 0.1% of the world chickpea area (FAO 1991), but the average yield of the crop is one of the highest in the world (1.76 t ha^{-1}). The average chickpea area between 1987 and 1991 was over 9000 ha (Table 4.1.1 and Fig. 4.1.3).

Table 4.1.1. Important chickpea-producing regions in Egypt (mean of 1987–91).

Region	Area (ha)	Production (t)	Yield (t ha^{-1})
North Delta			
New area in the Northwestern Coast and near Alexandria	600 (6.4)[1]	500	0.83
Beheira	1962 (20.9)	3022	1.88
Sharkia and Ismailia	203 (2.2)	284	1.40
Upper Egypt			
Assuit	5880 (62.7)	6700	1.14
Sohag	400 (4.3)	820	2.05
Qena	336 (3.6)	632	1.88

1. Percentage of the total chickpea-producing area in Egypt.

Source: Department of Agricultural Statistics, Ministry of Agriculture, Cairo, Egypt.

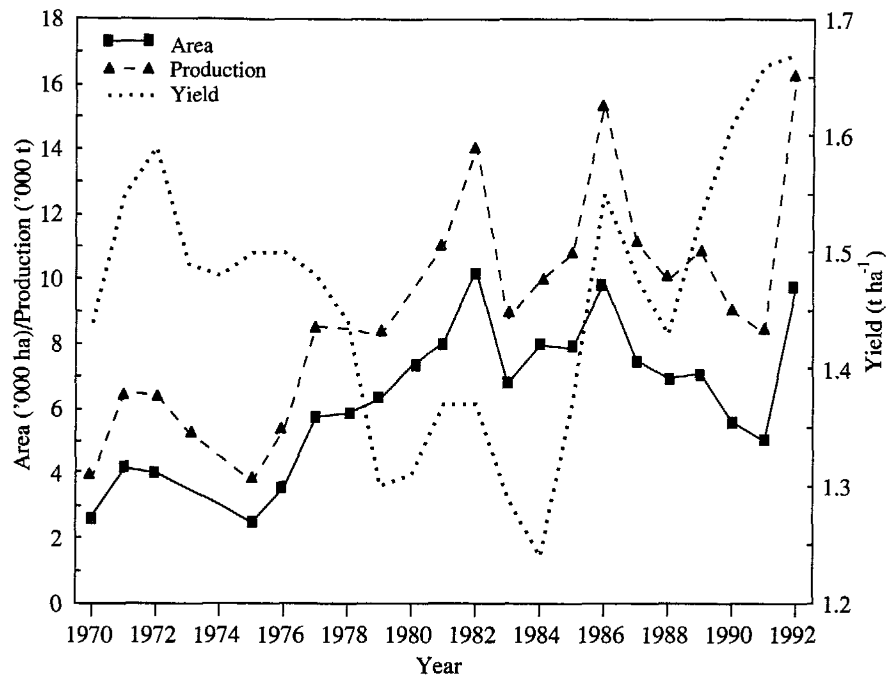


Figure 4.1.3. Trends in chickpea area, production, and yield in Egypt, 1970–92.

The important chickpea-growing areas in Egypt are listed in Table 4.1.1. Most of the chickpea is grown in the governorates of Assuit (62.7%) in the south, Beheira (20.9%) in the north, and a little in Sohag (4.4%). While Assuit, Sohag, and Qena governorates are the traditional chickpea-growing areas, Alexandria, Beheira, Sharkia, and Ismailia governorates are new production areas. Chickpea cultivation has gradually shifted towards the north of the country where average yields are around 1.3 t ha^{-1}.

The high-yielding varieties that have been recently introduced on newly reclaimed land in Bostan district (Beheira and Yahreir regions) and in the beet-growing area near Alexandria have made the crop highly competitive and profitable. Demand has further increased due to the relatively low inputs of irrigation and fertilizers required by the crop, the high price it fetches, and its high yield potential on sandy and calcareous soils.

The average yield of chickpea is high in the governorates of Sohag (2.05 t ha^{-1}), and Beheira and Qena (1.88 t ha^{-1}). The low yield (less than 1 t ha^{-1}) recorded in the Northwestern Coastal region and around Alexandria (Table 4.1.1) is most probably due to the cultivation of chickpea on newly reclaimed areas with calcareous soils (up to 39% $CaCO_3$) and under rainfed conditions. Chickpea yields are higher in other parts of the country where it is grown under irrigated conditions.

Climate, Soil, and Crop Distribution

A detailed physiographic description of Egypt is given by Al Sayyad (1976). Traditionally, three climatic regions are recognized in Egypt: North Delta, Middle Egypt, and Upper Egypt (Fig. 4.1.4).

North Delta

The North Delta region covers areas north of latitude 30°20' N to the Mediterranean sea. Winter is mild in this region and the average temperature ranges from 9 to 20°C. Winter rainfall ranges from 60 mm in the east to 150 mm in the west in the coastal area (Fig. 4.1.5). An exceptionally high rainfall of 250 mm was received during the 1991 chickpea-growing season, and no supplemental irrigation was required for chickpea that year. Soils on which chickpea is cultivated are sandy loam and high in calcium carbonate. The dominant soil types in the chickpea-growing areas of this region are Aridisols and Calciorthids (Fig. 4.1.6).

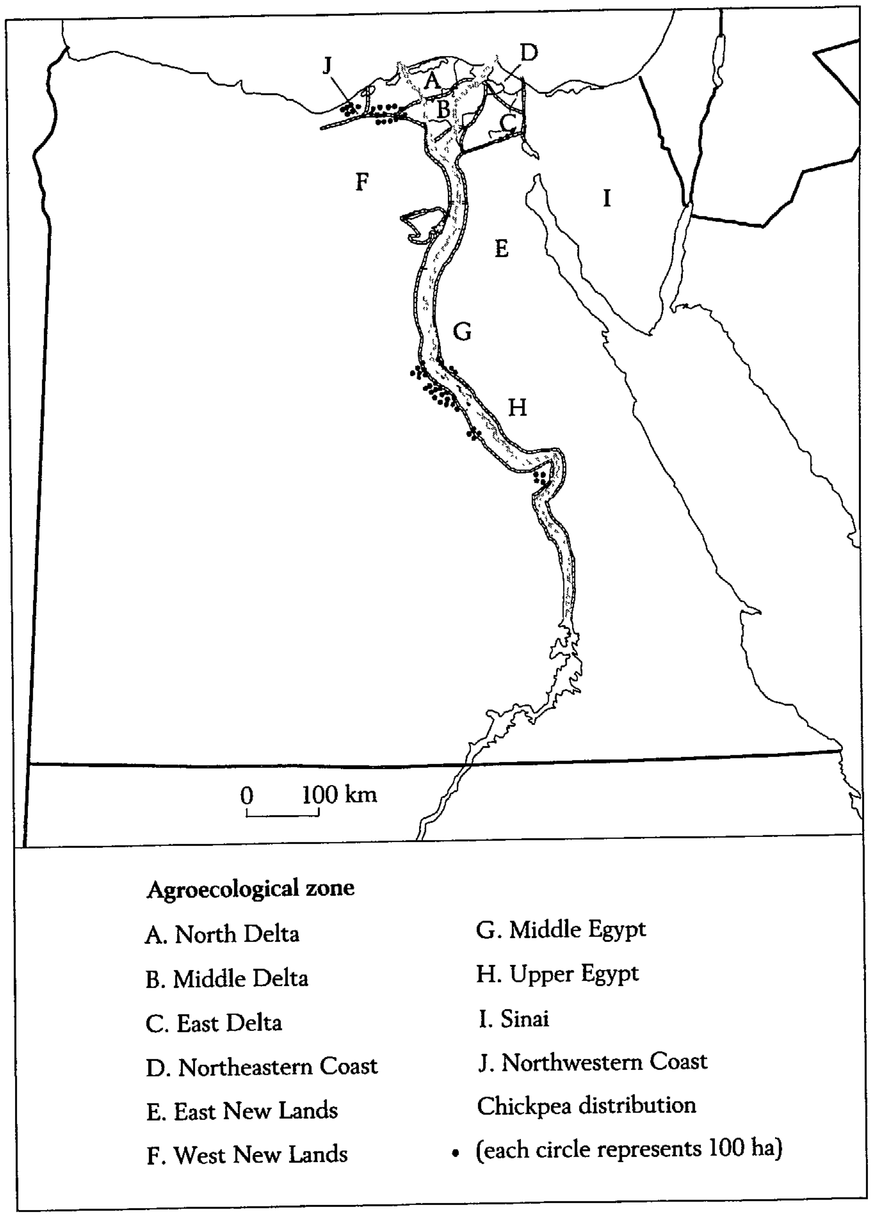


Figure 4.1.4. Agroecological zones in relation to chickpea distribution in Egypt.

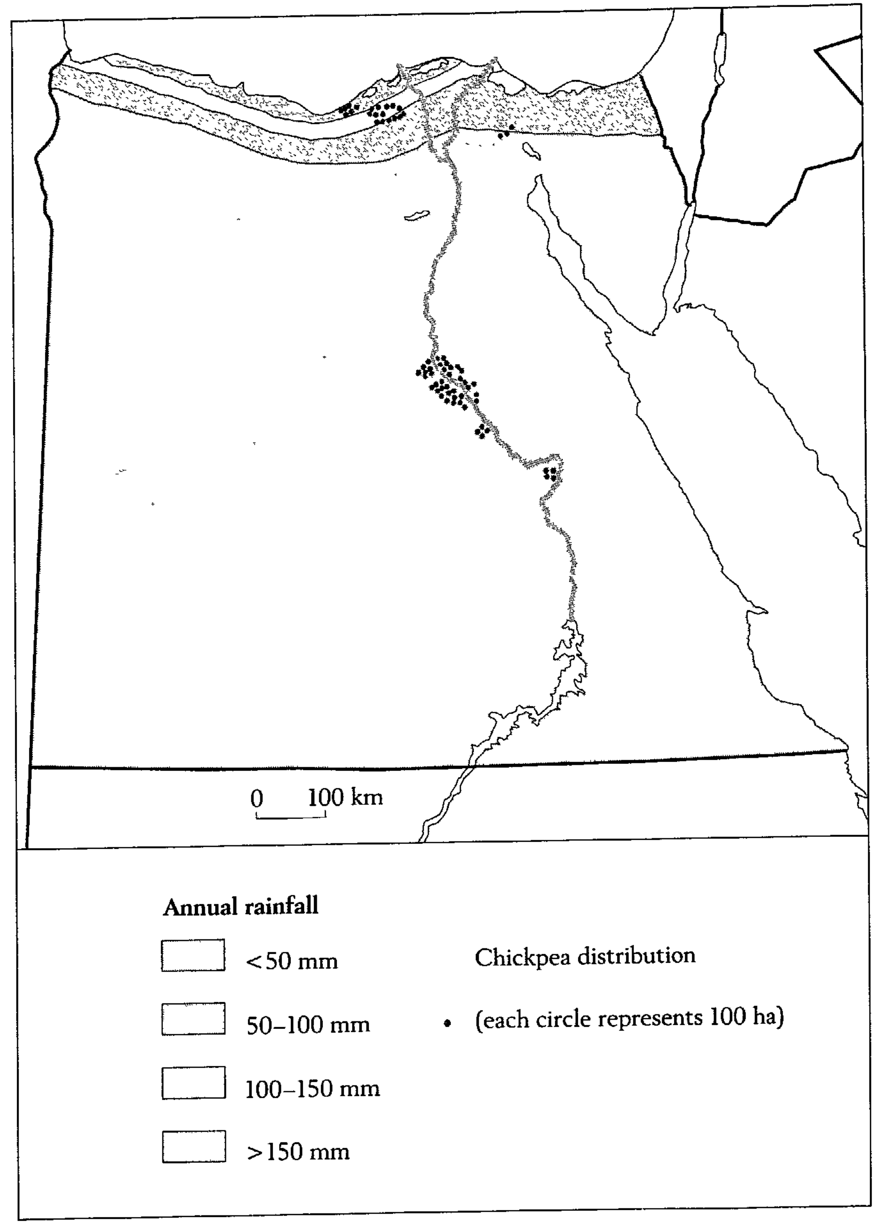


Figure 4.1.5. Mean annual rainfall in relation to chickpea distribution in Egypt.

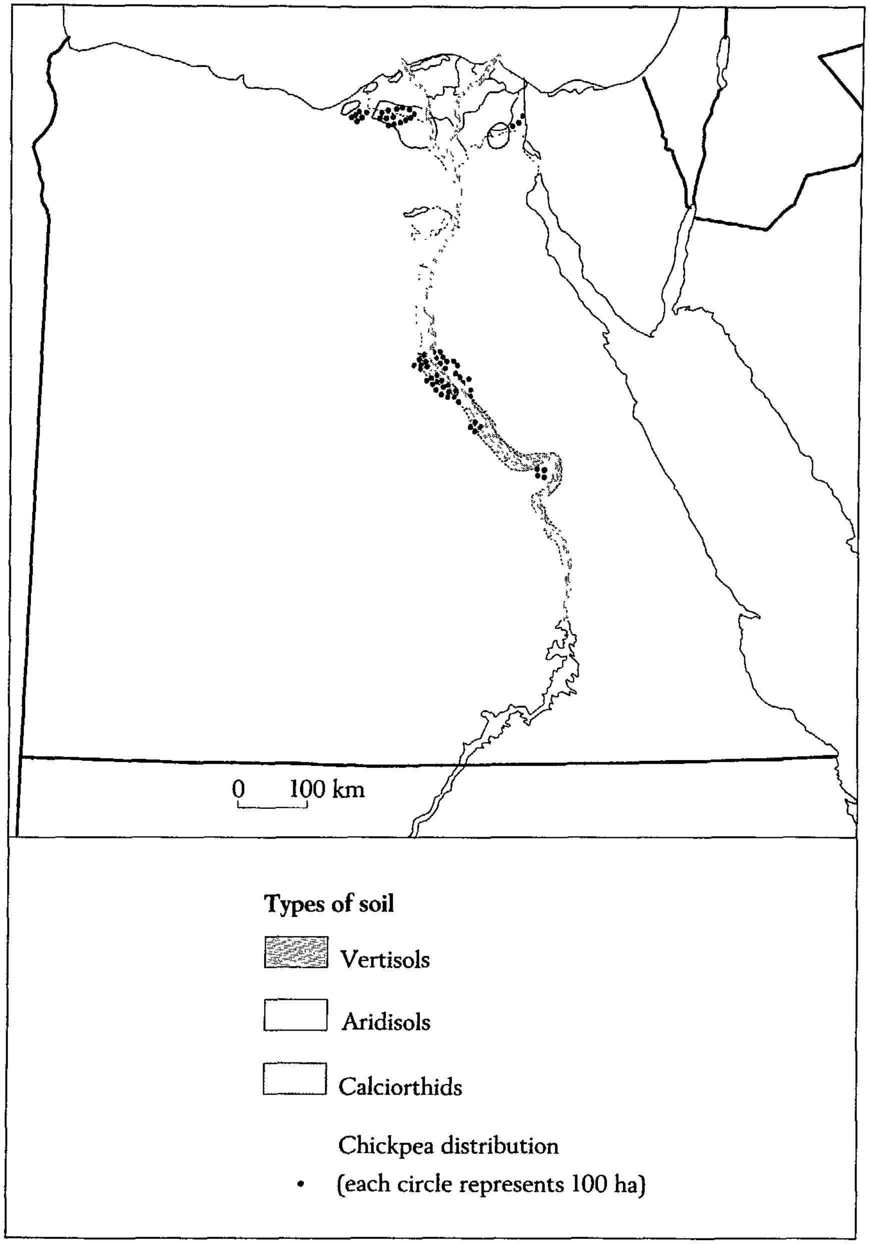


Figure 4.1.6. Soil types in relation to chickpea distribution in Egypt.

Middle Egypt

The Middle Egypt region includes all the area between 28° and 30° 20' N latitudes. Although chickpea is grown here to some extent, Middle Egypt is currently not an important chickpea-growing region. However, there is considerable scope for expanding the crop in this region, especially on the newly reclaimed land in the Minia, Beni-Suef, Fayoum, and Giza governorates.

Upper Egypt

Upper Egypt includes the area south of 28° N latitude. The climatic characteristics of the region are a high mean maximum annual temperature (33°C), a large difference in diurnal temperatures between winter (22°/7°C in Jan) and summer (40°/23°C in Jul), a moderate to low atmospheric humidity (51% in Jan to 21% in May), and very low annual rainfall (<50 mm). Chickpea is grown on noncalcareous Vertisols with 35% clay content (Fig. 4.1.6) (Hamdi et al. 1973).

Cropping Systems

In Egypt, chickpea is grown in winter during Nov to Apr. It is traditionally sown on clayey soils in Upper Egypt after a heavy irrigation. When produced for seed, it is sown from Oct to mid-Nov and harvested in spring or early summer (Nassib et al. 1990). Climatic conditions during the crop-growing season in some important chickpea areas in Egypt are shown in Figure 4.1.7. In the North Delta region, summer crops that are grown in rotation after chickpea are water melon, cantaloupe, sesame, and vegetables, whereas in the Upper Egypt region sorghum, sesame, and medicinal plants follow chickpea.

Early-sown (Oct) chickpea is mainly used as a vegetable (*malianeh*). Giza 88, the variety that is commonly grown for this purpose

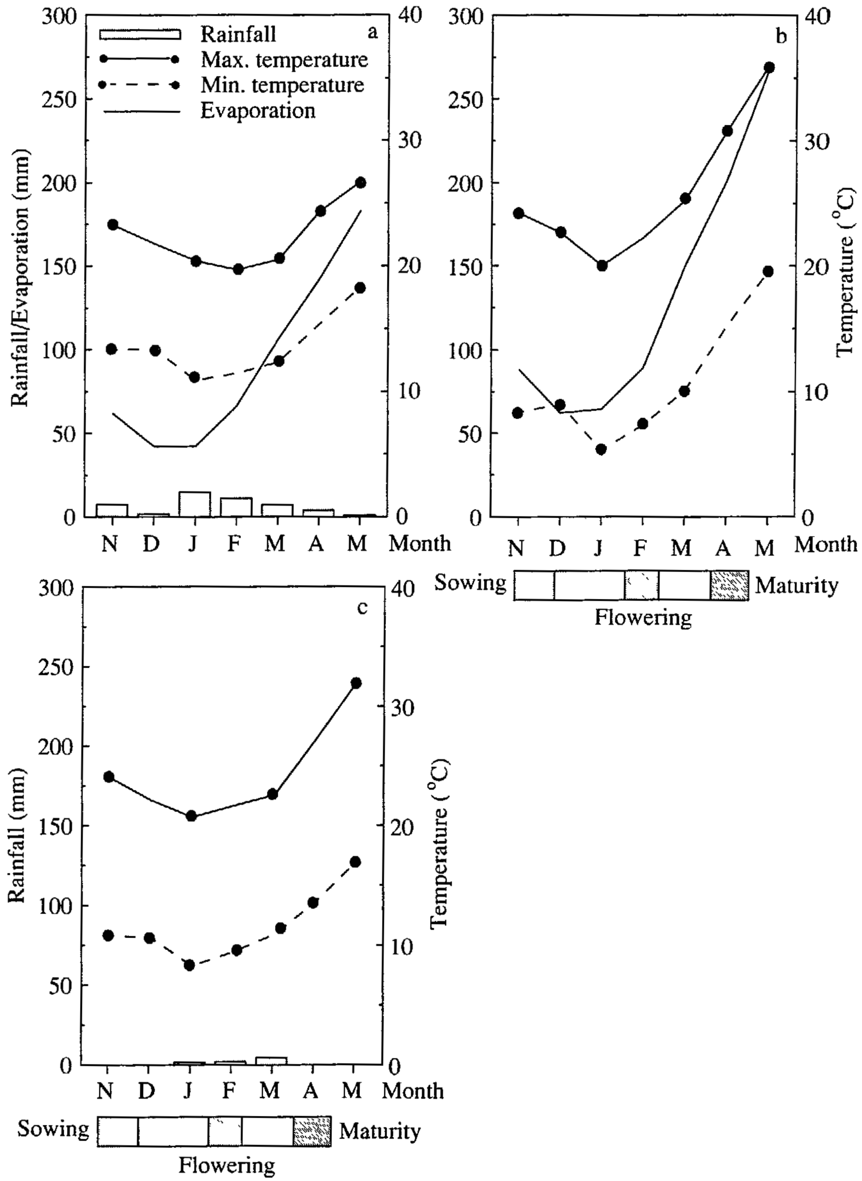


Figure 4.1.7. Crop phenology of winter-sown chickpea in relation to climatic conditions in Egypt: (a) Behiera (North Delta); (b) Assuit (Upper Egypt); and (c) Ismailia (East Delta), 1987–91.

has 15% higher productivity than local cultivars. Green chickpea arrives in the market around the time of Easter, when the demand for it is high.

Research

The development of high-yielding kabuli-type chickpea with stable resistance to soilborne diseases (root rot and wilt complex), and the seed multiplication of such varieties, are given a high priority in national research and development programs in Egypt. Giza 88, an improved chickpea variety, was released in 1987 (Khattab 1987). Among the promising genotypes that are being tested, Giza 195 (ILC 195 from ICARDA) and Giza 531 (landrace no. 55) are likely to be released shortly. The performance of some promising genotypes in multilocational trials is given in Table 4.1.2.

Table 4.1.2. Performance of promising chickpea genotypes in multilocational trials, Egypt, 1988–91.

Genotype	Yield ($t\ ha^{-1}$)	Number of test sites	Increase over control (%)
Giza 1	1.80	10	-
Giza 88	2.10	10	16.7
Giza 531	2.10	12	16.7
Giza 195	2.12	8	17.8
FLIP 80/14	1.96	12	8.9
Line 70	2.00	12	11.1

Production Constraints

The major constraints to chickpea production, in order of importance, are: root rots (*Rhizoctonia* spp), wilt (*Fusarium oxysporum*), aphids (*Aphis craccivora*), virus diseases, low plant stands, weeds, bruchids

(*Callosobruchus* spp), salinity, stem rot (*Sclerotinia sclerotiorum*), drought, ascochyta blight (*Ascochyta rabiei*), cold and frost, leafminers (*Liriomyza cicerina*), and heat.

Abiotic Constraints

Poor plant stand is the most important abiotic constraint to chickpea production in Egypt. Some of the major reasons for poor stands are poor seed germination and emergence due to non adoption of large-seeded types recommended for heavy clay soil, broadcast method of sowing, incidence of pre- and postemergence damping-off diseases, and salinity. Substantial increases in yield can be expected by sowing the crop in paired rows on ridges with 60-cm interrow and 10-cm intrarow spacing.

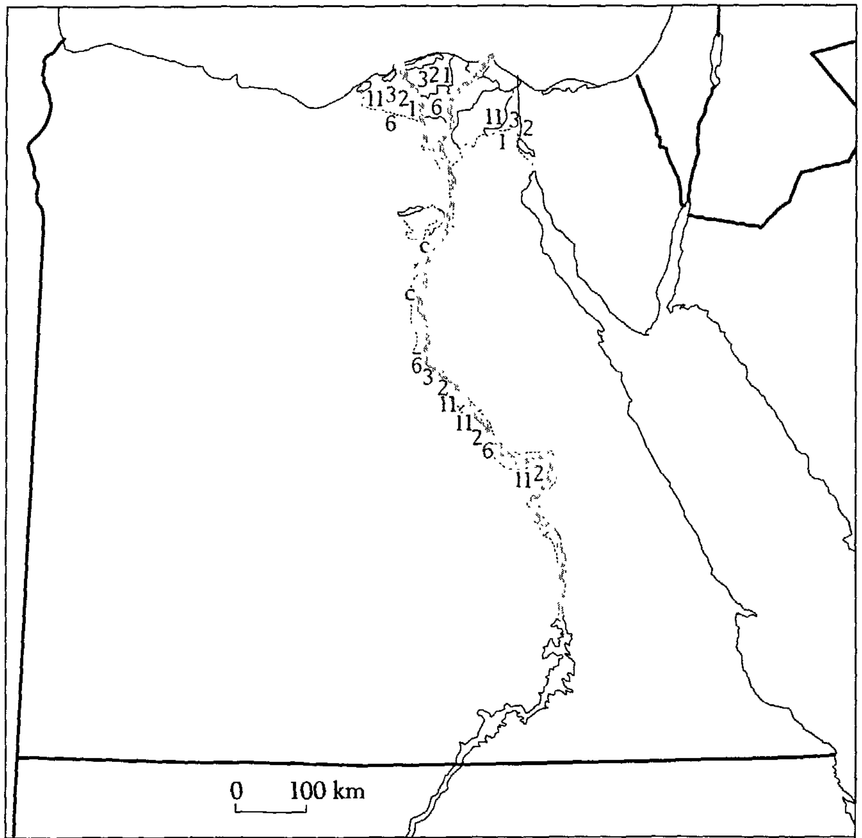
Cold and frost are occasional constraints in the Assuit and Sohag governorates, and in the North Delta region. Drought is a problem on the northwestern coast and in Sinai. It adversely affects chickpea yields in some years.

Salinity is common in some areas of the Delta region and is increasingly becoming a problem in the newly reclaimed areas near Nubaria and Fayoum. To overcome this problem, farmers tend to avoid growing chickpea in saline fields.

Biotic Constraints

Diseases

Root rots, wilt, stem rot and ascochyta blight are the major diseases that cause considerable yield losses in chickpea. Among these, wet root rot (*Rhizoctonia solani*), dry root rot (*R. bataticola*), fusarium wilt, and verticillium wilt (*Verticillium* spp) are most important in



	Severe	Moderate	Low
Ascochyta blight	-	1	1
Fusarium wilt	-	2	2
Root rot	-	3	3
Stem rot	-	6	6
Necrotic yellows virus	-	11	11
Aphid	c	-	-

Figure 4.1.8. Disease and insect pest incidence on chickpea in Egypt.

Upper Egypt (20–30% incidence). All these diseases have a relatively low incidence (10–15%) in North Delta (Salem et al. 1990; Khattab and Omer 1992). The important chickpea diseases and the severity of their incidence at various locations of Egypt are shown in Figure 4.1.8.

Although sclerotinia stem rot has been reported from the Shandaweel and Malawi Research Stations in Upper Egypt and the Gimmeza Station in Middle Egypt, its incidence has been low (10%). Ascochyta blight is important in North Delta, Beheira, and the northwestern Coast. With the increasing use of sprinkler irrigation in the region, there is a danger that this disease might spread to other areas (Abdel Moneim et al. 1986; Khattab et al. 1986).

Insect pests

Seed yield losses in chickpea caused by insect pests are relatively low in Egypt. *Aphis craccivora*, an important vector of bean leaf roll virus causing chickpea stunt disease, is a serious pest. It is also a vector of the necrotic yellows virus that causes necrosis of foliage in the governorates of Beni-Suef and Minia in Middle Egypt in recent years (Fig. 4.1.8). Loss in plant stand due to this disease can reach as high as 40%.

Chickpea leafminer is not common in Egypt and no serious damage has been reported so far. *Callosobruchus* spp are the most damaging pests of stored grain.

Weeds

Early crop growth (up to 65 days after sowing) is affected by competition from weeds. Some important weeds of chickpea in Egypt are *Anagallis arvensis*, *Chenopodium* sp, *Convolvulus arvensis*, *Melilotus* sp, and *Beta vulgaris*. The average losses due to weeds are estimated at around 46% in seed yield and 16% in straw yield (Al-Marsafy et al. 1986).

Mechanical Harvesting

Chickpea is currently hand-harvested. Most of the chickpea genotypes currently grown, or those being considered for release, are erect types and are therefore suited for mechanical harvesting. Mechanized cultivation practices are being adopted by some private companies and also by some farmers who have large holdings in new cultivation areas.

Future Prospects

Chickpea is receiving great attention at present because of its ability to grow in sandy soils. A large increase in grain yield can be expected with the introduction of new varieties and adoption of improved agronomic practices. Yields obtained on experimental stations with the new varieties and improved practices are often 30–50% higher than in farmers' fields. Demonstration of high production potential of the crop on sandy and calcareous soils in the newly reclaimed areas with modern irrigation systems has opened up possibilities of expanding the chickpea area. Target areas for such expansions are in the Northwestern Coast, the beet-growing area of Bostan district, the border areas between Ismailia and Sharkia, and the region on the west of Minia and Assuit governorates (Fig. 4.1.9). Development of varieties specifically adapted to these regions and of high-yielding large-seeded kabuli varieties would provide greater opportunities for export.

Early-maturing kabuli varieties resistant to root rot-wilt complex and aphids should be developed for stabilizing yield in traditional chickpea-producing areas. The Egyptian agricultural program plans to develop varieties with yield potential of 2 t ha^{-1}, seed mass of 30 g seeds 100^{-1}, combined with resistance to wilt, root rot, and aphids.

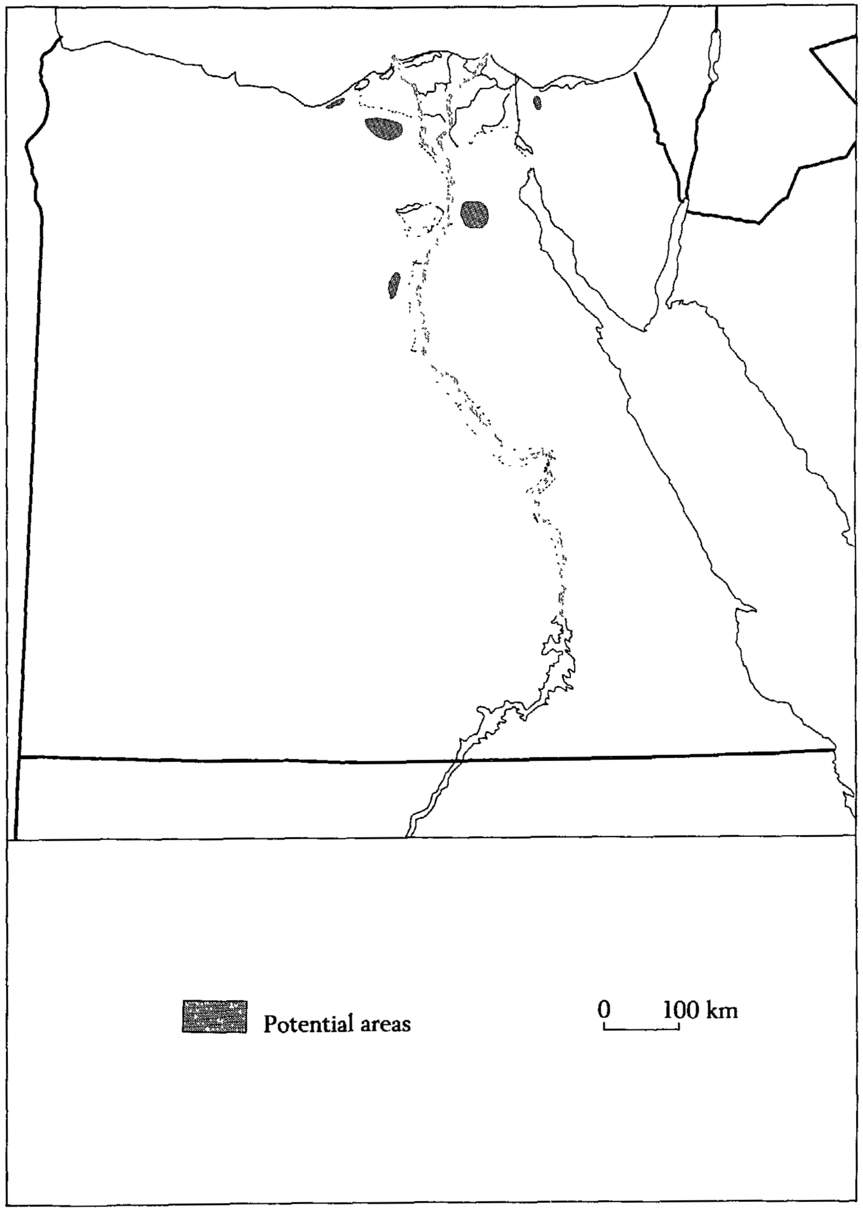


Figure 4.1.9. Potential areas for expansion and/or intensification of chickpea cultivation in Egypt.

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4.2. Chickpea in Ethiopia

G Bejiga and M Eshete[1]

Latitude	3–15° N
Longitude	33–44° E
Altitude	120–2300 m
Total population	54.6 million
Economically active	22.3 million
Economically active in agriculture	16.3 million
Total area	122.2 million ha
Cultivated area	13.2 million ha
Rainfed area	13 million ha
Annual rainfall	700–2000 mm
Chickpea rank among legumes	First
Crop season	Spring and autumn

Introduction

Ethiopia is located in the horn of Africa and lies entirely within the tropics (Bejiga 1980). Chickpea (*Cicer arietinum*) is one of the important pulse crops of Ethiopia. The administrative boundaries of the country are shown in Figure 4.2.1 and the chickpea distribution in Figure 4.2.2.

According to the Ethiopian Grain Agency (1972–77, 1978–81), about 10 000 t of chickpea per year used to be exported in the early 1970s. But exports decreased to less than 1 t around the beginning of 1980s due to a drastic reduction in chickpea production, and to higher domestic prices and demand for the crop compared with the international market.

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Uses

Chickpea is consumed in different ways in Ethiopia: green, cooked (*nifro*), roasted (*kollo*) or germinated seeds are served as snacks (Bejiga 1980; Yetnberk 1991). Split seeds (*kik*) and flour of chickpea seeds (*shiro*) are used to make *wot* (sauce) taken with *injera* (bread). Its straw is used as animal feed and stalk and roots as fuel.

Chickpea is an important component in food preparations, especially during Easter when Christians do not normally consume meat except fish. During this period, chickpea flour is used to make *shimbra asa* or "chickpea fish", which is used as a substitute for fish in places where it is not available.

Area, Production, and Productivity

Bejiga (1980) has described in detail chickpea production in Ethiopia. In the 1970s, chickpea occupied 34% of the total pulse area and accounted for 40% of the total pulse production in the country (CSA 1975). Since then, both the area and production of chickpea have declined (Hawando 1987) due to its substitution by other such high-yielding pulses as faba bean (*Vicia faba*), or by cereals.

In the 1980s, chickpea area fluctuated between 130 000 and 180 000 ha (Fig. 4.2.3), but since 1987, the area and production of the crop have stabilized. Chickpea-growing regions in Ethiopia are shown in Figure 4.2.4.

According to surveys conducted in the early 1980s by the Ministry of Agriculture (1984), the total chickpea area was around 158 000 ha and production 116 000 t with an overall average yield of 0.6 t ha^{-1}. Shewa is the most important chickpea-growing province followed by Gonder, Gojam, Tigre, and Welo (Table 4.2.1 and Fig. 4.2.2). In the other provinces, there is only a small area under chickpea.

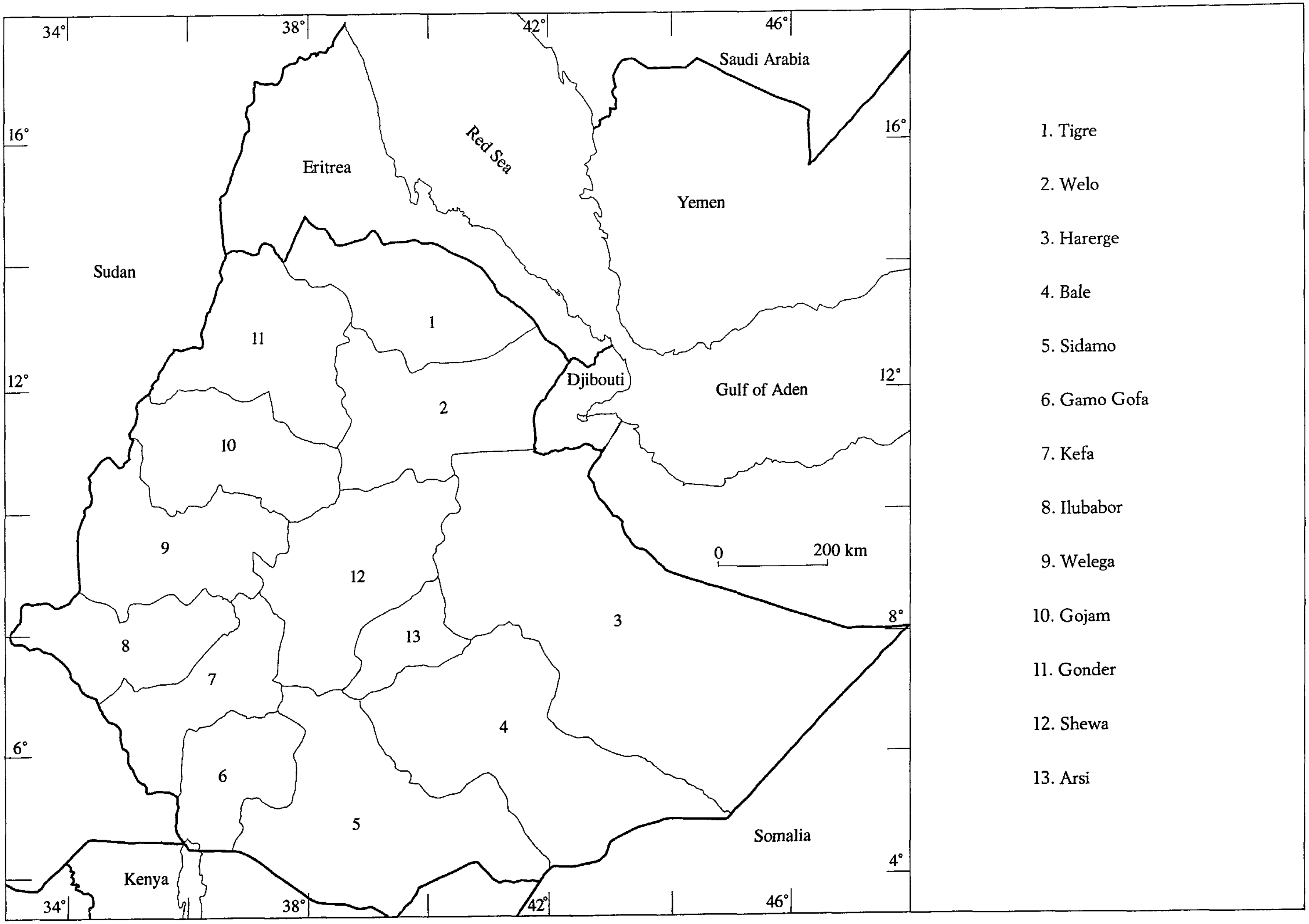

Figure 4.2.1. Administrative boundaries of Ethiopia.

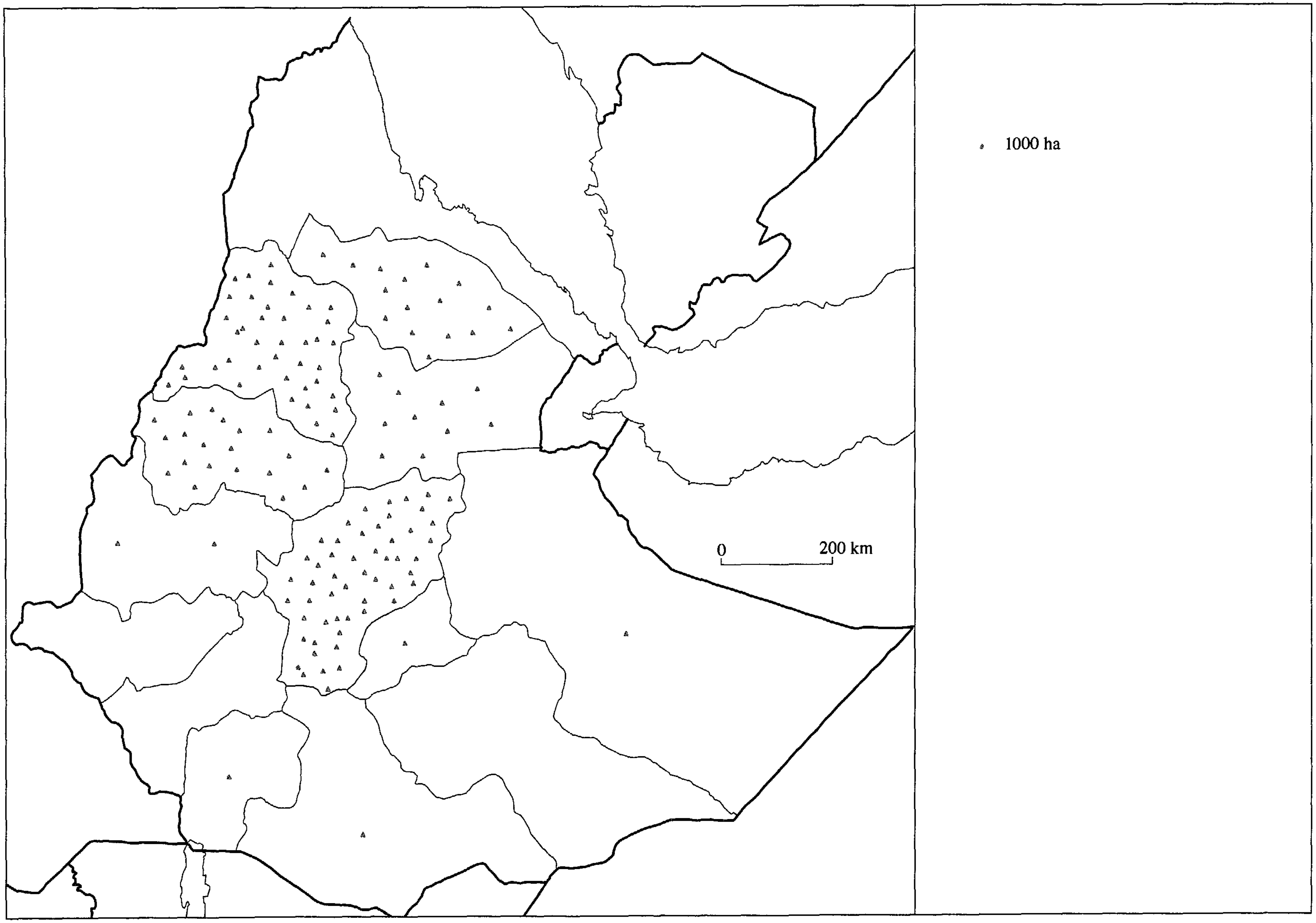

Figure 4.2.2. Chickpea distribution in Ethiopia.

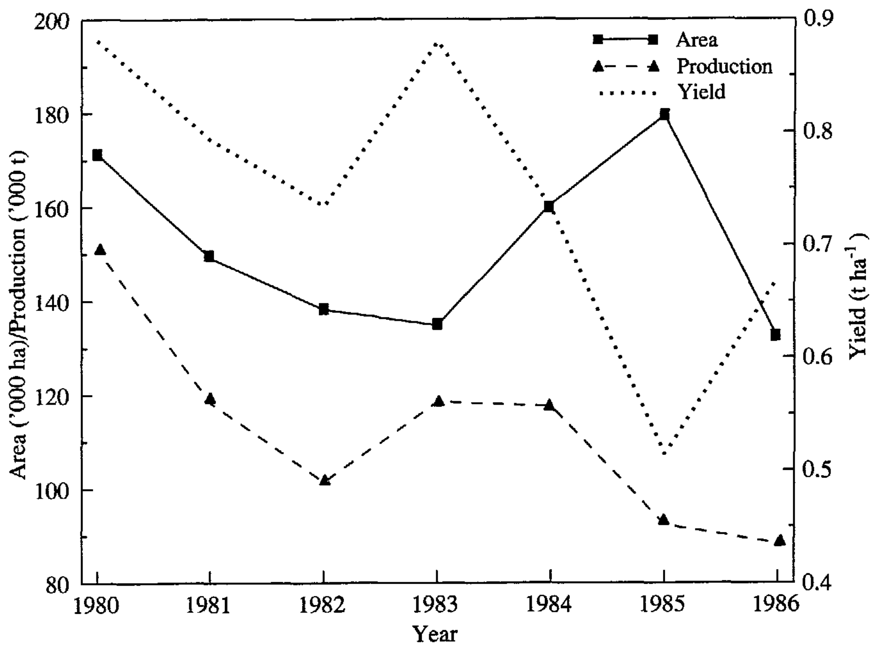

Figure 4.2.3. Trends in chickpea area, production, and yield in Ethiopia, 1980–86.

Table 4.2.1. Area, production, and yield in the important chickpea-growing provinces of Ethiopia (average of 1979/80 to 1985/86.

