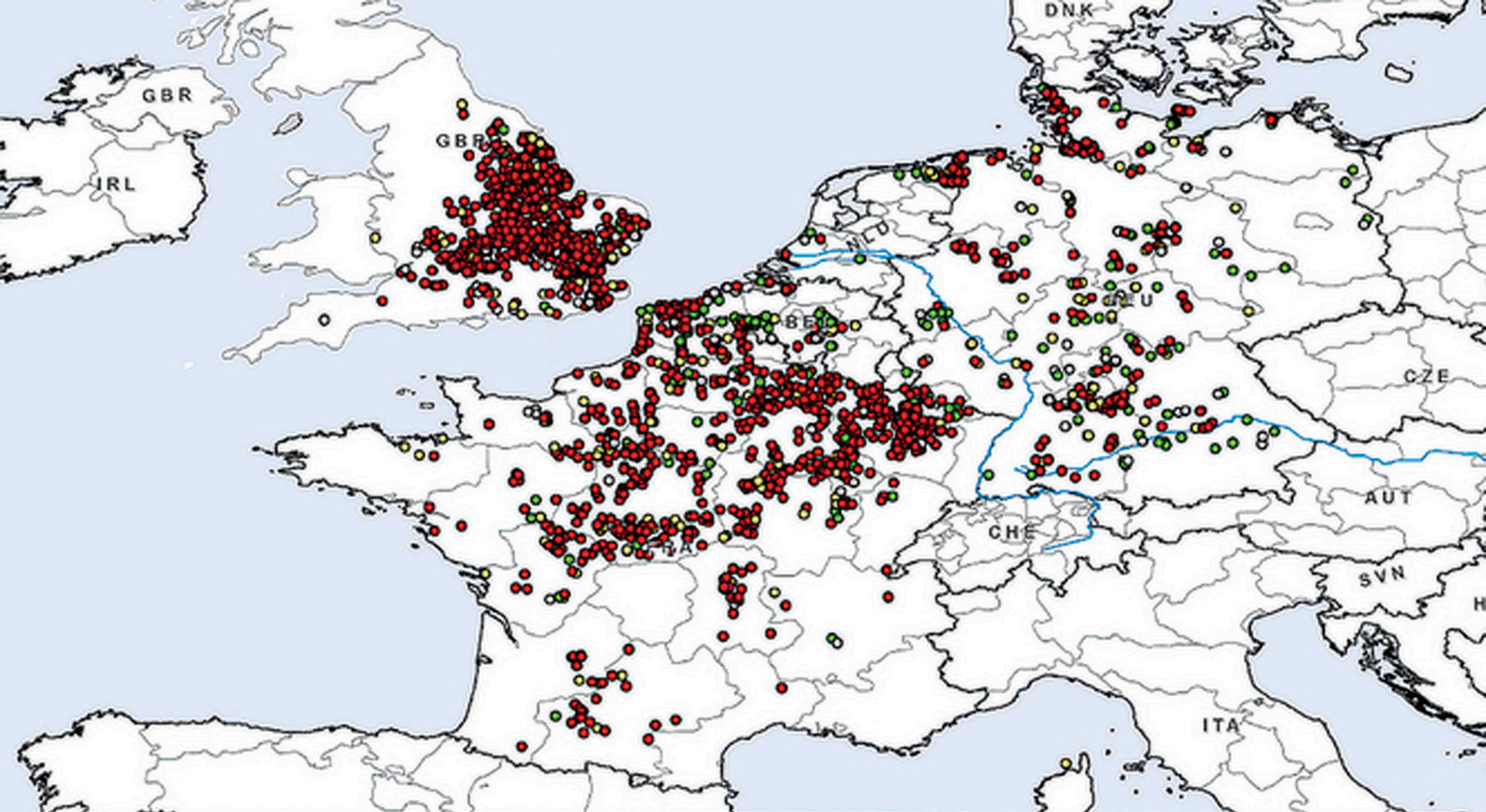

ATLAS OF WEED MAPPING

Edited by **Hansjörg Krähmer**

WILEY Blackwell

Atlas of Weed Mapping

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Edited by

Hansjörg Krähmer

formerly of Bayer CropScience, AG
Frankfurt, Germany

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My special thanks go to all regional coordinators: to Kristin Hanzlik (now BASF Ludwigshafen), Michaela Kolářová (Prague), Terho Hyvönen (Jokioinen), Albinas Auskalnis who has passed away too early and his wife Ona Auskalniene (Dotnuva), Baruch Rubin (Rehovot), Garifalia Economou (Athens), Ahmet Uludag (Canakkale Onsekiz Mart University, Çanakkale, and Düzce University, Düzce, Turkey), Maja Mezeldzija (Novi Sad) and many members of the EWRS Weed Mapping Working Group. Josef Soukup invited me to Prague in April 2012 to discuss the whole project with him and his colleagues. This invitation created new ideas and additional chapters. Stefan Fraenzle from IHI Zittau assisted with the conception of the aquatic weeds chapter.

Jacques Haury (Rennes) provided with plant material. Khawar Jabran from Pakistan (formerly at Faisalabad, Pakistan, presently at Adnan Menderes University in Turkey) read my contributions for his home country and for India and provided valuable comments and suggestions. I have inserted some of his statements in the rice chapters. Roland Gerhards, Ortrud Jäck, Alexander Menegat and Pi Wang (Hohenheim) discussed my maps on China and provided some literature data. Kateřina Šumberová from the Czech Republic remarked on parts of the chapters on aquatics and wetlands. Terho Hyvönen, Jukka Salonen and Professor Gerhards sent us many valuable comments on the last chapter of the atlas.

Finally, I would like to mention Karl Hurle, who read through most chapters of the atlas before publication. The discussions with him always resulted in improvements of the written text and, more importantly, also in new ideas.

Introduction

Hansjörg Krähmer
Bayer CropScience, AG, Frankfurt, Germany

What would the world be, once bereft
Of wet and of wildness? Let them be left,
O let them be left, wildness and wet,
Long live the weeds and the wilderness yet.

Gerald Manley Hopkins, Inversnaid, 1883

Weeds are plants interfering with man's interest (Krähmer and Baur, 2013). On arable fields, they compete with crops and reduce yields, some of them are toxic, some cause problems for harvesting, others have a negative impact on crop quality. Weed control is therefore a considerable economic factor in modern agriculture. Almost $US17 billion were spent in 2010 on herbicides worldwide (*Markets and Markets*, Dallas, Sept. 26, 2011; Wallstreet Online). At the same time, weeds are indicators of ecological changes and of changes in farming practices. Global trade is leading to a worldwide distribution of species which adapt to a wide range of environmental conditions. The *Atlas of Weed Mapping* provides an overview of the most common weeds affecting the major crops in the world. Holm et al. (1977) entitle their book, *The World's Worst Weeds: An Inventory of the Principal Weeds of the World's Major Crops*. It shows the worldwide distribution of many weeds in different habitats. In Holzner and Numata's *Biology and Ecology of Weeds* (1982), various authors describe the occurrence of frequent weeds in selected parts of the world. Also, the factors are analysed that contribute to the competition of weeds and crops in this compilation. Agriculture has changed considerably in many parts of the world in the past 30 years and so has the weed flora. Genetically modified crops are now grown on more than 100 million hectares worldwide (Krähmer & Stübler 2012). A considerable acreage is used for the production of energy crops, especially for fuel. In some countries, however, the weed spectrum of arable fields has remained almost constant despite changed weed control measures. We will try to explain here why changes have happened in some countries and why the weed spectrum has remained almost constant in others. This is nothing new; others have explained changes in weed infestation before (e.g. Hanf 1999). Our weed mapping atlas, however, adopts a context approach, that has not been attempted previously.