Province	Area (ha)		Production (t)		Yield (t ha^{-1})
Shewa	54 400	(38.7)[1]	43 000	(39.2)[2]	0.79
Gonder	40 000	(28.4)	30 600	(27.9)	0.68
Gojam	20 100	(14.3)	16 300	(14.9)	0.72
Tigre	16 300	(11.6)	10 500	(9.6)	0.57
Welo	9 900	(7.0)	6 600	(6.0)	0.67
Total	140 700		107 600		

1 Figures within parentheses in this column indicate percentage of the total chickpea-producing area.
2. Figures within parentheses in this column indicate percentage of the total chickpea production.

Climate, Soil, and Crop Distribution

A detailed agroclimatic description of Ethiopia is given in the World Atlas of Agriculture (Anonymous 1976). There are 15 agroecological zones in Ethiopia (Fig. 4.2.5). Chickpea production is concentrated in the central highlands (which include Shewa, Gojam, and parts of Welo), Tana highlands (Gonder, including the Fogra plains), and in the northern highlands (mainly Tigre), where chickpea is sown after flood waters recede. Altitudes of these highlands range from 1800 to 2300 m above sea level and the average annual rainfall from 700 to 2000 mm (Fig. 4.2.6) (Bejiga 1980; Smithson et al. 1985; Saxena 1987; Tullu 1990). These regions are characterized by moderately cool, moist winters and dry, hot summers (85 to 150-day cropping season) (Tullu 1990). Chickpea is produced primarily in the 950 to 1800-mm annual rainfall zone, where the crop is grown on residual soil moisture, particularly in the waterlogged valleys and high plateaux (Hawando 1987).

Shewa, which is the most important chickpea-producing province in the country, receives high but unevenly distributed rainfall, due to differences in topography in the spring and autumn chickpea-growing areas. The length of growing period of spring chickpea in this province is short (around 66 days on the lower slopes of the escarpment in the Robit Valley) as the spring rains are insufficient, especially towards the east (Goebel and Odenyo 1984).

Although chickpea is grown on different kinds of soils on moisture conserved in the soil profile from the preceding rainy season, farmers prefer to cultivate it on Vertisols which are deep and have a high water-storage capacity (Fig. 4.2.7). But in Shewa, Arsi, and parts of Gojam and Gonder, Vertisols cause problems of waterlogging. The geographic distribution of Verrtisols in Ethiopia overlaps with that of chickpea-producing regions (with 950–1600 mm rainfall) (Figs. 4.2.6 and 4.2.7) (Hawando 1987).

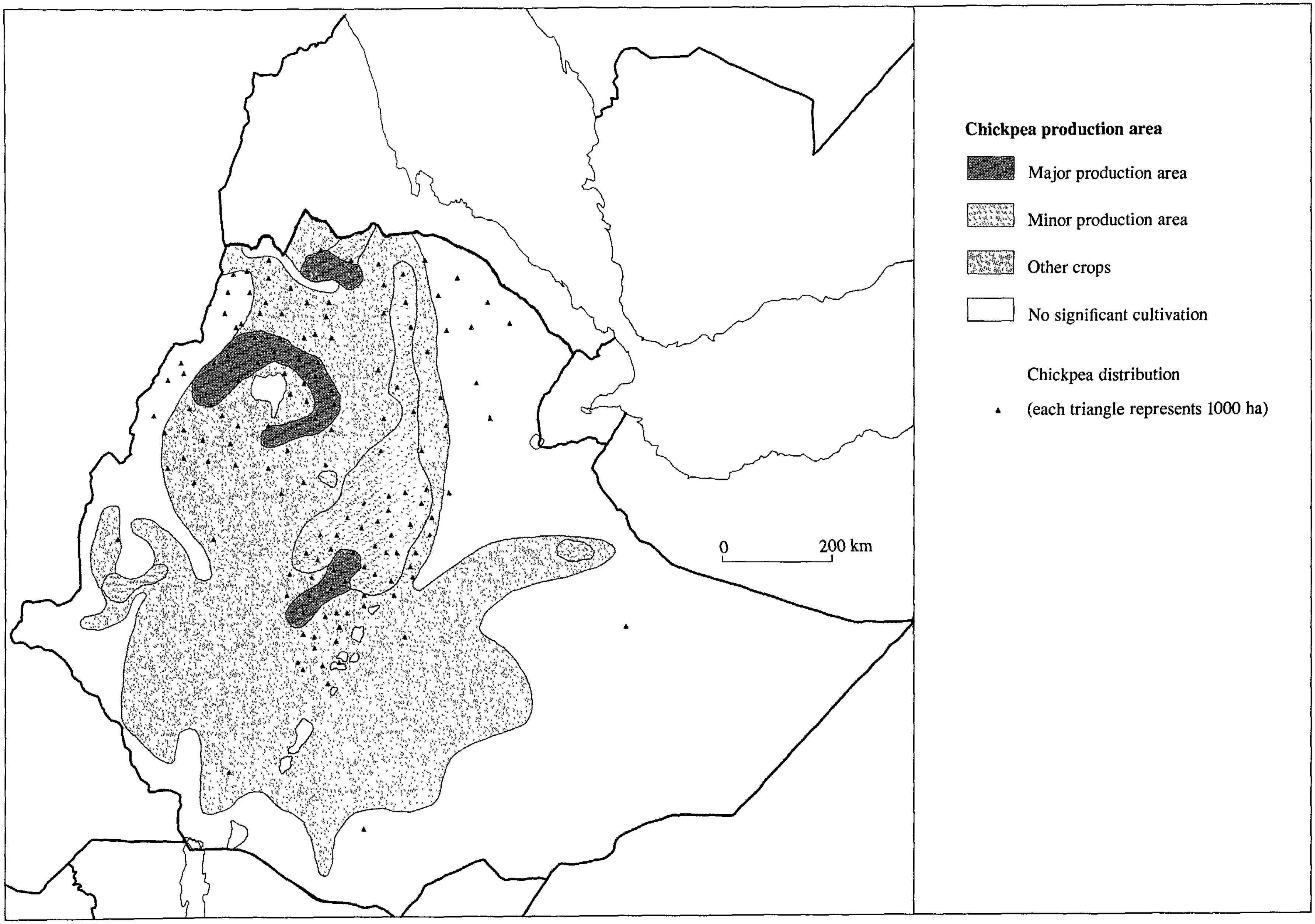

Figure 4.2.4. Chickpea production areas in Ethiopia.

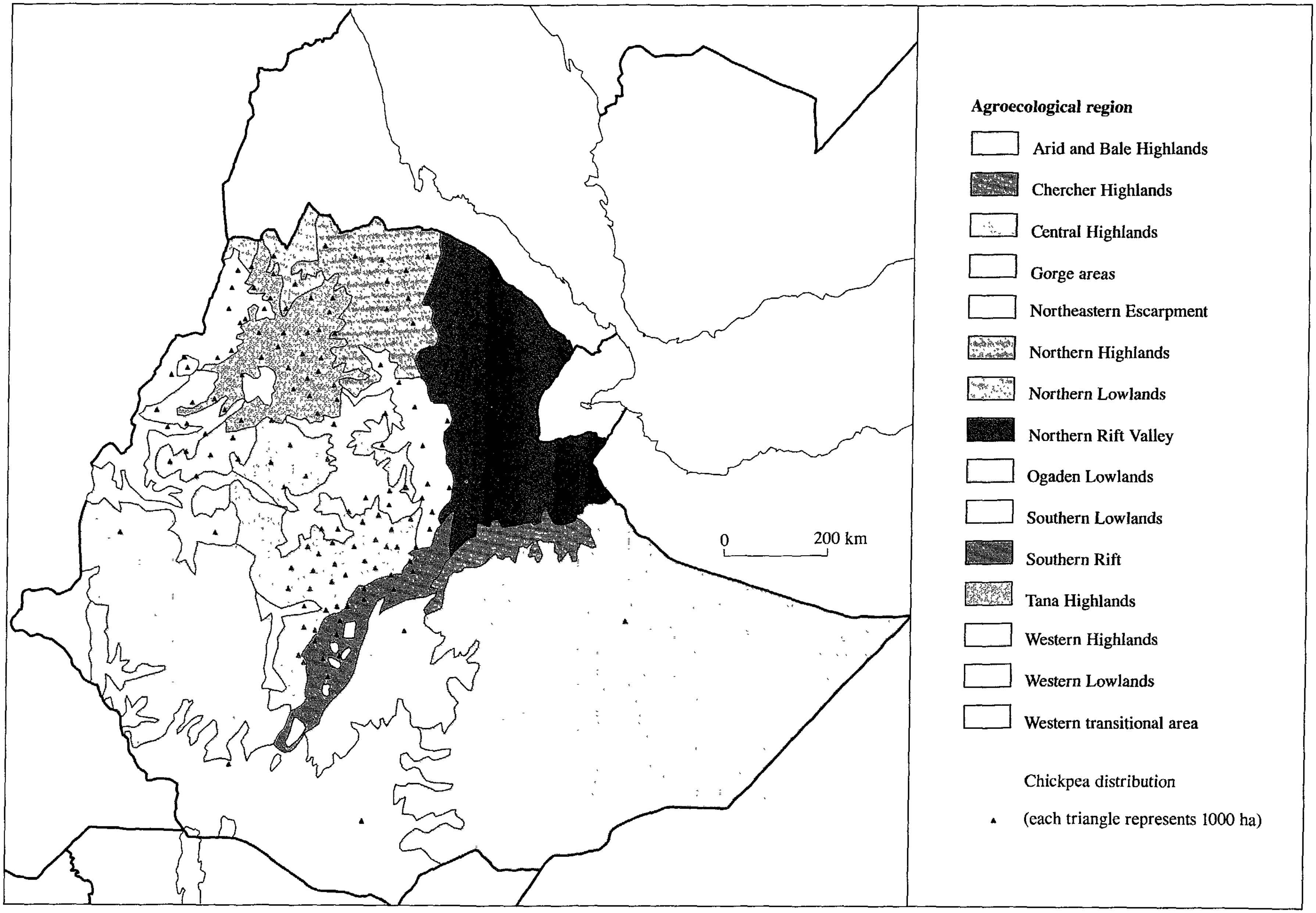

Figure 4.2.5. Agroecological regions in relation to chickpea distribution in Ethiopia.

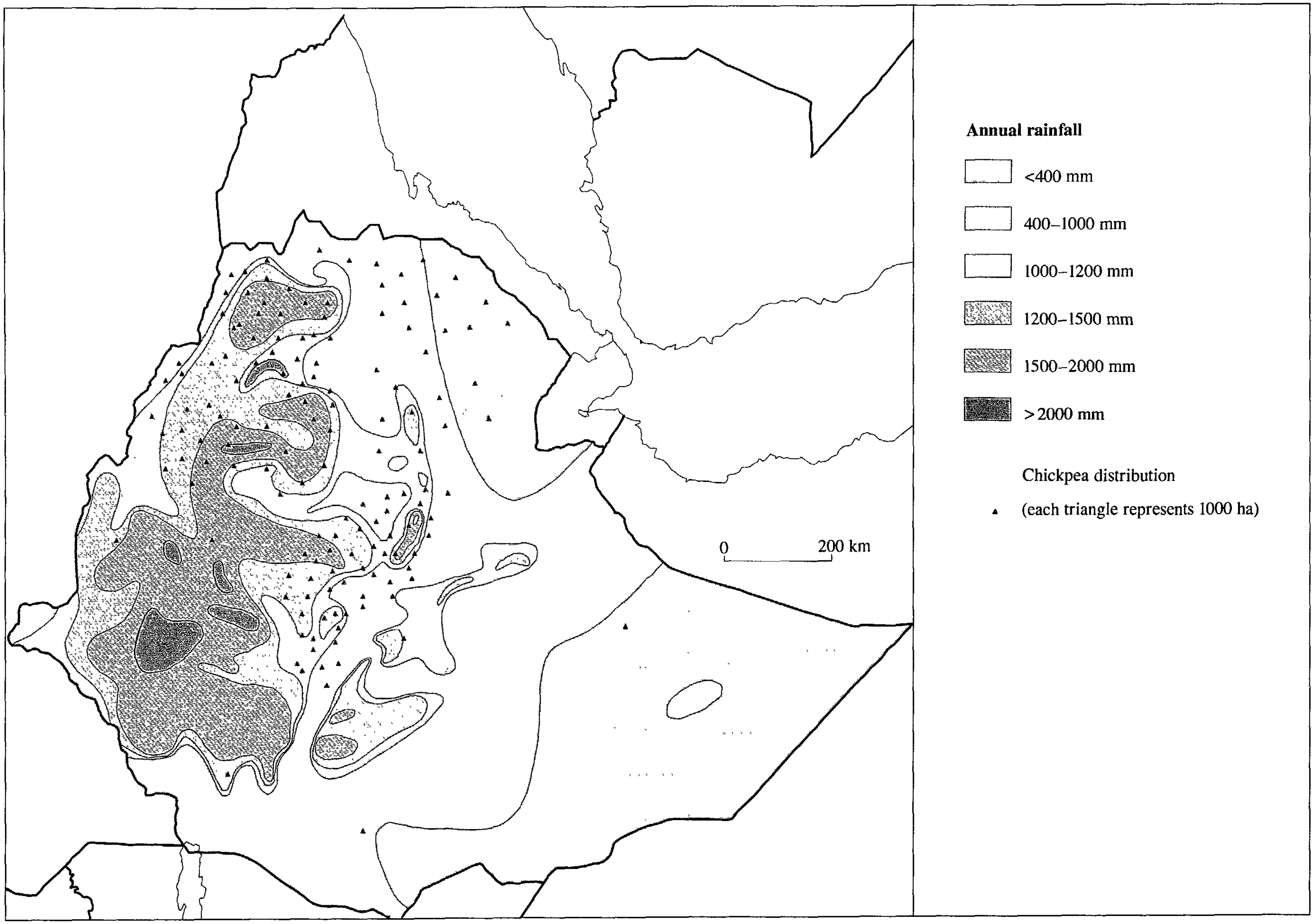

Figure 4.2.6. Mean annual rainfall in relation to chickpea distribution in Ethiopia.

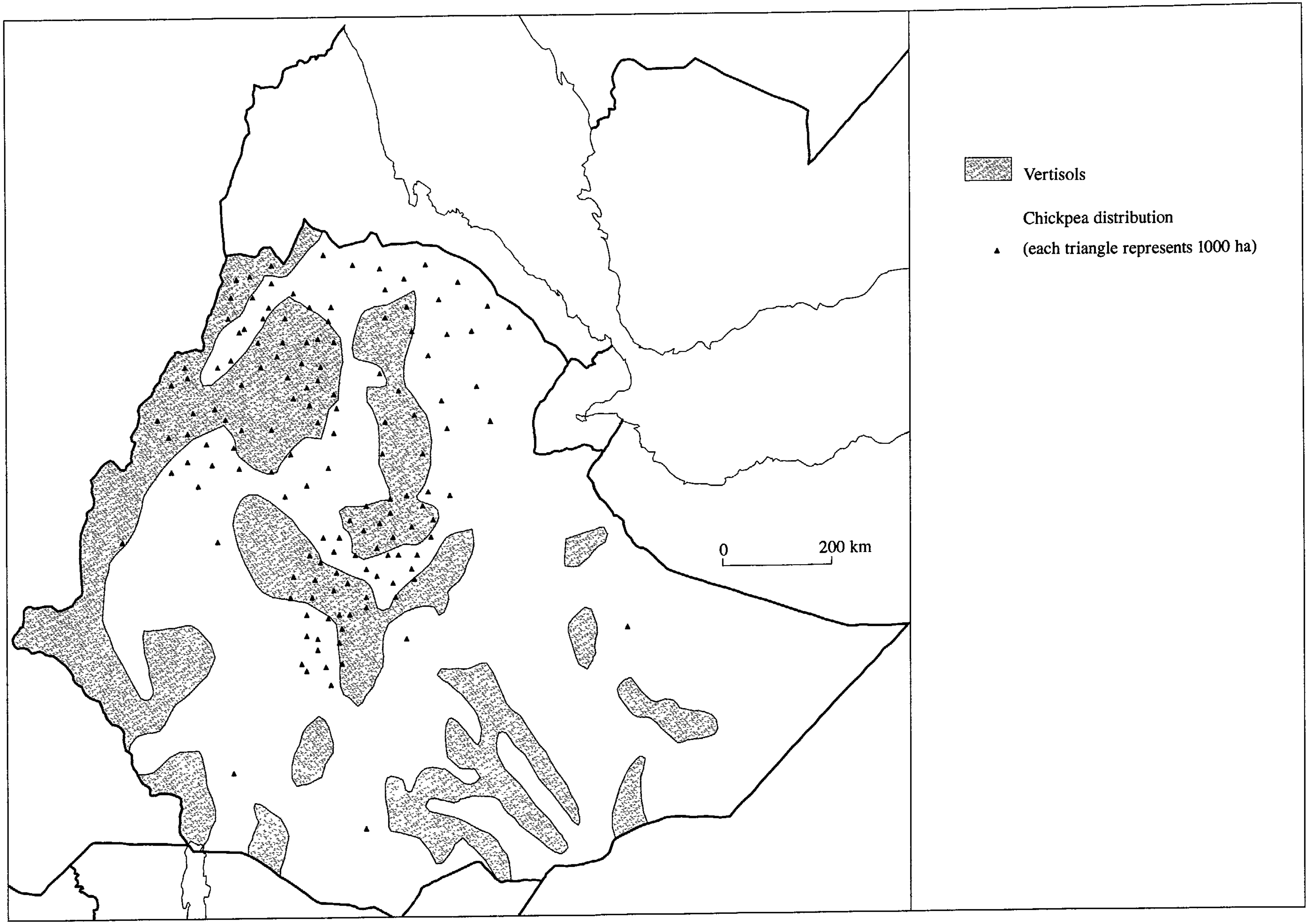

Figure 4.2.7. Vertisols in relation to chickpea distribution in Ethiopia. (Source: Hawando 1984.)

Chickpea sowing is delayed until Sep (after the end of the rainy season) in regions with hydromorphic soil.

Symptoms of phosphorus deficiency are sometimes observed on chickpea grown on Vertisols in the Ada region (near Debre Zeit) (Hawando 1987), but not on light soils in adjoining areas. In general, chickpea does not respond to phosphorus application in Ethiopia.

Cropping Systems

Chickpea and lentil (*Lens culinaris*), crops well adapted to the post-rainy season, are the only pulses that are included in rotation with winter crops, such as teff (*Eragrostis tef*), wheat (*Triticum aestivum*), and barley (*Hordeum vulgare*) on the heavy clay soils (Vertisols).

The role of chickpea in improving soil fertility and enhancing yields of the succeeding teff crop is well known to farmers. Fields sown to chickpea are also relatively weed-free, because most of the weeds are smothered while preparing the land.

Chickpea is usually sown in Sep and harvested in Jan/Feb (Fig. 4.2.8). In areas which are flooded with water, chickpea is sown after the flood waters recede. The average length of the growing season for different chickpea-producing regions is shown in Figure 4.2.9.

Agronomic studies have revealed that an advance in sowing date from mid-Sep to late Aug or early Sep could substantially increase the seed yield (Bejiga 1990). The most favorable sowing period for chickpea has been found to be between late Aug and early Sep (Bejiga and Tullu 1982; Bezuneh 1976). If sown earlier than Aug, the crop has a poor emergence and sometimes is completely destroyed because of excessive rains. If sown later, the crop duration and yields are reduced. A variety adapted to early sowing, Mariye (K 850-3/27 × F 378), has been recently released. Short-duration genotypes selected at ICRISAT Asia Center, India, have been found suitable for late sowing conditions in Ethiopia.

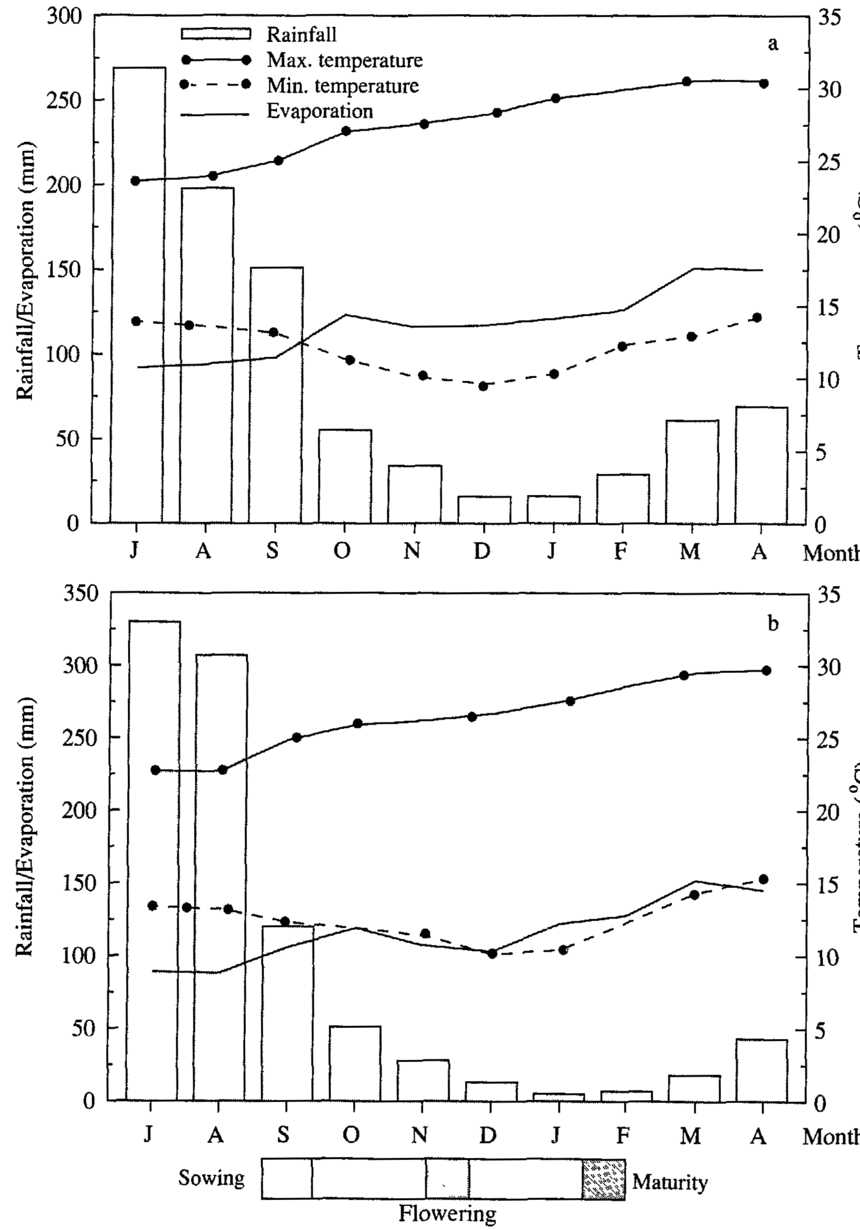

Figure 4.2.8. Crop phenology of chickpea in relation to climatic conditions in two provinces in Ethiopia: (a) Shewa; (b) Gonder, 1931–60.

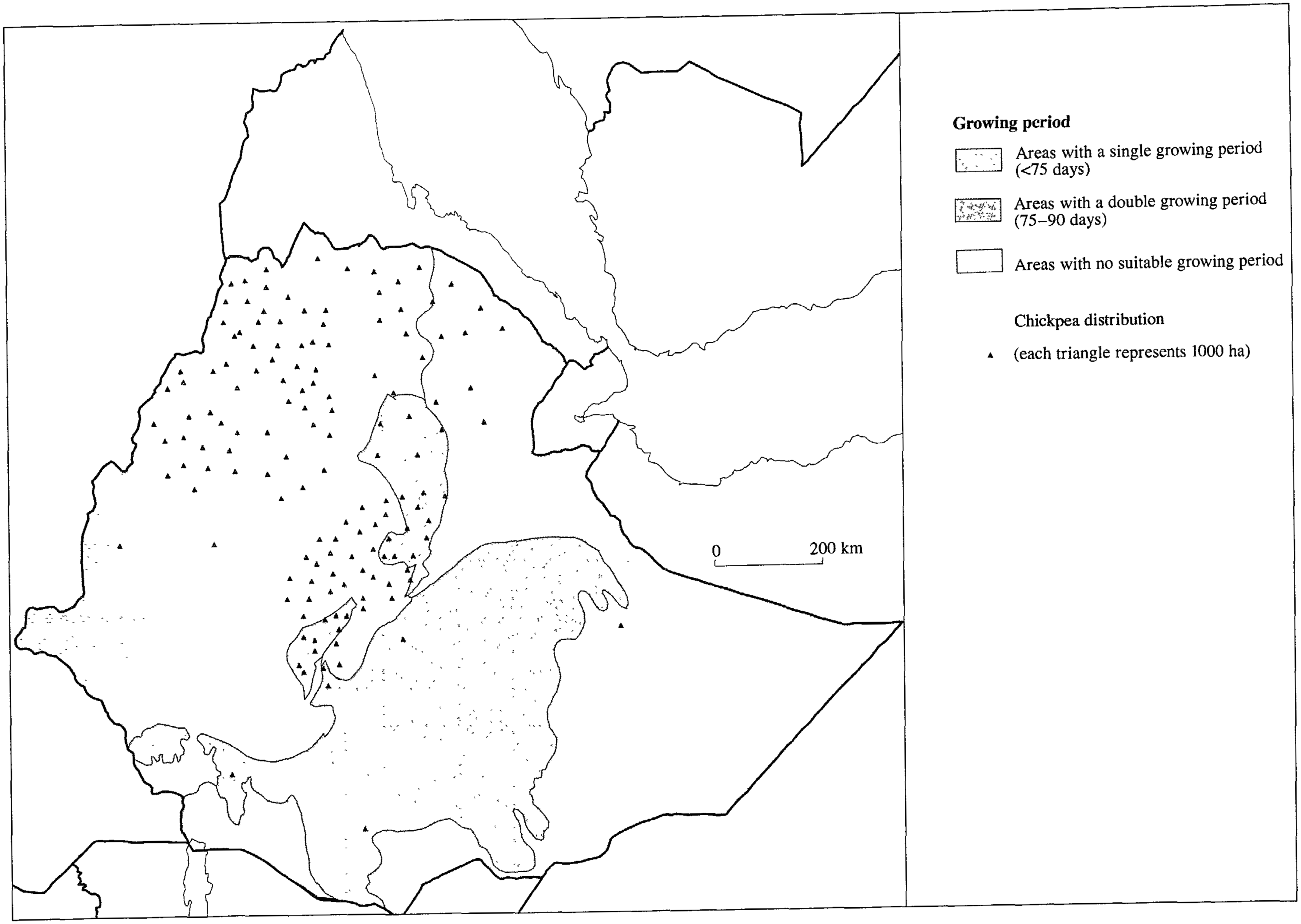

Figure 4.2.9. Crop-growing periods in relation to chickpea distribution in Ethiopia.

Production Constraints

Abiotic Constraints

Drought

Drought is the most important abiotic constraint to chickpea production in Ethiopia. It is therefore necessary to identify chickpea genotypes that tolerate drought stress. In general, as the crop is sown late in Sep, the effects of drought are heightened. As the soil starts cracking and roots get pruned, the crop-growing period is shortened (Saxena 1987). Land is prepared for sowing after the rainy season and seeds are sown on seed beds that dry out rapidly, as the air temperatures are high during this period. These conditions result in low seedbed moisture at sowing time, leading to poor germination and plant stand. Yields have been reported to increase by more than 50% if sowing is advanced from Sep to late Aug (Bejiga and Tullu 1982). Work on screening for drought tolerance has begun at Alem Tena.

Frost

Frost is not a common problem in the regions where chickpea is usually grown. However, when it coincides with the flowering/podding stages (in Oct/Nov), it causes complete crop loss. No attempt has yet been made to introduce frost-tolerant genotypes.

Waterlogging

Waterlogging is a major constraint to Aug-sown chickpea. In years when rainfall is high, it may even kill the crop. Evaluation of kabuli and desi chickpea for tolerance for waterlogging has not been successful so far and a trial conducted earlier was lost due to flooding.

Biotic Constraints

Diseases

The importance of the major diseases attacking chickpea are, in order of importance, fusarium wilt (*Fusarium oxysporum*), dry root rot (*Rhizoctonia bataticola*), collar rot (*Sclerotium rolfsii*), and wet root rot (*R. solani*) (Mengistu 1978; Bejiga 1980, 1990; Beniwal et al. 1992; van Rheenen et al. 1991) (Fig. 4.2.10). *Rhizoctonia bataticola* was found to be important (20–25% incidence) in the northwestern region of Ethiopia. Collar rot is a major soilborne disease that has caused more than 50% seed yield loss in some years (Virgu 1967). Wilt and root rots cause considerable damage and significant yield reductions on poorly drained fields in the Debre Zeit region (Mengistu 1978). Stunt disease (bean leaf roll virus), has also been reported in the country (Fig. 4.2.10). Surveys made in the Ada region (around Debre Zeit) revealed that stunt incidence was more severe in fields with widely spaced and thinly-populated plants. Ascochyta blight (*Ascochyta rabiei*) has been observed on research stations where chickpea is sown early (Jul-Aug) on light soils (Bejiga 1984).

Insect pests

Pod borer (*Helicoverpa armigera*) is a significant yield reducer of chickpea (van Rheenen et al. 1991). Its distribution in Ethiopia is shown in Figure 4.2.11. Occasionally, it causes more than 80% pod damage on early-sown chickpea. In the 1991/92 season, it caused heavy damage to late Jul-sown chickpea in Alem Tena; the damage was more severe on kabuli than on desi chickpea. However, no systematic screening for tolerance for *Helicoverpa* has been undertaken so far. Potentially, cutworms (*Agrotis* spp) can cause considerable damage to chickpea seedlings but this rarely occurs. Bruchids (*Callosobruchus* spp) are major storage pests.

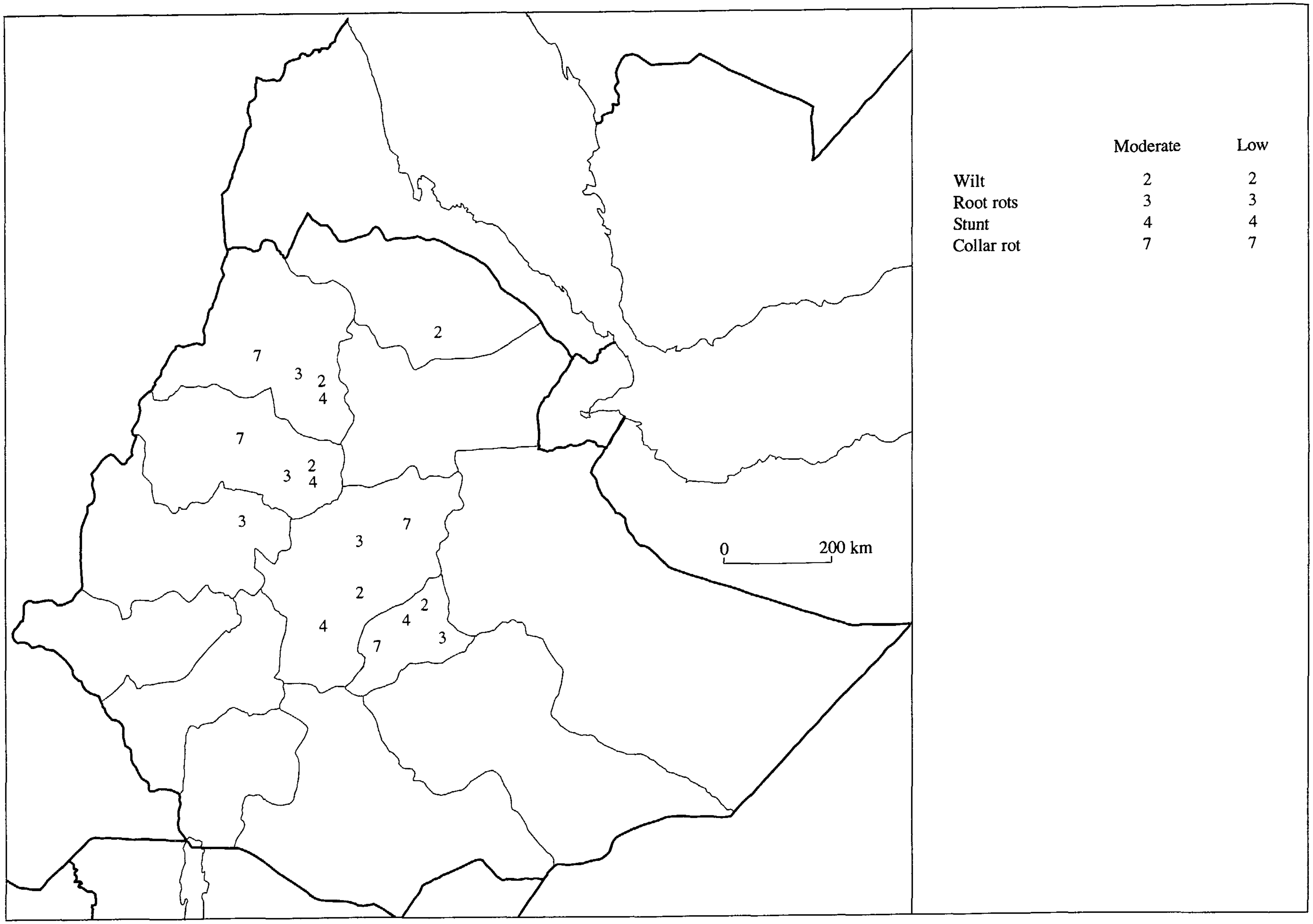

Figure 4.2.10. Disease incidence on chickpea in Ethiopia.

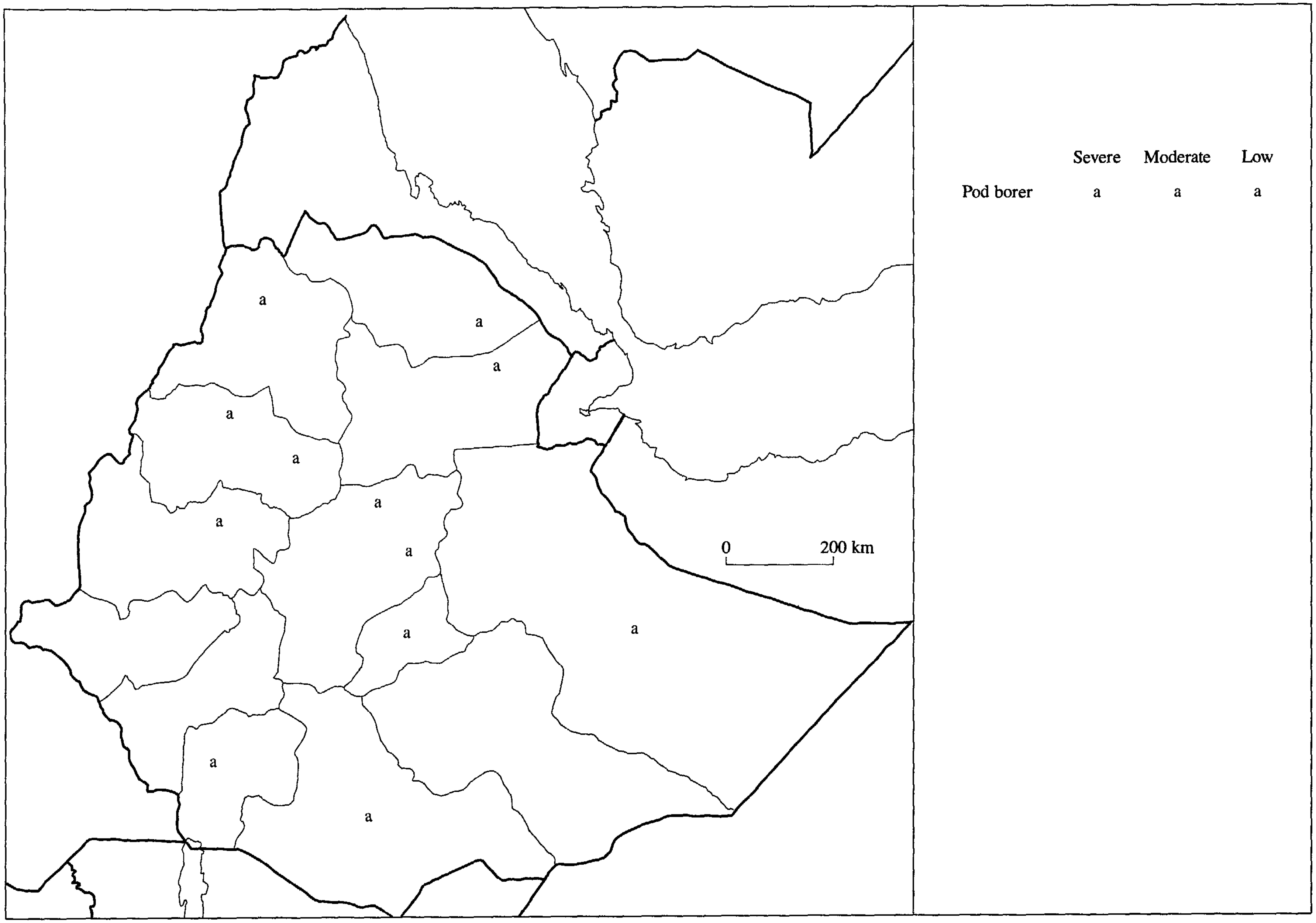

Figure 4.2.11. Pod borer incidence on chickpea in Ethiopia.

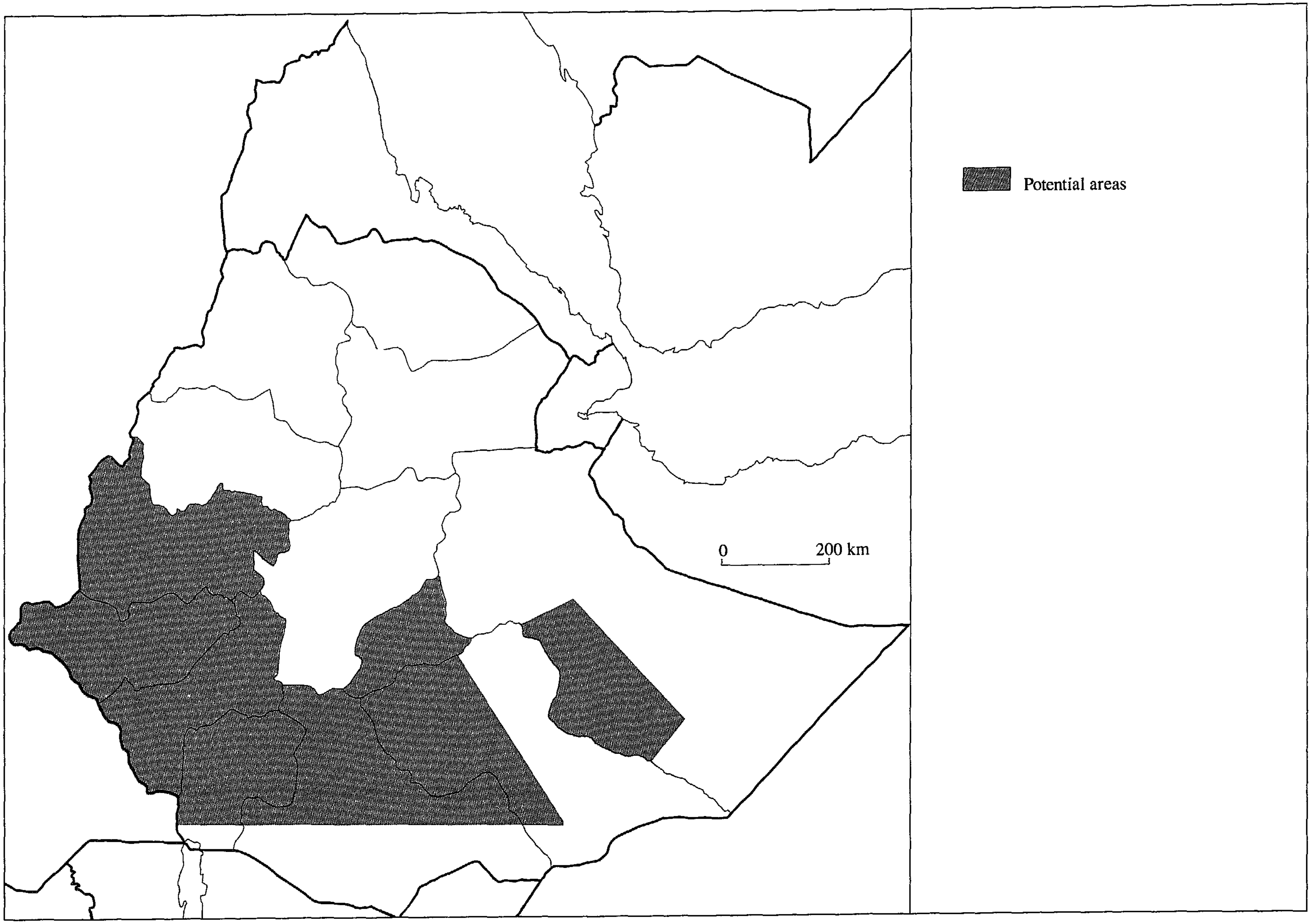

Figure 4.2.12. Potential areas for expansion and/or intensification of chickpea cultivation in Ethiopia.

Weeds

Weeds, in general, are not a serious constraint to chickpea. Field surveys are being conducted to identify major weed species. Some weeds that were not common earlier, are becoming increasingly important around Debre Zeit. These weeds grow vigorously during the spring season and are a constraint to most of the postrainy-season crops, including chickpea. Hand-weeding is generally practiced.

Mechanical Harvesting

Chickpea plants are hand-pulled at harvest and left in heaps in the field for sun-drying before threshing. Threshing is done by draft animal. Combines designed for cereals can be used for threshing chickpea, with minor adjustments in the speed of the rotating drum and selection of appropriate sieves. But this possibility has not yet been adequately explored. No efforts have been made to mechanize chickpea harvesting and threshing in Ethiopia.

Future Prospects

Chickpea is the most popular pulse crop in Ethiopia and will continue to be in great demand as sources of animal protein become increasingly expensive. The crop is well suited to rotation with major cereal crops, such as teff and wheat, as it improves and maintains soil fertility, particularly for subsistence farmers, who cannot afford to apply costly fertilizers.

The prospects for increasing chickpea cultivation by introducing the crop into nontraditional systems, in areas where cereal crops such as sorghum are monocultured, are promising. At the Alem Tena Research Station, varieties that will fit into such cropping system niches are being developed for the Rift Valley, where *Phaseolus* is currently the only legume which is used to a limited extent in rotation with cereals. Expansion of chickpea in the central highlands (Chefe Donsa) is proposed, where crop duration is long and yield potential high. The province of Kefa in the south is an important potential area for chickpea production.

It is possible to grow chickpea on light or sandy soils by advancing the sowing date from Sep to Jul, as is common for other pulses. Preliminary results showed that advancing the sowing date doubled the seed yield compared with sowing at the end of Aug at Alem Tena (in the Rift Valley). However, there would be a risk of ascochyta blight attack on early sown chickpea. It is therefore necessary to develop ascochyta blight resistant varieties.

Goebel and Odenyo (1984) have given a detailed climatic characterization of existing and potential chickpea cultivation areas in Ethiopia.

Nurseries supplied by ICARDA, Syria, are being evaluated to select frost-tolerant genotypes. If successful, this would open up opportunities for introducing chickpea in crop rotation with durum wheat and barley in the highlands.

Surveys are being done in collaboration with the Nile Valley Regional Program (NVRP), ICARDA, to plan future research and extension strategies. Potential areas for chickpea expansion in Ethiopia are shown in Figure 4.2.12.