I was encouraged to prepare such an atlas several years ago by Karl Hurle from the University of Hohenheim, by Helmut Walter, BASF, and by Martin Schulte, Syngenta, before I became President of the EWRS (European Weed Research Society). I could not believe that it would be possible to compile the enormous amount of data required for such an enterprise. Very soon, however, I found out that many countries of the world have a long tradition of weed surveys, such as Canada (e.g. Leeson et al. 2005), Hungary (e.g. Novák et al. 2009) or Finland (e.g. Salonen & Hyvönen 2011). Soon a few colleagues interested in weed mapping issues had started to exchange their ideas.

Together with around 30 scientists, the EWRS Weed Mapping Working Group was founded in 2009. One of the tasks of this working group is the preparation of European and global weed maps. More than a hundred colleagues from all over the world have joined the group in the meantime. Regional coordinators ensure that data can be collected for different crops. Presentations and abstracts of meeting contributions can be found at http://www.ewrs.org/weedmapping/default.asp. Our first results have been summarized in Krähmer and Barberi (2016).

The approach to our objective is new insofar as we do not rely on species distribution ranges in the first instance. To make it clear from the beginning, we will not be able to achieve anything that is comparable or comes even close to some of the outstanding maps produced by several teams of ecologists in the last century, for example, by Meusel et al. (1965, 1978; Meusel & Jäger 1992) . We have a different aim as we do not want to produce new distribution maps. We want to rank weeds according to frequency and we want to show where the most frequent weeds occur in major crops. This is an approach which has been criticized by phytocoenologists, for instance, by Whittaker (1962). He made it clear that a view driven by dominant species cannot be used for the creation of a system that

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describes plant communities. Our atlas, however, is not devoted to phytosociological aspects in the first instance. We want to demonstrate where dominant plant species are preventing biodiversity and where farmers or landscape managers are being forced to invest in tools to safeguard food production or ecosystems. Unfortunately, weed survey data are not available for all European countries for the same years. The first EWRS maps are the result of data for a time span of about 20 years, i.e. from 1990 to 2010. Some literature used for the European maps can be found at: www.ewrs.org/weedmapping/docs/EWRS_Weed_Mapping_Report-1.pdf and www.ewrs.org/weedmapping/weed-mapping_references.asp#.

The ways of ranking weeds according to frequency vary considerably. The most common weed is not necessarily related to weed density, i.e. the number of weeds per m^2. Often it has to do with the constant appearance of weeds in surveyed plots. Greig-Smith (1984) discusses the relationship between frequency and density and makes it clear that weed patterns are important when describing this relationship. Chapter 42 in our atlas will discuss assessment methodology and terms such as frequency and density in more detail. Most weed surveys are restricted to some countries or states. The compilation of data from different national or regional surveys often results in artificial maps that create the impression that weeds respect national borders. It is much more appropriate to use ecological zones instead of political borders for the visualization of environmental factors influencing the occurrence of weeds. This approach was chosen by Leeson et al. (2005) for the Canadian Prairies. Most data available outside Canada are, however, the result of national surveys. Also, more detailed or precise overviews of the real situation are dependent on the degree of fine mapping. The information in the maps presented here resembles the political situation in a country. Many countries are run by representatives of one or two major parties but the voting situation in single counties or provinces may, however, vary considerably. This means, we show here only the large-scale trends and hope that future surveys and methods will allow us to get ever improving maps with more and more local details. One valuable source confirming our results here and on the above-mentioned EWRS website is http://grassworld.myspecies.info/content/distribution-0.