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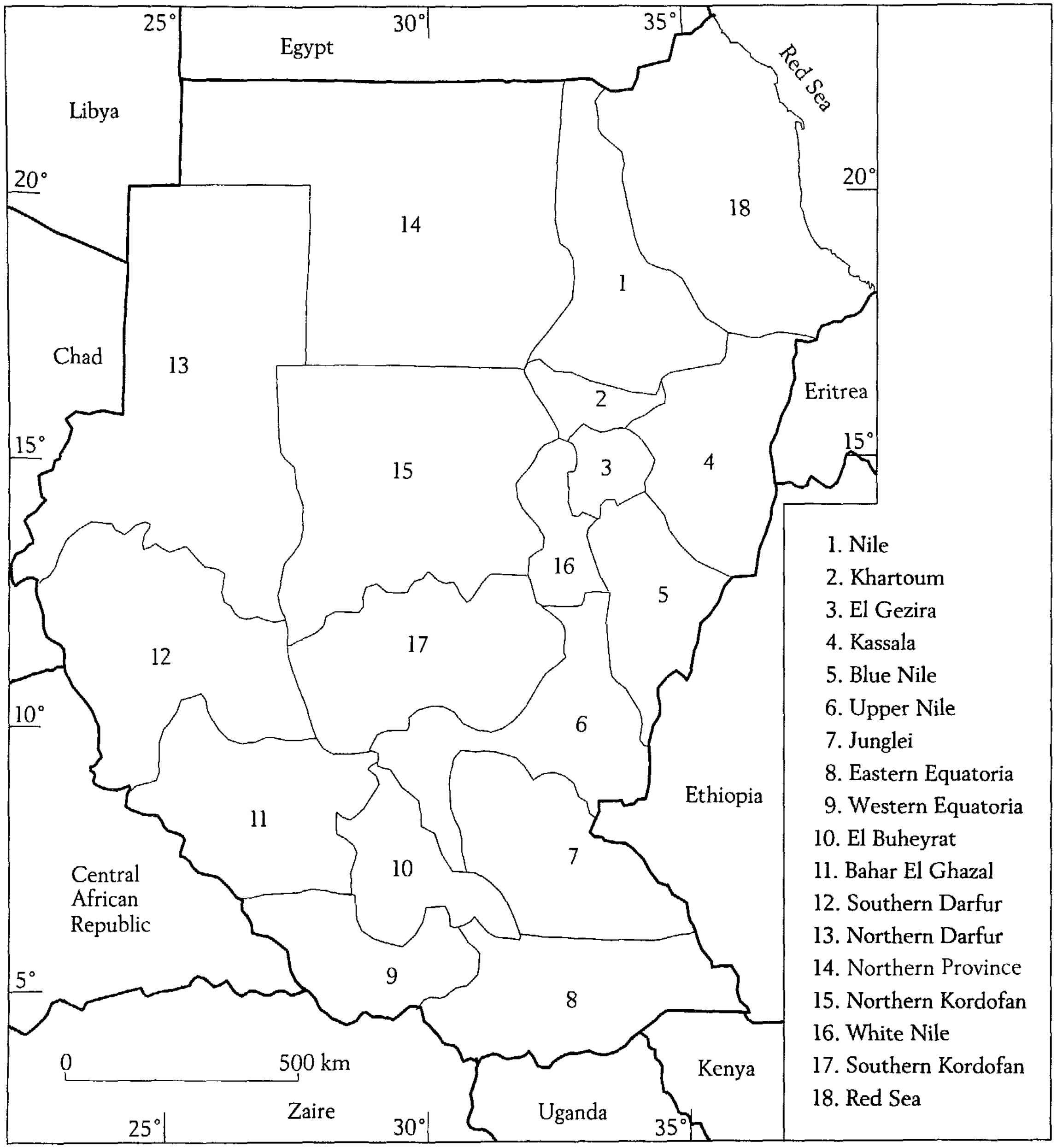

Figure 4.3.1. Administrative boundaries of Sudan.

4.3. Chickpea in Sudan

H Faki[1], A I S Mohamed[2], and M E K Ali[2]

Latitude	4–22° N
Longitude	22–39° E
Altitude	200–3000 m
Total population	27.4 million
Economically active	8.9 million
Economically active in agriculture	5.1 million
Total area	250.6 million ha
Cultivated area	12.9 million ha
Rainfed area	11 million ha
Annual rainfall	0–1600 mm
Chickpea rank among legumes	Third
Crop season	Winter

Introduction

Sudan is the largest country in Africa and the Arab world. Agriculture in Sudan is both rainfed and irrigated. Rainfed cropped area varies from 3.8 to more than 10 million ha, depending on the amount of annual rainfall. Traditional and modern cultivation practices are

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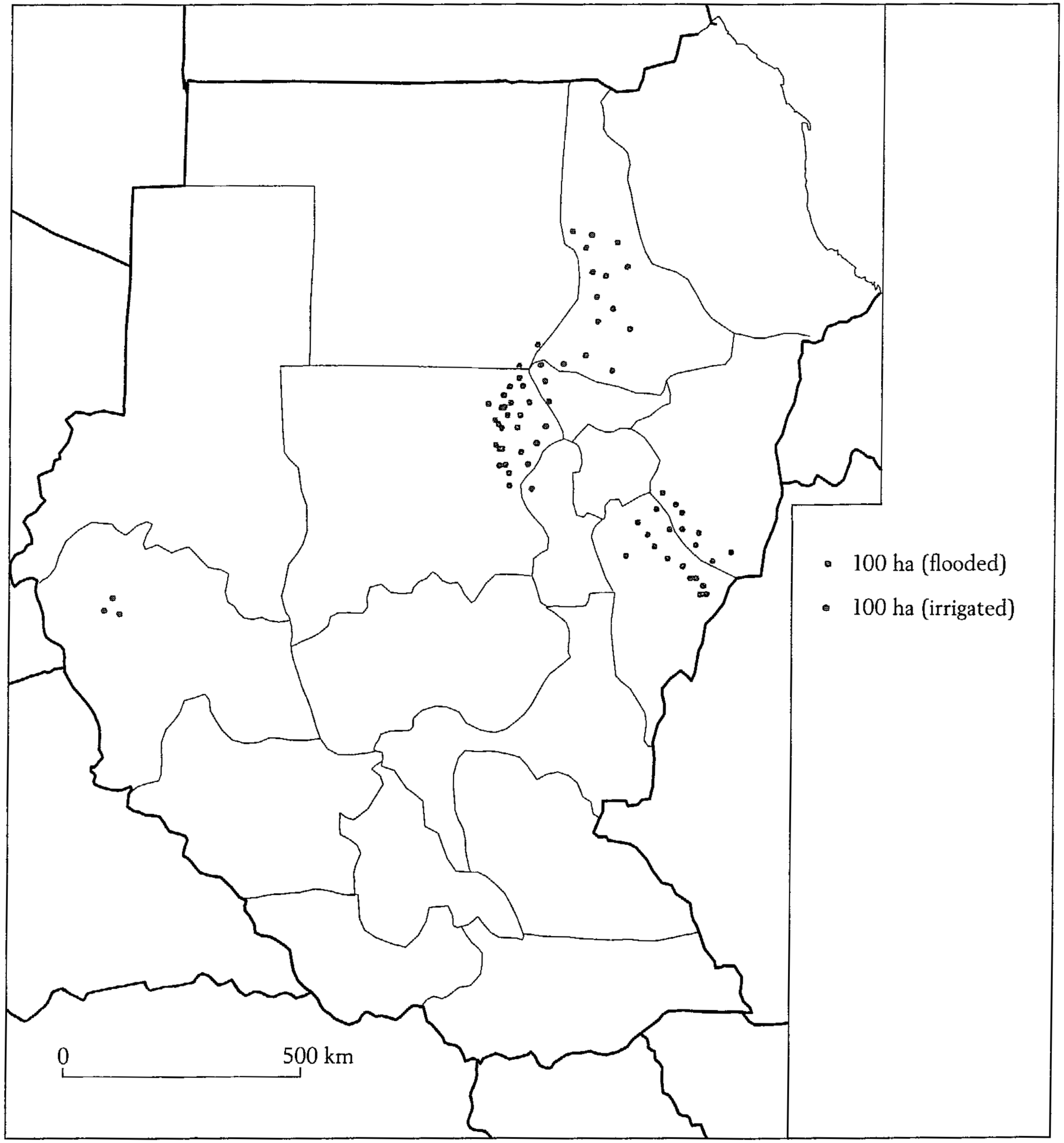

Figure 4.3.2. Chickpea distribution in Sudan.

adopted both in the rainfed and irrigated production systems. Modern irrigated agriculture is common on large government-operated projects, while modern rainfed cultivation is practiced on privately-owned farms in eastern and central Sudan. Sorghum (*Sorghum bicolor*) is the major food crop, but wheat (*Triticum aestivum*) is widely consumed in urban areas. Millet (*Pennisetum glaucum*) is a common food in western Sudan. The main cash crops are cotton (*Gossypium* sp), groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum*), and gum arabic (*Acacia arabica*). Together with livestock, these crops are the main source of foreign exchange earnings for the country. Chickpea (*Cicer arietinum*) is the third most important cool-season food legume crop, after faba bean (*Vicia faba*) and lentil (*Lens culinaris*). The administrative boundaries of Sudan are shown in Figure 4.3.1 and the chickpea distribution in Figure 4.3.2.

Uses

Chickpea is consumed mostly as boiled seed (*balila*) during the month of Ramadan or in the form of *tamia* (fried cakes made of chickpea seed soaked, crushed, and mixed with vegetables and spices). Sweets (e.g., *humusia*) are also made of chickpea, especially during festivals. However, the crop is mostly used in urban rather than rural areas.

Chickpea is consumed only in small quantities in areas where sorghum or millet are the major food crops, as bread made of these cereals does not go well with chickpea preparations. Wheat bread on the other hand is generally preferred with food legumes, particularly faba bean and chickpea. Since wheat and cool-season food legumes are expensive, they have been little used among the rural poor.

Area, Production, and Productivity

There have been large year-to-year fluctuations in area, production, and yield of chickpea in Sudan. For example, all the three increased steadily from 1987 to 1990 in northern Sudan, the most important chickpea-producing region of the country. Since then, area and production have decreased drastically, but yield has gone up (Fig. 4.3.3). This increase in yield is largely due to a sharp rise in prices of chickpea which has encouraged farmers to use better management practices, including improved technology, especially improved varieties and better irrigation practices.

In the early 1960s, the area under chickpea was much larger (Ministry of Agriculture 1970), averaging around 3140 ha during 1962–64; but it was mostly confined to the flood basins. Yields were however low, averaging around 0.73 t ha^{-1}.

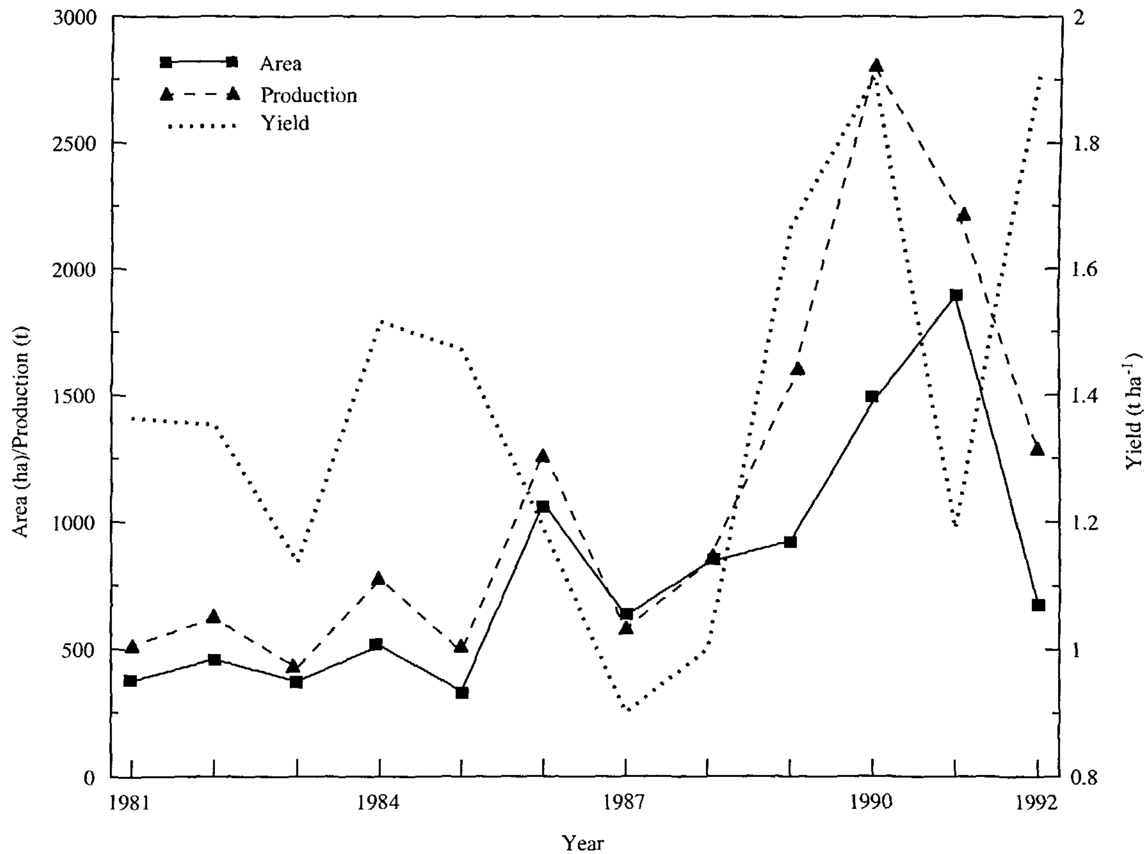

Figure 4.3.3. Trends in chickpea area, production, and yield in northern Sudan, 1981–92.

Chickpea is also grown in areas other than northern Sudan. Around 1500 to 2500 ha are estimated to be under chickpea along the Rahad river in the central region (Ahmed and Bushara 1992). Yields are low in this region, ranging between 0.25 and 0.70 t ha^{-1}. Another minor area of chickpea production is Jebel Marra district in western Sudan, where winter chickpea is grown on an area of about 350 ha. During years of good rainfall and high river flood, the total area under chickpea in Sudan goes up to 3600 ha with a total production of over 3500 t.

Climate, Soil, and Crop Distribution

Unlike other cool-season food legumes that are predominantly grown under the relatively mild climate of northern Sudan, chickpea cultivation is fairly widespread, although the total area is small. It is grown under a wide range of agroclimatic conditions, ranging from desert climate to humid areas, and sea level to high altitudes (Fig. 4.3.4).

There is a large variability in the amount and distribution of rainfall in Sudan. Rainfall ranges from 0 (in the north) to 1000 mm (in the far south), and may exceed 1400 mm at high elevations (Fig. 4.3.5). The rainfall would be adequate for cultivation were it not for the very high rate of evaporation which makes irrigation essential in many areas.

The rainy season extends in most areas from Apr to Oct and peaks in Jul and Aug. There is, therefore, hardly any association between rainfall and the production of cool-season food legumes which are grown exclusively with irrigation in winter, whereas most of the rainfall is received in summer. An exception to this pattern is the eastern fringe of the Red Sea Hills which has a Mediterranean climate with rainfall in winter.

Sudan has a pronounced and often prolonged dry season when all but the largest rivers run dry. The north-south rainfall

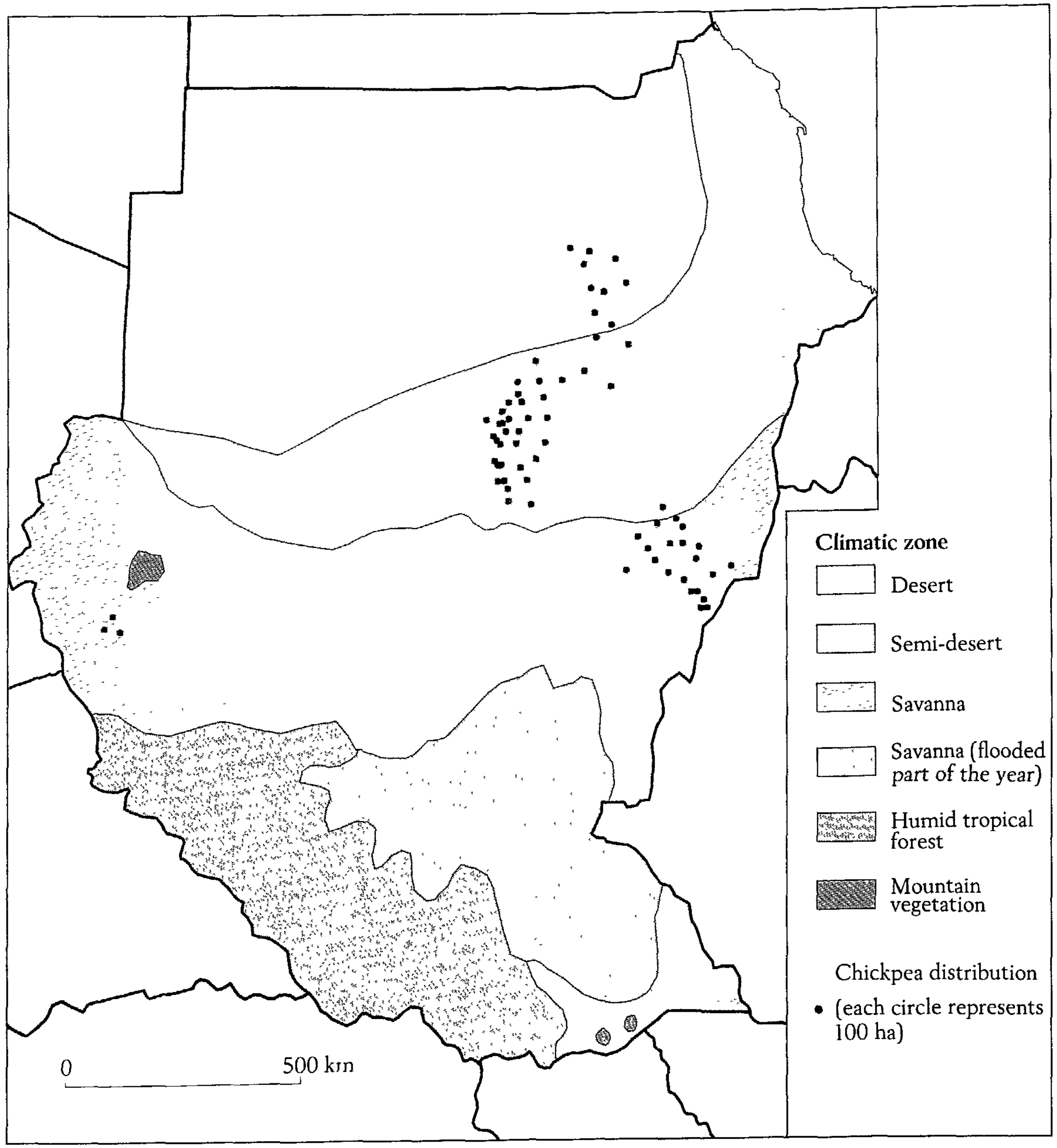

Figure 4.3.4. Climatic zones in relation to chickpea distribution in Sudan.

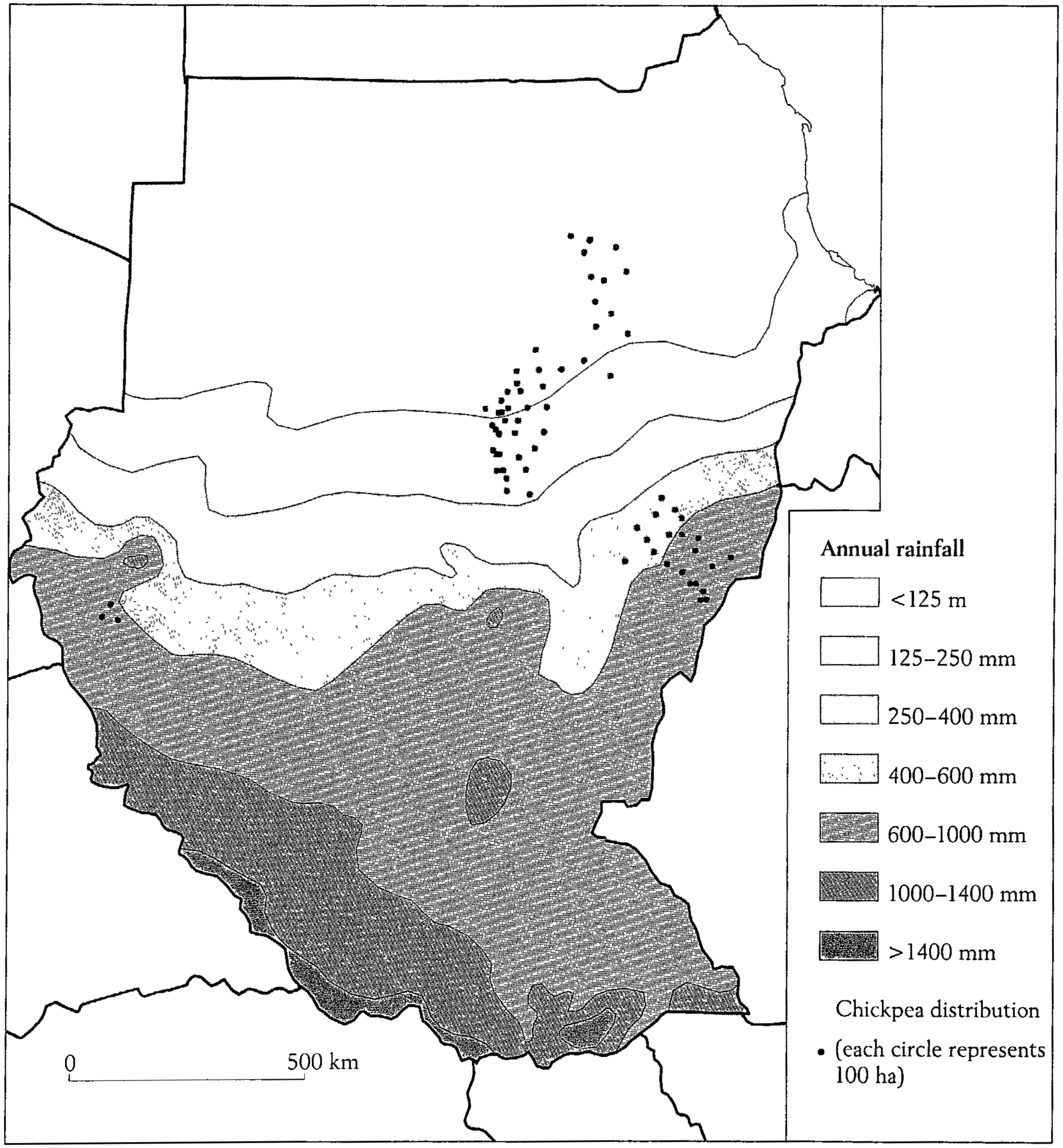

Figure 4.3.5. Mean annual rainfall in relation to chickpea distribution in Sudan.

gradient is associated with an increase in the length of the crop-growing period, from 0 to 270 days (Fig. 4.3.6). Temperatures generally follow a north-south trend similar to rainfall (Fig. 4.3.7).

Soils in Sudan can be grouped into five major classes as shown in Figure 4.3.8: (1) desert soils in the north; (2) heavy dark soils of the Central Clay Plain that crack easily; (3) sandy soils in western and northern Sudan; (4) patchy gravelly soils mainly in the west; and (5) laterites and red loams in the southwestern region.

Cropping Systems

Five chickpea production systems can be recognized in Sudan. They are: (1) river banks in northern Sudan; (2) pump-irrigated system in northern Sudan; (3) basins of northern Sudan; (4) flooded system in central Sudan; and (5) high-elevation areas.

River Banks in Northern Sudan

The river banks in northern Sudan have been the traditional chickpea-growing areas of the country. Chickpea is generally sown in Oct/Nov after flood waters recede (Nourai 1987). The soils in this region are made up of silt deposited by flood water; they are perme-

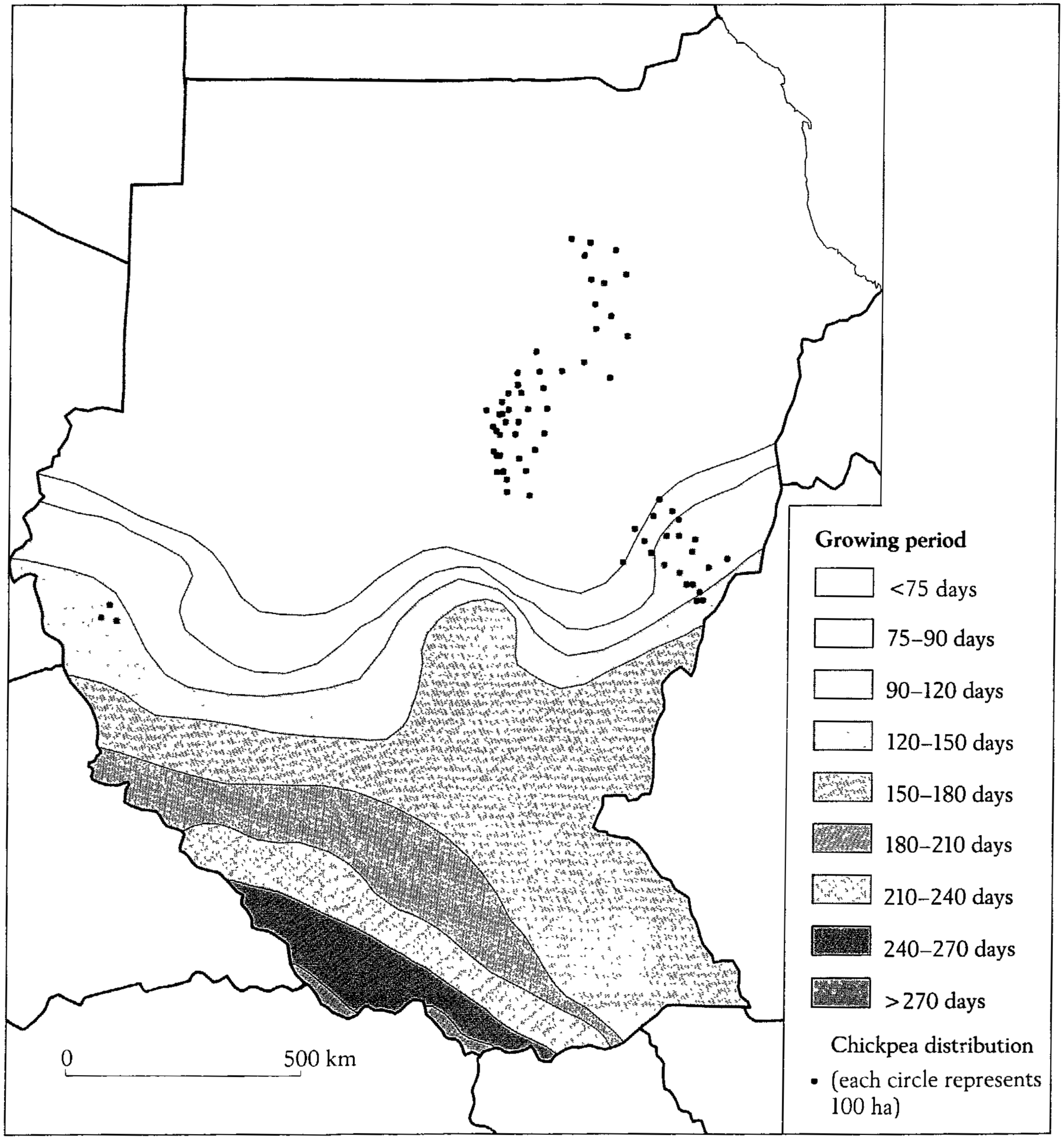

Figure 4.3.6. Length of crop growing period in relation to chickpea distribution in Sudan.

able and very fertile (Nourai 1987). Figure 4.3.9a shows the climatic conditions prevailing during the chickpea-growing season in these regions. Temperatures are high during the reproductive stage of the crop. However, the microclimate becomes cooler nearer the river or if vegetation is present. Flowering begins around 50 days after sowing and the crop matures in about 110 days when soil moisture is still adequate. Yields are around 1.4 t ha^{-1} and the seed quality is good. The area sown to chickpea is quite small in this system.

Pump-irrigated System in Northern Sudan

The pump-irrigated system was introduced recently in the country. It is confined to the outer strips of cultivated land along the Nile river. In this fully irrigated production system, chickpea is grown with other food legumes and cereals. Irrigation is done by lifting water with pumps. Soils are sandy loam with pH ranging between 7.3 and 8.0. Land is plowed using tractors and levelling is often done using animal traction. Chickpea is sown in furrows opened by hand hoes, behind a plow or by using a small metal tool with an L-shaped wooden handle called a *naggama*, which is normally used as an implement for weeding. Sowing is generally done during Nov to take

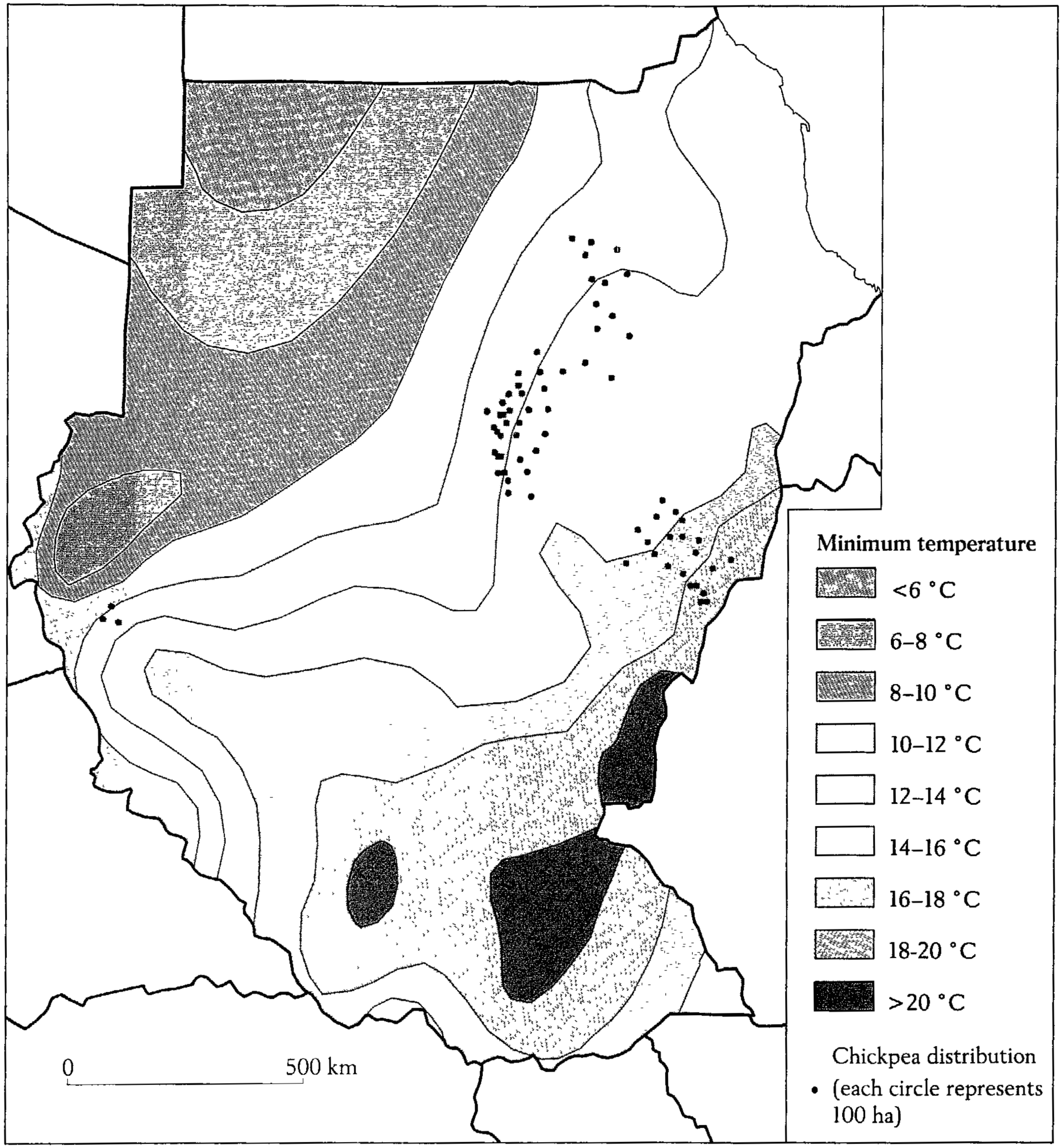

Figure 4.3.7. Minimum temperature in relation to chickpea distribution in Sudan.

full advantage of the cool weather (Fig. 4.3.9b). Flowering begins 7–8 weeks after sowing and the crop matures in another 8–9 weeks (Salih 1980). Yields are relatively high (maximum 2.8 t ha^{-1} and average 1.9 t ha^{-1}).

Among the various winter cash crops that are now being cultivated, chickpea—because of high demand—is preferred by farmers for crop diversification. Moreover, as it tolerates drought when the river water subsides and recedes from pumping sites, it reduces risk to farmers in this production system (Faki et al. 1989). The limited amount of available water is then diverted to more drought sensitive crops such as wheat, lentil, or faba bean.

Farmers believe, from experience, that chickpea production practices are easier to follow and that the crop is much more tolerant of weeds than the other two cool-season food legumes.

Basins of Northern Sudan

Chickpea is a traditional crop in two large basins on the western bank of the Nile river, north of Khartoum. It is also grown as one of the cash crops in areas near the important market of Umdurman. The crop is sown on stored soil moisture in the outer parts of the basins after the flood waters subside. The sowing date varies from mid-Sep to early Oct (Fig. 4.3.9c). Crop duration ranges from 90 to 100

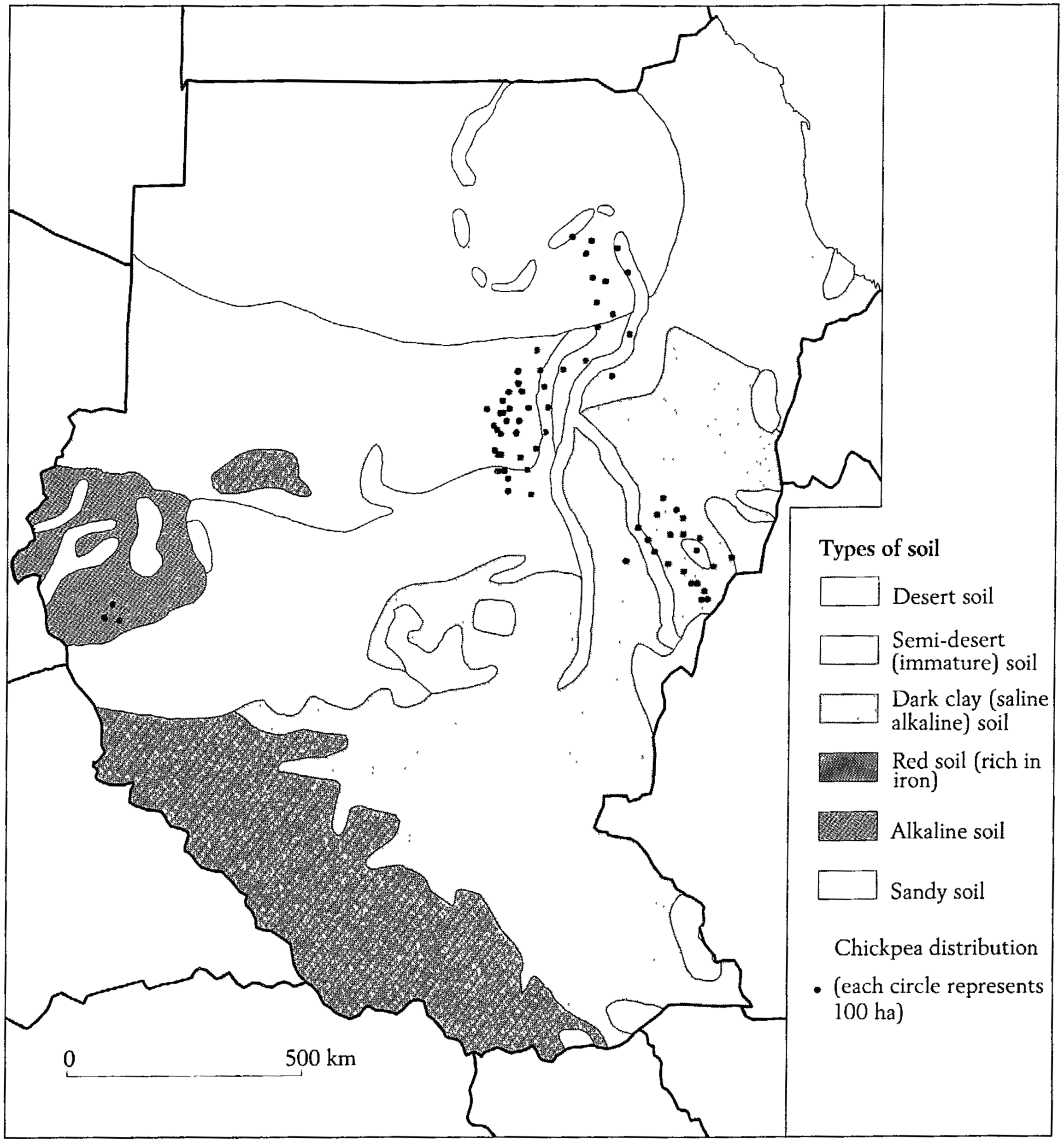

Figure 4.3.8. Soil types in relation to chickpea distribution in Sudan.

days depending on the amount of stored soil moisture.

Soils are heavy in this region and the silt deposited by floods forms a thick crust that cracks easily. Chickpea is grown generally as a sole crop but is sometimes intercropped with sorghum. In years when flood levels are high, yields are as high as 2.4 t ha^{-1} with an average of around 1.3 t ha^{-1}.

In some parts of this region, chickpea is also grown with irrigation, which is used to partly simulate conditions of flood. Two methods are common. In the first, after the land is prepared for sowing, it is flooded twice or even three times. The seedbed is then plowed and sown. Another irrigation is applied later in the season, if there is a permanent pump site. In the second method, sowing is done on dry land after preparatory tillage operations. Two irrigations are applied, the first for seed germination and plant establishment and the second at flowering. If necessary, another irrigation is applied at the pod-setting stage.

Flooded Systems in Central Sudan

Chickpea has a long history of cultivation in this region. The climatic conditions and crop management practices in this area are different from those in the northern region. Summer rainfall is more than 500 mm and minimum temperatures are generally favorable

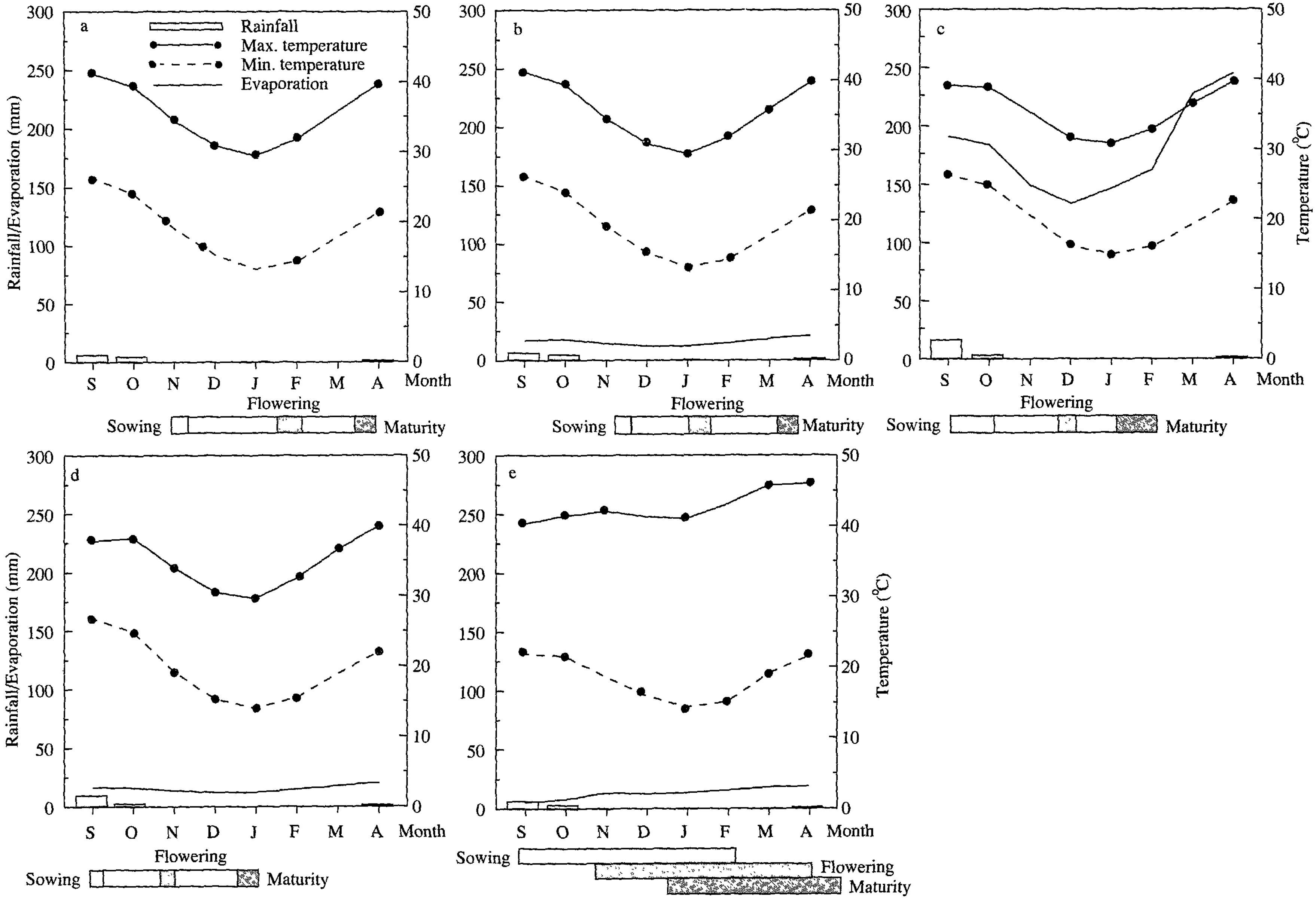

Figure 4.3.9. Crop phenology of winter-sown chickpea in relation to climatic conditions in five chickpea-growing regions in Sudan: (a) Hudeiba, river bank production system; (b) Rubatab, pump-irrigated system; (c) Shendi, northern Sudan basin; (d) Wad Hamid; and (e) Hawata, 1931–60 (both d and e represent the flooded system in central Sudan).

ensuring a longer crop duration as can be seen from the meteorological data of Um Benein Station (Table 4.3.1). Cultivation of chickpea and other crops is spread along both banks of the river Rahad, which is a seasonal river, after the rainy-season water recedes (Ahmed and Bushara 1992). Chickpea is either grown on cropped lands near the river or is part of an agroforestry system in which it is intercropped with forest trees (mainly *Acacia seyal*) in a type of shifting cultivation organized by the Forestry Department.

Table 4.3.1. Mean monthly minimum and maximum temperatures (°C) in major chickpea-producing areas in Sudan, 1961–90.

	Hudeiba		Shendi		Um Benein	
Month	Min. temp.	Max. temp.	Min. temp.	Max. temp.	Min. temp.	Max. temp.
Jan	13.3	29.5	14.0	29.6	14.3	34.0
Feb	14.4	31.9	15.5	32.5	15.1	36.3
Mar	17.9	35.9	18.9	36.5	19.0	39.3
Apr	21.4	39.7	22.0	39.9	21.6	41.5
May	25.3	42.3	26.1	40.8	24.0	40.3
Jun	26.9	42.7	27.8	40.8	23.5	37.5
Jul	26.9	40.8	26.1	38.5	22.1	34.0
Aug	26.1	40.4	26.3	36.5	21.9	32.9
Sep	26.3	41.2	26.8	37.8	21.9	34.2
Oct	24.0	39.3	24.8	38.2	21.5	36.4
Nov	19.1	34.5	19.2	34.0	18.6	27.1
Dec	15.3	30.9	15.3	30.5	15.9	34.7

Source: Meteorological Stations of Hudeiba, Shendi, and Um Benein, Sudan.

The sowing date primarily depends on the time of recession of water from the seasonal river rather than on weather conditions. Sowing extends from mid-Oct to mid-Feb (Fig. 4.3.9d and e). Harvesting and sowing operations may overlap in this production system, with early-sown areas being harvested while new areas continue to be sown as the river waters recede. Crops sown later than Jan could suffer from heat stress. Hill-sowing is done in rows which are wide apart (50 × 50 cm). Large numbers of seeds per hill are dibbled to compensate losses in plant stand due to insects and birds. Hand-hoeing is practiced to conserve soil moisture. No irrigation is applied and the crop duration is short, around 90 days. Yields are around 0.7 t ha^{-1}.

Although desi chickpea is reported to be grown in this area (Ahmed and Bushara 1992), kabuli types predominate.

High-elevation Areas

Small areas of winter chickpea are grown with pump irrigation in the Jebel Marra area. Little is known about the practices adopted but the mild temperatures and the highly fertile volcanic soils promise high yields. The Nov-sown crop has a duration of about 110 days. With improved varieties, yields as high as 3 t ha^{-1} can be obtained. As the area receives rain in summer and temperatures are favorable, some chickpea is also grown during this period.

Production Constraints

Chickpea cultivation in Sudan is generally labor-intensive because it is not mechanized. The threshing operation alone is mechanized in some areas of northern Sudan, and this practice is becoming popular for most of the winter crops in the region.