A number of distribution maps for invasive species can be found on the internet as described by Krähmer and Barberi (2016). The quality of information that led to our own maps varies considerably. We could rely on elaborate documentation in many cases. A great amount of data is, however, restricted to distinct areas within a state, province or district. Some publications just make qualitative statements about the frequency of weeds. The extrapolation to a whole region remains risky from a scientific point of view. The application of kriging tools should make such extrapolations sounder in the future. Often, we even came to our conclusions based on the opinion of local experts only. Therefore, many maps shown here will have to be improved by detailed studies in future. They present a first approach towards an update of the maps produced by Holm et al. in 1977.

As described above, it is obvious that weed spectra have changed greatly since the publication of *The World's Worst Weeds* (Holm et al. 1977). Blackgrass or *Alopecurus myosuroides* and silky bentgrass or

Figure I.1 *Tripleurospermum maritimum* and *Centaurea cyanus* in a barley field near Frankfurt, Germany, June 6, 2011.

Apera spica-venti, for example, are mentioned as being 'a principal weed of wheat in one or more countries of northern Europe' in 1977. Holm et al. in *World Weeds: Natural Histories and Distribution* (1997) already list *Alopecurus myosuroides* as 'one of the most serious grass weeds in cereal fields of western Europe'. Today, both weed species are dominating large areas of several arable crops. The continuous application of herbicides with the same mode of action has led to resistant biotypes which have replaced other species in many parts of the world.

Some plant protection experts are trying to map pests or diseases (e.g. Savary et al. 2012) in order to make epidemiological predictions in the same way we do here. Grassland weeds and aquatic weeds differ to some extent from weeds in arable crops. Therefore, separate chapters handle these habitats separately.

The book *Weed Anatomy* by Krähmer and Baur (2013) is devoted almost only to terrestrial weeds. This is why the anatomy of aquatics deserves special attention in Part X on aquatic weeds here.

Biodiversity is a central issue in agricultural policy today. Landscape aesthetics (Fig. I.1) and conservation have become important factors for recreation areas and tourism centres. Production efficiency is no longer the only factor contributing to the profit of farmers globally. Subsidies are essential income sources for farmers around the world. They are usually connected to sustainability, biodiversity and cross-compliance measures. We will stress the role of aesthetics in agriculture, of rare weed species and of biodiversity in several chapters. One may ask if all the structural features in plants are the result of a meaningful evolution from our perspective, and if natural selection without human interference would inevitably lead to plant communities with the maximum degree of biodiversity. Considerations of these questions often lead to rules and to environmental legislation that appear to go beyond the practical interests of modern societies. By definition, weed populations are the result of human civilization. This is why an idealistic or normative approach to weed science has to be regarded to some extent as artificial. There are not many scientists around now who have an overview of the vast number of morphological variations in plant science, like the botanists of the nineteenth century and the beginning of the twentieth. Based on their knowledge of these forms, scientists like Agnes Arber were able to write books such as *The Natural Philosophy of Plant Form* (1950). The observation that function follows the modification of structure in nature is contrary to the human intention to form the environment according to ideas. On the other hand, we do not want to create the impression that adaptation is dependent only on visible structures and forms. Physiological and biochemical traits are often more important than morphological traits.

We hope that our atlas will help to answer a few key questions in weed research independent of philosophical or ethical aspects: Why does a weed occur where it does?; why do weed spectra change?; can we predict future weed changes?; can we associate weeds with specific crops or environmental conditions?; and, finally, is it actually possible to prevent the occurrence of frequent and dominating weeds and to conserve rare weeds at the same time?

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PART I

Continental views of weed infestation maps

Hansjörg Krähmer
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The basis of the weed maps presented in the following chapters

Literature data are the central basis for the maps shown in the following chapters. All weeds were ranked according to their relative frequency, as shown, for instance, in country-wide surveys with relative frequency data. Good examples are the surveys from Finland (e.g. Salonen et al. 2011) or from Denmark (e.g. Andreasen & Streibig 2011). In addition, the following experts and coordinators were asked to compile lists for the most common weeds in cooperation with regional specialists or to check proposed lists:

Argentina	S. Cepeda (Bayer CropScience)
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Canada	N. Harker (Lacombe)
China	Zhenguo You (Bayer CropScience)
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Nigeria:	S. Adejoro (Akure)
Pakistan:	A. Shabbir (Lahore, presently St Lucia, Australia)
Russia:	Kiril Kalakoutski (Bayer CropScience)
South Africa:	Charlie Reinhardt (Pretoria) and colleagues
Turkey:	N. and S. Uygur (Adana), A. Aksoy (Bayer CropScience), H. Mennan (Samsun)
USA:	Tom Kleven (Bayer CropScience)

For many chapters, the original literature was used and we translated it into maps. All maps were produced using ArcGIS/ArcView 9 software provided by ESRI. Each weed species received its own colour code as documented in the Appendix at the end of the atlas. The maps show average weed infestations only. They do not reflect the results of regional differences, as one would expect from precise local mapping results. Fine regional mapping is required to achieve more precise maps with time, as already mentioned. Weed frequencies may vary from year to year, depending on weather variations and varying crop management practices. In some cases, the differences between the most frequent, the second most frequent and even the third most frequent species are not great. This is why the following chapters often contain figures for the two or three most frequent species. Monocots and dicots are usually presented separately. Maps were prepared for the economically most important arable crops or for those with the largest cultivation area only. Weed mapping in Israel has received special attention with the enhanced spread of invasive species in recent years. T. Yacacoby (Bet Dagan) and H. Eizenberg (Newe Yaar) have started a few research initiatives. Unfortunately, the agricultural areas of Israel are relatively small in comparison to the large acre crops in other countries.

The high value of cash crops and special problems, such as parasitic weeds (e.g. the *Orobanche* species), however, make weed mapping a valuable tool to study the infestation of agricultural fields on a relatively small scale also. The only plantation crops included in our atlas are sugar cane in Brazil and cassava in a few African states. Plantation crops such as olives, grapes or citrus definitely deserve more weed mapping activities in the future. Unfortunately, just a few selected countries in Africa, Asia and Latin America could be analysed. The maps shown here should provide the basis for a continuous world-wide discussion with experts. The weed ranks will vary with time, as already emphasized, and should be continuously updated.

CHAPTER 1

Europe

Hansjörg Krähmer
Bayer CropScience, AG, Frankfurt, Germany

We start our series of graphs with European weed spectra as the Weed Mapping Working Group of the EWRS collected data for Europe first, and most data were available in the beginning for this continent. Holzner and Immonen (1982) tried to use phytogeographical zones and chorological groups to describe the distribution of weeds in Europe more than 30 years ago. Guillerm and Maillet (1982) use bioclimatic sub-regions for this purpose. They list *Lolium rigidum* and *Avena* species among the most frequent grass weed species as well as *Papaver rhoeas* and *Cirsium arvense* among the dicot species in western Mediterranean cereals. Some of the weeds they mention are still quite common today. The agricultural situation, however, has changed considerably in the meantime. According to EUROSTAT, the European cropping areas (EU27) for cereals (including maize and rice) in 2007 were 57.4 million hectares, for forage and grain, maize 13.3 million ha, and for oilseed rape 6.6 million ha, and the total arable land equalled 99.5 million ha. In consequence, three crops amount to almost two-thirds of all arable land in Europe. Wheat, maize and oilseed rape were selected as the most important crops for our maps here. Weed infestation in Turkish wheat is referred to in more detail in Chapter 2. Due to similarities in some areas of Turkey, the maps for Europe contain the most frequent weeds in Turkey also. Large areas of Russian wheat production are characterized by continental climates similar to Kazakhstan and are referred to in detail under Asia in Chapter 2. Literature from 23 countries with frequency data was used as listed in the references for Europe. Many European countries have a rich source of survey data, such as the Czech Republic, Finland, Hungary, Latvia or Russia. A compilation of data in English is, however, not always available. This is why local experts are important for the interpretation of historical data. Sometimes, overviews are provided by western European authors, such as a German overview on plant production in the former Commonwealth of Independent States (Spaar & Schuhmann 2000). The results of surveys of different authors for the same country may differ considerably. For some countries, finer and more precise maps are required. This becomes apparent when considering the climatic and agronomic differences in Italy, for instance, as described by Franzini (1982) more than 30 years ago.