Abiotic Constraints

Heat and drought are the major constraints to chickpea production in Sudan. Minimum winter temperatures sometimes exceed 15°C in winter in the main chickpea-producing regions of Sudan (Table 4.3.1 and Fig. 4.3.7). Moreover, if sowing is delayed because of late recession of flood waters, the crop suffers from terminal heat stress. In irrigated areas, the crop could be subjected to drought because of nonavailability of adequate amounts of irrigation water. Drought reduces yield by 50% when it coincides with the crop's reproductive phase.

Poor plant stands are common due to inadequate land preparation and inappropriate sowing methods, suboptimal seed rates, and inefficient management of soil moisture. Adverse physical soil conditions could be a constraint in some areas but these have not been quantified. Although salinity is fairly widespread, it is not a constraint to chickpea, as the crop is not cultivated on saline soils.

Biotic Constraints

Diseases

Wilt (*Fusarium oxysporum*) and root rots (*Rhizoctonia bataticola* and *R. solani*) are potentially the most important diseases of chickpea in northern Sudan (Ali 1992) (Fig. 4.3.10). Fusarium wilt is severe particularly on chickpea grown in flood basins. At present, wilt and root rots are less severe on chickpea under the pump irrigation schemes in northern Sudan. Stunt (bean leaf roll virus) incidence is generally low but in some years, 15% incidence has been reported (Salih 1980). Powdery mildew (*Oidiopsis taurica*) generally appears very late in the season (towards crop maturity).

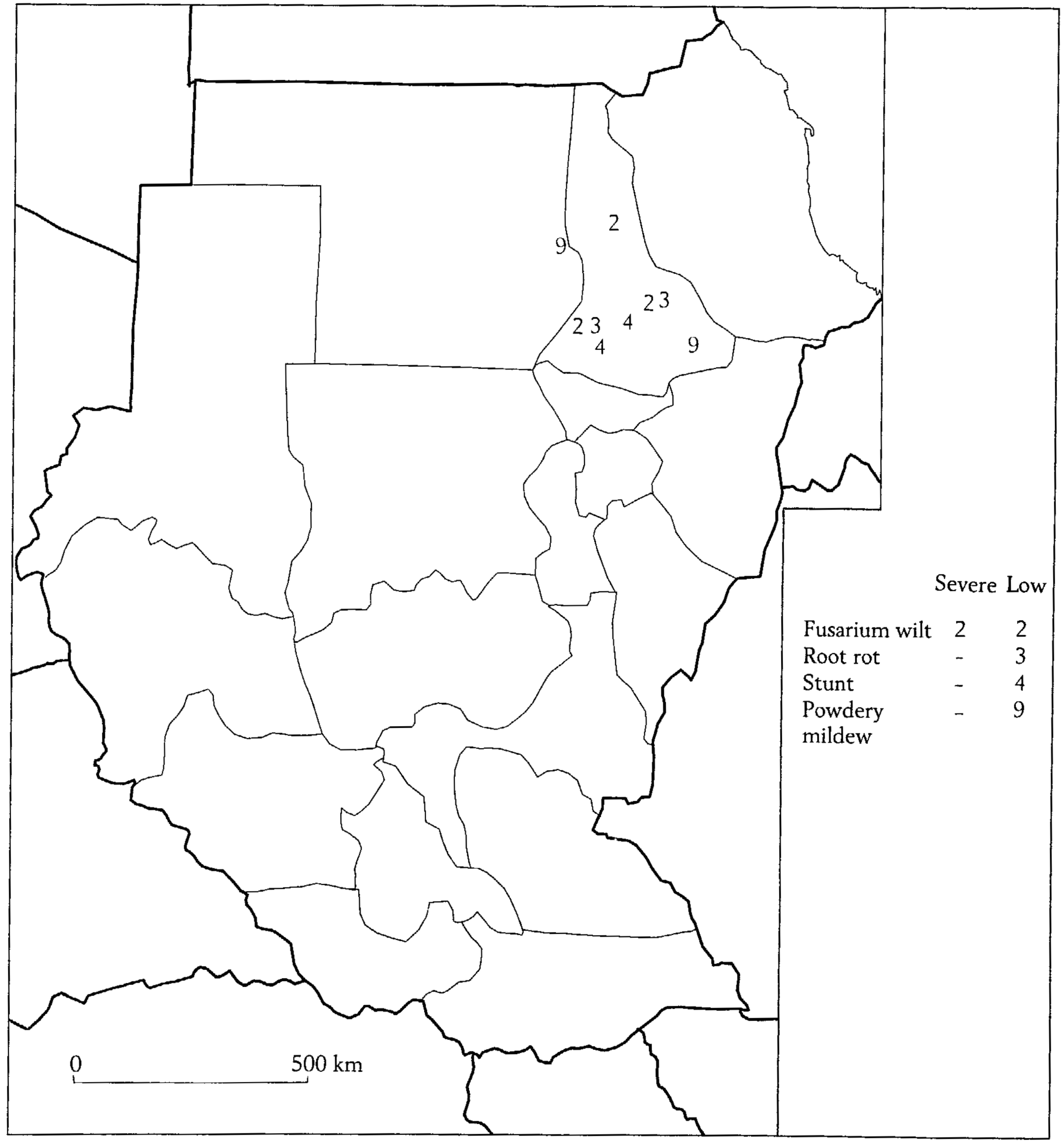

Figure 4.3.10. Disease incidence on chickpea in Sudan.

Insect pests

Insect pests, both in the field and in storage, are very important constraints across all chickpea-growing areas (Fig. 4.3.11). Pod borer (*Helicoverpa armigera*) causes most damage in the flood basins (Faki et al. 1989; Salih 1980). Armyworm (*Spodoptera exigua*) is also reported in those areas but farmers avoid this pest by sowing late in the season. Mole crickets (*Gryllotalpa africana*) are of primary importance in central Sudan. Cutworms (*Agrotis ipsilon*) and pod borers are of secondary significance in this area. Insecticides are generally not used, although sometimes seeds are treated.

Storage pests, particularly bruchids (*Callosobruchus* spp) and beetles (*Trogoderma granarium*) cause considerable damage. High yield loss and deterioration of seed quality because of insect damage during storage, compel farmers to sell the produce immediately after harvest when prices are very low. Traders and retailers also suffer heavy economic losses due to storage losses. Insect-damaged seeds fetch much lower price and are mostly used for making *filafel* or *tamia*, where crushed chickpea seeds are used, while better and more expensive seeds are used for making *bilabel*, a popular preparation where the seeds are kept whole. Apart from periodically exposing the stored seed to the sun, no other control measures are used.

Figure 4.3.11. Insect pest incidence on chickpea in Sudan.

Weeds

Weeds are serious constraints to chickpea production in Sudan causing 26–57% yield losses, depending on location and season (Mohamed et al. 1992). *Cyperus rotundus* and *Amaranthus* sp are most prevalent in the basins, while *Sorghum* sp and *Dinebra retoflexa* are found in areas further north. In the basin area, preparing the land after the fields have been flooded is effective in controlling weeds. If necessary, one hand weeding is done to control weeds in the pump-irrigated areas of northern Sudan. Weed incidence is less severe in central Sudan.

Economic Constraints

Farmers have no means of selling the produce directly in the markets and farm-gate prices are lower than those of retail. Chickpea marketing is monopolized by a few middle men. Chickpea prices are sometimes three times as high at sowing as at harvest. Domestic consumption is small and mostly confined to urban areas. Thus, farmers have little incentive to expand chickpea area in spite of a consistent price rise over time. The lack of proper storage facilities also discourages farmers from storing seed for sowing; therefore, they are obliged to buy it from the open market at the time of sowing, when prices are at their maximum (Ahmed and Bushara 1992). As a result, the cost of cultivation increases and farmers use suboptimal seed rates, which leads to poor plant stands and low yields.

Future Prospects

Future prospects for expanding chickpea production in Sudan are primarily related to the alleviation of marketing constraints. The domestic demand for the crop is low in rural areas because the various uses of chickpea are not known there. Therefore, alternative uses of chickpea need to be promoted. Lowering of retail prices by overcoming yield losses during storage and reducing transport costs should encourage greater use of the crop. Historically, Sudan has been an exporter of legumes, including chickpea; high demand and production may again encourage its export.

Chickpea is being introduced under many irrigation schemes in central Sudan because of its low requirement for water and its good adaptation to poor soil conditions. Despite the low yields, the adaptation of the crop to a wide range of conditions and the attractive price of the produce provide good incentives for its expansion under irrigation, if marketing constraints are alleviated. Potential areas for chickpea expansion are shown in Figure 4.3.12. The scope exists for expansion of the crop both in traditional growing areas and in new areas in central and eastern Sudan.

Future prospects are closely linked to technological improvements in productivity and to profitability of the crop. Benefits of chickpea research, which began in the early 1970s (Salih 1980), are now reaching the farmers. The improved cultivar NEC 2491/ILC 1335, a kabuli type, has been released under the name 'Shendi' (Mohamed 1990). Yields of improved varieties with good management technology were 68% higher than those on the traditional farms in the basins of northern Sudan in the 1991/92 season (El-Sarrag et al. 1992). Crop profitability was high as reflected in a marginal rate of return of 546%.

Current emphasis is on the development of high-yielding varieties with acceptable seed quality, adapted to different production systems (Mohamed 1990). Work on improving the resistance levels to wilt and root rot diseases is in progress (Ali 1992). Attention will now be focused on heat tolerance and early maturity for introducing chickpea in various production systems.

With increased adoption of improved technology, promotion of local consumption, and tapping of export potential, the prospects for increasing chickpea production in Sudan seem promising.

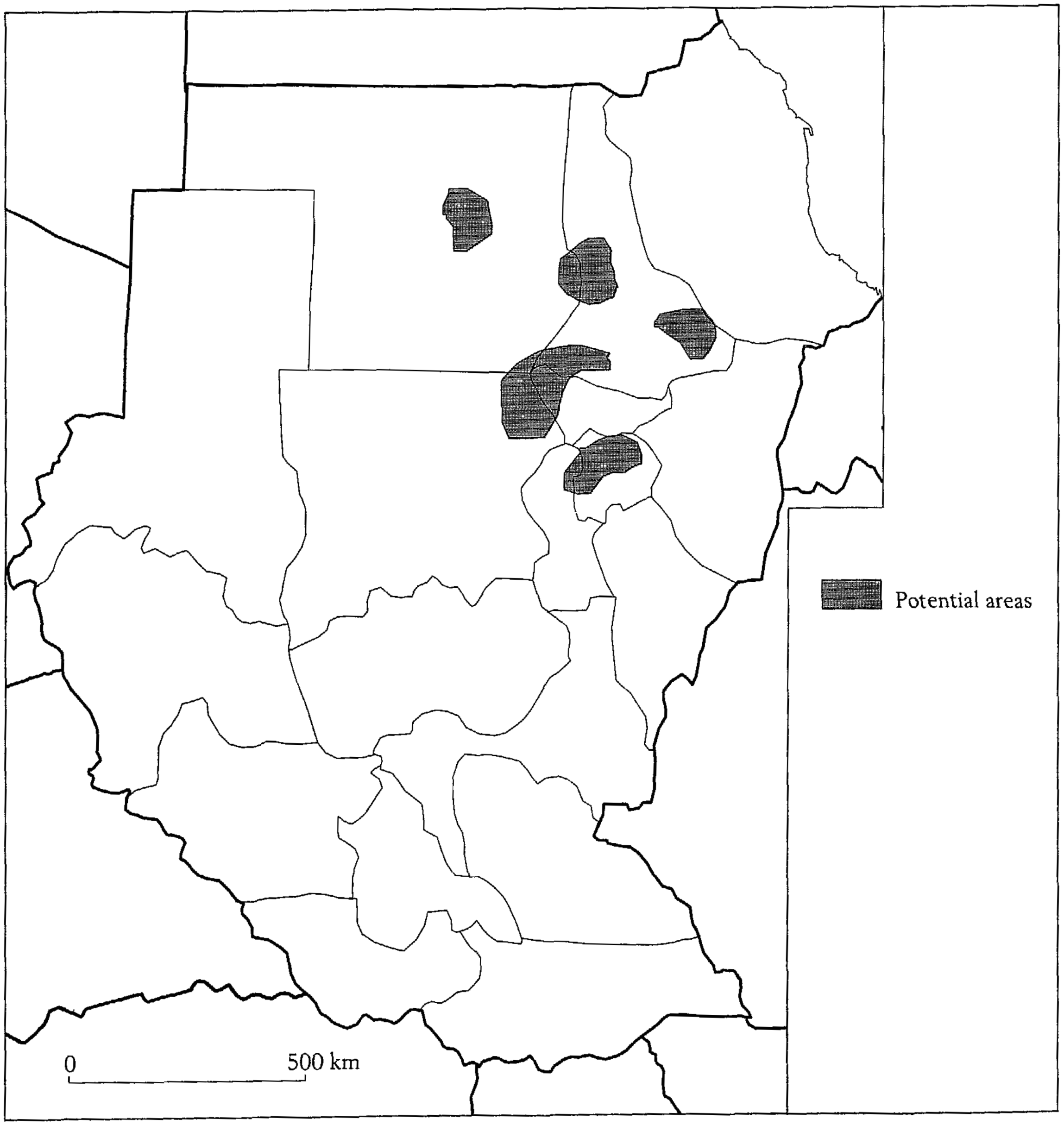

Figure 4.3.12. Potential areas for expansion and/or intensification of chickpea cultivation in Sudan.

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4.4. Regional Summary: Nile Valley

M C Saxena[1] and M B Solh[2]

The Nile Valley (3 to 31°N and 21 to 48°E) is characterized by a very diverse environment with respect to chickpea production. Agriculture in Egypt and Sudan is confined mainly to areas at sea level, while in Ethiopia, chickpea is grown in the highlands, ranging from 1500 to 3000 m. There are large differences in rainfall pattern, thermal regimes, and soil types. These differences in agroecological conditions in the chickpea-growing areas of the three countries of the Nile Valley have been clearly highlighted in Sections 4.1, 4.2, and 4.3.

Chickpea is the second most important food legume crop in the Nile Valley after faba bean. The largest area of chickpea (ranging from 130 000 to 180 000 ha) is in Ethiopia. Currently, nearly 8000 ha in Egypt and 3000 ha in Sudan are sown to chickpea and nearly all of this area is irrigated, in contrast to chickpea in Ethiopia which is predominantly grown as a rainfed crop.

The average yields in the Nile Valley are the highest in the world: 1.75 t ha^{-1} in Egypt, 1.2 t ha^{-1} in Sudan, and nearly 1 t ha^{-1} in Ethiopia. Within the Nile Valley, there are interesting contrasts in the type of chickpea grown and consumed. Ethiopians predominantly grow and consume the desi type, Egyptians the kabuli type, while Sudanese have both. In Ethiopia, there is increasing interest in growing kabuli chickpea in order to regain its earlier position as chickpea exporter.

The production trends have been variable in the three countries; there has been a decrease in chickpea production in Ethiopia over the years and an increase in Egypt and Sudan. The average yields have, however, increased slightly. Recent economic changes in the three countries, leading to removal of restrictions on prices and free disposal of produce in the market, are likely to have a positive influence on future production trends.

The national agricultural research systems (NARS) in all the three countries have developed appropriate production practices and improved cultivars, and verified them in farmers' fields. The benefits of improved technology have been demonstrated to farmers in several major production areas through an effective researcher-extensionist-farmer linkage in the Nile Valley Regional Program (NVRP) operated by the NARS in collaboration with ICARDA.

Amongst the production constraints, the need for inoculating chickpea plants with efficient *Rhizobium* strains has been identified both in Sudan and Egypt through trials conducted under NVRP.

Root rot and wilt diseases, have emerged as important constraints common to the region that need research attention. The major wilt problems are caused by *Fusarium oxysporum*, and in some places by *Verticillium* spp. Collar rot (*Sclerotium rolfsii*), wet root rot (*Rhizoctonia solani*), and dry root rot (*R. bataticola*) are also responsible for causing considerable loss of plant stand in chickpea fields in these countries. Chickpea stunt is commonly observed in all the three countries, but the damage appears to be more in Ethiopia. Ascochyta blight (*Ascochyta rabiei*) is a disease of considerable potential importance in both Egypt and Ethiopia. Particularly in Egypt, where sprinkler irrigation systems are sometimes used for the chickpea crop, great care is needed to prevent the development and spread of ascochyta blight, primarily through the use of disease-free and fungicide-treated seed.

Pod borer (*Helicoverpa armigera*) has been identified as the most important pest in the Nile Valley region, and in parts of Sudan, cutworm (*Agrotis ipsilon*) is also a serious threat. Aphids (*Aphis craccivora*) are particularly important as the vector of some important viruses and have caused some alarm, especially in Egypt where they have recently become more active because of earlier-than-normal

1 Germplasm Program, ICARDA, PO Box 5466, Aleppo, Syria.
2 Nile Valley Regional Program, ICARDA, PO Box 2416, Cairo, Egypt.

warming-up of the season. The high intensity of cropping, particularly in Egypt and Sudan, favors easy transfer of insect pests from one crop to another. Bruchids, both *Bruchus* spp and *Callosobruchus* spp, are important in the region, but good progress has been made in identifying safe methods to store chickpea seeds. In Sudan, some of these methods have been extended to farmers through extension activities. Weeds are an important yield-reducing factor in all the three countries, and integrated weed control techniques have been developed using on-farm research methodology.

Drought has been identified as the most important abiotic stress for chickpea production in Ethiopia and heat in Sudan. Salinity is potentially a constraint in Egypt and Sudan. Waterlogging in the heavy Vertisols of Ethiopia is also a major production constraint, but the research work done on developing the 'broadbed-and-furrow' system has led to practical recommendations for managing this problem in the field. The technology permits farmers to sow chickpea early in the season, giving 50–80% increase in yield compared with the traditional sowing done at the end of the rainy period, when the soil begins to dry up.

Marketing and low farm-gate prices have been identified as the major constraints to increased economic returns to farmers, particularly in Egypt and Sudan. However, with the changing economic scenario and opening up of the economy, the situation is likely to improve, leading to increased incentives for farmers. This could allow them to avoid forced sale immediately after the harvest when farm-gate prices are at their lowest.

Future prospects for expanding the chickpea area in the Nile Valley look promising because of increasing demand for the crop and high retail prices. Chickpea is being introduced in nontraditional areas in all the three countries. In Ethiopia, drought-tolerant cultivars have been recently used in lowland areas. In Egypt, chickpea appears to be the most adapted cool-season food legume in the new areas with sandy and calcareous soil that are being developed and reclaimed from the desert. The crop is being introduced in Sudan in different cropping systems in the new areas of Putatab and Jebal Marra and the traditional areas in Wad Hamid, as it has been recognized to be more drought- and heat-tolerant than lentil and faba bean.

In all the three countries, the importance of the crop in the cropping system is well recognized. For example, in Ethiopia, farmers reduce the nitrogen fertilizer application for their cereal crops after growing chickpea. Thus the crop's importance in sustaining the productivity of low-input agriculture enhances its prospects in such areas.

Through research efforts, improved production packages are available to farmers for use in different cropping systems in the Nile Valley region although research on chickpea has started here fairly recently. In Sudan, improved production packages increased chickpea yield by 68% over traditional practices giving a marginal rate of return of over 500%. Similar results are available from Ethiopia and Egypt. Most of the production constraints are being tackled through on-farm research with emphasis on technology transfer. The increases in prices and in domestic and regional demand for chickpea, as well as the increasing world trade are good indicators for better marketing opportunities and promotion of exports. Therefore, there are good prospects for the Nile valley to expand chickpea production and, for Ethiopia in particular, to recapture its traditional export markets.

5. Critique and Synthesis

5.1. Climatic Adaptation of Chickpea in WANA[1]

G K Walker

Introduction

Apart from Turkey which is the dominant producer, chickpea production is very low in the WANA; only seven countries produce more than 10 000 t annually. In this section, chickpea production will be analyzed in relation to climate in the principal production areas. Ethiopia is not included in the climatic analysis because chickpea environments there are more close to those of the semi-arid tropics than to the rest of WANA.

Climatic Environment

The WANA region has a typical Mediterranean climate, with a cool, wet winter and a hot, dry summer. However, the looseness of this description masks important geographical variations in the means and extremes of temperature, and seasonal distribution of precipitation.

In West Asia, much of the chickpea-growing region is at altitudes above 900 m, and elevation plays an important moderating effect on the thermal environment. In these highlands, the peak precipitation period tends to be in spring (Apr-May) rather than in winter (Dec-Feb).

The range of climates in which chickpea is grown in WANA, therefore, appears to be fairly broad (Table 5.1.1). For example, in the coastal plain regions of North Africa, Jan mean temperatures are typically 10°C or higher, while in northwestern Iran the Jan mean is below zero. However, because the crop is almost exclusively spring-sown, chickpea-growing regions have certain climatic aspects in common. These include a cropping season that begins after the (normal) peak rainfall period, so that the crop is grown on residual moisture; high temperatures (daily maximum near or exceeding 30°C); low mean relative humidity (near or below 50%) during the pod-filling stage; and negligible risk of damage from frost.

Table 5.1.1. Some weather parameters of important chickpea-growing areas in WANA.

Country/Region	Mean annual rainfall (mm)	Wettest month	Mean temperatures (°C)	
			Hottest month	Coldest month
Western Morocco	550	Dec	25	9
Southern Syria	300	Jan	25	8
Southern Turkey	500–600	Jan	27	2
Anatolia	300–800	Apr	23	2
Western Iran	400–550	Apr	27	2
Northwestern Iran	350	Apr	26	–2

Despite these similarities, important environmental differences remain. The sowing date of spring chickpea is related to temperature: the chickpea-growing regions of WANA with the mildest winters have earlier (Feb) sowing, a longer growing season, and shorter mean daylength than the regions that have very cold winters and sowing in May. Thus, in phenological terms, there is a broad spectrum of environments for spring chickpea in WANA.

For winter chickpea, which is sown before the normal peak precipitation period, the important environmental aspects are obviously somewhat different. Tolerance for frost is much more important and for high temperatures less important during the pod-filling stage, than

1. Produced posthumously from the notes and overhead transparencies of Dr G K Walker, ICARDA, PO Box 5466, Aleppo, Syria.

in the case of spring chickpea. However, because the winter crop is new and has not yet been widely adopted, it is not possible to fully describe its preferred climatic settings. This creates an opportunity for a multidisciplinary and systematic, rather than an empirical approach for the popularization of the winter crop in the WANA countries. Identifying regions that meet crop-sensitive climatic criteria is in principle a relatively straightforward task, that should contribute to more streamlined introduction of new germplasm and/or agronomic management packages adapted to the climatic environment.

Chickpea Distribution in Relation to Climate

Climate is one of the several factors that determine chickpea distribution. Other factors include demand for chickpea, prices, competition from other crops, and availability of labor or land. The geographical distribution of chickpea, therefore, is an outcome of a variety of influences, from which isolating the influence of one factor is hazardous. So any climate-based analysis of crop distribution is subject to uncertainties due to interactions with non-climate factors.

Moreover, a full climatic analysis of the distribution is complicated by the nature of published agricultural statistics which are generally used to describe the distribution. These statistics are published based on primary—or at best secondary—national administrative levels, which do not usually respect ecological boundaries (Syria is an exception, since it collects statistics jointly at administrative and ecological levels). Unless very detailed, e.g., sub-district or village-level statistics are available, it is better to use not only agricultural statistics, but also land capability maps and/or legends describing land use. Alternatively, anecdotal or other information on crop distribution can be utilized. These help to avoid fuzziness in describing where a crop is grown, which would in turn lead to difficulties in defining the appropriate climate.

Some country-based findings that contribute to a better understanding of the ecological limits of dryland spring chickpea cultivation are presented below.

Turkey

Chickpea can be grown on the Anatolia plateau (Fig. 2.5.2, Section 2.5) where average annual precipitation is as low as 300 mm (Fig. 2.5.8, Section 2.5), but the average temperature of the hottest month (when the crop is at the pod-filling stage) is only about 22°C (Fig. 2.5.12, Section 2.5). In contrast, in southeast Anatolia (north of the Syrian border), chickpea cultivation is less frequent, even though precipitation is between 400 and 600 mm. Lentil, which is winter-sown, is the predominant food legume in this area. Chickpea is not cultivated in northeastern Turkey as the climate is not warm enough (more than 6 months with mean temperature greater than 10°C is needed). It is also rarely grown where humidity is high, which rules out areas near the northern (Black Sea) coast and the Mediterranean coast.

Syria

Chickpea is grown in the northwest in an extension of the belt in southeastern Turkey (Fig. 2.4.2, Section 2.4), where precipitation averages more than 400 mm (Fig. 2.4.4, Section 2.4) and the mean temperature of the hottest month is less than 28°C. There is some cultivation now in the northeast (maybe 7000 ha) where summers are hotter, but this is mostly winter chickpea. In the Hauran area of southern Syria, the density of cultivation is high (about 7% of the total land area in Daraa province), yet precipitation is on average less than 400 mm, and in some parts less than 300 mm. Despite this, two additional factors contribute to the success of chickpea in this region.

First, the average temperatures are lower than in northwestern Syria, and second, in very dry years farmers may drastically cut back on sown area. By sowing in Mar, farmers already know if there is enough water stored in the soil profile to sustain a spring-sown chickpea crop, as less than 20% of the average Sep-Aug precipitation falls after mid-Mar in this area. Figure 5.1.1 shows the variability of sown area in Daraa and El-Sweda provinces of southern Syria.

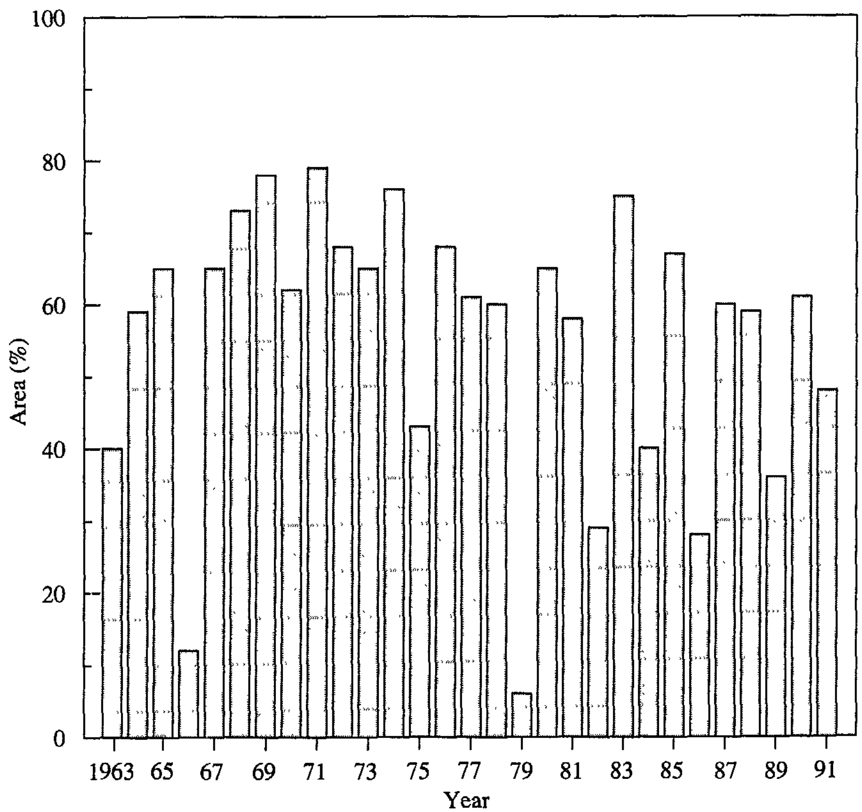

Figure 5.1.1. Yearly variation in chickpea area in Daraa and El-Sweda provinces as percentage of the total chickpea area in Syria.

Iran

Published Iranian agricultural statistics aggregate food legumes, so it is not possible to separate chickpea from lentil and faba bean. However, chickpea is the dominant food legume, so the distribution of food legumes does give a reasonable picture (supported by additional information) of where chickpea is concentrated.

Density of chickpea cultivation is the highest in northwestern and western Iran (Fig. 2.1.2, Section 2.1). In this region precipitation is mostly between 300 and 500 mm, of which up to 50% may fall as snow and is probably less effective than an equivalent amount of rainfall. The average temperature of the hottest month in the dominant provinces for chickpea ranges from 24 to 27°C, and the region has 7 months with an average temperature exceeding 10°C, so summers are about as long, but hotter, than on the Anatolian plateau.

Algeria

Chickpea cultivation is mostly concentrated in the western coastal and adjoining interior plains in a triangle roughly defined by Oran, Sidi-Bel-Abbes, and Tlemcen, and in the eastern coastal and/or interior plains between Skikda and Annaba on the coast, to Guelma, Constantine, and Mila (Fig. 3.1.2, Section 3.1). The eastern region has higher and more reliable rainfall—around 450 to 550 mm on average, while the western region is drier. Spring chickpea cropping mostly occurs between the 300 and 400 mm isohyets. Late (Apr) frost is a concern in the higher areas, and frost combined with drought limits chickpea cultivation in these areas. In the main regions of chickpea cultivation, the temperature of the hottest month is about 25°C.

Morocco

Most spring chickpea in Morocco is produced in areas where annual average precipitation is near or above 500 mm, though some chickpea cultivation is found in areas with about 300 mm (Fig. 3.2.3, Section 3.2). In chickpea-producing areas of Morocco, 10 to 12 months have a mean temperature above 10°C, and the temperature of the hottest month ranges from 22 to 26°C. However, in contrast to most of West Asia, the crop matures well before the hottest time of the year (because of earlier sowing).

Climatic Constraints to Expansion of Chickpea Area

From the above analysis, we can determine that the principal climatic constraints that define the current boundaries of spring chickpea cultivation are:

- Inadequate rainfall to meet evaporative demand, as in southeastern Anatolia, north-central, and parts of northeastern Syria and northwestern Iraq (high temperature stress may also be a limitation), and in the southern parts of the North African countries (Algeria, Morocco, and Tunisia);
- Low summer temperature and a growing season that is too short to achieve crop maturity (northeastern Turkey); and
- High rainfall and humidity, leading to disease constraints and problems of sowing in wet soil (coastal areas of Turkey and Syria), though this seems to be less of a restriction in North African countries.

Prospects for Expanding Chickpea Area

In order to expand the adaptation zone of chickpea in WANA countries, urgent attention is required to find solutions to the constraints listed above. The first of these constraints has received maximum attention from breeders and agronomists who have recommended winter rather than spring sowing to break this climatic barrier. The growing season of winter-sown chickpea would avoid the period of high evaporative demand and temperatures. The largest potential area for expansion is in southeastern Anatolia (Turkey) and extreme northeastern Syria, where precipitation mostly exceeds 400 mm. However, frost is common in Mar for a few days, and may even occur in Apr, so cold tolerance is an important requirement.

Winter chickpea could also replace spring chickpea within the existing zone of adaptation. Regions with minimal risk of frost are obviously most suitable for winter sowing. However, these regions also tend to be relatively wet, and sowing would coincide with the wettest time of the year, e.g., parts of northern Morocco (Fig. 3.2.7, Section 3.2), giving rise to complications due to sowing difficulties, disease incidence, or waterlogging.

Replacing spring with winter chickpea in the relatively dry regions that have low risk of frost (e.g., southern Syria) is a debatable option for farmers, because spring sowing gives them the choice whether or not to sow depending on soil moisture status. However, areas where rainfall—though low—is more reliable than in southern Syria, would be a better option for replacement with winter chickpea.

Winter chickpea may also be a viable alternative to spring chickpea in the extremely cold regions of WANA, i.e., western and northwestern Iran. In Iran, the growing season is short due to the high spring and summer temperatures late in the season, and sowing can be delayed because it coincides with or follows the wettest month (Apr). Yields are consequently low. With autumn sowing, these problems can be avoided. The crop will be insulated by snow for much of the winter, and as air temperature rises very rapidly in spring, late frost may not be much of a threat. Some experimentation with autumn sowing has now begun in western Iran. This could also be adopted in parts of the Anatolian plateau.

Chickpea Yield and Production in Relation to Climate

The mean chickpea yields in WANA range from less than 0.5 t ha^{-1} (Algeria) to about 1 t ha^{-1} (Turkey) (Fig. 5.1.2). The high yields in Turkey are not surprising in view of the relatively high mean rainfall, and the relatively low summer temperatures on the Anatolian plateau where most of the crop is grown. Yields in Algeria seem low for WANA, given the importance of the crop in the eastern Guelma-Skikda region, which has an average precipitation of around 500 mm.

Chickpea yield, however, does not give a complete picture of the impact of weather variability on its production. For example, in Syria, farmers reduce the area sown to chickpea if they judge conditions to be too dry to obtain a profitable yield. In the important southern provinces of Daraa and El-Sweda, the average annual precipitation is among the lowest (Fig. 2.4.4, Section 2.4) in the main chickpea-producing regions in WANA. When precipitation is below the average in these provinces (as in 1979 when Izra weather station recorded only 140 mm—about 50% of normal), farmers may not sow the crop at all.

Chickpea yield trends in Turkey, Syria, and Algeria are shown in Figure 5.1.2. The most striking aspect of this figure is the lack of any positive yield trends. In Turkey the slightly negative trend is most likely related to the replacement of fallow lands with chickpea, and so a shifting of chickpea cultivation to drier conditions has occurred since 1980, when the fallow replacement program began in earnest. In Syria and Algeria, chickpea yield shows a negative trend over the 1980s. In Algeria, yield is negatively correlated with area.

The absence of positive yield trends implies either a deteriorating climate that offsets any technological gains, or a systematic shift to drier areas, or, alternatively, limited technological advances and/or slow adoption by farmers. Given that the phenomenon is widespread across WANA, the last explanation seems most likely.

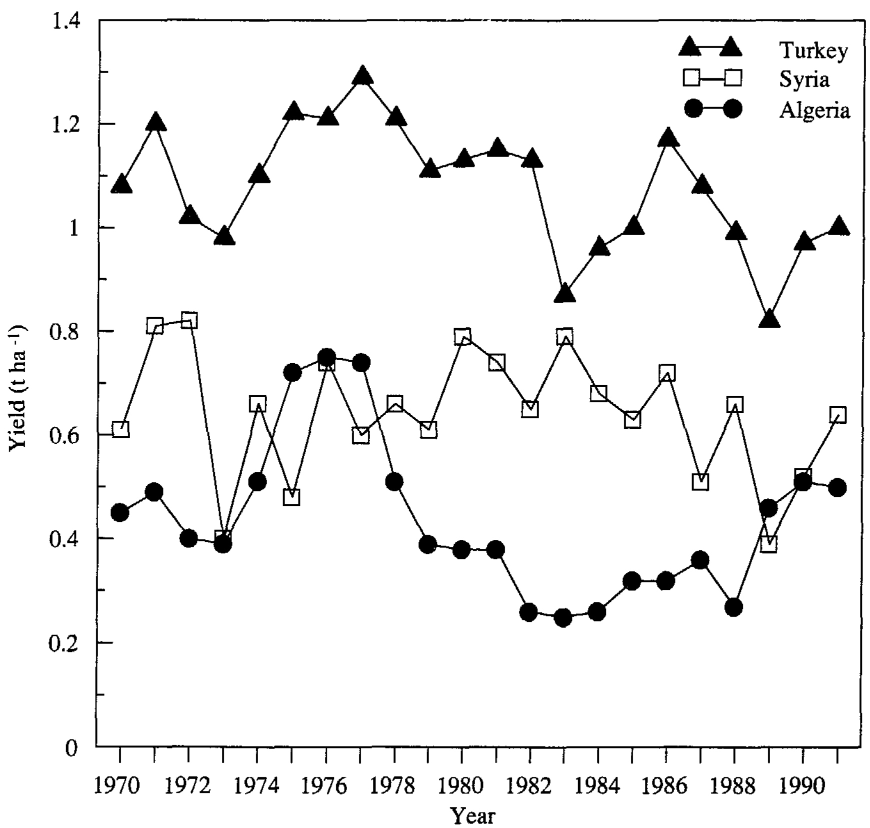

Figure 5.1.2. Yearly variation in chickpea yield in three important chickpea-growing countries in WANA.

Fallow Replacement by Chickpea

In Turkey replacement of fallow over the last decade or so, especially by lentil and chickpea has been very high (50%). Together, these two crops have replaced about 1.5 million ha of fallow since 1980. Fallows were replaced in areas where the production from continuous cropping exceeded that from fallow cropping over the 2-year cycle depending on precipitation, soil depth, temperature, and relative humidity. A climatological index was derived to predict where fallows could be replaced. Areas recommended to be retained under fallow have less than 400 mm annual average precipitation. This can be used as a guideline for other countries for fallow replacement.

Iran has about 6 million ha of fallow (M Pala, ICARDA, unpublished), the bulk of which lies in areas too dry to contemplate continuous cropping. Fallows are being replaced in Iran to some extent, particularly in Bakhtaran province, most of which receives 400–550 mm annual average precipitation. Bakhtaran has about 340 000 ha of cereals, 120 000 of fallow, and about 70 000 ha of chickpea. Chickpea area is increasing at the expense of fallow there, and elsewhere in the country, as the food legume area increased steadily from 430 000 to 617 000 ha between 1984 and 1989. There appears to be good potential for fallow replacement by food legumes in the relatively wet west-central provinces of Bakhtaran, Lorestan, Ilam, and Kordestan (Fig. 2.1.4, Section 2.1). Prospects for fallow replacement in the drier areas of the northwestern region are more marginal (western and eastern Azerbaijan, Hamadan, and Zanjan).

In Algeria, there are about 1.5 million ha of fallow, of which about 25% lies in areas where annual precipitation exceeds 400 mm (Section 3.1). This offers some scope for increased cropping intensity.

Syria has minimal prospects for replacing fallow with food legumes, as farmers are already required to practice continuous cropping above a certain rainfall isohyet.

Fallow area in Morocco is estimated at more than 2 million ha and in Tunisia at 0.4 million ha (M Pala, ICARDA, unpublished). The potential for significant replacement certainly exists in these countries.

Summary and Conclusions

The total area sown to chickpea in WANA has several constraints, including adverse climatic factors. To expand the zone of adaptation, it would be necessary to have new germplasm or management practices that would overcome the current climatic barriers. The primary barriers in different parts of the region are:

- High summer temperatures and/or low precipitation, sometimes in combination with risk of winter/spring frost (southeastern Anatolia, north-central and northeastern Syria, and parts of North Africa);
- Low summer temperatures (northeastern Turkey); and
- Wet/humid conditions (coastal regions throughout WANA).

Within existing areas of adaptation, the best chances for replacing spring with winter chickpea exist in places where:

- Risk of frost is low and precipitation, although not high, is relatively reliable (possibly near coastal areas of North Africa); and
- Winter snow fall is sufficient to insulate the crop (wetter parts of western Iran, and possibly parts of the Anatolian plateau).

Winter or spring chickpea may be a suitable crop for replacing fallow in Morocco, Algeria, Tunisia, and Iran.

Average chickpea yields in WANA appear to be unaffected by technology over the last 20 years. Yields could be improved by making the crop cycle shorter to increase transpiration at the expense of evaporation from the soil surface, and to maximize the transpiration that is achieved at low air saturation deficit. Together, these changes would bring about dramatic improvements in water-use efficiency. Based on experience with cereals that are dual-purpose, and on paired yield trials of winter and spring chickpea, this is the surest way of bringing about yield gains.

5.2. Comparisons of Abiotic Constraints to Chickpea Production in WANA and SAT

C Johansen[1], N P Saxena[1], and M C Saxena[2]

Introduction

The major objective of this section is to summarize abiotic constraints affecting chickpea production across the WANA region. These constraints will be compared with those in the SAT. For this purpose, the chickpea-growing regions of South Asia will be considered as representative of SAT environments, although it is recognized that the crop is grown, but to a much lesser extent, in other SAT environments such as in Australia, Mexico, and eastern Africa. These constraints will then be prioritized in terms of yield loss and potential for alleviation, on the basis of current knowledge. Ways of appropriately mapping these constraints using geographic information systems (GIS) technology will also be considered. It is intended that these efforts will assist in the formulation of relevant research agendas aimed at alleviation of the stresses, with rational allocation of tasks between national agricultural research systems (NARS) and international agricultural research centers (IARC).

The major difference between the chickpea-growing environments of WANA and SAT is the pattern of rainfall, temperature, and photoperiod during the year. In the Mediterranean environment of WANA, the main rainfall period coincides with the period of lowest temperatures and shortest photoperiods. Chickpea can be sown at either the beginning (winter sowing) or the end (spring sowing) of the main rainy season, but in both cases, the crop is exposed to a period of increasing drought and heat stress. Chickpea-growing areas of the SAT on the other hand, normally receive most of their rainfall during the high-temperature, long-day period of the year. Chickpea is generally sown after the rainy season on residual soil moisture in the cooler part of the year. These differences in climatic patterns and cropping systems provide the basis for differences and similarities in the moisture- and temperature-related stresses facing chickpea in WANA and SAT. Underlying these climate-based differences are the differences in soil types across regions. But in this case, similarities predominate as, across each region, chickpea cultivation is mainly confined to soils with high clay content, high water-holding capacity, and neutral to alkaline reaction.

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Prioritization of Constraints

Important abiotic constraints are:

- Water deficit (drought);
- Excess of water (waterlogging);
- Low temperature (cold);
- High temperature (heat);
- Deficiencies of essential mineral elements; and
- Mineral toxicities (including salinity).

The degree to which these constraints impose a limitation to chickpea yield in each country of the WANA and SAT regions was ranked and an attempt was made to estimate the potential for alleviation of each constraint, through a concerted research and extension effort (Tables 5.2.1 and 5.2.2.).

This evaluation takes into account abiotic constraints to currently cultivated varieties that are generally adapted to the region where they are normally grown, (e.g., they have the appropriate photoperiod response and phenology). The estimates are based on both published and judgmental information, as explained by Johansen et al. (1994).

Constraints in WANA

Drought stress, especially terminal drought stress, is by far the most serious yield reducer of chickpea across the WANA region (Table 5.2.1). It results from exhaustion of the stored soil moisture and rising atmospheric evaporative demand before the pod-filling phase is complete. Terminal drought stress and the limited wet season in Mediterranean climates dictate early flowering. Countries where terminal drought stress is not a serious problem include those where chickpea is grown in higher rainfall zones, such as Turkey and Ethiopia, or where it is widely irrigated, such as Egypt. Waterlogging damage to chickpea can occur in zones where heavy rainfall occurs after sowing and soils have a high clay content and poor drainage (Table 5.2.1).

Low temperature stress becomes increasingly severe with increase in latitude, such as in Turkey (Table 5.2.1). Cold stress (sub-zero temperatures with frost) injures or kills plants at the seedling or early vegetative growth stage, as the crop is sown either just before, during, or just after the coldest period of the year. By contrast, high temperature stress effects on chickpea become important as low latitudes are approached, unless they are moderated by high altitude as in Ethiopia (Table 5.2.1). Temperatures above 30°C interfere with pod filling (Summerfield et al. 1984). Mediterranean climates are characterized by rapid increases in temperature in spring, where chickpea faces forced maturity under the combined effects of terminal drought and heat stress. High temperature stress assumes importance as a yield reducer for irrigated chickpea at lower latitudes, as in Egypt.

Table 5.2.1. Ranking[1] of abiotic constraints of chickpea and their potential for alleviation[2] in the major chickpea-producing countries of WANA (adapted from Johansen et al. 1994). Area and yield estimates for 1990 are indicated (FAO 1991).

Production/	West Asia			North Africa				
Constraint	Iran	Syria	Turkey	Algeria	Egypt	Ethiopia	Morocco	Tunisia
Area ('000 ha)	112	55	800	60	8	130	27	45
Yield (t ha^{-1})	0.72	0.66	1.08	0.33	1.75	0.97	0.77	0.62
Drought	1C	1B	3C	1B	×	3B	1B	1A
Waterlogging	–	–	×	×	?A	?B	×	×
High temperature	3C	3C	×	2C	2C	×	2C	2C
Low temperature	3A	2A	2A	3B	×	×	3B	3B
High soil pH	×	×	×	3C	2C	?C	3C	3C
Low soil pH	×	×	×	×	×	?C	×	×
Salinity	2C	3C	×	–	–	–	–	–
N_2 fixation	?A	3A	3A	3A	3A	?A	3A	3A
P deficiency	3A	3A	3A	–	–	–	–	–

1. Ranking of constraints: 1 = Severe yield reducer (> 50% yield loss in some years); 2 = Moderate yield reducer (15–50% yield loss across years); 3 = Minor yield reducer (< 15% yield loss in any year); ? = Problem suspected but status unknown; × = Known to be not a problem; – = Inadequate or no knowledge concerning the problem.
2. Potential for alleviation: A = High (regional production breakthrough probable in the medium term, e.g., 3–7 years); B = Moderate (production breakthrough possible over the longer term, e.g., 7 years); C = Low (only marginal improvement expected or substantial improvement only after a decade or more).

Sources: Smithson et al. 1985; Saxena, M.C. 1987; Saxena and Singh 1987; Summerfield 1988; van Rheenen and Saxena 1990; Wolde Amlak et al. 1990.

Nitrogen (N) and phosphorus (P) deficiencies are the most frequently cited nutrient deficiencies for WANA (Table 5.2.1). Some deficiencies associated with alkaline soils, such as iron (Fe) or zinc (Zn), are also known to reduce chickpea yields. However, reports of yield reductions due to other nutrient deficiencies are rare, but it is not clear whether they indeed do not exist or are yet to be diagnosed. The predominant mineral toxicity stress facing chickpea in most WANA countries is salinity (Table 5.2.1). Salinity is widespread throughout the region (UNEP 1992), but chickpea cultivation is avoided in saline zones, even if the climate may be suitable, as this crop is particularly sensitive to salinity (Subbarao and Johansen 1994).

Comparison with SAT

As in WANA, drought is the major abiotic constraint of chickpea in South Asia (Table 5.2.2). In this region also, terminal drought stress is the prime manifestation and there is a clear increase in severity as lower latitudes are approached (Saxena, N.P. 1987). Waterlogging (surface soil saturation) is only an important consideration in Bangladesh, where excessive winter rainfall is received in poorly drained rice fallow fields in which chickpea is normally grown (Table 5.2.2). However, in the subtropics of South Asia, soil water close to field capacity causes excessive vegetative growth leading to crop lodging and susceptibility to such foliar diseases as botrytis gray mold or ascochyta blight.

In chickpea-growing areas of the SAT at higher latitudes, freezing temperatures are not so frequent or severe as to cause plant death. Extremely low temperatures occur at the early reproductive stage and temperatures in the range of 0–10°C prevent or delay pod setting (Saxena 1980a). Consequently, the vegetative growth stage is extended causing the reproductive stage to be postponed to a period when conditions are more favorable for insect pest (e.g., *Helicoverpa* pod borer) and foliar disease incidence, and towards maturity, the crop is exposed to terminal heat and drought stress. This is the type of cold stress referred to in Table 5.2.2. The terminal heat stress facing chickpea in SAT environments (Table 5.2.2) is the same as in WANA. It becomes particularly important for chickpea if it is sown after the optimum sowing time, which is usually the case for chickpea grown in rice fallows, a major cropping pattern in South Asia. As in WANA, it is also an important stress for irrigated chickpea at low latitudes.

The occurrence and extent of nutrient deficiencies and salinity affecting chickpea production are similar between SAT (Table 5.2.2) and WANA (Table 5.2.1).

Table 5.2.2. Ranking[1] of abiotic constraints of chickpea and their potential for alleviation in the major chickpea-producing countries of South Asia (adapted from Johansen et al. 1994). Area and yield estimates for 1990 are indicated (FAO 1991).

Production/ Constraint	Bangladesh	India	Myanmar	Nepal	Pakistan
Area ('000 ha)	100	6495	134	28	1002
Yield (t ha^{-1})	0.65	0.65	0.75	0.59	0.54
Drought	2B[1]	1B	1C	3C	2B
Waterlogging	3C	–	–	–	–
High temperature	2C	2C	3C	×	3C
Low temperature	3C	2B	×	2C	2C
Lodging[2]	3C	3C	?C	×	3C
High soil pH	×	3C	×	×	3C
Low soil pH	3C	×	?C	3C	×
Salinity	×	2C	×	×	2C
N_2 fixation	3A	3A	3A	3A	3A
P deficiency	2A	3A	3A	3A	3A
S deficiency	2A	–	–	–	–
B deficiency	3A	–	–	–	–

1. See Table 5.2.1 for definition.
2. Exacerbated by wind, heavy rain, or hail.

Sources: Smithson et al. 1985; Saxena, M.C. 1987; Saxena and Singh 1987; Baldev et al. 1988; Summerfield 1988; van Rheenen and Saxena 1990; Jagdish Kumar 1991.

Representation of Constraints

Abiotic constraints to chickpea can generally be clearly depicted on GIS as they depend on climate and soil databases, which are generally more comprehensive and stable over time than those available for biotic constraints. Plots of length of growing period (LGP), calculated from rainfall, potential evapotranspiration (PET), and soil water-holding characteristics (FAO 1978), best depict zones prone to terminal drought stress. It should also be possible to depict variability of LGP across years, based on annual variation in rainfall. Areas prone to waterlogging can also be easily depicted, as indicated by excess of rainfall over PET and soil water infiltration and water-holding characteristics.

Temperature isotherms, which are generally readily available, can be used to define zones where chickpea is subject to heat or cold stress at sensitive stages of the growth cycle. Probability considerations also apply here, as temperature extremes can show considerable annual variation although mean temperatures may not vary much from year to year. It is necessary to know the probability of occurrence of temperature extremes to assess the expected impact of genetic improvements in low or high temperature tolerance.

Nutrients maps, drawn by plotting zones of similar values of soil chemical tests for nutrient availability, have been used to depict zones of probable nutrient deficiencies (e.g., Ghosh and Hasan 1979). These zones normally correspond with particular soil classes, for which soil maps are also generally available. However, it is rare that soil chemical tests have been adequately calibrated against crop yield response. Secondly, there is likely to be large field-to-field variation in crop response to nutrient application due to effects of cropping and fertilizer history. Thus, nutrient maps at a country level can only give a very approximate depiction of yield loss due to nutrient deficiency. On the other hand, soil measurements of mineral toxicities can reasonably well predict crop performance, as critical levels are more clear-cut. Salinity maps are available for the major chickpea-growing regions of the world (e.g., UNEP 1992).

Alleviation of Abiotic Constraints

Prospects for expanding the area of irrigated chickpea, to alleviate drought effects on the crop, are quite good in both WANA and SAT but the motivation to do so depends on economic considerations. As the emphasis of the Chickpea in WANA Project is mainly on rainfed chickpea, ways to maximize yield in water-limited, rainfed environments will be considered here. First of these is the use of short-duration varieties so that the crop can escape from terminal drought stress, but as the crop duration is shortened, its yield potential also declines (Saxena, N.P. 1987). The crop duration of traditional landrace varieties is such that they usually face terminal drought stress in areas where they have evolved. Fitting of appropriate crop phenology can be conveniently guided by LGP maps. In peninsular India, progress has been made in developing varieties that are better able to escape terminal drought stress and it is recommended that this approach be used more widely.

Another way to escape terminal drought stress is to advance the sowing date. This has been successfully exploited in the development of winter chickpea technology for WANA (Singh 1987). It has relied on the development of genotypes that have resistance to cold and ascochyta blight. This is a good example of a combined agronomic and genetic approach to escaping drought. Advancement of sowing date to escape drought has also been tried in peninsular India. Significant yield advantages have been obtained by advancing sowing by 1 month from the normal sowing date of mid-Oct (ICRISAT 1984). However, this has limited scope for widespread application in South Asia, because: (a) a rainy-season crop would prevent early sowing of a subsequent chickpea crop; (b) sowing is difficult in heavy soils until after the rainy season; and (c) early-sown chickpea is susceptible to high temperature and disease (e.g., *Colletotrichum* blight) stresses.

Even with appropriate fitting of crop phenology to the probable period of soil moisture availability, there are further options for minimizing effects of drought stress, by exploiting drought resistance mechanisms. These include more exploitative root systems, smaller leaf area, large seed size, and twin pods at basal nodes (Saxena and Johansen 1990). Genetic progress in yield under drought has been achieved by selecting plants with larger root systems (ICRISAT 1993).

As waterlogging is not a very widespread problem for chickpea, it does not need much attention. Agronomic methods, such as suitable drainage systems, would be effective in checking this problem wherever it occurs.

Although manipulating the sowing date would help the plant to escape from low or high temperature constraints, it is not always practical to do it keeping in view other factors such as cropping system pattern and soil-water availability. Thus, it is necessary to enhance tolerance for extremes of temperature through genetic means. Progress in genetic incorporation of cold tolerance, along with resistance to ascochyta blight, has facilitated winter sowing technology in WANA (Singh 1987), and there are prospects for further enhancing cold tolerance by transferring the trait from related wild species (Singh 1993). In SAT, genotypes with the ability to set pods at low temperatures in sub-tropical winters have been identified and are being used in breeding programs (van Rheenen et al. 1990). However, improved sources of cold tolerance for SAT conditions and their incorporation into suitable agronomic backgrounds are still needed.

Genotypes with shorter duration than locally adapted landraces will also escape terminal heat and drought stress. But sources of heat tolerance at the pod-filling stage in both WANA and SAT, and also at the seedling stage to allow early sowing in SAT environments, will have to be identified. Although field techniques for screening for heat tolerance appear simple—by growing chickpea with irrigation in such a way that the critical growth stage coincides with a hot period (e.g., maximum temperature above 35°C), little research has been reported in this regard.

Mineral imbalances are normally best tackled through management, particularly by adding fertilizers and amendments to overcome nutrient deficiencies. Some micronutrient deficiencies, such as that of Fe, can be alleviated through genetic improvement because of large genotypic differences in response and ease of screening for the distinctive symptoms (Saxena 1980b). As the cost of fertilizers and amendments will certainly go up in future, genetic improvement in the crop's ability for nutrient acquisition and efficiency of nutrient use is a viable research goal. Chickpea is adapted to alkaline soil because it can, more than many other crops, exude acids from its root system (Marschner and Römheld 1983). These acids can dissolve precipitated forms of P and perhaps other essential nutrients (Ae et al. 1991). Genetic differences with regard to this property need to be systematically explored in chickpea as well as differences in the crop's ability to access and use other nutrients that may be deficient (e.g., Zn). Aspects of N nutrition of chickpea are covered in Section 5.5.

Good sources of salinity tolerance need to be identified for genetic improvement of salinity tolerance (Saxena et al. 1993). Landrace types or related wild species that have evolved in moderately saline habitats offer the best prospects for this; but little work seems to have been done in this area.

Conclusions

Geographic information systems can adequately depict abiotic stresses of chickpea and are therefore a valuable guide to constraint analysis and formulation of research priorities. Such depiction can assist in demonstrating the extent of problems and can indicate the possible gains from research on these problems. The use of GIS can complement earlier attempts to define crop suitability in relation to soil and climatic factors, as was done in the FAO Agroecological Zones Project, on a global basis (FAO 1978). However, it is now possible to define more clearly the constraining factors to yield than in that project. For example, more sophisticated soil-water balance models can be used to more accurately calculate the period over which soil water is available for use by the crop (i.e., LGP). Analyses of abiotic stresses, aided by GIS, are perhaps best done at the country level, or separately for major agroecological divisions of large countries such as India, in order to achieve the necessary degree of precision for decision-making.

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5.3. Chickpea Diseases: Distribution, Importance, and Control Strategies

S P S Beniwal[1], M P Haware[2], and M V Reddy[2]

Introduction

Chickpea, the third most important grain legume crop in the world, is traditionally grown as a spring-sown crop in WANA, and as a postrainy season crop in East Africa on conserved soil moisture. In South Asia, it is grown as a winter-season crop. Decreasing trends in chickpea production and yield in WANA and SAT are considered to a large extent to be due to disease incidence.

Although more than 70 pathogens have been reported so far on chickpea from different parts of the world (Nene et al. 1984), only a few of them are widespread and internationally important. These include ascochyta blight (*Ascochyta rabiei*), botrytis gray mold (*Botrytis cinerea*), fusarium wilt (*Fusarium oxysporum*), dry root rot (*Rhizoctonia bataticola*), and stunt virus. These diseases are responsible, to a large extent, for the instability in the yield of the crop in the major production areas in the world. Of these, on a global basis, ascochyta blight and fusarium wilt are the two most important diseases. In this section, the distribution and importance of chickpea diseases and strategies for their control in WANA, East Africa, and South Asia are discussed.

Important Diseases of Chickpea

The important diseases affecting chickpea in WANA, East Africa, and South Asia and their relative importance are listed in Table 5.3.1. The major diseases in different regions, in decreasing order of importance, are:

West Asia: Ascochyta blight, fusarium wilt, stunt, and diseases caused by nematodes;

North Africa: Ascochyta blight, fusarium wilt, stunt, and seed and seedling diseases;

East Africa: Fusarium wilt, dry root rot, stunt, and seed and seedling diseases;

South Asia: Fusarium wilt, ascochyta blight, dry root rot, botrytis gray mold, stunt, and seed and seedling diseases.

Table 5.3.1. Major diseases of chickpea and their relative importance in West Asia, North Africa, East Africa, and South Asia.

Disease	West Asia		North Africa		East Africa	South Asia
	W[1]	S[1]	W	S		
Seed and seedling diseases	3[2]	3	3	5	5	5
Ascochyta blight	9	9	9	9	1	8
Botrytis gray mold	1	1	1	1	1	6
Fusarium wilt	3	5	5	7	7	9
Dry root rot	3	3	3	3	7	7
Stunt	3	5	3	5	5	5
Diseases caused by nematodes	3	3	2	2	-[3]	3

1. W = Winter-sown, and S = Spring-sown chickpea.
2. Rated on a 1-9 scale, where 1 = not important; 3 = slightly important; 5 = moderately important; 7 = important; 9 = very important.
3. Information not available.

1. ICARDA Regional Program, PO Box 39, Emek, 06511, Ankara, Turkey.
2. Crop Protection Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Ascochyta blight

Ascochyta blight is reported from almost all the chickpea-growing countries in WANA, East Africa, and South Asia as a major and widespread constraint to chickpea production (Nene 1984). Infected seeds and diseased crop debris are the main sources of primary inoculum for the development of the disease.

Fusarium wilt

Fusarium wilt is widespread and known to occur in most of the chickpea-growing countries of these regions. However, it is particularly important in Tunisia, Morocco, Iran, Ethiopia, India, and Pakistan. The disease is seed- and soilborne. It can survive in the soil in the absence of a host for more than 6 years (Haware et al. 1990).

Dry root rot

Dry root rot is known to occur in Ethiopia, Iran, Lebanon, Syria, India, and Pakistan. The disease is more important in central and southern India, and in Ethiopia (Beniwal et al. 1992), and is much less important in WANA. The causal fungus is soilborne through black sclerotia that serve as the chief source of inoculum.

Botrytis gray mold

Botrytis gray mold is the second most important foliar disease of chickpea. It has been reported from Bangladesh, India, Nepal, Pakistan, and Turkey. The fungus is seedborne and also survives as black sclerotial bodies on infected seed and plant debris.

Stunt virus

Chickpea stunt, caused by the bean leaf roll virus (BLRV) and other related viruses belonging to the luteovirus group, is the most important viral disease of chickpea. The disease has been observed in Algeria, Libya, Morocco, Tunisia, Lebanon, Syria, Turkey, Egypt, Ethiopia, Sudan, Bangladesh, India, and Pakistan. The causal virus is phloem-specific and not transmissible mechanically.

Seed and seedling diseases

Seed and seedling diseases (*Sclerotium rolfsii*, *R. solani*, *F. solani*, *Pythium ultimum*) are important in those chickpea-growing regions where soil moisture is abundant at the seedling stage. These diseases can kill seedlings up to 6 weeks after the seeds are sown and can thus adversely affect plant stand and yield. They are known to occur in India, Pakistan, Bangladesh, Egypt, Ethiopia, Sudan, Iran, Syria, Turkey, Tunisia, and Morocco.

Nematodes

Among the nematodes that infect chickpea, the root-knot nematodes *Meloidogyne incognita* and *M. javanica* are important in India and Nepal, and *M. artiella* in Syria (Nene and Sheila 1992). The chickpea cyst nematode (*Heterodera ciceri*) and the root-lesion nematode (*Pratylenchus thornei*) have caused marked yield losses in Syria (Greco 1987). The reniform nematode (*Rotylenchulus reniformis*) is also a common pathogen on chickpea in India (Greco and Sharma 1990).

Crop Losses

Although information on crop losses caused by ascochyta blight in all the countries is not available, severe incidence of the disease in several countries has resulted in heavy crop losses. In Pakistan, the disease caused extensive losses in 1980 (48%), 1981 (up to 15%), and 1982 (42%). The damage in Pakistan caused a shortfall in chickpea production and resulted in massive imports of pulses (US$ 7.45 million) in 1982/83 (Malik 1986). In 1971, Morocco lost US$ 10 million worth of chickpea harvest due to ascochyta blight. In Syria, the crop loss to the disease ranged from 5–30% in 1981/82, while 40% loss was reported from Tunisia in 1981. Susceptible chickpea varieties are completely killed by the disease, whereas yield reduction in resistant cultivars (ILC 183 and ILC 202) is less than 10% (Reddy and Singh 1990a).

No precise information on losses caused by fusarium wilt in chickpea is available. An annual loss of US$ 1 million was reported from Pakistan (Sattar et al. 1953) and an annual average of about 10% is roughly estimated for India (Singh and Dahiya 1973). At ICRISAT, early wilting caused a greater loss than late wilting (Haware and Nene 1980). Seeds harvested from late-wilted plants were lighter than those from healthy plants and dull in color.

Botrytis gray mold of chickpea occurs in epiphytotic form in Bangladesh, Nepal, Pakistan, and in northern India. During 1978/79, the disease destroyed around 20 000 ha of chickpea in the *Tal* area of Bihar state in India. In 1980/81, it caused serious losses in the northern states of India (Grewal and Laha 1983). During the 1987/88 season, the loss due to the disease in Nepal was estimated to be 40% (Reddy et al. 1988).

Yield loss estimates due to stunt are not available, although it is particularly serious in northern India, Pakistan, Ethiopia, and Tunisia. Infection during early stages of plant growth leads to a total yield loss. If plants survive up to the pod-setting stage, very few pods are produced. Many plants die prematurely (Nene and Sheila 1992).

No precise information is available on the yield loss due to nematode diseases of chickpea. However, survey results indicated that losses due to root-knot nematodes in India could be negligible to very high in many parts of India, and in the *Terai* region of Nepal (Greco and Sharma 1990). In Syria, damage due to *M. artiella* was found to be more severe in spring than in winter chickpea. The chickpea cyst nematode is reported to cause complete crop failure in fields infested with more than 64 eggs g^{-1} of soil (Greco 1987).

Present Status of Disease Control

So far, the major emphasis on controlling chickpea diseases has been the use of chemicals, cultural practices, and host-plant resistance.

Chemical Control

Foliar sprays of fungicides have been tested in controlling ascochyta blight and botrytis gray mold. These are generally ineffective and uneconomical in susceptible varieties under epiphytotic situations. Moreover, these are not popular with farmers. However, their use in controlling seedborne infection is very effective. Calixin-M® (11% tridemorph + 36% maneb) and thiabendazole (Tecto-60®) eradicates seedborne inoculum of *A. rabiei* effectively (Reddy and Kabbabeh 1984). Seedborne inoculum of fusarium wilt can be successfully eradicated by seed dressing with Benlate-T® (benomyl 30% + thiram 30%) at 1.5 g kg^{-1} of dry seed (Haware et al. 1978). Similarly, seedborne *B. cinerea* can be eradicated through dry-seed dressing with vinclozolin (Ronilan®), a combination of methyl benzimidazole carbamate (MBC) + thiram or MBC alone (Grewal and Laha 1983). Preemergence damping-off phase of dry root rot is reduced by seed treatment with captan, thiram, or PCNB at 2.5 g kg^{-1} of seed.

Cultural Practices

Certain cultural practices have been used to control/reduce diseases of chickpea. Use of crop rotation, clean cultivation (removal of diseased crop debris), and deep plowing (10 cm and deeper) have been recommended to eliminate or reduce the primary source of *A. rabiei* inoculum. Use of healthy seed has been recommended to control the seedborne primary inoculum. For northern India, cultivars that can mature by the end of Feb, should be able to escape the severe effect of the disease in Mar (Nene and Sheila 1992).

Clean cultivation and use of healthy seed is recommended against botrytis gray mold. Use of cultivars with erect and compact growth habit at wider spacing is known to reduce disease severity.

Normal crop rotations are not effective against fusarium wilt as the fungus can survive in the soil for up to 6 years. In India, the disease decreased when sowing was delayed until Oct or Nov when it is cooler than in Sep, when the crop is traditionally sown. Soil amendments with oilseed meal reduced the fungus population in soil and also the disease incidence. In WANA, winter-sown chickpea is observed to have loswer wilt incidence than the spring-sown crop. Use of inoculum-free seed is important to guard against the chances of introduction of the pathogen into new areas. Soil solarization reduced the pathogen population and wilt incidence (Chauhan et al. 1988), but its use in extensive rainfed agriculture is not feasible.

Early sowing, use of short-duration genotypes, and irrigation have been suggested to minimize dry root rot incidence. Soil amendment with mature crop residue of wheat or oat is reported to significantly reduce the pathogen population and also the infection in a pot experiment.

Host-plant Resistance

Considering the socioeconomic status of most farmers in WANA, East Africa, and South Asia, the use of resistant varieties promises to be the most practical and effective method of controlling the economically important diseases of chickpea. Effective methods for field screening and a rating scale to screen large numbers of chickpea germplasm and breeding populations for resistance to ascochyta blight have been developed and standardized (Nene et al. 1981). Greenhouse screening techniques have also been developed at ICARDA and ICRISAT. A system for multilocational evaluation has been developed by ICARDA, which has proved to be effective. Several resistance sources have been identified (Table 5.3.2). Also, sources of resistance to multiple *A. rabiei* races have been identified (Singh and Reddy 1990a). These include three lines (ILC 202, ILC 3856, and ILC 5928) with resistance to five races, six lines (ILC 72, ILC 201, ILC 2506, ILC 2956, ILC 3279, and FLIP 83-48C) resistant to four races, and three (ILC 190, ILC 482, and ICC 3996) resistant to three races. Ninety-two kabuli breeding lines resistant or moderately resistant to ascochyta blight under both field and greenhouse conditions have also been identified (Singh and Reddy 1992). Resistant lines with other desirable characters such as earliness, large seed, and tallness are listed in Table 5.3.3. Several chickpea lines resistant to ascochyta blight have also been identified and released for cultivation in Tunisia, Morocco, and Algeria.

Table 5.3.2. Selected sources of resistance available for chickpea diseases.

Disease	Resistance sources
Ascochyta blight	ILC 72, ILC 195, ILC 201, ILC 202, ILC 2506, ILC 3274, ILC 3279, ILC 3956, ILC 4421, G 688
Fusarium wilt	ICC 3634, ICC 4200, ICC 4248, ICC 4368, ICC 5124, ICC 6981, and ICC lines, ICCC 32, ICCV 2, ICCV 3, ICCV 4, ICCV 5, ICCV 10, JG 315
Botrytis gray mold	ICCV 87322, ICCV 88510, ICC 4102-21, ICC 4102-41
Chickpea stunt	ICC 403, ICC 591, ICC 685, ICC 2285, ICC 2546, ICC 3718, ICC 6433, ICC 6934, ICC 10425, ICC 40596

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Table 5.3.3. Ascochyta blight resistant lines with desirable characters identified at ICARDA.[1]

Characteristics	Line
Resistant lines with a disease rating of 3	FLIP 84-124C, FLIP 90-96C, FLIP 91-18C, FLIP 91-26C, FLIP 91-62C
Short-duration (130 days to 50% flowering) and blight-resistant lines	FLIP 88-83C, FLIP 90-98C, FLIP 91-22C, FLIP 91-45C, FLIP 91-46C
Large seeded (40–50.6 g 100-seed mass) and blight-resistant lines	FLIP 91-2C, FLIP 91-18C, FLIP 91-24C, FLIP 91-50C, FLIP 91-54C
Short-duration, large resistant lines	FLIP 91-18C
Tall (50–58 cm) and blight-resistant lines	FLIP 90-56C, FLIP 91-4C, FLIP 91-6C, FLIP 91-11C, FLIP 91-14C, FLIP 91-26C, FLIP 91-53C
Tall, large-seeded, and blight-resistant lines	FLIP 91-3C, FLIP 91-8C, FLIP 91-12C, FLIP 91-13C, FLIP 91-15C, FLIP 91-19C, FLIP 91-21C, FLIP 91-37C, FLIP 91-39C

1. Source: Singh and Reddy (1992).

Progress has been made in identifying resistance in desi and kabuli chickpeas to fusarium wilt at ICRISAT. Field, pot, and water-culture techniques to screen for resistance have been developed and perfected (Nene et al. 1981). Good sources of resistance and resistant lines are now available in India (Table 5.3.2), Tunisia (Halila et al. 1984), and Ethiopia (Ahmed et al. 1990). Some of these lines have resistance against other major soilborne and foliar diseases (Table 5.3.4).

Chickpea lines with resistance to botrytis gray mold and stunt have been identified (Table 5.3.2). Kabuli types are generally less susceptible to botrytis than desi ones.

Table 5.3.4. Lines/varieties identified for multiple disease resistance in chickpea[1].

Diseases	Line/Variety
Wilt, dry root rot, black root rot	ICC 7862, ICC 9023, ICC 10803, ICC 11560, ICC 11551, ICC 12235 to ICC 12269
Wilt, ascochyta blight, botrytis gray mold	ICC 1069
Wilt, dry root rot, stunt	ICC 10466
Wilt, sclerotinia stem rot	ICC 858, ICC 959, ICC 4914, ICC 8933, ICC 9001
Wilt, ascochyta blight	FLIP 83-43C, FLIP 85-20C, FLIP 85-29C, FLIP 85-30C

1. Adapted from Nene (1988).

Integrated Control

Few attempts towards integrated control of chickpea diseases have been made so far. Generally, a combination of host-plant resistance and fungicides is mostly used, e.g., to control ascochyta blight (Reddy and Singh 1990b; M.H. Halila, personal communication), and botrytis gray mold (Reddy et al. 1992).

Multiple Disease Control

Since more than one disease often affects chickpea in a given situation (Nene 1988), genotypes with multiple disease resistance are required. Chickpea genotypes resistant to two or more diseases are listed in Table 5.3.4. In Tunisia, good progress has been made in combining resistance to ascochyta blight and fusarium wilt, and 10 resistant lines are now in yield trials (Halila and Harrabi 1990).

Gaps in Knowledge

Gaps in our knowledge of major chickpea diseases have been earlier identified by Reddy et al. (1990); Haware et al. (1990); Kaiser et al. (1990); Greco and Sharma (1990), and Beniwal et al. (1992). These gaps are briefly highlighted here, in order to indicate possible future areas of research.

Ascochyta blight

- Lack of complete understanding of the disease epidemiology;
- Insufficient understanding of pathogenic variability and its geographic distribution;
- Unavailability of high levels of stable genetic resistance in large-seeded varieties; and
- Inadequate disease monitoring.

Fusarium wilt

- Unavailability of sources of resistance in large-seeded kabuli chickpeas for WANA;
- Lack of information on variability in *F. oxysporum* f. sp *ciceri* and on the distribution of its races in WANA and East Africa;
- The need to develop wilt-sick plots in certain countries to support breeding for disease resistance;
- Insufficient information on the distribution of wilt and root rots and their epidemiology in WANA and East Africa; and
- Integrated management of wilt and root rots.

Botrytis gray mold

- Lack of proper understanding of the disease epidemiology;
- Unavailability of desired levels of genetic resistance;
- Lack of information on pathogenic variability and its geographic distribution; and
- Lack of knowledge of the effects of cultural practices on disease incidence.

Stunt

There is a need to:

- Document occurrence and severity of the disease in different geographic areas;
- Identify sources of resistance;
- Understand the disease epidemiology;
- Determine pathogen variability and its geographic distribution; and
- Understand the influence of cultural practices on disease development.

Seed and seedling diseases

More information is required on:

- Distribution and importance of these diseases in WANA and East Africa;
- Influence of cultural practices on their incidence and build up; and
- Seed treatments with chemicals for multiple disease control.

Nematodes

More information is needed on

- Distribution, races, and biology of nematodes in different agroecological regions;
- Yield losses due to nematodes;
- Sources of resistance; and
- Influence of cropping systems and management practices on nematode populations.

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Future Strategies for Disease Control

Integrated Disease Management

The best strategy for controlling chickpea diseases in WANA, East Africa, and South Asia will be through integrated disease management (IDM) of multiple chickpea diseases. IDM should be effective particularly for management of diseases where the desired levels of resistance are not available in germplasm. This approach would also be economical and environment-friendly. However, its relevance will depend upon the nature and severity of disease incidence.

The IDM option will combine various methods including chemical, cultural, and host-plant resistance. Its applicability will depend upon such factors as the socioeconomic status and attitudes of farmers in the target area.

Host-plant resistance is the most efficient, safe, economical, and convenient method of disease control. However, greater emphasis is required on the identification of sources of multiple disease resistance. High-yielding varieties with durable multiple-disease/race resistance in agronomically acceptable genetic backgrounds need to be developed.

The effects of cultural practices in IDM crop rotation, use of disease-free seed, sowing time, tillage practices, management of crop residues after harvest, fertilizer application, cropping system, and eradication of alternative pathogen hosts, particularly on soilborne diseases caused by fungi and nematodes, are important. These cultural methods have proved to be effective in developing countries where there is a long history of their use.

Although fungicides have been used to control various diseases, their use is limited in developing countries, as the chemicals are expensive and also because dry conditions prevail during the crop-growing season in many regions. However, they will have to be used in certain situations (Nene 1988). Similarly, the use of seed dressing with fungicides has tremendous scope for controlling seedborne pathogens and seed and seedling diseases. These include captan, thiram, mancozeb, or systemic benzimidazole used individually or in combination (e.g., the first three in mixtures with fungicides specific to oomycetes or with systemic benzimidazole).

Multiple Disease Management

It is essential to develop effective management practices against diseases that occur together in certain chickpea-growing areas (e.g., ascochyta blight and fusarium wilt together in WANA; ascochyta blight and botrytis gray mold in the northern parts of India and Pakistan). The best method to address this situation will be to develop varieties with multiple-disease resistance combined with the use of recommended cultural practices. As suggested by Reddy et al. (1990) and Nene and Sheila (1992), development of cold-tolerant chickpeas that can mature by end of Feb in India, Pakistan, Bangladesh, and Nepal may help in avoiding major foliar diseases as the low temperatures (<15–25°C) prevailing at that time will not favor their epiphytotics.

Short- and Long-term Strategies

In the short term, the major emphasis should be on managing ascochyta blight and fusarium wilt in WANA; fusarium wilt and dry root rot in East Africa; and ascochyta blight, fusarium wilt, dry root rot, and botrytis gray mold in South Asia. The remaining diseases in these regions should receive a lower emphasis in the short term. For the various diseases, the following areas should be given high priority:

Ascochyta blight: Epidemiology; variability in *A. rabiei* and its distribution; genetics of resistance; good and stable genetic resistance in large-seeded varieties.

Fusarium wilt: Development of wilt-sick plots to aid breeding programs; variability in the causal fungus and its distribution in WANA and East Africa; distribution of wilt and root rots in WANA and East Africa.

Botrytis gray mold: Good level of genetic resistance; variability in the causal fungus and its distribution; influence of cultural practices on disease development and build up; epidemiology.

Chickpea stunt: Distribution and importance in different geographic areas; influence of cultural practices on disease development.

Seed and seedling disease: Distribution and importance in different regions; identification of new fungicides for seed treatment to control multiple diseases.

Nematodes: Distribution and importance in different regions.

In the long term, aspects of ascochyta blight, fusarium wilt, and botrytis gray mold not mentioned in short-term strategies but highlighted under "Gaps in knowledge" should receive attention. Management of less important diseases such as stunt, seed and seedling diseases, and nematodes should be included in the long term strategy.

Future Action

In order to address the major diseases of chickpea, the following action will be required:

- Concerted research efforts to fill the gaps in knowledge;
- Development of IDM technology for multiple disease control;
- Efforts on transfer of IDM technology;
- Enhanced efforts by ICARDA and ICRISAT, and laboratories in developed countries in complementing NARS research efforts; and
- Development of national and/or regional networks, and formation of working groups.

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5.4. Chickpea Insect Pests: Distribution, Importance, and Management Strategy in WANA and SAT

S Weigand[1]

Introduction

A wide range of about 60 insect species have been reported to feed on chickpea (Reed et al. 1987), but only relatively few are considered major pests. In general, chickpea is not much favored for insect feeding. But, some of the insects that do attack the crop, cause extensive damage to it. Effective control methods therefore need to be developed urgently. Many of the main insect pests are common throughout the world, although the extent of damage and economic losses vary in different agroecological regions. The main insect pests of chickpea and their relative importance in WANA and SAT are listed in Table 5.4.1.

Table 5.4.1. Relative importance[1] of the main insect pests of chickpea in WANA and SAT.

Insect pest	WANA	SAT
Leafminer	xxxx	x
Pod borers	xxx	xxxx
Armyworm	x	xx
Cutworms	xx	x
Aphids	xx	xx
Bruchids	xxx	xxx

1. x Low priority to xxxx high priority.

1. Germplasm Program, ICARDA, PO Box 5466, Aleppo, Syria.

Leafminer (*Liriomyza cicerina*)

Leafminer is the main pest of kabuli chickpea grown in West Asia and around the Mediterranean Sea. It occurs fairly severely and regularly in several countries (Syria, Lebanon, Turkey, Jordan, Iraq, Iran, Morocco, and Algeria) (Cardona 1983; Reed et al. 1987). It has not been reported from the Nile Valley countries (Egypt, Sudan, and Ethiopia) and has been observed only recently in isolated chickpea fields in northern India (Naresh and Malik 1986).

Pod Borers (*Helicoverpa armigera, Heliothis viriplaca*)

Helicoverpa armigera is the major pod borer species on chickpea and is reported from almost all the countries in WANA and SAT where chickpea is cultivated (Reed et al. 1987). In India, Pakistan, and Bangladesh where more than 85% of the world's chickpea is grown and in some regions of WANA, *H. armigera* is a pest of considerable economic significance. It is polyphagous, multivoltine, highly fecund, and capable of migrating long distances.

Heliothis viriplaca is common on chickpea in the eastern Mediterranean countries (Syria and Turkey), but occurs at lower population densities and produces only one generation per year.

Armyworm (*Spodoptera exigua*)

Spodoptera exigua larvae are known to occur on chickpea during the vegetative stage in Syria, Sudan, and India, but rarely cause any significant damage in most areas.

Cutworms (*Agrotis* spp)

Several species of *Agrotis* have been reported to attack chickpeas in most countries of WANA and SAT. Cutworms are not of widespread importance in chickpea, but can be very damaging locally, especially under high rainfall conditions, as was observed in Syria, Iran, Sudan, Ethiopia, and India.

Aphids (*Aphis craccivora*)

Aphis craccivora occur on chickpea in most countries of WANA and SAT. In general, higher infestations are found generally towards the end of the season. The pest does not cause severe crop losses as a direct result of its feeding. However, it is an important vector of the bean leaf roll virus that causes chickpea stunt disease, which can be damaging in some areas.

Bruchids (*Callosobruchus* spp)

Callosobruchus chinensis and *C. maculatus* are the most damaging insect pests of stored chickpea seeds occurring in all chickpea-growing areas. Other species of insects have been recorded to feed on stored seeds but none is of widespread importance.

Crop Losses

In general, the information available on economic importance and yield losses caused by insect pests in chickpea is rather limited. The high variability in the occurrence of even the main insect pests as well as of chickpea yields in different regions and/or years makes it difficult to accurately relate yield losses to insect pest incidence. Even for the most damaging pest, *H. armigera*, information on pod damage is available but not on associated seed yield losses to evaluate those in economic terms. It has been shown that pod damage at maturity is closely related to seed yield while damage to young pods is compensated (Seghal 1990). Thus pod damage (%) cannot be considered equivalent to yield loss (%). In India, a reevaluation of the importance of *H. armigera* showed that pod borer is not a major biotic constraint to chickpea yields in most agroecological zones. High pod damage (> 20%) mainly occurs in the northwestern plain, the eastern, and the southern zones (Pimbert and Seghal 1989). Large differences in pod damage were found between research stations and farmers' fields, pod damage being consistently higher on experimental stations. According to surveys and insecticide trials conducted at ICRISAT, Reed et al. (1987) estimated less than 20% crop losses in most years when *Helicoverpa* was the dominant pest.

In Syria, damage and losses vary greatly across areas and years. In the south, high pod borer damage is common, whereas in the north, damage is low (Al-Soud et al. 1992), but has been increasing over years. At the ICARDA station, where the increase has been significant, studies were conducted to find out whether it is a problem linked to the research station or is due to increased summer crop sowings around the station. Advancing the chickpea sowing date from spring to winter was shown to increase pod borer infestation (Al-Soud 1992; ICARDA 1993). Although yields were still higher in the early-sown chickpea, care has to be taken to avoid build-up of *H. armigera* populations and damage in following summer crops.

Yield losses caused by chickpea leafminer were shown to vary greatly in northern Syria between none and 20% (Reed et al. 1987; Weigand 1989), mainly depending on weather and general growing conditions. No information is available from other WANA countries. Leafminers cause more yield loss in spring-sown than on winter-sown chickpea (Weigand et al. 1993). When leafminer populations reach high densities in late Apr, winter chickpea is already in the podding stage and starts maturing, thus escaping yield loss. At that time, spring chickpea is just in the flowering stage and is vulnerable to leafminer incidence for a longer period. In winter chickpea, loss of leaves caused by leafminer does not result in high yield loss, whereas it does in spring chickpea.

Since leafminer causes damage through indirect effects on green leaf area interactions with abiotic stresses, particularly temperature, rainfall (terminal drought), and genotypic differences in response to these abiotic stresses, it is necessary to consider separately the effects of yield losses due to leafminer and those of abiotic stresses.

Storage insect pests cause high yield losses wherever unsatisfactory seed storage practices encourage high infestations, but data on economic yield losses are not available.

Present Status of Insect Control

Different components of pest management, i.e., chemical, cultural, biological control, and host-plant resistance have been studied. The present emphasis is to integrate all these control methods. At present, chemical control is the most effective technique available, whereas most other techniques are still under investigation.

Chemical Control

Leafminer can be effectively controlled by applying endosulfan or other insecticides at flowering. As an alternative to conventional insecticides, sprays of neem seed extract were shown to reduce the mining (%) and even more effectively the pod damage (%) in Syria (Weigand et al. 1993; ICARDA 1993) and India (Seghal and Ujagir 1990).

In the case of high pod borer infestations, insecticide application might be necessary. Several insecticides, cypermethrin, deltamethrin, fenvalerate, endosulfan, and monocrotophos were shown to provide effective control (Seghal and Ujagir 1990; Al-Soud 1992). However, *H. armigera* has been shown to rapidly develop resistance to insecticides (Wolfenbarger et al. 1981; Singh 1990) as was observed after the heavy use of insecticides on cotton. But in general insecticide use on chickpea by farmers is low.

Cultural Control

Sowing chickpea in winter reduces the crop yield losses due to leafminer infestation, and can be recommended as a practice. However, it remains to be seen if the damage would increase when large-scale winter sowing of chickpea is adopted. Winter sowing encourages pod borer damage, and delayed sowing decreases it in the WANA region. However, delayed sowing reduces the yield potential of the crop, hence its use as a cultural control method has adverse side effects. Intercropping is not practiced by farmers in the WANA region and the effect of this practice on insect damage has not been studied. In India, farmers use such traditional cultural methods as manipulation of the sowing date and intercropping or mixing chickpea with wheat, barley, mustard, rapeseed, or linseed to limit pod borer damage (Pimbert 1990). Early-sown chickpea in India results in less damage as the crop is harvested before the peak abundance of *H. armigera* is reached (Prasad et al. 1985).

Host-plant Resistance

For leafminer, most emphasis has been given to host-plant resistance at ICARDA. Several lines showing consistently lower levels of leafminer damage have been identified and are being extensively used in breeding.

Pod borer damage in the WANA region generally is too low to justify screening for resistance. At ICRISAT, screening for pod borer damage resulted in the identification of a few genotypes with low damage. These have been used in multilocational testing studies and in crop improvement programs (Lateef 1990; Lateef and Pimbert 1990; Lateef and Sachan 1990; Pimbert 1990).

Collaborative research by ICRISAT and ICARDA with the Max Planck Institute for Biochemistry, Munich, Germany on the biochemical basis of resistance to *H. armigera* and *L. cicerina*, showed correlation of resistance with the concentration of malic acid in the leaf exudates of chickpea (Rembold et al. 1990; Weigner 1993). However, to what extent the analysis can be used as a biochemical tool in host resistance screening needs to be determined, since the leaf exudate—amount and composition—also depends on environmental conditions and might be only one of the factors involved. In the case of leafminer, leaf size was shown to be even more important (Weigner 1993).

Screening for resistance to *Callosobruchus* spp has been widely carried out. Although some variation between genotypes was found, no acceptable degree of resistance with suitability for human consumption was found (Salunkhe and Jadhav 1982; Weigand and Pimbert 1993). *Callosobruchus* spp resistance discovered in seed of wild *Cicer* needs more evaluation of its practical value (Weigand and Tahhan 1990; Weigand and Pimbert 1993).

Biological Control

Biological control of several insect pests of chickpea has been studied. The main parasitoids have been identified and the parasitization rates recorded (Weigand et al. 1993). The use of naturally occurring parasitoids as biological control agents could be promising for control of leafminer if methods can be developed to enhance them early in the season (Weigand and Tahhan 1990).

Only larval and pupal parasitoids of the pod borer have been recorded in chickpea in Syria (Al-Soud 1992) as well as in India (Yadav 1990); but these are not very efficient and are costly to handle. More emphasis has been given to microbial control, i.e., the use of *Bacillus thuringiensis* or Nuclear Polyhedrosis Virus (NPV) formulations (Rabindra and Jayaraj 1988; Khalique et al. 1989; Pawar and Thombre 1990), which alone may not provide sufficient control but may complement other control measures.

Gaps in Knowledge and Future Strategies

In all important chickpea-growing regions, the main insect pests have been identified and their status studied. However, even for the most important pests, i.e. leafminer, pod borer, *Callosobruchus* spp, little information on the extent of yield losses and practically none on economic losses is available. However, the knowledge of the severity and extent of pest damage is an important prerequisite for setting priorities in research on pest control. More information is needed on the occurrence and population dynamics of the pest species and plant damage in relation to weather data, mainly temperature and rainfall in different regions and years. If reliable biotic stress maps could be generated for the main chickpea-growing areas, this would allow specific targeting of pest management research and crop improvement work to regional differences and needs.

The development of an integrated pest management system is the final objective in chickpea pest control. Different components of pest management have been studied, but these are not suitable for transfer to farmers (Table 5.4.2). Chemical control is the most effective technique available and should receive less attention—except for research on such alternative botanical insecticides as neem products, and for studies on the economics of pest control and establishment of economic threshold levels. Because of disadvantages associated with the use of insecticides, research on other control methods should receive increased emphasis.

In WANA, the use of cultural control for pest control is limited as, in general, yield is more constrained by the environment and the pests are not of such overriding importance that the agricultural system should revolve around IPM considerations. Only in the case of epidemic pest outbreaks would farmers accept mixed cropping or change of sowing date to limit pod borer damage.

Table 5.4.2. State of development[1] of integrated pest management techniques for the two main chickpea insect pests.

Liriomyza cicerina	xxx	Chemical control
	x	Neem extract
	x	Host-plant resistance
	x	Enhancement/use of parasitoids
Helicoverpa armigera	xxx	Chemical control
	xx	Bt and NPV spray
	xx	Host plant resistance
	xx	Intercropping, sowing date
	x	Use of parasitoids

1. xxx Most effective technique presently available.
xx Moderately effective technique available.
x Technique under investigation.

Adapted from Pimbert (1990) and Weigand et al. (1993)

Also, the development of biological control systems is difficult, because chickpea crops are of short duration in the field and do not provide a stable ecosystem for rearing and release of natural enemies on an economical scale. Yet the use of parasitoids for control of leafminer and microbial control for pod borer have some prospects and need more investigation.

In host-plant resistance much has been achieved, but insect resistance needs to be combined with other desirable characters, such as high-yield potential and resistance to abiotic stresses and diseases.

In addition to further research on each control method, the interaction and compatibility of the different components, i.e., effect of resistant lines, mixed cropping, neem sprays on natural enemies as well as their interaction with the environment need to be studied. Studies on insect control in chickpea have shown that, except for chemical control, none of the control methods alone will provide effective control. These have to be considered as one of the components of an overall IPM and crop management strategy.