In a few countries, the information on weed infestation was very limited (Belarus: Soroka et al. 2000; Bulgaria: Atanassova & Koteva 2005; Dimitrova 2002; Glemnitz et al. 2007; Spaar & Schuhmann 2000; Ukraine: Ivashchenko 2000). For others, a great amount of data was available but only one source is listed as an example (France: Reboud & El Mjiyad 2005, the background is a whole database with all sorts of data available at: www2.dijon.inra.fr/bga/araf2009/). For the following countries, personal contacts with experts exist but only a few publications are listed (Croatia: Knežević et al. 2003; Greece: Dhima & Eleftherohorinos 2001; Travlos et al. 2008; Italy: Berti et al. 1992; Zanin et al. 1992; Norway: Torresen & Skuterud 2002; Poland: Zajac & Zaja, 2001; Golebiowska & Rola 2006; Romania: Chirla & Berca 2002; Berca & Chirla 2004; Serbia: Stanojević et al. 2001; Radivojevic et al. 2006; Šilc et al. 2009; Vrbničanin et al. 2009; Spain: Gonzalez-Andujar & Saavedrab 2003; Torra & Recasens 2006; Sweden: Boström et al. 2002, 2003; Switzerland: Delabays et al. 2006).

Some countries have a long tradition of surveys and several sources were used for the preparation of maps, at the same time, discussions with country representatives were possible (Czech Republic: Kropáč 2006; Soukup et al. 2006; Juroch & Lvončik 2007; Lososová et al. 2008; Beranék & Juroch 2009, 2010; Kolářová et al. 2013a, 2013b; Denmark: Andreasen et al. 1991, 2008, 2009; Andreasen & Streibig 2011; Estonia: rankings and literature were provided by Lauringson et al. 2001, 2002; Talgre et al. 2004, 2005, 2008; Uusna 2006; Finland: Salonen et al. 2001, 2011; Germany: Albrecht & Bachthaler 1989; Arlt et al. 1995, Tóth et al. 1999; Zwerger et al. 2004; Mehrtens et al. 2005; Goerke et al. 2008; Hungary: Dorner et al. 2004; Nagy et al. 2004; Dancza 2006; Tamas et al. 2006; Novák et al. 2009; Pál & Csete 2008; Pinke et al. 2009; Latvia: rankings and literature were provided by Ineta Vanaga: – Vanaga 2001a, 2001b, 2002a, 2002b, 2003a, 2003b, 2004, 2005; Vanaga & Lapins 2000; Vanaga et al. 2002, 2006; Vanaga & Gurkina 2004; Vanaga & Zarina 2008; Lithuania: rankings were provided by Albinas Auškalnis; literature provided by Pilipavicius & Lazauskas 2000; Čiuberkis 2001; Velykis & Satkus 2006; Nedzinskiene et al. 2008; Turkey: rankings and most publications were provided by Professor F.N. Uygur and Professor S. Uygur: Uygur et al. 1986; Boz 2000; Kaya & Zengin 2000; Oksar & Uygur 2000; Kitis & Boz 2003; Mennan & Isik 2003; the UK: Clarke et al. 2000; Marshall et al. 2002; Preston et al. 2002; Moss et al. 2005; Bayer CropScience, 2006; Green 2006; Walker et al. 2006).

Our final decision on which results to use in our maps may be regarded as biased. We hope that these maps will, however, offer

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an opportunity for experts to discuss different views and to derive conclusions for future and more precise presentations.

Wheat

Growing conditions

North of the Alps, winter wheat is the dominant crop in most European countries. It is usually planted in autumn (September to December) and harvested in the summer of the following year (June to August). It only flowers after vernalization induced by low winter temperatures. Winter cereals in many Mediterranean areas (e.g. in Spain or in Israel) are actually spring wheat forms planted in autumn. They do not need the very low temperatures of winter cereals in the north for flower induction. In Italy, soft wheat and durum wheat are planted between September and December, depending on the area. Soft wheat is harvested then between July and August. Durum can be harvested a little earlier, that is, between June and July.

Spring wheat in northern Europe is normally planted between March and May and harvested in July and August. Tillage and climate have a large influence on the occurrence and emergence of weeds.

Statistics

Wheat was grown on an area of about 25,5 million ha in the EU (harvested area, FAO, 2012 data), the countries with the largest areas were France (5.3 million ha), Germany (3.1 million ha) and Poland (2.1 million ha). Most of the wheat planted is rain-fed. The acreage of spring wheat in northern Europe is rather low compared with the acreage of winter wheat. In Germany, for example, spring wheat was grown on around 50,000 ha, whereas winter wheat was grown on about 3 million ha in 2013 (destatis, 29 May 2013).

Weeds

Monocots

Winter wheat north of the Alps

The dominant grass weeds of winter wheat are *Alopecurus myosuroides* Huds. or blackgrass and *Apera spica-venti* (L.) P. Beauv. or silky bentgrass, as shown in Fig. 1.1. In the more recent past, fields were usually infested either with blackgrass or silky bentgrass. Both did not often occur in the same fields, but this seems to have changed now. *A. myosuroides* is often associated with the dicot *Galium aparine* L. or cleavers, as shown in Fig. 1.2. *A. myosuroides* and *A. spica-venti* start emerging in autumn and continue germinating all over winter and spring. Late germinating plants usually escape herbicide treatments. These late emerging individuals remain small due to the dominant crop. They are, however, able to plant seeds for the next planting period. Both species are of high economic importance in northern Europe. *Apera* is more common but less difficult to control. Both species have developed resistance to a number of herbicides. *Poa annua* L. is frequent in the winter wheat of Great Britain (blue in Fig. 1.1). It is, however, not regarded as a serious weed problem in most cases.