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5.5. Symbiotic Nitrogen Fixation by Chickpea in WANA and SAT

D P Beck[1] and O P Rupela[2]

Introduction

The ability of chickpea to fix atmospheric nitrogen lessens its dependence on soil N and reinforces its role in the cropping systems of WANA and SAT. However, the crop is often considered inferior in this regard to other legume crops grown in wheat-based rotations (Papastylianou 1987; Keatinge et al. 1988). Published estimates of N_2 fixation by chickpea in the WANA region range from 0 to 176 kg ha^{-1} per season, with the proportion of total N from fixation (P_{fix}) varying between 0 and 82%, depending on the method of measurement, cultivar, presence of appropriate rhizobia, and environmental variables (Rizk 1966; Papastylianou 1987; Keatinge et al. 1988; Beck et al. 1991). Nitrogen fixation has a positive effect on soil N_2 balance and growth of the subsequent crop (Evans 1982; Heichel 1987; Keatinge et al. 1988). Therefore, practices which increase N fixation will minimize the quantity of soil N utilized by the crop, and thereby increase yields in the subsequent non-legume crop.

The main strategies for improving biological nitrogen fixation (BNF) in chickpea are similar to those for most legumes. Because the process of N_2 fixation is photosynthate-driven, increasing chickpea yield is the simplest and generally the most successful strategy to improve BNF. Breeding for improved N_2 fixation is rarely done because it gets less priority than that for yield and resistance to biotic/abiotic stresses, and also because measuring N_2 fixation may be a difficult and expensive process. Optimizing the host-rhizobia association, by inoculating the chickpea plants with selected rhizobia, is therefore, the most common approach to improve N_2 fixation.

Techniques for measuring N_2 fixation are essential to any attempts to improve BNF, and the strengths and weaknesses of various techniques should be well understood before a BNF program is initiated. Reviews of some of these techniques have been published by Witty (1983), Chalk (1985), Danso (1988), Witty and Minchin (1988), Witty et al. (1988), Peoples et al. (1989), Herridge et al. (1992), and Beck et al. (1993).

Agronomic and Environmental Constraints

Winter-sown chickpea enjoys more favorable soil moisture and temperature conditions during late vegetative and reproductive growth periods than spring-sown chickpea in the area around the Mediterranean Sea (Wery et al. 1988; Saxena et al. 1990). In a series of trials to measure N_2 fixation in spring- and winter-sown chickpea under varying agroenvironments, the results showed that winter sowing improved P_{fix} at all locations (Beck et al. 1991), due to the improved conditions prevalent during the period of maximum fixation. In Syria, N_2 fixation levels in winter-sown chickpea were high (80–81%), whereas P_{fix} values in spring-sown chickpea, where drought limited growth as early as anthesis, were negligible (8–27%). Differences between N_2 fixed in spring- and winter-sown chickpea in Montpellier, France—which has a Mediterranean climate similar to WANA—were found to be smaller because of extended moisture availability through the later stages of plant growth. N_2 fixation reached a maximum of only 55% in Montpellier, where fixation was depressed by high levels of soil nitrate (Beck et al. 1991).

High to moderate levels of available soil N are known to suppress N_2 fixation in legumes, by inhibiting nodulation and interfering with

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the fixation process (Munns 1977; Streeter 1988). This factor is particularly important in experiments conducted at research stations, where soil fertility (N in particular) tends to be high.

Critical tolerance level and degree of suppression vary with legume species (Harper and Gibson 1984). The limited research on chickpea indicates that levels of NO_3-N below 10 ppm will not adversely affect N_2 fixation (Rawsthorne et al. 1985), but variation with cultivars is expected (Rupela and Johansen 1992a).

Chickpea also appears to be a fairly efficient scavenger of soil N, especially under conditions where sufficient rhizobia are not present for efficient symbiosis (Beck 1992). The practice of fertilizing chickpea with 20 kg N ha^{-1} at sowing is widely recommended in SAT, probably because it sometimes helps to negate the adverse effect of high temperature on symbiosis (Rawsthorne et al. 1985).

Nitrogen fixation in chickpea seems to be more sensitive than grain production and N assimilation (which is mainly limited by availability) to high temperatures (Rawsthorne et al. 1985) and drought (Wery et al. 1988). In field studies with six chickpea cultivars in Syria (ICARDA 1992), drought stress depressed P_{fix} more than N uptake (Fig. 5.5.1). A line-source sprinkler was used over 2 seasons in these studies, where P_{fix} increased more rapidly than yield at lower moisture levels, indicating that fixation was severely limited at the lower end. Values for P_{fix} in different cultivars at lower moisture levels varied widely from 15 to 38%. Fixation efficiency reached an average maximum of 68% at about 5000 kg ha^{-1} dry matter produced. Nitrogen uptake from soil remained constant until moisture became sufficient for maximum fixation, when soil N uptake increased (Fig. 5.5.1). The correlations between dry matter produced and N yields were high, with coefficients of 0.92 for total N and 0.90 for fixed N.

The high correlation between dry matter production and N yield indicates that N_2 fixation in chickpea, under conditions where adequate rhizobia are present, is yield-driven, and that environmental

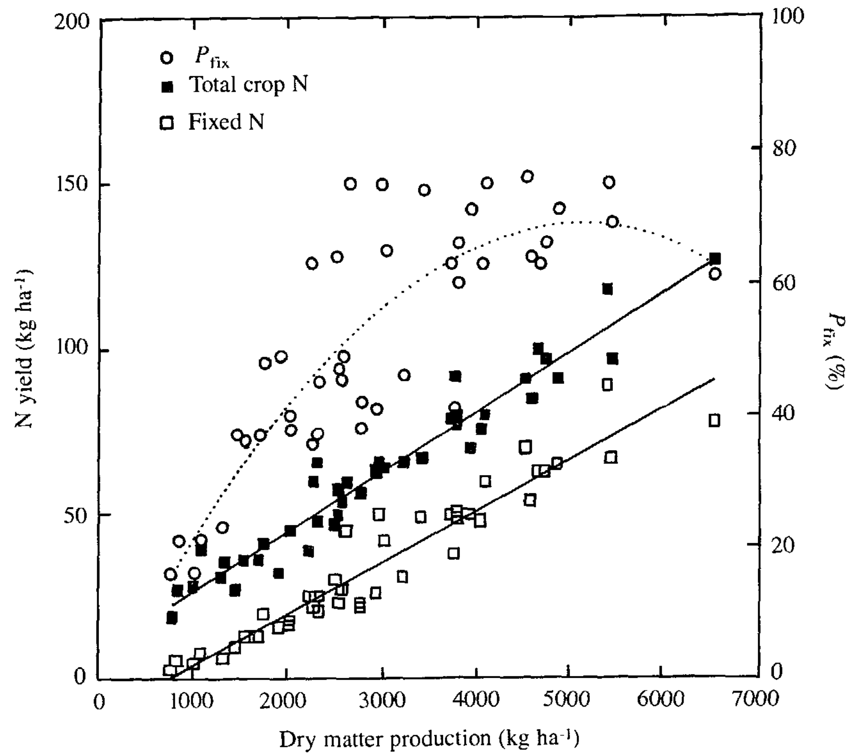

Figure 5.5.1. Relationship of dry matter production with N yield and source in chickpea cultivars, northern Syria, 1987–91.

constraints on plant yield will limit N_2 fixation. These results may partly explain why N fertilization improves yield of nonirrigated chickpea in low N soils, but does not affect yield in the irrigated crop (ICRISAT 1992).

Breeding for Improved N_2 Fixation

Agronomic and environmental considerations often limit the biomass yield of a legume crop and therefore the capacity of that crop to fix

N_2. Yield is also determined genetically, for example, low N yield may be a characteristic of some species. In studies over a range of environments and agronomic practices, N yield and N_2 fixation by chickpea were consistently less than for the other cool-season food legumes (Rennie and Dubetz 1986; Evans and Herridge 1987; Smith et al. 1987; Beck et al. 1991). Average yields were 100 kg N ha^{-1} for chickpea, 196 kg N ha^{-1} for lentil, 185 kg N ha^{-1} for field pea, and 200 kg N ha^{-1} for faba bean. These studies did not indicate that the inherent capacity of chickpea for nodulation and N_2 fixation was less than for the other species. It may be concluded, therefore, that increasing N yield of chickpea may result in increased N_2 fixation.

Plant breeders select for high yield within the constraints of local environments and crop yields largely determine the amount of N_2 that is fixed by the crop, particularly in low N soils (Hardarson et al. 1984; Kumar Rao and Dart 1987). Therefore, breeders who mostly work in low N soils will tend to select for material with good capacity for N_2 fixation. Breeding for symbiotic characteristics in chickpea is possible. Examples of possible strategies to exploit are nitrate tolerance (i.e., the ability of the plant to nodulate and fix N_2 in the presence of soil nitrate), the capacity to fix N_2 at low available moisture levels, and general nodulation capacity. Chickpea cultivars selected for drought tolerance seem to vary in their capacity for N_2 fixation under drought stress. Natural variation for nitrate tolerance (Rupela and Johansen 1995) and nodulation capacity (Rupela 1994) also exist in chickpea. It may be impossible to produce a legume that is dependent solely upon N_2 for growth and cannot use nitrate, but there is scope to improve P_{fix} in the presence of nitrate for chickpea.

Some argue that legumes should be able to use both atmospheric and soil N sources so that they can scavenge nitrate from the soil which would otherwise be lost through leaching and denitrification, while others argue that in many soils, nitrate is relatively stable over time and can be considered as a stable pool of N. Secondly, if depletion of soil nitrate was considered necessary, it would make more sense to use a cereal crop with a higher demand for N and greater economic return.

Because N yield and dry matter production are generally highly correlated (Mytton 1983), the following procedure could be followed to enhance N_2 fixation in chickpea:

1. Screen a large and diverse germplasm (500–1000 genotypes) of chickpea, inoculated with highly effective rhizobia, for production of dry matter under low N conditions (preferably in the field, but it could be done in a greenhouse).
2. Select superior genotypes (e.g., top 10%) for further evaluation. The second round of screening is ideally done in the field on low N-fertility soil, again with a mixture of highly effective rhizobia. Assessments should include measurements of grain yield and total N yield.
3. Compare elite genotypes over a range of edaphic (particularly soil N fertility) and environmental (including diverse rhizobial population) conditions for grain yield, N yield, and N_2 fixation, the latter using ^{15}N methods.

Genotypes that are identified at this stage as superior in all three attributes and adapted to the soils and environments for which they are likely to be used would have immediate commercial application. High N_2-fixing genotypes that produce low grain yields or grain of low quality could be used as donor parents in a breeding program.

It is also important to remove the effect of crop duration on N yield. Increased N yield due to high growth and assimilation rates is more useful because it can be expressed in any environment; whereas increased crop N due to longer crop duration can only be expressed if the duration of the season in a particular environment or cropping system is sufficiently long. In commercial agriculture, individual crops must fit into cropping systems which are determined by seasonal changes in temperature, moisture availability, radiation, availability of land and resources to grow and harvest the crop, marketing arrangements, etc. The optimum duration of any crop is therefore determined by several factors, the least important of which is N yield or N_2 fixation.

Inoculation

Local production or import of inoculants for farmers can only be justified if the legume benefits from inoculation are shown by increases in yield or in N_2 fixation in field trials and farmers' fields. It is essential to determine the need for inoculation before initiating any program on inoculant development, production, distribution, or use. Response to inoculation by legumes has been shown to be influenced mainly by cropping history (Brockwell et al. 1982), soil N availability (Somasegaran and Bohlool 1990), and most importantly, the indigenous population of rhizobia that nodulate the host (Thies et al. 1991). Various methods to determine the need for inoculation are described in detail by Beck et al. (1993).

The introduction of cold-tolerant, ascochyta blight resistant lines for winter sowing into new, drier production areas of WANA has been accompanied by nodulation deficiency in several areas (M Solh and S P S Beniwal, personal communication). In these new production areas, soils are less likely to contain adequate populations of the *Cicer*-specific rhizobia than traditional chickpea areas, and crops may show significant yield increases when seeds are inoculated with selected rhizobial strains. Extensive surveys of native rhizobia-nodulating chickpea have been recently conducted in Syria and Turkey, where symbiotic effectiveness and size of native populations were measured (Keatinge et al. 1995). It was found that even within the major chickpea-growing regions, many soils contained rhizobial populations either at very low levels or with low symbiotic effectiveness on the cultivars tested. It has been suggested that this deficiency may be one reason for the generally low average chickpea yields from these areas.

The highly specific rhizobial requirement of chickpea extends to strain-cultivar specificity for N_2 fixation (Beck 1992). This implies that limited effectiveness of naturalized rhizobial populations with newly introduced cultivars may restrict the genetic potential for dinitrogen fixation. Necessity for inoculation may therefore also exist where introduced cultivars—selected for high yields—cannot express their full capability for N_2 fixation in symbiosis with native rhizobial populations that have developed in adaptation with local landraces.

In trials conducted over 4 seasons (1987/88–1990/91) in northern Syria (seasonal rainfall of 300–500 mm), variations in N_2 fixation and yield of chickpea cultivars inoculated with selected *Rhizobium* strains were evaluated. The purpose was to establish base-line values for P_{fix} in recommended cultivars so that improvements through rhizobial strain selection and legume breeding could be quantified. Use of ^{15}N methodology and nonnodulating chickpea and barley as reference crops allowed accurate evaluation of N_2 fixation under a wide range of environmental conditions. Indigenous chickpea rhizobial populations based on the most probable number (MPN) estimations in the field soils were low to moderate, ranging from 9.1×10^1 to 4.2×10^3 rhizobia g^{-1} soil. Rhizobial strains were selected according to the N_2-fixing performance in aseptic hydroponic culture in greenhouse trials.

Inoculation had no general effect on crop dry matter yields at lower rainfall sites (Fig. 5.5.2). At 340 mm rainfall, however, cultivars began to show differential yield effects with rhizobial inoculation, ranging from no response to a 750 kg ha^{-1} increase. Under conditions of higher moisture (504 mm), the average inoculated cultivar yielded about 800 kg ha^{-1} more dry matter than when not inoculated (Fig. 5.5.2). Cultivar yields, which differed little at low rainfall, varied widely at high rainfall; yield response to inoculation varied from no response in cultivar ILC 5396 to 1.9 t ha^{-1} in ILC 482.

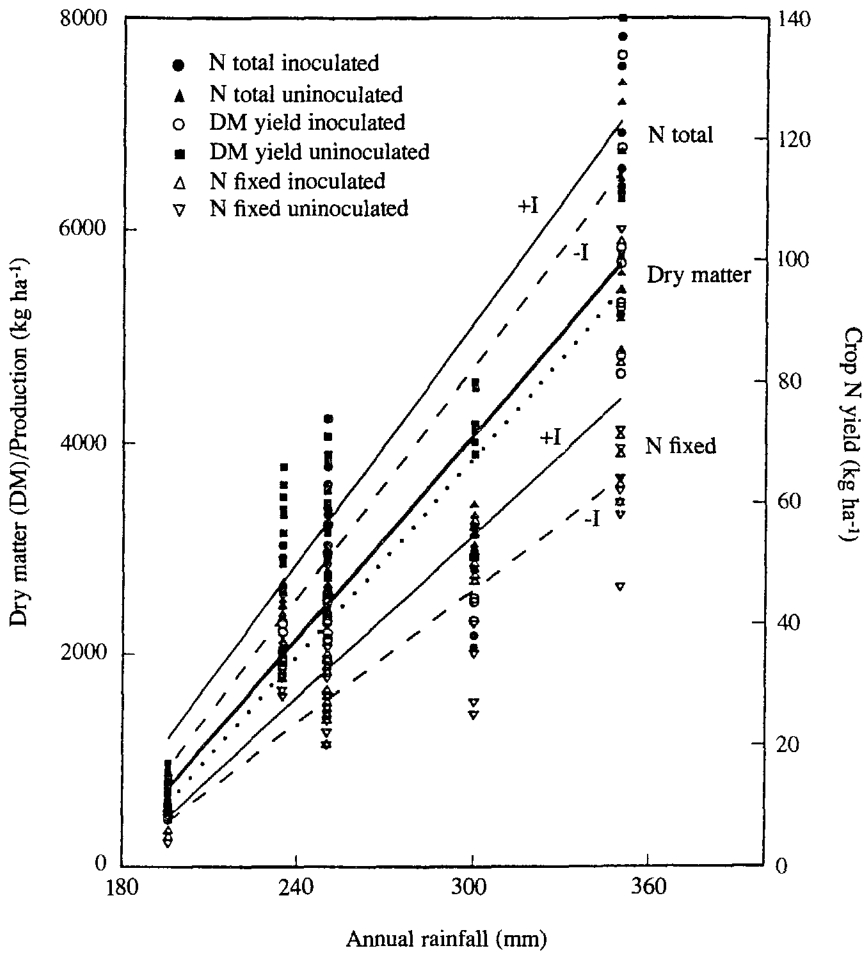

Figure 5.5.2. Effect of inoculation on dry matter production and N yield in chickpea, northern Syria, 1987–91.

In uninoculated cultivars, P_{fix} remains relatively constant at about 60% between 2000 and 7000 kg ha^{-1} dry matter production (Fig. 5.5.3). The effect of this constant proportion of fixed- to soil-derived N in the plant is that with increasing dry matter (and N) production, the quantities of soil N taken up by the crop increase. Figure 5.5.3 shows average soil N uptake (the distance between total N and fixed N curves) increasing from 20 kg ha^{-1} to nearly 50 kg ha^{-1} over the range of dry matter produced in the trials. In contrast, the efficiency of N_2 fixation has clearly increased at higher yield levels as a result of rhizobial inoculation (Fig. 5.5.4). In inoculated cultivars, P_{fix} increases with dry matter production, reaching a maximum of 80% at the highest yield levels. Increased fixation efficiency with yield results in a high proportion of fixation-derived N in the plant and a low, relatively constant fraction of soil-derived N (Fig. 5.5.4).

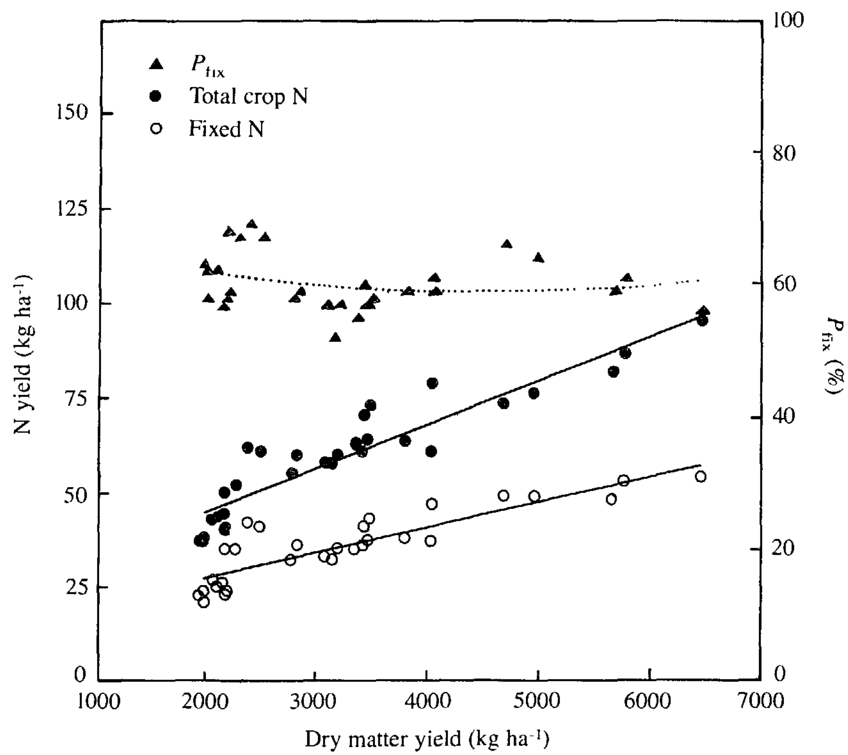

Figure 5.5.3. Nitrogen yield and source in uninoculated chickpea cultivars, northern Syria, 1988–90.

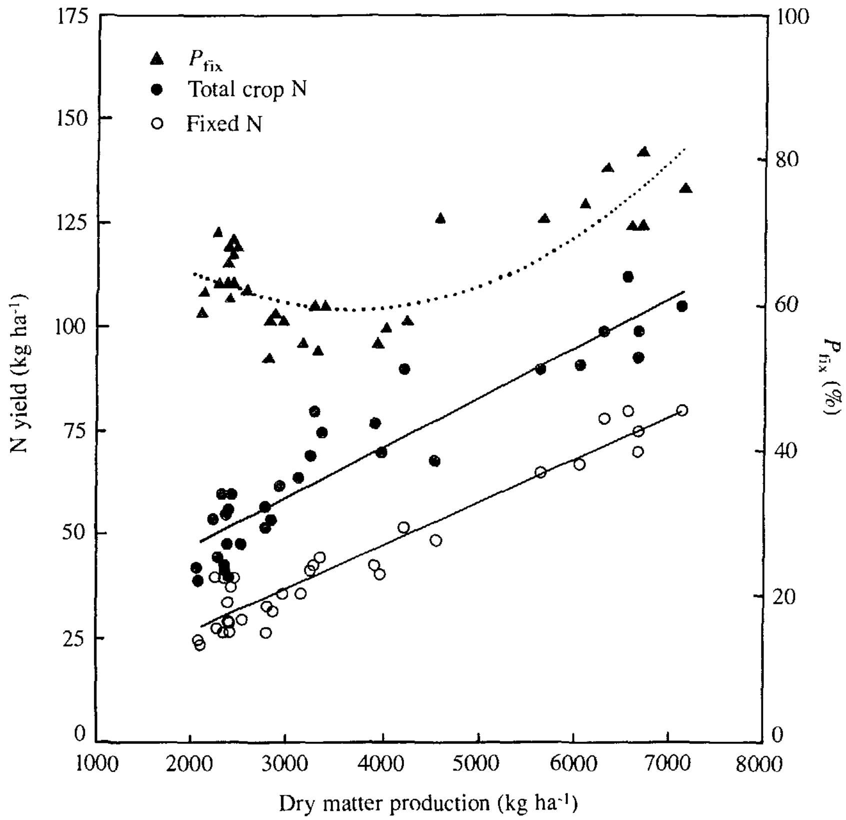

Figure 5.5.4. Nitrogen yield and source in inoculated chickpea cultivars, northern Syria, 1988–90.

In most cultivars tested, inoculation did not increase the amount of crop N per unit dry matter produced. The proportion of crop N derived from fixation was, however, often increased by inoculation. The effect of this improvement—that can be detected only with N_2 fixation measurement techniques such as those incorporating ^{15}N—is improved soil fertility. Although the effects of inoculation on yield are limited, the quantities of soil N preserved could be significant in a systems context. Farmers, however, will not adopt inoculant technology if they do not get as a result of applying the technology, increased yields of the legume or of the subsequent cereal crop.

The interaction between strains and cultivars for N_2 fixation efficiency, in addition to a similar interaction for competition and nodule formation, complicates the approach to wide-scale inoculation of chickpea cultivars, especially where new improved cultivars are being released on a regular basis. Two strategies may be used to increase N fixed by the chickpea crop. Selection of cultivars for high N_2 fixation with a broad range of rhizobia reduces the need for inoculation with specific strains. This, however, may fail where native strains are absent or ineffective. Alternatively, mixtures of highly effective strains may be used as inoculants. This works with some cultivars, but is dependent on strain-cultivar interaction for competitiveness in nodule formation, and on the successful use of inoculant technology by farmers.

Even where inoculation can increase yields, its effectiveness is heavily dependent on the quality of the inoculant and the way the product is applied. Experience has shown that successful transfer of inoculant technology to farmers for improvement of BNF is difficult at best (Thompson 1991). *Rhizobium* inoculants are biological products and therefore susceptible to major problems with manufacturing (quality control), distribution (loss of viability during transport and distribution), and extension (Roughley 1988). Distribution of poor quality inoculants is not uncommon, and is generally followed quickly by farmer disinterest in inoculation.

Contribution of N_2 Fixation to Cropping Systems

Results from legume-based rotation experiments in rainfed cropping areas of many countries have been published in recent years (e.g., Evans and Taylor 1987; Evans et al. 1989). These experiments reflect the growing concern of scientists and farmers in those areas about declining levels of N fertility in the soils and reduced production of cereal grain and protein. In all the trials where wheat followed grain legumes, its yield was higher than when it was continuously cropped, irrespective of the species of legume (Herridge et al. 1992).

In a long-term two-course rotational trial in Syria, soil N levels were measured after 6 years of rotation. Total soil N in the surface 40 cm of the chickpea-wheat rotation that did not receive any fertilizer N, did not differ significantly from that in the continuous wheat and fallow-wheat rotation (H Harris and A Matar, unpublished data). Soil organic carbon levels in the three rotational treatments also did not differ (0.9–1.0%), but incubation measurements of the N mineralization potential (Matar et al. 1991) showed large differences between rotational treatments. Mineralization potentials of soils in continuous wheat with 75 mg N kg^{-1} soil and fallow-wheat with 61 mg N kg^{-1} soil, were similar. In the chickpea-wheat soil, however, mineralization potential was 118 mg N kg^{-1} soil, indicating an increased capacity to supply plant-available N from the total N pool. These data are supported by studies at 40 northern Syrian sites under different crop rotations, where mineralization potential measurements gave the best indication of N uptake in wheat under legume-cereal rotations (Matar et al. 1989).

Potential improvements in chickpea N_2 fixation are therefore important to system productivity and sustainability. Research to improve chickpea N_2 fixation will ultimately have impact beyond increased chickpea yields, increasingly so in view of the present trends toward continuous cereal production and coincident soil fertility degradation.

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5.6. Genetic Improvement and Agronomic Management of Chickpea with Emphasis on the Mediterranean Region

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Chickpea-growing areas can be demarcated into five major eco-geographic regions: South Asia, Mediterranean region, East Africa, Latin America, and Oceania. Long-term data (FAO 1971, 1981, 1992) show a decrease in world chickpea area, a marginal increase in production, and a reasonable increase (35.3%) in productivity from 517 kg ha^{-1} in 1951 to 710 kg ha^{-1} in 1991, at an average rate of increase of 4.8 kg ha^{-1} per year.

The decrease in area seems to be the result of yield instability due to biotic and abiotic stresses, low yield potential of cultivars, and lack of cultivars responsive to applied inputs. Another reason for the decrease is the greater competitiveness and availability of high-yielding, input-responsive, and disease-resistant cultivars of cereal crops.

Although the development of chickpea genotypes with high and stable yields has been a major breeding objective for many years, it has resulted in only limited gains. Landraces continue to dominate in farmers' fields, even though they have low yield potentials and are susceptible to various biotic and abiotic stresses. Traditional agronomic management practices do not favor high yields. The current status of genetic improvement and agronomic management practices in chickpea is reviewed in this section and future strategies to increase and stabilize chickpea yield with emphasis on the WANA region are recommended.

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Genetic Improvement

Selection in germplasm has been a common approach for identifying promising chickpea cultivars. It has been mostly effective because of the general and specific adaptation of the landraces to local conditions. Hybridization and selection are now focusing on combining desirable traits from different landraces or source populations (Singh 1987). Many chickpea cultivars have been released using these procedures (Singh 1987; Smithson et al. 1985).

In cereals, a change in plant type—from tall and lodging to stiff-strawed, semidwarf, and non-lodging type—for greater responsiveness to irrigation and fertilizer has increased yields substantially. Ideotypes for obtaining high yield have also been proposed in chickpea but have not been developed to any significant extent. Developing resistance to biotic and abiotic stresses has been the major objective of crop improvement programs.

Biotic Stresses

Diseases

The chickpea diseases and screening procedures have been described in detail by Beniwal et al. (Section 5.3). They are considered here for genetic and management improvement.

Fusarium wilt and black root rot

Reliable screening techniques are available for fusarium wilt (*Fusarium oxysporum*) and several sources of resistance have been identified (Nene and Haware 1980; Nene et al. 1981; Nene and Reddy 1987; Jimenez-Diaz et al. 1993). Five sources—ICC 10803, ICC 11550, ICC 11551, ICC 11322, and ICC 11323—have proved to be durable and have retained their resistance under high levels of pressure (Nene and Haware 1980). Three kabuli lines, FLIP 82-78C, FLIP 84-43C, and FLIP 84-130C, developed at ICARDA were also found resistant to fusarium wilt at Cordoba in Spain. Combined but moderate levels of resistance to fusarium wilt and root rot (*Rhizoctonia bataticola*) have been identified in ICC 12237 and ICC 12269 (Nene 1988). At ICRISAT Asia Center (IAC), India, over 100 out of some 12 000 germplasm accessions screened have been identified as resistant (Pundir et al. 1988). Chickpea cultivars developed by ICRISAT jointly with various NARS and released for general cultivation are listed in Table 5.6.1. Hybridization and selection using pedigree, modified bulk pedigree, or backcross methods have been successful in enhancing resistance to these two diseases.

Inheritance studies show that resistance to fusarium wilt is oligogenic. Two recessive genes, and in one case a partially dominant gene, conditioning late wilting of chickpea (Singh et al. 1987) have been recognized. The combination of any two confers complete resistance. Resistance to race 1 of fusarium wilt disease is controlled by at least 2 loci (Kumar and Haware 1982; Sindhu et al. 1983; Upadhayaya et al. 1983a and b; Singh et al. 1987, and Singh et al. 1990b). Recessive alleles at each locus separately result in conditioning late wilting and together confer an almost complete resistance.

Table 5.6.1. Releases of chickpea genotypes developed by ICRISAT in collaboration with national programs.

Country	Cultivars released	Year of release	Specific features
Ethiopia	Mariyo (Sel. from 850-3/27 × F 378)	1988	Large seeds
India	ICCC 4 (ICCV 1)	1983	Released in Gujarat
	RSG 44 (Sel. from ICC 12366)	1984	Short-duration, released in Rajasthan
	Anupam (Sel. from ICC 14302)	1984	Released in Uttar Pradesh
	GNG 149 (Sel. from L 550 × L 2)	1985	Released in Rajasthan
	Swetha (ICCV 2)	1989	Short-duration, wilt resistant
	ICCV 2	1991	Released in Maharashtra
	Kranthi (ICCC 37)	1989	High-yielding, short-duration, wilt-resistant, released in Andhra Pradesh
	Bharathi (ICCV 10)	1992	Short- to medium-duration, wilt-resistant, released for central and southern India
Kenya	ICCL 83110	1986	
Myanmar	Schwe Kyehman (Sel. from K 850 × F 378)	1986	Large seeds
	Yezin 1 (ICC 552)	1986	High-yielding
Nepal	Sita (ICCV 1)	1987	High-yielding
	Radha (ICC 6098)	1988	Short-duration, wilt-resistant
	Kosheli (ICCV 6)	1990	Wilt-resistant, kabuli
	Kalika (ICCL 82108)	1990	Wilt-resistant, desi
USA	Aztec (ICC 8521)	Mid 1980s	

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In spite of the occurrence of physiological races (Haware and Nene 1982) and differences between early and late wilting, many genotypes with durable resistance have been developed and released for cultivation (Kumar et al. 1985; Buddenhaggen and Richards 1988). Avrodhi, BG 246, ICCC 32, and ICCC 42 were found resistant at several locations in India. A few national agricultural research systems (NARS) have developed and released several resistant cultivars, including WR 315 and CPS 1 by the Indian NARS, Amdoun 1 by the Tunisian NARS, and Surutato 77, Sonora 80, and Santa Domingo by the Mexican NARS. The University of California has released two cultivars UC 15 and UC 27. Some countries including Spain have developed improved sources of resistance to fusarium wilt and released them for commercial exploitation.

Ascochyta blight

Ascochyta blight (*Ascochyta rabiei*) is a major constraint in the Mediterranean region, Pakistan, and northwestern India, and sometimes causes total crop failure. Progress made in breeding for ascochyta blight resistance from 1930 to 1984 has been summarized by Singh (1987). Genetic improvement of resistance was initiated around 1940. Selections made in germplasm resulted in the release of several cultivars, including F 8, VIR 32, ILC 72, ILC 195, ILC 202, ILC 482, and ILC 3279. Hybridization and selection work which began in the 1940s produced several cultivars in Pakistan (C 12/34, C 727, C 44) and India (C 235, G 543). The extensive resistance breeding work undertaken in the ICARDA/ICRISAT chickpea project over the past 10 years has helped identify and develop several blight-resistant, high-yielding kabuli cultivars for the Mediterranean region (Table 5.6.2).

Resistance to ascochyta blight seems to be governed by a single recessive or a single dominant gene (Singh and Reddy 1983, 1989, 1991).

Cultivars at different locations have been found to react differently to blight; there appear to be 13 races of blight in chickpea (Reddy et al. 1992). New races have emerged and resulted in the breakdown of sources that were earlier resistant in many countries. A recent example is the breakdown of resistance in ILC 482 in Syria (K.B. Singh, unpublished data). Strategies for incorporating durable resistance should, therefore, be adopted through pyramiding of genes from sources resistant to different physiological races.

Nematodes

Several nematodes—cyst (*Heterodera* spp), root-knot (*Meloidogyne* spp), and root-lesion (*Pratylenchus* spp)—have been reported from several countries. Root-knot nematodes are the most widespread and damaging plant-parasitic nematodes. Among them, *M. incognita*, *M. javanica*, and to some extent *M. arenaria*, are important in South Asia and *M. artiella* is important in the Mediterranean region. Spring-sown chickpea is more susceptible to *M. artiella* than winter-sown chickpea. However, nematode problems are mostly of localized significance. Field techniques for nematode screening need to be simplified. A pot-culture technique for screening resistance to cyst nematode has been developed at ICARDA (Di Vito et al. 1988). Efforts to identify resistance to root-knot (Sandhu et al. 1981) and cyst nematodes (Di Vito et al. 1988) in cultivated species have not been rewarding. But sources of resistance to cyst nematode have been identified in wild *Cicer* species (Singh et al. 1989a). Most of the resistant sources to cyst nematode are found in *C. bijugum* and *C. pinnatifidum*.

Insect Pests

Insect pests on chickpea and screening methods have been described by Weigand (Section 5.4). Leafminer (*Liriomyza cicerina*) and pod

Table 5.6.2. Chickpea cultivars developed by ICARDA and released by national programs.

Country	Cultivars released	Year of release	Specific features
Algeria	ILC 482	1988	High-yielding, blight-resistant
	ILC 3279	1988	Tall, blight-resistant
	FLIP 84-79C	1991	Cold- and blight-resistant
	FLIP 84-92C	1991	Blight-resistant
China	ILC 202	1988	High-yielding, for Ginghai province
	ILC 411	1988	High-yielding, for Ginghai province
	FLIP 81-71C	1993	High-yielding
	FLIP 81-40C	1993	High-yielding
Cyprus	Yialousa (ILC 3279)	1984	Tall, blight-resistant
	Kyrenia (ILC 464)	1987	Large seeds
Egypt	ILC 195	1993	Blight- and wilt-resistant
Ethiopia	DZ 10-16-2	1994	For mid-altitude areas, high-yielding, tolerant of wilt/rust
France	TS1009 (ILC 482)	1988	Blight-resistant
	TS1502 (FLIP 81-293C)	1988	Blight-resistant
	Roye Rene (FLIP 84-188C)	1992	Cold- and blight-resistant
Iraq	Rafidain (ILC 482)	1991	Blight-resistant, high-yielding
	Dijla (ILC 3279)	1991	Tall, blight-resistant
Italy	Califfo (ILC 72)	1987	Tall, blight-resistant
	Sultano (ILC 3279)	1987	Tall, blight-resistant
Jordan	Jubeiha 2 (ILC 482)	1990	High-yielding, blight-resistant
	Jubeiha 3 (ILC 3279)	1990	High-yielding, blight resistant
Lebanon	Janta 2 (ILC 482)	1989	High-yielding, wide adaptation
	FLIP 85-5C	1993	Blight-resistant
Libya	ILC 484	1993	Blight-resistant, high-yielding
Morocco	ILC 195	1987	Tall, blight-resistant
	ILC 482	1987	High-yielding, blight-resistant
	Rizki (FLIP 83-48C)	1992	Large seed, blight-resistant
	Douyet (FLIP 84-92C)	1992	Large seed, blight-resistant
Oman	ILC 237	1988	High-yielding, irrigated conditions

Continued

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Table 5.6.2. *Continued.*

Country	Cultivars released	Year of release	Specific features
Pakistan	Noor 91 (FLIP 81-293C)	1992	High-yielding, blight-resistant
Portugal	Elmo (ILC 5566)	1989	Blight-resistant
	Elvar (FLIP 85-17C)	1989	Blight-resistant
Spain	Fardan (ILC 72)	1985	Tall, blight-resistant
	Zegri (ILC 200)	1985	Medium height, blight-resistant
	Almena (ILC 2548)	1985	Tall, blight-resistant
	Alcazaba (ILC 2555)	1985	Tall, blight-resistant
	Atalaya (ILC 200)	1985	Medium height, blight-resistant
Sudan	Shendi (ILC 1335)	1987	High-yielding, irrigated conditions
	Jeb el Mara 1 (ILC 915)	1994	High-yielding, irrigated conditions
Syria	Ghab 1 (ILC 482)	1986	High-yielding, blight-resistant
	Ghab 2 (ILC 3279)	1986	Tall, blight-resistant
	Ghab 3 (FLIP 82-150C)	1991	High-yielding, cold- and blight-resistant
Tunisia	Chetoui (ILC 3279)	1986	Tall, blight-resistant
	Kassab (FLIP 83-46C)	1986	Large seeds, blight-resistant
	Amdoun 1 (Be-sel-81-48)	1986	Large seeds, wilt-resistant
	FLIP 84-79C	1991	Blight- and cold-resistant
	FLIP 84-92C	1991	Large seed, blight-resistant
Turkey	ILC 195	1986	Tall, blight-resistant
	Guney Sarisi 482	1986	High-yielding, blight-resistant
	Damla (FLIP 85-7C)	1994	For cultivation in Transitional Zone, blight-resistant
	Tasova 89 (FLIP 85-135C)	1990	Blight-resistant
	Akcin (87AK71115)	1991	Tall, blight-resistant
	Aydin 92 (FLIP 82-259C)	1992	Large seed, blight-resistant
	Menemen 92 (FLIP 85-14C)	1992	Large seed, blight-resistant
	Izmir 92 (FLIP 85-60C)	1992	Large seed, blight-resistant
	Aziziye (FLIP 84-15C)	1994	Blight-resistant, for cultivation in Erzurum region
USA	Sanford (Surutato × FLIP 85-58C)	1994	Blight-resistant
	Dwelley (Surutato × FLIP 85-58C)	1994	Blight-resistant

borers (*Helicoverpa* spp) cause most damage in Mediterranean environments, whereas pod borers are the most important insect pests in the semi-arid environments. Among storage insects, bruchid (*Callosobruchus* spp) infestation is widespread.

Pod borer

Since 1976, more than 14 000 chickpea germplasm accessions and breeding lines have been screened for resistance to pod borer (*H. armigera*) under open field conditions at ICRISAT. Some of the selections, ICC 506, ICCV 7, ICC 6663, ICC 10817, ICCL 86012, ICCL 86013, ICC 4935-E 2793, ICCX 730041-8-1-B-BP, PDE 2, and PDE 5, showed good level of resistance to pod borer across the different agroecological zones of India (Lateef and Sachan 1990). A major limitation in genetic improvement of pod borer resistance is the lack of effective screening methods. However, repeated cycles of selection for low damage under field conditions over different generations have been effective in identifying genotypes that are less susceptible (Lateef and Sachan 1990).

Resistance to pod borer damage seems to be governed by additive gene action (Gowda et al. 1985). A pedigree method of breeding for developing high-yielding resistant genotypes is followed at ICRISAT. An integrated approach, involving nonpreference (antibiosis), and early-podding genotypes (increasing podding duration) could help the plants to escape from *Helicoverpa* damage (Singh et al. 1992). Nonpreference (antibiosis), perhaps mediated by malic acid exudation from stem and leaf surfaces, is most likely to be quantitatively inherited, and can be increased through recurrent selection.

Leafminer

Screening of 6800 kabuli chickpea germplasm lines for leafminer resistance under natural field infestation at ICARDA, revealed that only 31 lines were tolerant. Of these, only four, ILC 726, ILC 1776, ILC 3350, and ILC 5901, were promising resistance sources. Most of the leafminer-resistant genotypes have smaller leaflets and seed. The most tolerant genotype, ILC 5901, has characteristic multipinnate leaves. The breeding program for leafminer resistance at ICARDA has made limited progress as it lacks efficient screening techniques. A negative selection for leafminer tolerance is being followed and elite breeding material developed at ICARDA are being screened.

Abiotic Stresses

Drought

Terminal drought is the most important abiotic stress (Saxena et al. 1993). In the Mediterranean region, it is frequently associated with heat stress (Wery et al. 1993). Two common strategies are followed for the genetic management of drought: development of short-duration cultivars to escape drought, and genetic enhancement of drought resistance. Development of the short-duration kabuli cultivar ICCV 2, and desi cultivars such as ICCV 88201 and ICCV 88202, are good examples of the first approach (Kumar et al. 1985). Of the two components of drought resistance, yield potential and drought escape (Silim and Saxena 1993a and b), the latter may have a limited impact on rainfed yield in winter-sown chickpea in WANA as the early-formed flowers may not set pods at extremely cold temperatures. Five kabuli cultivars, Krasnokutskyi (K) 195, Jubilant, K 123, K 28, and Volgagrad 10 have been found tolerant of drought and heat at Kroshy Kut Research Station Saratov, Russia (Nadazda, personal communication).

Using a field-screening technique, a short-duration drought-resistant germplasm (ICC 4958) has been identified (Saxena 1987c), and is being used in genetic enhancement of drought resistance at

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ICRISAT (ICRISAT 1989). At ICARDA, FLIP 87-59C has been identified in the same way and is being used in the breeding program (ICARDA 1994).

In addition to the field-screening techniques described by Johansen et al. (Section 5.3), a technique involving late spring (mid- to late-Mar) sowings in Mediterranean-type environments has been evaluated at ICARDA to screen chickpea for drought and high temperature stress (ICARDA 1992). It has been effective in identifying some promising drought-resistant genotypes. Saxena et al. (1993) have established several criteria for identifying drought-resistant genotypes, e.g., empirical methods, yield-based criteria (Saxena 1987c), morpho-phenological traits such as early maturity, early growth vigor, rapid ground cover, relatively large seed size, and large root biomass associated with drought-tolerance sources. Integrating these with a visual rating for yield in defined drought environments will help to make rapid progress in genetic enhancement of drought resistance in chickpea.

Cold

Cold stress occurs at various crop growth stages—emergence, seedling, vegetative, or flowering—depending upon the ecoregion and sowing time. Extremely cold temperatures coinciding with the flowering stage cause failure of pod setting (Saxena and Johansen 1990). Tolerance for freezing cold at vegetative stages is an essential component of winter chickpea technology that has been introduced in WANA (Singh et al. 1989c). Research on the mechanisms of cold tolerance is in progress in Italy and France (Wery 1990; Malhotra and Saxena 1993).

Sources resistant to cold have been identified (Singh et al. 1989c; Singh et al. 1990a; Wery et al. 1992) and used in genetic enhancement programs (ICARDA 1993) and for studies on the inheritance of cold tolerance (Malhotra and Singh 1990, 1991a). Some of the cold-tolerance sources in cultivated species include ILC 794, ILC 1071, ILC 1251, ILC 1256, ILC 1444, ILC 1455, ILC 1464, ILC 1875, ILC 3465, ILC 3598, ILC 3746, ILC 3791, ILC 3857, ILC 3861, FLIP 82-85C, FLIP 82-131C, FLIP 84-112C, FLIP 85-4C, FLIP 85-49C, and FLIP 85-81C (Singh et al. 1989c).

The level of cold tolerance was found to be higher in wild *Cicer* species than in cultivated species (Singh et al. 1990a). Cold tolerance is governed by both additive and nonadditive gene effects, with preponderance of additive gene action (Malhotra and Singh 1990). Also, additive × additive and dominance × dominance interaction with duplicate epistasis have been reported (Malhotra and Singh 1991a). Selection for cold tolerance is more effective after a few generations of selfing, when dominance and epistatic effects are reduced.

Responsiveness to Inputs

Fertilizer

In general, responses to fertilizers inputs are minimal, possibly because the chickpea crop has been developed under low-input conditions (Smithson et al. 1985). Genotypic differences in response to phosphatic fertilizers have been reported (ICARDA 1991), but there are no published reports on breeding for P responsiveness in chickpea.

Irrigation

In recent years, chickpea has been introduced as an irrigated crop in many countries. It is grown exclusively with irrigation in Egypt and Sudan. In other countries such as India, Iran, Pakistan, Mexico, Syria, and USA, small areas are grown with supplemental irrigation and genotypic differences in irrigation response have been observed. The yield of winter-sown rainfed chickpea in the Mediterranean environments could be increased by more than 50% by using irrigation-responsive genotypes and applying 100 mm of supplemental irrigation (ICARDA 1989). One of the cultivars responsive to irrigation, ILC 237, has been released in Oman. Other cultivars identified as irrigation-responsive include, ILC 104, ILC 202, ILC 482, FLIP 83-69C, FLIP 83-71C, and FLIP 84-116C (ICARDA 1989).

Exploitation of Wild *Cicer* Species

More than 200 accessions of eight annual wild *Cicer* species were evaluated for resistance to ascochyta blight, fusarium wilt, leafminer, cyst nematode, and seed beetle and to cold (ICARDA 1990). Resistance to seed beetle and cyst nematode was found only in the wild species (Singh et al. 1989a, b). In general, the degree of resistance to most of the stresses was greater in wild than in cultivated species. Many accessions have combined resistance to four or even five stresses. Therefore, genes for resistance in blocks for several stresses could be transferred to cultivated species.

Crosses of C. *echinospermum* and C. *reticulatum* with cultivated species were made by Ladizinsky and Adler (1976) and Singh and Ocampo (1993). Recently, crosses have also been reported between cultivated species and C. *bijugum*, C. *judaicum*, and C. *pinnatifidum* (Verma et al. 1990). Work on interspecific hybridization has been initiated to transfer the genes for resistance to cyst nematode from C. *reticulatum*, and for cold tolerance from C. *echinospermum* and C. *reticulatum* (ICARDA 1994).

Biotechnology and Chickpea Improvement

Cellular and molecular biology (CMB) techniques, e.g., restriction fragment length polymorphism (RFLP), promise to be useful in genetic enhancement of resistance. Some progress has been made in DNA fingerprinting of *A. rabiei* isolates and also of improved cultivars (ICARDA 1993). Gene transfer using nonradioactive probes, for oligonucleotide fingerprinting, is currently being explored jointly by ICARDA and the University of Frankfurt, Germany. Application of CMB techniques to improve resistance to drought and other stresses in chickpea needs to be explored. Utilization of gene coding for the production of insect toxin found in the spores of *Bacillus thuringiensis* (Bt) could be important for enhancing tolerance for *H. armigera*. Highly virulent strains of *Agrobacterium tumefaciens* have been identified (Weigand and Saxena 1989). These could eventually be used as vectors for transferring Bt through a nontissue-culture technique.

International Testing Program

International testing networks (ITN), for the desi type (ICRISAT, since 1975) and kabuli type (ICARDA, since 1978) of chickpea have been very useful for genetic improvement work. Various types of nurseries, including segregating populations, improved stocks with different genetic backgrounds, elite improved high-yielding lines, and sources of resistance to various biotic and abiotic stresses are developed and shared with ITN members for evaluation. These networks have been effective in the development and dissemination of high-yielding germplasm tolerant/resistant to various stresses, and of improved technology.

Several kabuli and desi chickpea cultivars have been released through these joint efforts by NARS in many countries (Tables 5.6.1 and 5.6.2) (ICARDA 1994). Some of these are also used as parents in crop improvement programs. Several agronomic trials have recently been conducted through ITN in WANA. Through these trials, scientists have been successful in identifying the most important agronomic constraints and suitable agronomic management practices, such as appropriate date of sowing, plant geometry, herbicide, orobanche (parasitic weed) control, and rhizobial inoculation requirements. These nurseries were also useful in identifying G × E interactions (Multize et al. 1987; Malhotra and Singh 1991b) and key testing sites.

Crop Improvement: Current Status

At least 159 cultivars—102 desi, 51 kabuli, and six unclassified—have been released in 20 countries up to 1983 (Singh 1987). More than 100 of these were selections made in local or introduced germplasm, and 50 through directed crop improvement efforts. Up to 1989, more than 80 disease-resistant cultivars have been released (Singh and Reddy 1991). Some of the cultivars released using the materials supplied through ITN are listed in Tables 5.6.1 and 5.6.2.

Agronomy and Management

Chickpea in WANA is grown primarily in areas with annual rainfall between 350 and 550 mm. It is traditionally a spring-sown crop (from late Feb to early Jun) grown on soil moisture stored during the winter months. Large areas continue to be spring-sown. Winter chickpea technology for WANA (Singh 1990), in which sowing is advanced from spring to early winter, has demonstrated that an integrated agronomic management practice results in large increases in seed yield. Components of winter chickpea technology are discussed below.

Sowing Date

Spring-sown chickpea suffers from temporal and spatial variability in rainfall (Saxena 1990; Pala and Mazid 1992). Advancing the sowing date from spring to early winter in lowlands, or from spring to late winter in highlands results in rapid canopy development, a large shoot mass which supports high yield, and an increase in water-use efficiency (Saxena 1987a and b; Pala and Mazid 1992). As winter-sown chickpea crops are taller (40 cm height) than those of spring (25–39 cm) in WANA, they are suitable for mechanical harvesting. Direct drilling—which allows better utilization of surface soil moisture and early crop establishment (about 2 weeks) than with other sowing methods—enables earlier sowing of spring chickpea (late Feb to early Mar).

Sowing Methods

In environments favorable for chickpea cultivation in WANA, seeds are generally broadcast evenly on flat seed-beds, both for winter and spring sowings. They are then covered either by a duck-foot cultivator or a mold-board plow. Alternatively, the field is first ridged using a one-set duckfoot cultivator, with about 45 cm between the ridges. Seeds are then broadcast and ridges are bisected by another pass with the duck-foot cultivator. In all cases, seed depth varies from shallow (5 cm) to deep (15-17 cm) (Harris and Pala 1987; Saxena 1987a). In some cases seeds are hand-sown behind the duck-foot cultivator with an inter-row spacing of 40–45 cm, which results in early emergence and better crop development. Drilling seeds with a single pass planter with 40-cm row spacing (developed at ICARDA by mounting the seed and fertilizer boxes on a cereal drill with a duck-foot cultivator) resulted in better early crop development and substantial yield increases over the traditional broadcast method in on-farm trials conducted in Syria (Pala and Mazid 1992). Drills designed for cereals are generally satisfactory for sowing chickpea, with minor modifications (Papendick et al. 1988).

Weed Control

Weeds cause 40–94% seed yield losses in chickpea in South Asia, 40-75% in West Asia, 13–98% in North Africa, and around 35% in

Italy (Solh and Pala 1990). Although early weeding before the crop canopy covers the ground is most useful, limitations due to non-availability and high cost of labor often prevent the adoption of this method, particularly in WANA. Weeds are a more serious problem in winter-sown than spring-sown chickpea. Through ITN, effective chemical weed control measures have been identified. Preemergence application of herbicides such as terbutryne (2.5 to 3.0 kg a.i. kg^{-1}), chlorbromuron (1.5 to 2.5 kg a.i. ha^{-1}), methabenzthiazuron (3.0 kg a.i. ha^{-1}), or cyanazine (0.5 to 1.0 kg a.i. ha^{-1}) either alone or in combination with pronamide (0.5 kg a.i. ha^{-1}) have been effective for large-scale weed control. On-farm evaluation in northern Syria demonstrated yield increases of 17–105% with better weed control in chickpea, the effect being greater in the winter-sown crop (ICARDA 1986).

Mechanical weed control would encourage the expansion of chickpea area and production. Many farmers in WANA, especially in Algeria and Morocco, control weeds by inter-row cultivation, where the rows are usually wider than the row spacing recommended for maximum yield in a weed-free situation. The potential of inter-row cultivation for weed control of winter-sown chickpea has also been demonstrated in Syria (Pala 1991).

Mechanization of Harvesting

In contrast to fully mechanized cereal crop cultivation, lack of mechanization is a major constraint to the expansion of chickpea area in many countries (Buddenhaggen 1990; Oram and Belaid 1990; Osman et al. 1990). Mechanized harvesting of chickpea presents fewer problems than for other legumes because of the availability of tall cultivars, which permits the use of traditional cereal grain combines with some minor adjustments (Saxena et al. 1987). The introduction of winter sowing in lowlands and early spring sowing in highlands will improve plant vigor and yield and promote mechanical harvesting.

Yield losses due to mechanical harvesting using a plot combine for end winter- (early spring-) sown chickpea were 29% in ILC 482, a cultivar of conventional plant height, compared with no seed yield loss in ILC 3279, a tall cultivar (Saxena et al. 1987).

Mechanical harvesting of winter-sown ILC 482 (40 cm plant height) and ILC 3279 (60 cm), and a spring-sown Syrian local cultivar (25 cm), with a swath mower, caused 6 to 48% loss in grain yield. The highest yield losses were recorded in the local cultivar. Modified cereal combine harvesters could not be used to harvest the local cultivar due to its short plant height. The loss in seed yield due to combine harvesting was 18% in ILC 3279 and 26% in ILC 482. ILC 3279, because of its height, was the only cultivar where mechanical harvesting was found to be economical.

Fallow Replacement

Currently around 20 million ha of land are under fallow in WANA, contributing to a low cropping intensity (Pala 1992). However, recent data have shown that fallow-cereal rotations in the region do not store water as efficiently as was earlier believed. In the Anatolian plateau of Turkey, with relatively mild evaporative conditions in the spring and summer, low fallow efficiencies were reported by Durutan et al. (1989). In the lowlands of the region, low fallow efficiency was reported in areas with less than 300 mm annual rainfall, probably because rain water is unlikely to penetrate below 70 to 90 cm into soil profile; this was aggravated by improper traditional cultural practices. At a dry site in northern Syria with long-term mean annual rainfall of 280 mm, Harris (1989) found that by the beginning of the cereal season, less than 10% of the rain received during the fallow season remained in the soil profile, implying a very low efficiency.

Chickpea and other food legumes can replace inefficient fallow lands, improve crop water-use efficiency, and contribute to both improved productivity and sustainability of the system. Karaca et al. (1991) reported that wheat had a higher water-use efficiency when grown after chickpea than after fallow in the Central Anatolian Plateau of Turkey.

Due to marked increases in human populations and small ruminants, continuous cropping of cereals is becoming more frequent in WANA. However, monocropping is increasingly being recognized as an unsustainable system (Karaca et al. 1991; Harris 1990). The introduction of legumes to interrupt monocropping could improve productivity, as reported by several researchers (Saxena 1988; Harris 1990), not only because of reduced depletion of soil nitrogen, but also due to other associated beneficial effects.

Future Needs

- Enhanced resistance to ascochyta blight and cold for winter sowing and increased drought resistance for spring sowing are required.
- New, cheap, and effective herbicides need to be identified.
- Where water is available, scope for supplemental irrigation for greater and efficient use of irrigation water should be explored.
- Unavailability of seed of improved cultivars in adequate quantity is a major limitation, that could be removed through policy decisions such as seed multiplication by the private and public sector and attractive prices for improved seed.
- A large yield gap exists, ranging from 50–80% between research stations and farmers' fields (Saxena 1990), which could be bridged through demonstrations of improved technologies.
- There is a shortage of trained researchers in chickpea improvement programs and a lack of multidisciplinary teams among NARS in WANA. Human resource development, specifically for chickpea improvement, should receive priority attention.
- In the past, chickpea was used in South Asia both as food and feed but later became exclusively a human food because of its high prices. It is unlikely that its price will fall to the extent that it can be used again for feed, except as an ingredient in poultry feed. But if productivity increases substantially through the adoption of winter chickpea technology, the crop could be grown for cattle feed, especially in the Mediterranean areas of Europe.

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5.7. Socioeconomic Constraints to Adoption of Chickpea

N Tutwiler[1]

Introduction

The interaction between the chickpea plant and various aspects of its physical surroundings, such as climate, soil, nutrition, diseases, pests, etc., is discussed elsewhere in this book. This section focuses on the interaction between the crop and the socioeconomic environment. Some attention has also been paid to ways in which human beings can manipulate various aspects of the physical environment to alleviate constraints to increased crop productivity.

No technological improvements designed to improve the adaptation of chickpea in the physical environment will be used, unless they are equally adapted to the socioeconomic environment governing chickpea production. The term adaptation has been generally used to mean modifying existing chickpea production technology for particular environments in order to achieve increased productivity. The many alternative purposes and decisions available to chickpea producers constitute the foundation for understanding the socioeconomic environment for chickpeas.

Analysis of the socioeconomic environment of chickpea tends to be nonpredictive, as the data on which they are based are usually subjective and often prejudiced by the methods through which they are collected. Nevertheless, attention to the human circumstances of chickpea production is critical to the eventual application of improved technology, including new cultivars, inputs, machinery, or a new or improved agronomic practice.

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A Case Study in Morocco

Most biophysical scientists working on chickpea adaptation in the WANA region recognize the importance of considering the socioeconomic environment in the design and development of new production technology. Initial research priorities are often set by examining economic trends for agricultural commodities at national and international levels. At the farm level, problems are identified through diagnostic assessments in which farmers participate. The technological innovations are tested in farmers' fields, and sometimes the farmers' opinions of new technologies are solicited before the technology is declared ready for general release. Unfortunately, systematic consideration of the socioeconomic environment in technology development and transfer is still lacking.

A case study to illustrate the differential adaptation of winter sowing of chickpea to the socioeconomic environment of one WANA country, Morocco, is presented here.

Winter sowing was identified as a technology which promised to provide higher yields than spring sowing in the Moroccan environment. After years of testing, two varieties adapted to winter sowing were selected for release, based on yield—including resistance to ascochyta blight (*Ascochyta rabiei*)—that was substantially higher than the local control. At the time of release, however, researchers identified some aspects of the new technology that might prove disadvantageous in the prevailing socioeconomic circumstances. Among these were small seed size, the need for an early spring weeding, and possible conflicts with other land uses in the farming system.

In order to determine the acceptance of winter sowing, a program of demonstration trials was organized in which farmers across Morocco compared winter- and spring-sown chickpea. Farmers who participated in the demonstration trials were included in a survey of opinions and decision-making about the new technology. The survey also included farmers who did not participate in the demonstration program but had nonetheless heard about winter-sown cultivars, procured seeds themselves, and produced winter chickpea on their farms for at least 1 year. In total, 123 farmers with winter chickpea experience over a 5-year period (1986–90) were included in the sample.

The results have been extremely useful, not so much in evaluating winter chickpea in the physical environment (although the farmers' yield results are consistent with experimental results), but because they directly relate to its adaptation to the socioeconomic environment.

Preliminary Results

A full analysis of the results is not yet available. However, in Tables 5.7.1 and 5.7.2, a very broad comparison of winter- and spring-sown chickpea in terms of the former's adaptation to the socioeconomic environment is presented. Winter sowing of chickpeas is broadly considered to be adapted if it is accepted by potential producers, i.e., adoption is the key index of adaptation. Participants in the study were divided into four categories on the basis of their decision to adopt or not adopt winter-sown cultivars:

Independent adopters	Adopted winter sowing independent of the demonstrations.
Adopters from trials	Participated in demonstrations and chose to adopt winter sowing.
Non-adopters from trials	Participated in the demonstrations and chose not to adopt winter sowing.
Independent non-adopters	Tried winter chickpea independent of the demonstrations, but did not adopt it.

Although all participants had at least 1 year's experience with the new technology, some had grown winter chickpea for as long as 5 years. However, only those farmers who had grown winter chickpea for at least 2 consecutive years were considered as adopters.

The participants were located in four different provinces, each with a slightly different physical environment, farming system, and market infrastructure. Fes and Khemisset are traditional chickpea areas with reasonable rainfall and access to urban markets. Settat has a less favorable climate, low emphasis on chickpea, but with access to nearby Casablanca markets. Safi has the lowest rainfall among the four provinces, very little spring chickpea, and poor access to urban markets.

Table 5.7.1 presents several descriptors of winter chickpea adaptation to the socioeconomic environment according to provinces. Safi had the highest adoption rate among the participating farmers, with a total of 62% acceptance. Fes followed with 54% acceptance. Winter chickpea was not well adopted, on the whole, by farmers in Khemisset (33% acceptance) or Settat (21% acceptance). Overall, the technology was adopted by 42.5% of the participating farmers.

The yield differential gives the percentage of average winter chickpea yield among the participants in each province over or under the mean yield of spring chickpea during the study period (Table 5.7.1).

Table 5.7.1. Comparison of winter and spring chickpea by province in Morocco.

Province	Acceptance of winter chickpea (%)	Yield advantage/ disadvantage over spring chickpea (%)	Price disadvantage over spring chickpea (%)	Paid weeding for winter chickpea (days ha^{-1})
Fes	54	+39	−44	10.7
Khemisset	33	+36	−34	29.9
Safi	62	+27	−25	6.2
Settat	21	−20	−28	11.7

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Winter chickpea yield averaged 39% higher than spring among farmers in Fes, but it was 20% under spring yields in Settat. If yield alone governed acceptance within an environment, then the highest adoption should be in Fes, followed by Khemisset and Safi, with no or very little adoption in Settat.

The differential between farm-gate prices for spring and winter chickpea in each province shows that by this criterion alone winter chickpea has good prospects in Safi and in Settat (Table 5.7.1). The small seed size of winter chickpea results in a price disadvantage. Moroccan consumers prefer to eat chickpeas as boiled, whole seed, and market prices generally follow a scale in which larger seed means higher price, both for producers and consumers.

The cost of hired labor paid by farmers in each province for weed control of winter chickpea is an additional expense over that required for spring chickpea (Table 5.7.1). It is an important criterion for adoption of winter chickpea, e.g., in Safi winter chickpea might be better accepted than in other provinces, because of low weeding cost.

The data in Table 5.7.1 are categorized by physical location, and do not show the considerable influences of the socioeconomic environment on individual farmer decision-making. This is much better understood from the perspective of farmer differences, rather than geographical locations. Table 5.7.2 is organized on the basis of the fundamental distinction between farmers who adopted winter chickpea and those who did not, and between farmers who tried the technology by participating in demonstrations, and were assisted with material and information from extension and researchers, and those who did it without such support services.

'Independent adopters' enjoyed the highest yield gains, the best prices, the lowest weeding costs, and used mechanical harvesting (an important cost-saving measure) most frequently. They were followed in these advantages by the adopters who participated in demonstrations. 'Non-adopters from trials' tended to experience the worst combination of these factors. The seeming inconsistency is for the 'independent non-adopters', but if their yields are excluded, their experience with the other descriptors is consistent with the 'non-adopters from trials'. Looking more closely at the history of the 'independent non-adopters', we find that a high percentage of them had, in fact, decided to adopt winter chickpea until a disastrous ascochyta epidemic combined with severe weed infestations in 1988/89 dissuaded them from continuing to use the new technology. For the most part, they did not return to chickpea production, but grew cereals instead the following year.

Table 5.7.2. Comparison of winter and spring chickpea by adoption category in Morocco.

Adoption category	Yield advantage over spring chickpea (%)	Price disadvantage over spring chickpea (%)	Paid weeding for winter chickpea (days ha^{-1})	Average arable area per farm (ha)	Average chickpea area per farm (ha)	
					1990	1991
Independent adopters	+82	–20	8.9	189	8.7	45.9
Adopters from trials	+25	–35	11.6	90	2.0	3.9
Non-adopters from trials	+ 4	–39	16.0	57	3.5[1]	
Independent non-adopters	+30	–50	27.3	187	1.0[1]	

1. Spring chickpea area in 1991, dependent on rainfall.

The potential impact of winter chickpea is indicated by the decision of both types of adopters, to increase the area under winter chickpea in 1991. Thus, the area of winter chickpea shows a three-fold increase between 1990 and 1991. In fact, by the end of the 5-year study period, winter chickpea accounted for the majority of total chickpea production by all the participating farmers.

Conclusions and Recommendations

Preliminary findings suggest that winter chickpea is adapted to a particular combination of physical and socioeconomic environments, but that this combination does not include all the chickpea-producing environments in Morocco, nor does it cover all (probably not even the majority) of present chickpea producers in Morocco. The adopters of winter chickpea accept or reject the new technology on their own terms and in their individual circumstances, as they interpret them. Within the group of adopters, the 'independent adopters' would appear to be more committed to the technology than those whose initial adoption choice came about through participation in the demonstration program. This should not be understood as a criticism of the demonstration program. On the contrary, without the demonstration program, the benefits of winter chickpea would be narrowly shared among the farming population (and primarily restricted to large, commercial producers—see Table 5.7.2). Furthermore, without the demonstration program and the large number of farmers and farmer experience pool which it contacted, researchers would have little information from which to assess winter chickpea's adaptation to the socioeconomic environment.

It may not be possible for the researcher to develop a precise and predictive model to explain adoption or non-adoption. Clearly, yield improvement alone (although it may be necessary) is not a sufficient attribute for adoption. Similarly, increasing seed size may reduce the price differential in general, but there is no reason to believe that this would result in universal adoption any more than small seed size resulted in complete non-adoption. In fact, everyone would like to receive higher prices for the commodities they sell, but the fact that they do not, does not stop some producers from continuing to produce for sale.

Perhaps the most obvious conclusions that can be drawn from this case study is that adaptation to a biophysical environment alone will not result in production increases. There must also be adaptation to the socioeconomic environment. Biophysical environments in Morocco where winter-sown chickpea has enjoyed the highest yield differential are not the places where it has achieved the highest acceptance rating from farmers.

It must be also acknowledged that socioeconomic environments do not easily map onto biophysical environments. Socioeconomic environments are scattered within a population even though that population may share the same biophysical circumstances. Neighboring farmers, for example, may have very different marketing connections, and this difference may be instrumental in determining their land use patterns and production strategies. Even if a population considers a particular technology to be adapted to its socioeconomic environment, the adaptive niche may have different determinants. For example, almost a third of 'independent adopters' of winter chickpea considered mechanical harvesting crucial to their acceptance, whereas it is of minor importance to those who adopted it through the medium of demonstration trials.

Adaptation to a socioeconomic environment is a continuing process. In the case of winter chickpea in Morocco, the results show a need for continuing research and technology transfer along several fronts simultaneously. It is necessary to further characterize and monitor changes in the socioeconomic environments of chickpea—both winter and spring cultivation—in order to better identify and serve appropriate target groups of farmers. It is also necessary to develop ways to get the technology into the hands of farmers to allow them to adapt it to their own socioeconomic environments. Mechanical harvesting is a good example of farmers' initiatives in this regard, but participants also found the lack of information, seeds, and inputs, to be major constraints.

Research should find ways to broaden the adaptive niche for winter chickpea, by improving the seed size, devising more cost-effective weed control methods, and encouraging mechanical harvesting.

Finally, it should be recognized that winter-sown chickpea has little chance of completely displacing spring-sown chickpea. Many of the most enthusiastic winter chickpea adopters in Morocco never counted spring chickpea as part of their farming system. And many non-adopters continue to sow chickpea in spring because it suits their needs and purposes in ways that winter chickpea cannot. Therefore, we should consider winter chickpea as one strategy for chickpea adaptation that should be continued, but that other approaches to the problems of increasing chickpea production in WANA should also be followed.

5.8. Current Status of Chickpea in WANA and South Asia: Analysis of Trends in Production, Consumption, and Trade

T G Kelley and P Parthasarathy Rao[1]

Introduction

World production of pulses is estimated at 58 million t (1989–91 average). Chickpea ranks second among the pulses. India is the world's leading producer of chickpea with 68% of the total production, followed by Turkey (with about 11%), and Pakistan (with 8%).

Despite significant gains in the world pulse production during the last 2 decades (1.9% annual growth rate), chickpea production has grown only slowly (0.3% growth rate). Yields have risen by only 0.08 t ha^{-1} worldwide and the area under chickpea has been virtually stagnant. It accounted formerly for 15% of the world pulse production (1971–73), compared with 12% (7.1 million t) at present (Table 5.8.1) (FAO 1992a).

WANA and South Asia (i.e., India, Pakistan, Myanmar, Bangladesh, and Nepal) account for more than 90% of the world chickpea production and area. This section examines the trends in production, area, and yield of chickpea over the last 20 years and discusses the importance of supply and demand constraints to chickpea production in these regions.

Trends in Production, Area, and Yield in WANA

Pulse production in the WANA region increased by 1.5 million t (53% rise) during the last 2 decades (Table 5.8.1). Almost half of the gain (0.7 million t) can be attributed to increases in chickpea production. During 1971–73, chickpea represented 16% of the total pulse production in WANA. By 1989–91, it had risen to 27%, indicating the crop's increasing importance in the region.

Trends in chickpea production, area, and yield for WANA between 1971 and 1991 are shown in Figure 5.8.1. An almost secular rise in production is observed for the WANA region. The overall compound growth rate in production is 5.6% per year. The growth rate during the last 10 years is even higher (8.3% per year). Regional averages,

Table 5.8.1. Production of total pulses and chickpea in South Asia, WANA, and the world.

	Pulses			Chickpea			Chickpea share of total pulse production (%)		
	Production ('000 t)			Production ('000 t)					
Year	South Asia	WANA	World	South Asia	WANA	World	South Asia	WANA	World
1971–73	12547	2753	42537	5615	438	6474	44.7	15.9	15.2
1981–83	13320	3348	44948	5371	607	6266	40.3	18.1	13.9
1989–91	15371	4215	58030	5562	1115	7116	36.2	26.4	12.3

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

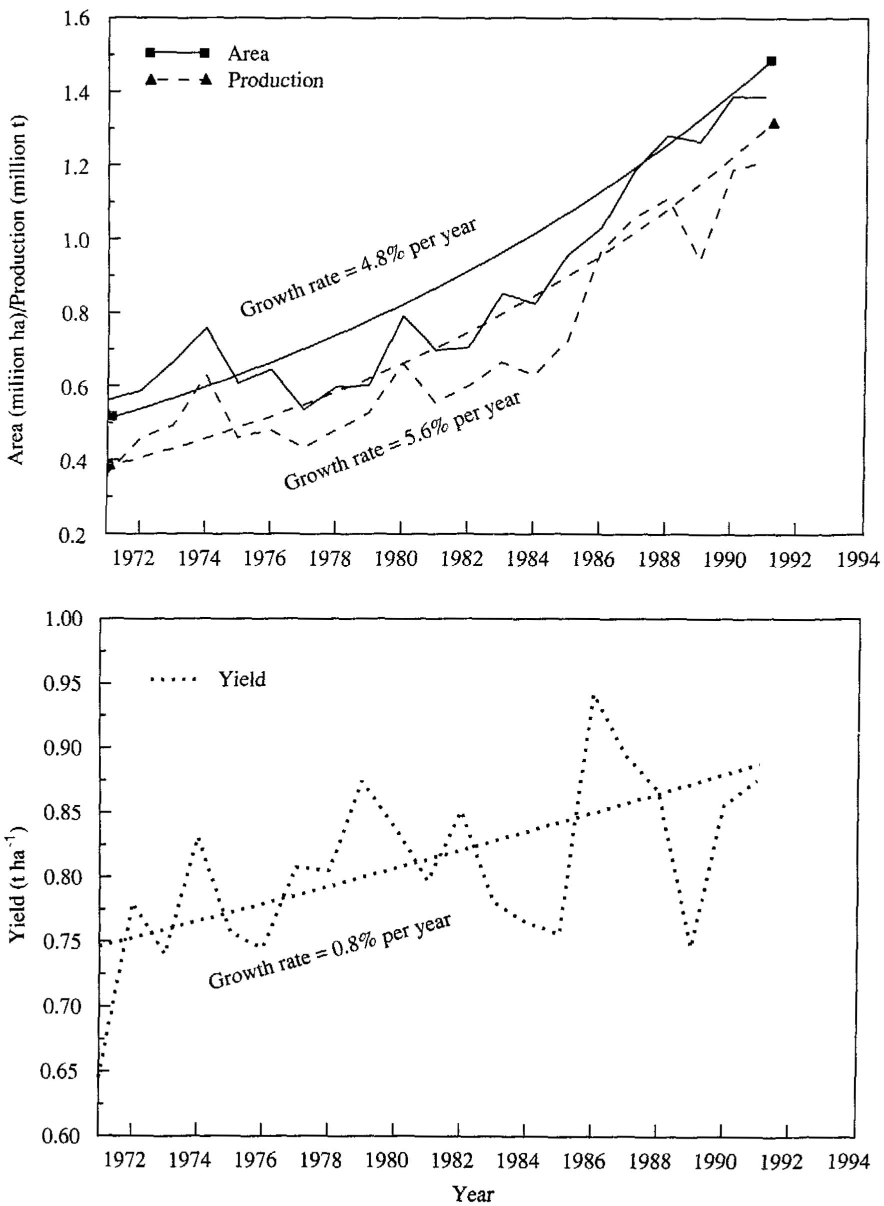

Figure 5.8.1. Trends in chickpea area, production, and yield in WANA, 1971–91.

however, mask deviations from this trend by several WANA countries (e.g., Ethiopia, Syria, Algeria, Iraq, and Sudan), as they are strongly influenced by the performance of Turkey. Turkey accounts for 65% of the production in the region and 70% of the cultivated area under chickpea.

Growth rates in production, area, and yield for WANA are given in Table 5.8.2. Turkey had an impressive 10% compound growth rate from 1971 to 1991 in production which rose from 170 000 t to 800 000 t during the last 2 decades. This growth is nearly equivalent to the net gain in chickpea production for the entire WANA region. Production increases in Turkey have come about mainly through expansion in chickpea area. Research and extension efforts aimed at better utilization of fallow areas have been highly successful. The area under fallow fell by 37% since 1982, chickpea accounting for about a third of this (Section 2.5). Turkey's phenomenal growth has also been spurred on by a strong demand from importers and an attractive export incentive policy of the government. Other WANA countries that registered positive—if less impressive—growth rates in production are: Lebanon (5.9%), Egypt (4.7%), Tunisia (3.6%), Iran (2.5%), and Morocco (2.3%). Sudan (–1.6%), Iraq (–1.3%)[1], and Ethiopia (–0.6%), however, had negative growth rates in production. Ethiopia is the second largest producer of chickpea in WANA (115 000 t annually), so its failure to increase production is of some importance to the WANA region.

Despite good growth rates in production for WANA, production variability is high. The coefficient of variation (CV) in production is 17%[2]. Most of this variability can be attributed to large year-to-year variability in area (CV of 15%). Yields fluctuate significantly less (CV

1 Compound annual growth rate for chickpea production in Iraq between 1970 and 1986, i.e., prior to the war, was 8.9%
2 Calculated after detrending.

Table 5.8.2. Chickpea area, production, yield, and compound growth rates in WANA and South Asia.

Country	1989–91 average			Compound growth rates (1971–91)		
	Area ('000 ha)	Production ('000 t)	Yield ($t\ ha^{-1}$)	Area ('000 ha)	Production ('000 t)	Yield ($t\ ha^{-1}$)
Turkey	850	801	0.94	11.0**	10.0**	−1.1**
Ethiopia	130	114	0.88	−1.7**	−0.6	1.1**
Morocco	73	55	0.76	−1.8	2.3	4.2*
Iran	120	49	0.41	3.9**	2.5**	−1.4**
Tunisia	55	30	0.54	2.1*	3.6	1.5
Syria	49	26	0.52	1.8	1.1	−0.7
Algeria	50	18	0.36	4.3**	0.9	−3.3**
Egypt	6	11	1.83	4.5**	4.7**	0.1
Lebanon	4	5	1.25	3.4**	5.9**	2.5**
Iraq	5	3	0.60	−2.0	−1.3	0.7
Jordan	2	1	0.57	−1.8	–[1]	–[1]
Sudan	2	1	0.67	−1.9	−1.6	0.3
WANA	1346	1115	0.83	4.8**	5.6**	0.8**
India	6897	4847	0.70	−0.7**	−0.4	0.3
Pakistan	1023	534	0.52	−0.1	−0.5	−0.4
Myanmar	129	97	0.75	0.6	3.9**	3.4**
Bangladesh	102	67	0.66	0.6	0.1	−0.5
Nepal	28	17	0.61	−1.3*	−1.2	0.1
South Asia	8180	5562	0.68	−0.6**	−0.2	0.5
World	10078	7116	0.71	−0.2	0.3	0.5*

** Significant at $P = 0.05$.
* Significant at $P = 0.10$.
1. Data not available.

Source: FAO (1992a).

of 6%). Because chickpea is primarily spring-sown, the decision to sow the crop is made with reasonably good information about moisture availability. When winter rains are insufficient to sustain reasonable crop yields, farmers leave their land fallow. On the other hand, winter rainfall in this region being highly variable, the CV values are high for winter chickpea area.

Growth rates in chickpea area for the WANA region match closely those for production, suggesting that the source of growth in production lies in area expansion and not yield growth. The area under chickpea in WANA has more than doubled in the last 20 years and now exceeds 1.3 million ha (Fig. 5.8.1). Again, this is largely due to the impact of Turkey which registered an 11% annual growth rate in area from 1971 to 1991. Area expansion through fallow replacement is likely to continue but at a slower rate. Substantial increases in chickpea area and production are projected in Turkey's Sixth 5-Year Plan (Section 2.5). The absolute growth in area under chickpea cultivation for Turkey between 1971–73 and 1989–91 (700 000 ha) nearly matches that for WANA, which indicates that the rest of WANA neither gained nor declined appreciably in area. Five countries in particular do not follow the overall WANA trend. Table 5.8.2 shows that Ethiopia and Morocco, the second and third largest producers of chickpea in WANA, as well as Iraq, Jordan, and Sudan had negative growth rates in area. The reasons for the decline vary between countries but, generally, chickpea has become less competitive than other crops. High production costs (principally labor for hand harvesting) and lack of appropriate machinery are the most cited economic reasons for this (Sections 2.2, 2.3, and 2.4).

Chickpea yields in WANA during the last 2 decades, despite considerable fluctuation, show a positive trend (Fig. 5.8.1). Yields in WANA rose from 0.77 to 0.85 $t\ ha^{-1}$ between 1971–73 and 1989–91. Turkey, though, had a negative growth rate in yield (−1.1% per year): the yields fell from 1.10 to 0.94 $t\ ha^{-1}$ between 1971–73 and 1989–91. Negative yield trends were reported also from several other WANA countries including Algeria (–3.3%), Iran (–1.4%), and Syria (–0.7%). Yet at the regional level, the yield trend was positive even though yields in these four countries—which together represent 80% of chickpea production in WANA—fell, because yields in Turkey, even in 1989–91, were still considerably higher than the average for WANA. The yield was low in Turkey because chickpea cultivation was extended to fallows which are generally of much poorer quality than existing cultivated land. Kusmenoglu and Meyveci (Section 2.5) mention that much of the expansion of cultivation through fallow replacement has been on marginal lands in eastern and central Turkey. Farmers consider chickpea to be a crop well suited to stony, steep, and nutritionally poor soils.

Trends in Production, Area, and Yield in South Asia

During the past 2 decades, pulse production in South Asia rose from 12.4 to 15.4 million t (Table 5.8.1). Chickpea has added nothing to the growth in pulse production during this time. Its production has in fact stagnated, losing ground to other pulses in the region. Whereas 20 years ago, it represented 45% of the total pulse production, it now represents only 36%. Though South Asia remains the largest chickpea producer (with more than 87% in 1971–73) in the world, its relative share is declining (78% in 1989–91). WANA produced less than 8% of the world's chickpea production 20 years ago, compared with 16% today.

Trends in chickpea production, area, and yield for South Asia between 1971 and 1991 are shown in Figure 5.8.2. Stagnant growth and large year-to-year fluctuations in production are evident, in sharp contrast to the rising trend in production observed for WANA. Indeed, from 1971 to 1981 production declined at a compound rate of 1.1%

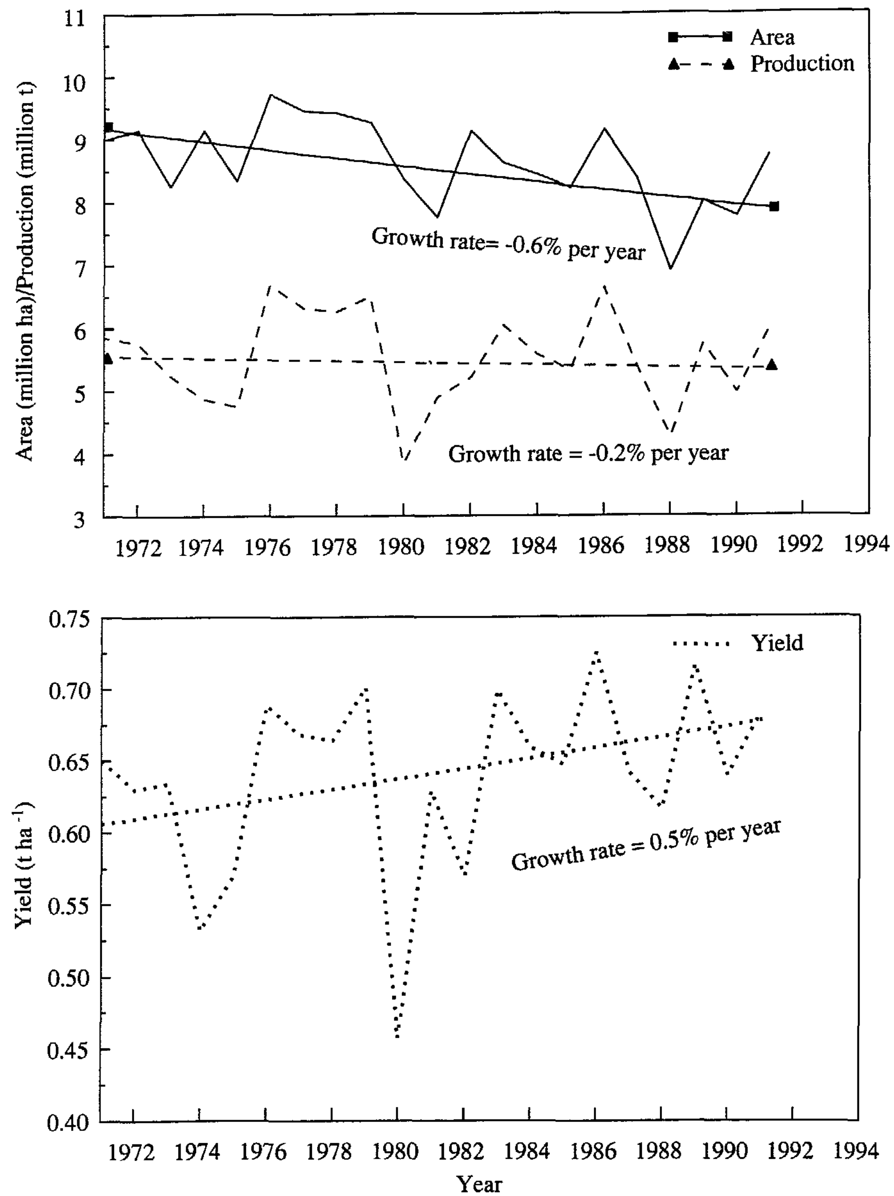

Figure 5.8.2. Trends in chickpea area, production, and yield in South Asia, 1971–91.

per year in South Asia. Since 1981, growth rates are also negative but not significant. Variability in production is actually less in South Asia than in WANA (CV of 13 versus 16%). Whereas most of the production variability in WANA is due to year-to-year changes in area, the variability in South Asia can be attributed largely to that of yield. The CV for chickpea area in South Asia is only 6%; it is almost twice that for yield (11%).

In South Asia, chickpea is grown under relatively less favorable conditions (e.g., the drought environment in Pakistan and central/southern India, and the disease pressures in northern India), where farmers generally neither weed nor apply inputs. This results in significantly higher yield variability than that observed in the WANA region. Yield levels are quite different too for both the regions. Average yields in Turkey are about 1.0 t ha^{-1}; those of India (0.7 t ha^{-1}), and Pakistan (0.5 t ha^{-1}) are relatively low.

India dominates the chickpea production trend for South Asia. Thus, stagnant production in South Asia largely reflects the situation of India. Pakistan, the second largest producer in South Asia, and Nepal have similar trends of declining production. Only Myanmar shows positive growth rates in chickpea production (Table 5.8.2).

Chickpea area in South Asia fell by 620 000 ha between 1971–73 and 1989–91 (Fig. 5.8.2), in contrast to the 750 000 ha of additional land brought under chickpea cultivation in the WANA region. In India, chickpea area was lost to other crops such as wheat and mustard/rape. Pakistan only marginally increased its area under chickpea during these two periods. The overall declining trend in chickpea area in South Asia is likely to continue, barring any major breakthrough in chickpea yield to enhance its competitiveness.

Though chickpea yields have fluctuated dramatically in South Asia, positive (but nonsignificant) growth rates have been observed. Yields rose from 0.64 to 0.68 t ha^{-1} between 1971–73 and 1989–91, probably due to good monsoons and availability of improved technology—both more evident in the 1980s. From 1971 to 1981, yield rate was actually negative (but insignificant). Only during 1981–91, a period with just two unfavorable monsoons, did it become positive. In addition, anecdotal evidence suggests that farmers in India are beginning to adopt improved and wilt-resistant cultivars. The Socioeconomics and Policy Division at ICRISAT is presently trying to document the spread of these varieties. Besides India, only Myanmar has a positive (and significant) growth rate in chickpea productivity in South Asia.

Chickpea in India: Past Trends and Present Status

A closer look at the status of chickpea in India is relevant since world area, production, and yield of chickpea are still dominated by the situation of its largest producer. Trends observed in India will, moreover provide important insights for prospects of chickpea elsewhere (e.g., in the WANA region).

Chickpea Area

Between 1971–73 and 1988–89, chickpea area declined by 1.7 million ha in the traditional chickpea-growing states of northern India: Haryana, Punjab, Rajasthan, Uttar Pradesh, and Bihar (Table 5.8.3). The states that increased the chickpea area were the central and southern states of India, including Madhya Pradesh, Gujarat, Orissa, Maharashtra, Andhra Pradesh, and Karnataka, which added 880 000 ha to their total chickpea-growing area. The latter three states represent new production environments for chickpea. These changes represent a significant shift in the production area in India. While 70% of India's chickpea area was concentrated in the five northern states in 1971, chickpea area in the central/southern states is now nearly equal to that in the north (Fig. 5.8.3).

Table 5.8.3. Area and yield for selected crops in North, Central, and South India.

		Area ('000 ha)			Yield (t ha^{-1})		
		Average of			Average of		
Crop	Region	1971–73	1988–89	Absolute change	1971–73	1988–89	Absolute change
Chickpea	North[1]	5022	3362	–1660	0.62	0.77	0.15
	Central[2]	1771	2292	521	0.65	0.68	0.03
	South[3]	568	907	339	0.32	0.52	0.20
	India	7547	6653	–894	0.61	0.70	0.10
Wheat	North	12907	17480	4573	1.45	2.49	1.03
	Central	3894	4069	174	0.89	1.39	0.50
	South	1226	1115	–111	0.49	1.01	0.52
	India	19062	23783	4721	1.28	2.18	0.91
Rape/ Mustard	North	2812	3233	421	0.48	0.90	0.42
	Central	272	728	455	0.45	0.99	0.54
	India	3463	4911	1448	0.48	0.87	0.39
Groundnut (postrainy)	South	278	868	590	1.24	1.51	0.27
	India	643	1416	773	1.39	1.46	0.07
Sunflower	South	61	1214	1153	0.54	0.37	–0.17
	India	157	1263	1106	0.68	0.38	–0.30
Cotton	Central	2497	1700	–796	0.15	0.20	0.05
	South	3724	3936	212	0.08	0.15	0.06
	India	7684	7337	–347	0.42	0.71	0.29
Pigeonpea	Central	606	818	212	0.72	0.98	0.26
	South	1003	1755	752	0.43	0.51	0.08
	India	2472	3537	1065	0.08	0.77	0.09
Soybean	Central	17	1635	1618	0.82	0.84	0.02
	India	38	1934	1896	0.71	0.84	0.13
Coarse cereals (postrainy)	Central	350	243	–107	0.84	0.87	0.04
	South	5767	5645	–122	0.37	0.47	0.10
	India	8606	6915	–1691	0.56	0.72	0.16

1. Rajasthan, Bihar, Punjab, Haryana, and Uttar Pradesh.
2. Madhya Pradesh and Gujarat.
3. Andhra Pradesh, Karnataka, and Maharashtra.

Source: Government of India (1970–91).

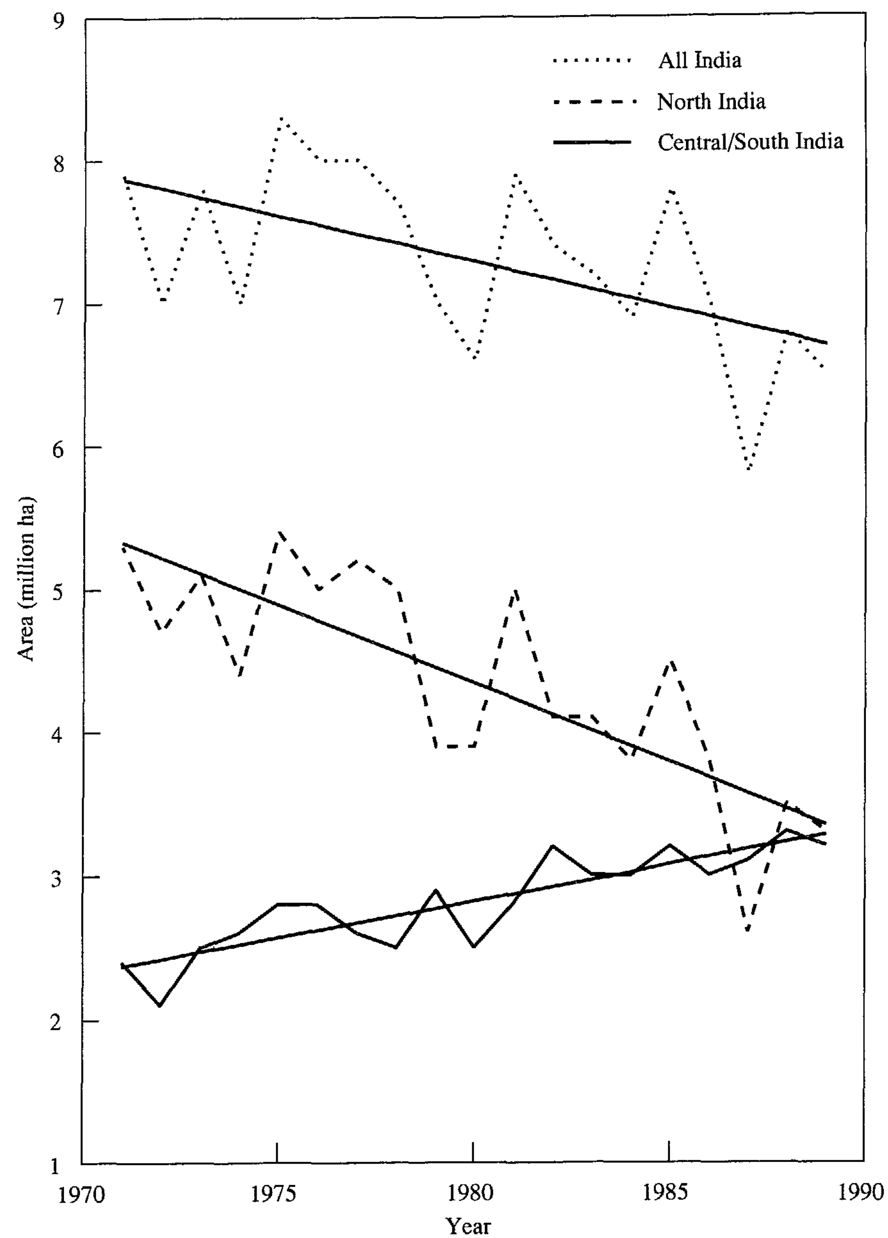

Figure 5.8.3. Trends in chickpea area in India, 1971–89.

The trend observed in the northern states is likely to continue due to the substitution of chickpea by more profitable postrainy season crops. With the expansion of irrigation in the north (favoring high-input crop technology) and the rapid advances in wheat productivity through research, chickpea's competitive position has weakened. As a consequence, wheat replaced chickpea in the most favorable areas. The area under wheat in the north increased from 12.9 to 17.5 million ha between 1971 and 1989. Chickpea was therefore relegated to the less favorable and more marginal environments. Yet, in spite of this, chickpea producers in the north did remarkably well by actually *increasing* chickpea yields during the last 20 years, from 0.63 to 0.77 t ha^{-1}.

The positive trend in chickpea area in the central/southern states is likely to continue since new desi and kabuli cultivars (e.g., short-duration varieties, well-adapted to drought-prone environments) and improved management practices, (e.g., early sowing) are made available to farmers (Jagdish Kumar, ICRISAT, personal communication). The data in Table 5.8.3 indicate less substitution of wheat for chickpea in the central and southern states. Even here, however, wheat and other postrainy season crops have replaced chickpea in the more favorable areas. Farm-level data from selected villages in central and peninsular India confirm that chickpea is losing its position to competing crops like wheat and postrainy season sorghum (Jodha and Subba Rao 1987).

Competitiveness

Perceptions about profitability drive crop choices. Changes in per unit production costs (i.e., technical change) and relative prices together determine the relative profitability or the competitiveness of a crop over time. An analysis of growth rates in trends for yield (as a proxy for technical change) and product prices may provide some insight for the shifts in area under various crops in India.

Time-series data from 1970 to 1989 for yield, area, and real prices for wheat, rape/mustard, and chickpea in India are used to examine the impact of yield and relative prices on area changes in these crops.[1] Figure 5.8.4 shows the linear trends estimated for each of these variables. In the case of wheat, a high growth rate in yield (3.1% per year) more than offsets the declining trend in real prices (–2.6% per year), translating into a 1.4% linear increase in area sown to wheat. Chickpea, despite a strong, positive trend in prices, shows a decline in area largely because its yield growth lags significantly behind that of other crops.

Rape/mustard have the fastest growth in area due to a high growth rate in yield accompanied by a modest decline in real prices. A much more thorough analysis is required before the relative impacts of yield and prices on area can be separated out more definitively. But even this brief analysis provides evidence that chickpea is losing its competitiveness mainly because of inadequate gains in yield growth.

Consumption

With chickpea production having become virtually stagnant during the last 2 decades, imports negligible (except very recently), and population expanding at the rate of 2.1% per year (World Bank 1991), the per capita availability of chickpea in India has declined. Table 5.8.4 shows per capita availability of the five major pulses in India for two points in time. Per capita availability of pulses in India has declined by about 1.2% per year since 1970. This is almost exclusively because of chickpea (the major pulse food crop in India) which registered a steep 32% decline in per capita availability, from 24 g day^{-1} to 16 g day^{-1}.

1 Ideally, changes in yields, output prices, and production costs should be considered together in their effect on crop area Detailed cost of cultivation time-series data for the relevant crops were not available for several years for such an analysis

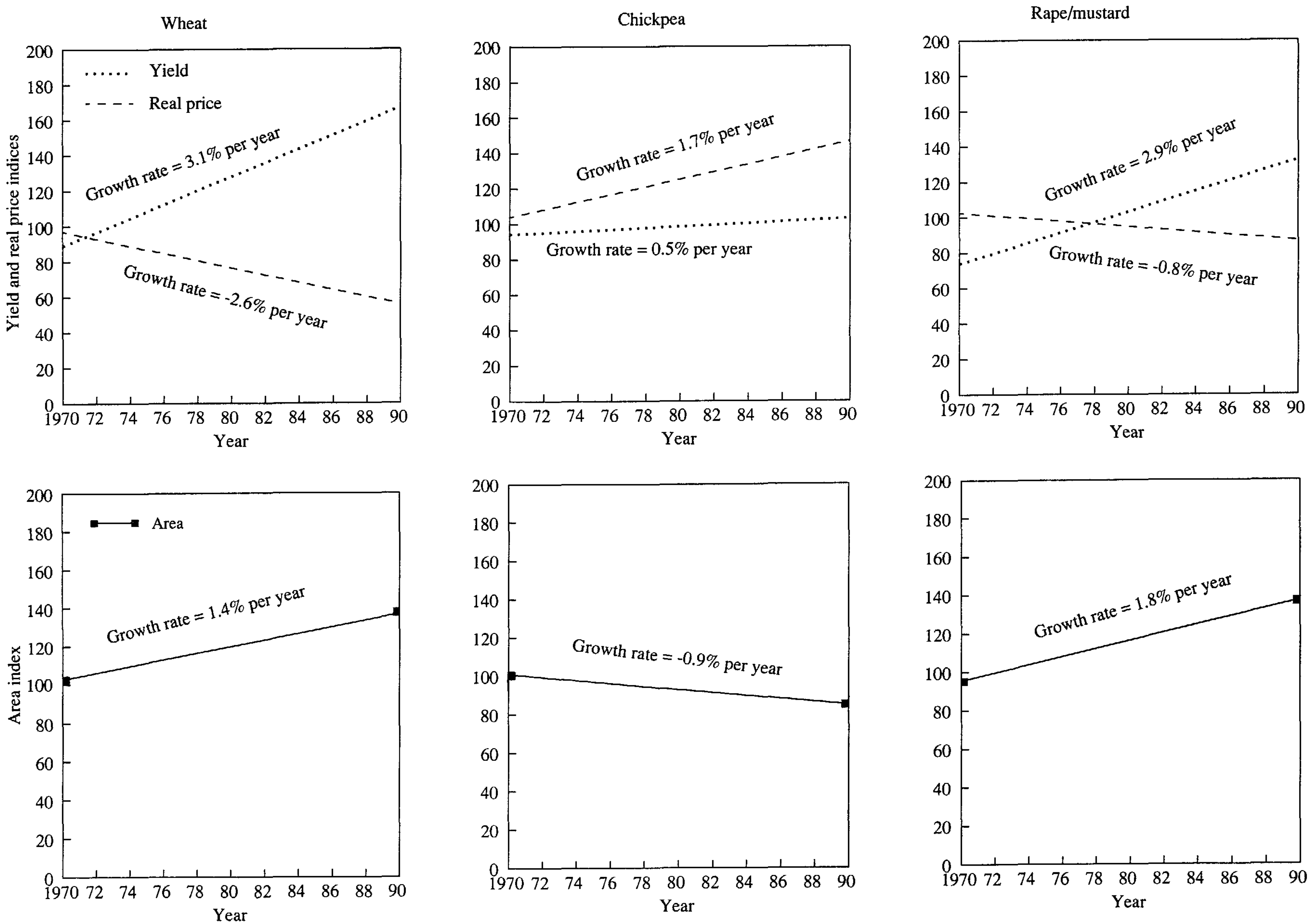

Figure 5.8.4. Trends in crop price, yield, and area indices in India, 1970–90 (base 1970=100).

The decline in production and per capita availability of chickpea in India accounts for the significant rise in its price. Real prices of chickpea increased at the rate of 1.9% per year throughout the 20-year period. However, real prices of pigeonpea rose by 1.1%, mung bean by 0.9%, and lentil by 0.8% per year. These pulse crops maintained production levels high enough to increase (or at least sustain) per capita availability over the level of 1970, and still register significant increases in real prices. This suggests that the demand for chickpea has not been strong enough to push its prices higher, or has not been sufficient to induce higher production to maintain the per capita consumption at 1970 levels. As a result of this, consumers have shifted away from chickpea to other pulses and to other commodities, such as livestock products. Also, it is more efficient to increase supplies of pulses through the rainy season production of pigeonpea, green gram, and black gram by increasing the area than through postrainy season production of chickpea. This is due to strong competition from wheat and mustard/rape in areas where the expansion in irrigation and rapid technical change have favored these crops. Pigeonpea faces much less competition from low-yielding and low-value rainy season crops, e.g., sorghum and pearl millet.

Further evidence of preference for other pulses by consumers can be seen from Table 5.8.5 where data on expenditure and price elasticities of demand for chickpea and other pulses are presented. These elasticities provide information on the change in the quantity demanded for a particular commodity as its price changes (price elasticities) and the income of consumers changes (expenditure elasticities). Expenditure elasticities for other pulses are higher than for chickpea in both rural and urban areas of India indicating that as incomes go up, consumers spend a higher share of their income on pulses other than chickpea. Higher negative price elasticities are observed for chickpea indicating that consumers reduce their purchases of chickpea proportionately more than they do for other pulses for equivalent increases in price.

Table 5.8.4. Production, per capita availability, and price index for major pulses in India.

	Production ('000 t)			Per capita availability (g day^{-1})				Real price indices (1970 = 100)			
	1970–72	1988–90	Change (%)	1970–72	1988–90	Change (%)	Growth rate (%) (1970–90)	1970–72	1988–90	Change (%)	Growth rate (%) (1970–90)
Chickpea	4939	4852	–2	24.3	16.4	–33	–2.5**	101.4	173.3	71	1.9**
Pigeonpea	1831	2625	43	9.0	11.9	32	0.0	99.8	125.2	25	1.1**
Green gram[1]	595	1336	124	2.9	4.5	55	2.1**	112.2	150	34	0.9*
Black gram[1]	601	1553	158	3.0	5.2	42	2.9**	126.6	127.1	0	0.0
Lentil[1]	350	718	105	1.7	2.9	71	1.6**	120	155.6	30	0.8*
Total pulses	10940	13509	23	53.8	46	–15	–1.2**	106	157	48	1.5**

** Significant at $P = 0.05$.
* Significant at $P = 0.10$.
1. 1988–89 (2-year average only).

Source: Government of India (1970–91); Government of India (1990); FAO (various years) and FAO (1992b).

Table 5.8.5. Estimated mean expenditure elasticities (Expenditure η) and mean direct-price elasticities (Price η).

	Rural expenditure classes[1]					Urban expenditure classes[1]				
	1	2	3	4	5	1	2	3	4	5
Expenditure η										
Chickpea	0.499	0.790	0.471	0.469	0.073	1.262	0.992	0.254	0.067	0.013
Pulses	1.821	1.016	1.035	0.533	0.457	1.475	0.960	0.720	0.437	0.141
Price η										
Chickpea	1.033	1.611	0.806	1.058	0.203	2.898	2.894	1.014	1.002	0.153
Pulses	1.429	0.911	0.630	0.362	0.477	1.067	0.675	0.588	0.385	0.294

1. Based on a 1–5 scale, where 1=very poor and 5 = not poor.

Source: Murthy (1983).

However, there are regions where demand for chickpea is very strong, and will remain strong. Nevertheless, aggregate figures indicate a significant decline in per capita consumption of chickpea compared with other pulses, with roughly similar price trends over time, and, higher price elasticities and lower expenditure elasticities for chickpea than for other pulses.

However, if alternative uses for chickpea could be developed and marketed, then this trend might change. New production technology in chickpea, if adopted, can bring about significant gains in productivity, lower per unit production costs, and ultimately, ensure relatively lower prices on the market. This would improve the crop's competitiveness, expand consumption of traditional preparations and encourage its substitution for other commodities in new uses. Without such gains in productivity, per capita chickpea consumption in India will continue to decline. To maintain present (low) levels of consumption up to 2000, average yields of chickpea will have to increase from the present level of 0.70 t ha^{-1} to 0.88 t ha^{-1}, assuming that there will be no increase in cropped area or significant change in imports.

Trade

The world market for chickpea is relatively thin. Less than 0.5 million t are traded annually, about 6.5% of the total chickpea produced. Exports of other pulses on the other hand, represent about 11% of world production; exports of wheat represent 18% and rice 24% (Oram and Agcaoili 1992). Nevertheless, an increasing trend in world trade is observed for chickpea (Fig. 5.8.5). Since 1975–77, the market volume has expanded by a factor of three.

Turkey ranks first in chickpea export (mainly kabuli), with 275 000 t exported annually between 1989 and 1991 (Table 5.8.6). This represents 58% of total world exports and 35% of the country's domestic production. It is the principal supplier of imported kabuli chickpea to the European Union and a major supplier to India. Except for a few years, e.g., 1985 and 1989, when crop failures seriously curtailed domestic production, chickpea exports have risen steadily at a remarkable rate of 13.4% per year since 1975. This owes much to the attractive export subsidy the Turkish Government has given to chickpea. There appears to be good potential for further growth in chick-

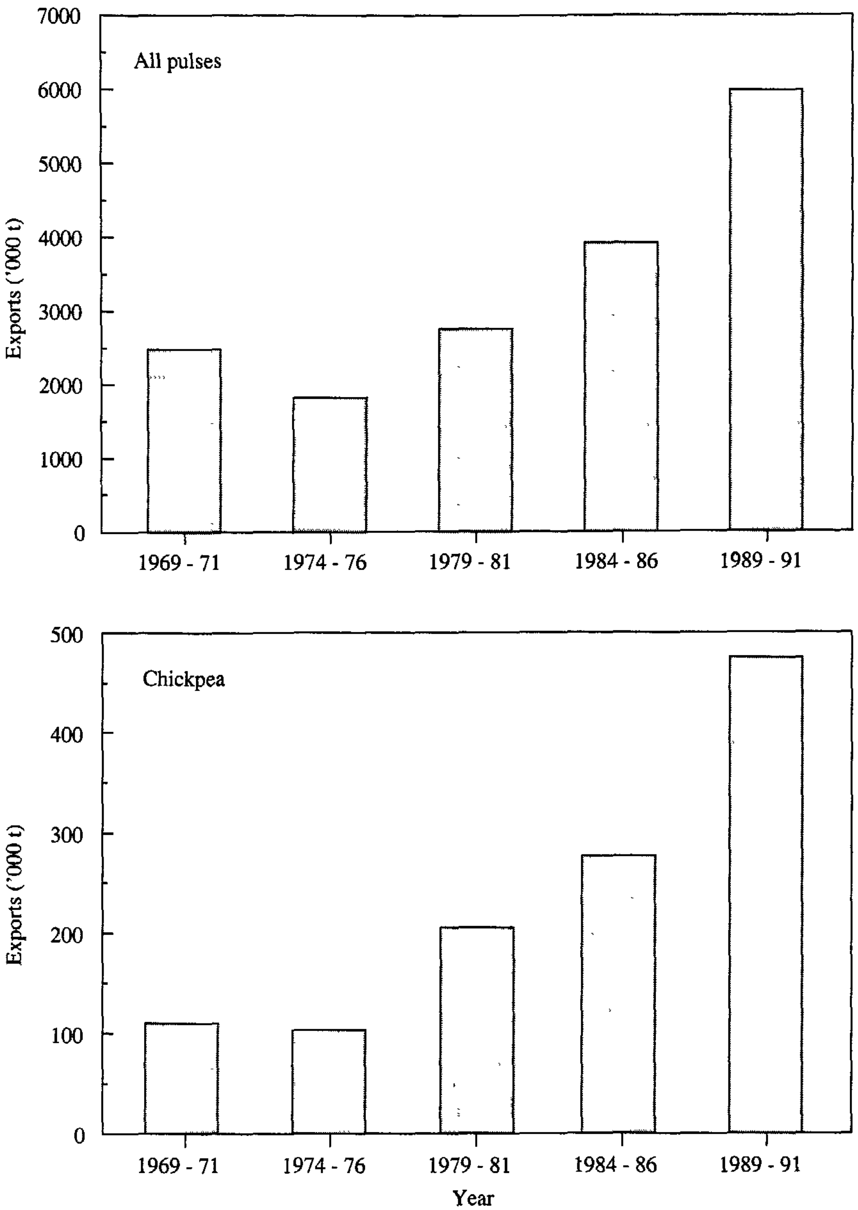

Figure 5.8.5. World pulse and chickpea exports (annual 3-year averages, 1969–91).

Table 5.8.6. Average annual chickpea imports and exports for WANA, South Asia and other countries, 1975–77 and 1989–91.

Imports ('000 t)			Exports ('000 t)		
	Average of			Average of	
Country	1975-77	1989-91	Country	1975-77	1989-91
Algeria	11.9	46.8	Turkey	23.4	274.4
Iraq	4.1	21.7	Morocco	19.4	8.3
Jordan	1.2	13.9	Syria	3.5	6.3
Lebanon[1]	0.2	9.0	Ethiopia	10.7	0.0
Iran[1]	0.6	7.0	Tunisia	5.5	0.1
Tunisia	0.0	3.6			
WANA	18.0	102.0	WANA	62.5	289.1
India	0.6	123.4	India	1.5	4.9
Pakistan	0.0	32.6			
Bangladesh	0.0	3.3			
South Asia	0.6	159.3	**South Asia**	1.5	4.9
Greece	0.0	8.7	Mexico	38.5	52.2
Italy	0.0	22.4	Australia	0.0	110.1
Portugal	0.8	7.0			
Spain	30.3	39.4			
USA	6.8	14.8			
Israel	4.2	0.4			
Malaysia	3.0	4.5			
Saudi Arabia	2.4	11.0			
Sri Lanka	0.0	8.2			
Brazil	2.4	1.2			
Colombia	0.7	2.7			
Venezuela	1.5	4.0			
Total	78.0	414.4		112.3	474.3

1. Based on data up to 1985.

Data source: FAO (1992b).

pea production and export in the country as more land is put under chickpea through the fallow replacement program (Oram and Agcaoili 1992).

Australia and Mexico are the second and third largest exporters of chickpea. Australia, virtually a non-producer of chickpea 15 years ago, today produces and exports more than 100 000 t annually. Very little is used in the country. Mexico has increased its exports only slightly since 1975–77 and presently exports about 50 000 t annually.

Besides Turkey, the other WANA countries exporting chickpea are Morocco and Syria, although in relatively small quantities. Morocco exports about 8000 t, (20 000 t in the mid-70s) and Syria, 6000 t, (3500 t in the mid-70s). Ethiopia, which formerly exported 11 000 t and Tunisia, 6000 t, no longer export chickpea. Indeed, Tunisia has gone from being a net exporter to a net importer.

Many other countries including, Algeria, Iraq, Jordan, Lebanon, and Iran[1], in WANA are or have recently become net importers of chickpea. These countries together imported about 80 000 t of chickpea annually between 1989 and 1991, while earlier, they imported less than 20 000 t annually. Except Turkey and Syria, exports have fallen or imports have risen for every chickpea-producing country in the WANA region.

The European Union (EU) also imports a significant amount of chickpea[2]. Whereas Spain, Portugal, and Greece formerly exported chickpea (Rees 1988), since the mid-70s and early 1980s, they have become net importers of chickpea. USA also imports chickpea, mainly from Mexico.

India is now the largest importer of chickpea in the world; chickpea imports to the country rose significantly during 1988–92. The severe drought of 1987 during which chickpea production declined by almost 2 million t (30% drop from the previous year's production) was largely responsible for the dramatic increase in chickpea imports in 1987/88. Imports increased from 8000 to 223 000 t in a single year. Imports have come down slightly since then (160 000 t in 1990 and 100 000 t in 1991) as domestic production recovered.

In contrast to international trade, chickpea trade within India—by far the largest consumer of chickpea—is significant. This is due to a widely distributed demand and regional concentration of production (von Oppen and Parthasarathy Rao 1987). Raju and von Oppen (1980) have estimated the marketable surplus of chickpea in India at 45%, while government statistics (Government of India 1980) gave lower estimates (35%), but showed a consistently increasing trend in the marketable surplus over time.

Market Growth Potential

World trade in chickpea is rapidly expanding, as new countries are entering the market and traditional exporters are significantly expanding domestic production to meet increasing demand from both developed and developing countries. Australia and Turkey in particular are expanding their exports as countries in the EU and India are increasingly importing.

Turkey, the driving force behind increasing exports from WANA, can continue to do so if it can sustain production trends above growth rates in domestic demand. This in turn will depend on such factors of supply as:

- The rate at which the area under chickpea expands, e.g., through fallow replacement, which in turn is a function of:
- Domestic price policies and their impact on relative prices of chickpea and competing crops, and,

1. Chickpea imports to Lebanon and Iran between 1989–91 were negligible due to the war situation. Prior to this they were each importing about 10 000 t annually.
2. Some EU countries record chickpea as 'dry peas', and therefore its imports may be underestimated. This may partially explain the discrepancy between total exports and imports in Table 5.8.6.

- The rate at which yields rise (or year-to-year fluctuations are reduced) through technical change, and on such factors of demand as:
- Population growth rates,
- Income growth rates and associated expenditure elasticities of demand for chickpea,
- Growth rates in chickpea production in major chickpea-consuming countries (e.g., India, EU),
- Trade policies of the major potential importers like India,
- Growth rates in supply from other exporters (e.g., Australia), and
- Growth in demand for specialty dishes in developed countries.

According to Rees (1988), Australia is well positioned to become a consistent (and major) supplier of relatively low-priced chickpeas for the world market, depending on domestic trade policies of India, the major importer of Australian chickpea. The reduction of import duty on food grain pulses in India will help stimulate world trade in chickpea.

In an environment where a free exchange of commodities will prevail, world exports of chickpea are likely to increase as production shifts to areas of greater comparative advantage. This seem to be happening already (e.g., domestic production declines in India with simultaneous increases in imports from Australia), but the international market in chickpea is still very limited. The relatively high and sustained levels of chickpea imports to India during the last 5 years reflect the inability of domestic production to satisfy demand at current (domestic) prices, and suggests that for some countries, imports with simultaneous utilization of domestic resources for crops of greater comparative advantage are more efficient. If this happens, it would result in higher aggregate production and consumption of chickpea (von Oppen 1990).

Supply and Demand Projections

Projections of future supply of and demand for chickpea can help to identify the constraints to the expansion of chickpea production in WANA and South Asia.

Supply and demand projections for chickpea to the year 2000 are listed in Table 5.8.7[1]. Chickpea production in South Asia is not expected to rise from its 1989–91 level of 5.6 million t. This is set against a rising demand for chickpea well above (33%) predicted supply levels. Considerable amounts of imports (1.85 million t) will be necessary to satisfy demand, a favorable prospect for exporters like Australia and Turkey. Without these imports, chickpea prices in India and Pakistan, the major deficit countries, will continue to rise rapidly and thus discourage demand and ultimately reduce consumption. Bangladesh and Nepal too will have relatively large production shortfalls.

The supply prospects for WANA are brighter, largely based on Turkey's capacity to sustain production increases of 7% per year to the year 2000. This is not an unrealistic proposition considering its impressive 14% per year growth rate during the 1980s. Chickpea production in Turkey is estimated to double from 0.8 million t to 1.6 million t[2].

Production in WANA is estimated to be 2.1 million t in 2000, against a total regional demand of 1.2 million t, indicating that the potential for export growth is excellent. Unfortunately, most other countries in WANA including Ethiopia, Algeria, Lebanon, and Jordan will not follow that pattern and are likely to face serious shortfalls in domestic supply. Egypt, Tunisia, and Syria, formerly self-sufficient or export-oriented, are projected to become net importers.

1. See Kelley and Parthasarathy Rao (1993) for details of the estimation procedure and assumptions.
2. If Turkey's compound growth rate between 1990 and 2000 is assumed to be 14%, comparable to the 1981–91 growth rate, then estimated production in 2000 will be 2.8 million t.

Conclusions and Implications

The demand for chickpea does not appear to be limiting particularly in WANA, despite a favorable supply-demand ratio for the region as a whole. Most WANA countries have scaled up imports, or scaled down exports, to meet rising demand despite high growth rates in production (2 to 3% per year). This confirms the hypothesis of Oram and Belaid (1989) who have concluded that pulse production in WANA was generally constrained by supply rather than demand factors. With the rise in population, income, per capita consumption, and imports into the region, the strong demand for pulses is apparent. If the projections for the future are correct, Ethiopia which used to export 10 000 t will need to import 50 000 t of chickpea by the year 2000. In most WANA countries, high market prices for chickpea—reflecting

Table 5.8.7. Domestic production/consumption ('000 t) of chickpea in WANA and South Asia countries (1989–91) and projected to 2000.

	1989–91			Projection to 2000		
Country	Domestic production	Domestic consumption	Surplus (+) Deficit (–)	Domestic production	Domestic consumption	Surplus (+) Deficit (–)
India	4847	4970	–123	4642	6337	–1695
Pakistan	534	567	–33	774	860	–86
Myanmar	97	97	0	95	121	–26
Bangladesh	67	70	–3	58	87	–29
Nepal	17	17	0	8	22	–14
South Asia	5562	5721	–159	5577	7427	–1850
Turkey	801	527	+274	1305	658	+647
Ethiopia	114	114	0	109	159	–50
Morocco	55	47	+8	181	63	+118
Iran	49	56	–7	80	78	+2
Tunisia	30	34	–4	25	46	–21
Syria	26	20	+6	15	32	–17
Algeria	18	65	–47	29	97	–68
Egypt	11	11	0	10	15	–5
Lebanon	5	14	–9	9	19	–10
Iraq	3	25	–22	26[2]	37	–11
Jordan	1	15	–14	2	20	–18
Sudan	1	1	0	2	1	+1
WANA	1115	930	+185	1793	1225	+568

1. Based on observed growth rates in production from 1981 to 1991.
2. Projected based on time-series data from 1976 to 1981; production fell dramatically since 1986 due to the war.

strong local demand—offer good prospects for increasing production provided the right technology is available.

Our supply and demand projections to the year 2000 further confirm the view that supply, not demand, is the limiting factor. Most countries in WANA will fall into a deficit position with respect to production and will require large increases in imports to satisfy demand. Even Turkey, with its surplus production, is unlikely to face demand constraints[1], as the potential outlook for expansion of exports to WANA, South Asia, and the EU looks favorable.

Most of the reports from Syria, Morocco, Algeria, Tunisia, Egypt, Jordan, Iran, and Ethiopia seem to suggest that abiotic and biotic constraints are more important than policy, marketing, and other socioeconomic-related constraints in limiting chickpea production[2]. An exception may be Iraq and Sudan. In Iraq, large areas of chickpea were replaced by wheat following the government's decision to give more support to wheat prices. The report from Sudan suggests market distortions (low farm-gate prices relative to retail prices) as an important constraint to chickpea production.

Supply and demand projections to the year 2000 for South Asia also confirm that chickpea production will be more limited by supply factors than by demand. Population and income growth combined with the relatively high income elasticities of demand for chickpea imply continued growth in demand for this food legume. This would occur despite a gradual shift from chickpea to other pulses and livestock products, i.e., a demand constraint in the long run.

The possibility for significantly reducing per unit costs of chickpea production (primarily by raising yields) and making it more competitive with wheat and mustard should be explored. Higher productivity will simultaneously increase the profitability of chickpea to producers and reduce the price paid by consumers. Relatively high price elasticities of demand for chickpea will also ensure large consumption with falling prices.

In both WANA and South Asia, improved technologies are already available to at least double chickpea yields in many areas (Jagdish Kumar, ICRISAT, personal communication). Winter-sowing technology in WANA and improved short-duration cultivars in peninsular India, for example, have the potential to significantly raise productivity in these regions. Much still needs to be done in identifying the on-farm constraints that are limiting the uptake of these new technologies. Scientists and economists must work together to assess whether the technologies are appropriate and how they need to be transferred or whether the infrastructure needs to be improved in order to alleviate the constraints to chickpea production.

1 Soon Turkey too will face a supply constraint. Growth in production through area expansion is an option which has limited scope in the future. Without gains in productivity, these lands are likely to shift to other crops which are more productive and more remunerative.

2. Several country reports mention rising labor costs as an important reason for substitution of chickpea to other competing crops. It is necessary to develop innovative technologies such as machine harvesting and specific variety types adapted to this which can profitably reduce labor demand.

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6. Future Research Priorities

6.1. Future Research Priorities for Chickpea in WANA and SAT

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An objective assessment of the needs and opportunities in chickpea research is essential for formulating plans so that the productivity of the crop is sustained in all chickpea-growing regions, especially of the WANA region. To achieve this objective, information on different aspects of chickpea production has been analyzed and documented in the first five chapters of this book. These chapters also cover the status of the crop in 11 important chickpea-growing countries in WANA. An interpretative regional summary of biotic, abiotic, and socioeconomic constraints to chickpea production in the three WANA regions—West Asia (Section 2.6), North Africa (Section 3.4), and Nile Valley countries (Section 4.4)—and across the WANA and SAT regions (Chapter 5) has been presented. A similar study of chickpea production in South Asian countries was undertaken earlier by Virmani et al. (1991). In this chapter, we will evaluate the need for continued research on the crop and suggest future areas of research thrust.

Role of Chickpea in Agricultural Production Systems

Due to the increasing need for legumes, chickpea is no longer considered a subsistence crop. The upward trend in its trade (Section 5.8) suggests that the crop is grown increasingly for the market. Our study contests the general belief that increasing use of input-responsive crops (particularly wheat) has relegated chickpea to marginal lands in the WANA region. Although the area and production of chickpea has decreased to some extent, its productivity and imports have been steadily going up (Section 5.8). Chickpea is now mostly cultivated as a sole crop in several countries.

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4. Farm Resource Management Program, ICARDA.

Research Needs and Opportunities

The available statistics on chickpea area, production, yield, price, and trade (Section 5.8) show that in most of the countries studied (Chapters 2, 3, and 4), the demand for the crop is greater than the supply. It is predicted that this trend will continue in the near future. Yet, it is surprising that even though a favorable economic environment exists, there has not been a large-scale expansion in chickpea cultivation and production in areas where the crop is habitually grown, except in Turkey and Australia. This apparent contradiction reflects a gap in our understanding of farmers' needs. We have to identify urgently and correctly their needs and transfer to them appropriate technologies to overcome constraints at the farm level.

Demand and Uses of Chickpea

Demand for a crop is generated by the diversity of its uses. Chickpea is consumed in different ways (Jambunathan 1991), generally with cereals (wheat and rice). There are many other uses of chickpea such as in snacks and sweets. It is also used as livestock and poultry feed, but increasing prices have discouraged this use. There are a few reports on the commercial use of the crop in the preparation of baby food, starch, and in plywood industries. Demand, for chickpea therefore, seems to be primarily driven by its use as a food crop.

Profitability of Chickpea Cultivation

The declining chickpea area and production, in spite of increasing demand, suggests that it may not be profitable to grow the crop in the prevailing production systems, because:

- improved technologies (varieties and management practices) either have not reached the farmers, or else
- farmers do not find them useful under their management conditions.

Research has shown that it is more profitable to grow chickpea than cereals and other nonlegumes in rainfed agriculture, because of its low dependence on expensive inputs (NP fertilizers) (Section 1.4). In the traditional chickpea-growing areas, e.g., in South Asia, the water requirement of the crop is low, due to the low evaporative demand of the atmosphere during the chickpea-growing season. Also, the cost of labor is generally low in the rainfed areas. These factors made chickpea a profitable crop in the past in low-input rainfed production systems. In many traditional chickpea-growing countries in WANA and SAT, this practice continued for many decades. Lately, however, irrigation and fertilizer, to which chickpea is not very responsive, are increasingly available. The cost of labor has also gone up coupled with increased disease incidence on chickpea. Due to these constraints, chickpea has lost its economic competitiveness vis-à-vis other crops in many countries and the area under it has consequently reduced.

Increasing demand for the crop in Turkey and Australia, however, has favored its expansion in these countries. In Turkey, where chickpea has been traditionally grown during spring, fallow lands have been replaced with spring-sown chickpea. In Australia, the crop was introduced in response to increasing demand from Asia. It is perhaps economical to grow the crop in Australia because of large-scale mechanized production.

Factors that determine productivity and profitability of chickpea depend upon the agroecological and socioeconomic environment in which it is produced. For example, in India (Section 5.8), a decrease in traditional chickpea-growing area (northern India) occurred due to lack of varieties responsive to high inputs. On the other hand, its cultivation increased in non-traditional areas in peninsular India (western and southern parts) due to the availability of irrigation in these warm subtropical environments. No radical change in production technology, chickpea varieties, or management technique, was involved in this large-scale area expansion in peninsular India. New areas where such opportunities exist or any improvements in existing technologies that would lead to the opening up of new opportunities need to be identified.

Factors that are important for boosting chickpea profitability in WANA are:

- Increase in productivity, and
- Reduction of production cost through
  - economic use of inputs, and
  - mechanization of field operations to reduce labor costs.

Increase in Productivity

Both genetic and agronomic options are available for enhancing yield and stability of chickpea production. In practice however, these are not two independent options but are components of an integrated crop management (ICM) strategy for increasing chickpea production.

Genetic options

Chickpea productivity can be increased through greater on-farm use of existing high-yielding genetic material. As past efforts for enhanc-

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ing the genetic yield potential of chickpea have not been very rewarding (Saxena and Johansen 1990), the current emphasis in genetic enhancement research is mainly on the incorporation of resistance to known biotic and abiotic stresses.

Ranking of various biotic and abiotic constraints to chickpea production based on realistic estimates of yield losses, is a prerequisite for researchers and planners to set priorities and allocate resources in order to overcome these constraints. Such prioritization of biotic and abiotic constraints in cool-season food legumes, including chickpea, has been done on a global scale by Johansen et al. (1994). Similar prioritizing of constraints in national programs would be very useful.

Environmental stresses. Drought appears to be the most widespread constraint (Section 5.2; Johansen et al. 1994) because more than 90% of the world chickpea area is rainfed. Variations of inter- and intra-seasonal rainfall (quantity and distribution) in WANA and SAT are well documented. It is, however, a matter of great concern that drought has not been accorded a high priority in applied research. Methods to alleviate drought effects, through escape and resistance mechanisms, are now available (Section 5.2) and could be exploited on farm. Problems related to temperature (heat, cold, and frost) effects on chickpea production are region-specific. Salinity is important only in some countries, (e.g., Iran). It should be given a low priority in breeding programs as salinity-resistant germplasm material is not available.

Diseases. Diseases appear to be the most important constraint that causes yield instability (Section 5.3). Concerted efforts are needed for enhancing resistance to diseases. Fortunately, sources of resistance to many of the soilborne and foliar diseases are now available, including multiple disease-resistant material (Table 5.3.3 in Section 5.3). For such diseases as ascochyta blight (*Ascochyta rabiei*) and botrytis gray mold (*Botrytis cinerea*), the resistance levels are low. Strategic research to increase levels of resistance through gene pyramiding is necessary. Instances of break-down of disease resistance (due to new races or pathotypes) are often reported. Durable resistance needs to be ensured in germplasm enhanced for disease resistance. Fusarium wilt (*Fusarium oxysporum*) is most widespread across the SAT and WANA regions. Most progress has been made in developing varieties with durable resistance to this disease. Yield losses caused by nematodes remain to be quantified. Progress in mapping the cyst nematode (*Heterodera ciceri*) (in WANA) by ICARDA and the root-knot nematode (*Pratylenchus* spp) (in SAT) by ICRISAT, and screening of germplasm should help in controlling these nematodes effectively.

Insect pests. Differences in insect pest importance (Section 5.4) between WANA—for leafminer (*Liriomyza cicerina*)—and SAT—for pod borer (*Helicoverpa* spp)—emphasize the regional differences in their distribution. *Callosobruchus* spp (stored grain pests) are common across WANA and SAT. Yield losses caused by various insect pests remain to be correctly estimated. Acceptable levels of resistance have not been found for any of these insect pests, but some genotypes with low levels of pest incidence have been identified.

Nutrient use and fertilizer economy. In recent years, research on biological nitrogen fixation (BNF) has helped to quantify its benefits to the nitrogen economy of the chickpea crop and the sustainability of production systems (Section 5.5). To enhance BNF benefits, it is necessary to identify high-nodulation material that increase yields, with tolerance for high soil nitrate levels to ensure an adequate symbiosis. Inoculation responses observed in WANA suggest large potential benefits of this cheap technology. Therefore, research on BNF needs to be strengthened in national programs. Interaction of BNF with drought and temperature suggests that screening of genotypes for high BNF efficiency should be conducted in well-defined soil moisture requirements.

The efficiency with which chickpea can exploit soil P, even from sources not used by other crops including legumes (Ae et al. 1991), has not been fully recognized and exploited. Also, genotypic differences in utilization efficiency of soil P in chickpea have not been evaluated. Such differences, if they exist, would be useful in further enhancing the efficiency of this trait.

Quality considerations. Seed quality considerations (other than nutritional) are determined by the uses of chickpea, and differ from country to country (Chapters 2, 3, and 4; Jambunathan 1991; Pushpamma and Geervani 1987). Where chickpea is used as whole seed (as in WANA countries), seed size is an important quality trait. One of the reasons for the relatively low adoption of winter chickpea technology by farmers in Morocco, was the relatively small seed size of new varieties released for winter sowing (Section 5.7).

Agronomic options

No systematic study has been conducted on agronomic factors as constraints to chickpea production, except for competition due to weeds. Poor plant stand in farmers' fields and competition from weeds are often stated as major constraints to chickpea production. The effects of land preparation, conservation of rainfall for spring sowings in WANA, and chickpea grown in stored soil moisture conditions in South Asia, are difficult to assess in the absence of empirical databases.

Plant stand. Information on plant stands, correlated with biotic and abiotic constraints and factors of poor management, needs to be documented. Since chickpea is mostly grown as a rainfed crop, poor plant stands in South Asia are often a result of inadequate soil moisture in the seedbed at the sowing time. Sowing methods which are effective in placing the seed at soil depths where adequate moisture is available, can overcome this constraint.

Matching crop duration to favorable soil moisture regimes. In WANA, winter chickpea technology has proved effective in increasing chickpea yields through alleviation of severe terminal drought which occurs in spring-sown chickpeas (Sections 5.2 and 5.6). The technology holds great promise and is being popularized. In spite of the large demonstrated potential benefits of the technology, its adoption is slow. Certain components of this technology that are being modified (enhanced ascochyta blight resistance, frost tolerance, weed control, and increase in seed size) would give the required impetus to its large-scale adoption. Winter sowing will, however, not replace all the spring-sown chickpea (Section 2.6) and the emphasis on the improvement of yield and production practices of spring-sown chickpea needs to be continued. A comparable approach in warm subtropical environments of peninsular India was made, by advancing the sowing date to end-monsoon to alleviate drought effects in chickpea, but this did not prove to be a viable option (Section 5.2).

Limited irrigation. Although chickpea in WANA is grown as a rainfed crop, except in Egypt and Sudan (Section 3.4), large responses in grain yield are observed when two to three irrigations are applied in spring chickpea in WANA and in warm, subtropical conditions in peninsular India. In such areas, irrigation is becoming increasingly available and this would probably contribute to the expansion of chickpea area in the target region. Since there is little danger of foliar diseases, and chickpea cultivars resistant to soilborne diseases are already available, this may be a feasible option in the future.

Integrated crop management. The strategies of integrated pest management (IPM) and integrated disease management (IDM) focus on the management of a particular constraint, either a given disease or a pest. Even with varieties which are resistant to important diseases, appropriate agronomic management is essential for the expression of their true genetic yield potential. Thus, the introduction of integrated crop management (ICM) strategies which include components of improved seeds, agronomic management practices, and the IPM-and IDM-based measures should enhance yields and crop profitability.

Reduction of Production Cost

Economy and efficiency in the use of inputs

It should be possible to recommend need-based fertilizer application for chickpea. The crop has a high efficiency of meeting its N needs from BNF and P needs from soil P. It effectively uses residual fertilizers in cropping sequences. Such practices should enhance the profitably of chickpea production considerably. It is necessary to make the farmers aware of these benefits of chickpea cultivation.

Mechanization of operations

Increasing labor costs for agronomic operations has been listed as an important constraint to sustainable chickpea production across many WANA countries (Chapters 2, 3, and 4 and Section 5.6). It is also becoming an important constraint in some SAT countries. Therefore, mechanization of sowing and timely management of weeds in the early stages of crop growth is essential. Mechanized options for harvesting are now available (Section 5.6). Concerted efforts for their adoption by farmers will have a significant impact on chickpea production.

Recommended Thrust Areas of Research

The following thrust areas should be emphasized as they probably will have a significant impact on the increase in the area and production of chickpea in many countries.

- Delineation of production systems in which chickpea can be introduced on a large scale or in specific niches;
- Identification of factors that enhance profitability of chickpea cultivation in current production systems and in areas where the crop is newly introduced; and
- Strengthening of research capabilities of NARS in conducting applied research to overcome major biotic and abiotic constraints to chickpea production under their conditions.

Multidisciplinary Approach

The concept of an ICM strategy, which includes IDM and IPM as components of management practices, makes multidisciplinary teamwork inevitable. To make the various multidisciplinary working groups function smoothly and effectively, it is necessary to:

- Recognize the comparative strength of each partner in discharging a task;
- Involve all partners in developing workplans and review of progress;
- Define roles and responsibilities of members in a given working group; and
- Share resources and credits fairly within a working group.

Networks and Working Groups

Aggregation of constraints to chickpea production at higher levels—national, ecoregional, and global—have helped identify activities of common research interests. Increasing interaction between scientists at regional and international fora have brought together research workers, who were earlier working in isolation through such networks and working groups as the Global Grain Legumes Drought Research Network (GGLDRN), Asia Working Group on Biological Nitrogen Fixation (AWGBNFL), Cereals and Legumes Asia Network (CLAN), etc. Participating scientists benefit from such collaboration through pooling of knowledge and resources, which allows a greater efficiency of utilization of available resources. The research objectives of each partner, individually and collectively, can be met through this framework. Coordination of such networks is important for enabling NARS to ensure effective implementation of workplans.

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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.

About ICARDA

The International Center for Agricultural Research in the Dry Areas (ICARDA) is one of 16 CGIAR-supported centers. Established in 1977, it is based in Aleppo, Syria. Its mission is to meet the challenges posed by a harsh, stressful, and variable environment in which the productivity of winter rainfed agricultural systems must be increased to higher sustainable levels; in which soil degradation must be arrested and possibly reversed, and in which the quality of the environment needs to be assured. ICARDA meets this challenge through research, training, and dissemination of information in a mature partnership with the national agricultural research and development systems.

ICARDA has a world responsibility for the improvement of barley, lentil, and faba bean, and a regional responsibility in West Asia and North Africa (WANA) for the improvement of wheat, chickpea, forage and pasture—with emphasis on rangeland improvement and small ruminant management and nutrition—and of the farming systems associated with these commodities.

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