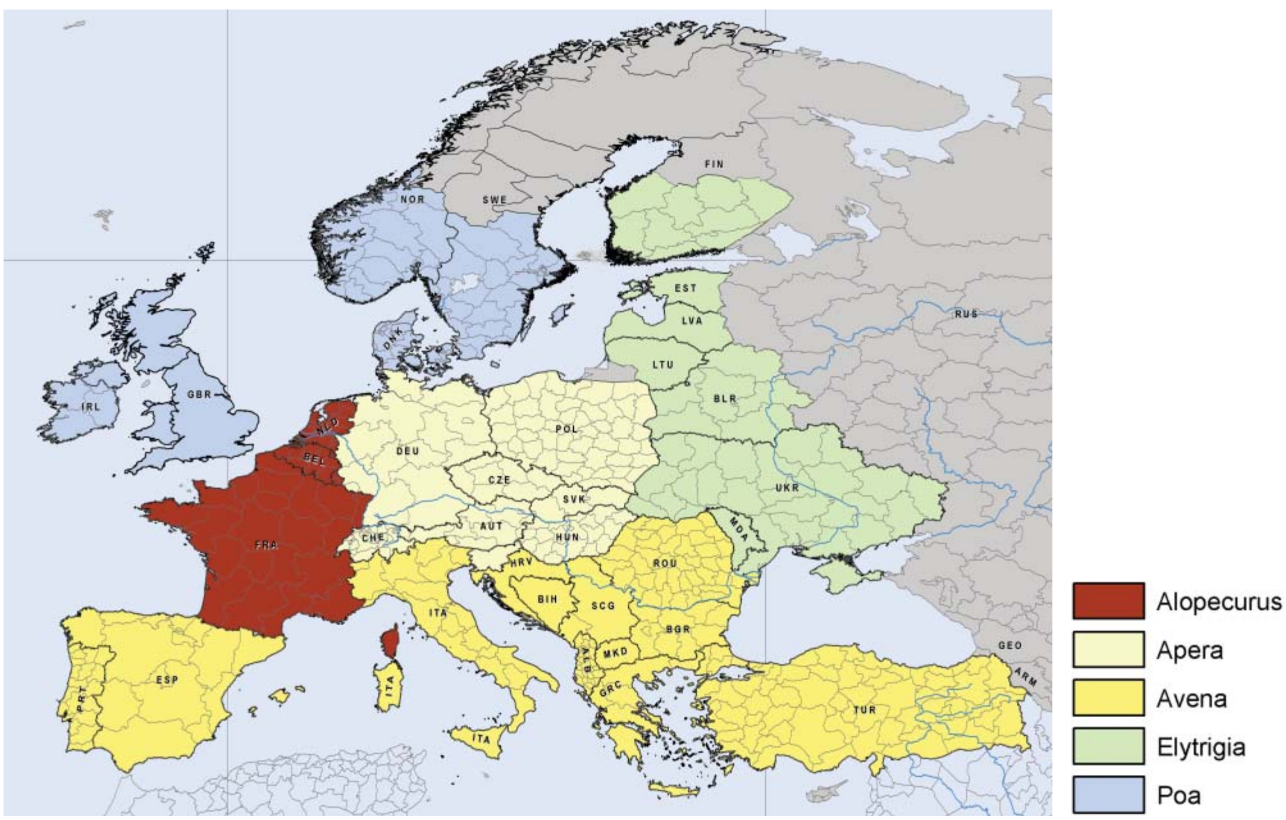

Figure 1.1 Average weed infestation in cereals, most frequent grasses.

Figure 1.2 Cleavers and blackgrass in a wheat field near Stuttgart, Germany, 10 June 2009.

Spring wheat north of the Alps

Wild oats, *Avena fatua L.* and *Avena sterilis L.*, used to be the dominant weed in northern Europe until the last quarter of the twentieth century when spring crops and especially oats were grown on much larger acreages there (Krähmer & Stübler 2012). Today, this weed problem is only minor in Northern Europe. *Poa annua* is a common grass weed of spring cereals in Scandinavia and Finland (Figs 1.1 & 1.3). Quackgrass, *Elytrigia repens* (L.) Nevski, used to be a considerable weed problem before the advent of selective grass herbicides and of glyphosate all over Europe. Despite these tools, this perennial species is still rather widespread in the spring wheat fields of the North. It is also dominant on a number of large eastern European farms with low or no tillage practice. It is of less importance in the Mediterranean area. *Alopecurus geniculatus* L. may occur in a few fields of Finland and Scandinavia. *Equisetum arvense* L. seems to be rather frequent there also (e.g. Salonen et al. 2011). This has to be stressed as this species does not fit into the monocot/dicot frame.

Wheat in the Mediterranean region

As mentioned above, wild oats are still the most frequent weed problem in the Mediterranean region (Fig. 1.1), including North Africa. Wild oats are even presumably the most frequent weed of arable crops in the world. This can be found on every continent and in various crops. Its drought tolerance allows growth even under extreme conditions.

Lolium multiflorum Lam. (Italian ryegrass), *Lolium rigidum* Gaudin (Wimmera ryegrass) and *Lolium perenne* L. (Perennial ryegrass) often become problem weeds in southern Europe (Fig. 1.3). They can be found in many habitats where wild oats also grow. The Mediterranean climate with cool but mild and rainy winters favours spring wheat planting in winter. Similar growth conditions can be found in Australian, Argentinian and Chilean wheat areas and will be referred to later on. *Setaria* species and *Phalaris minor*

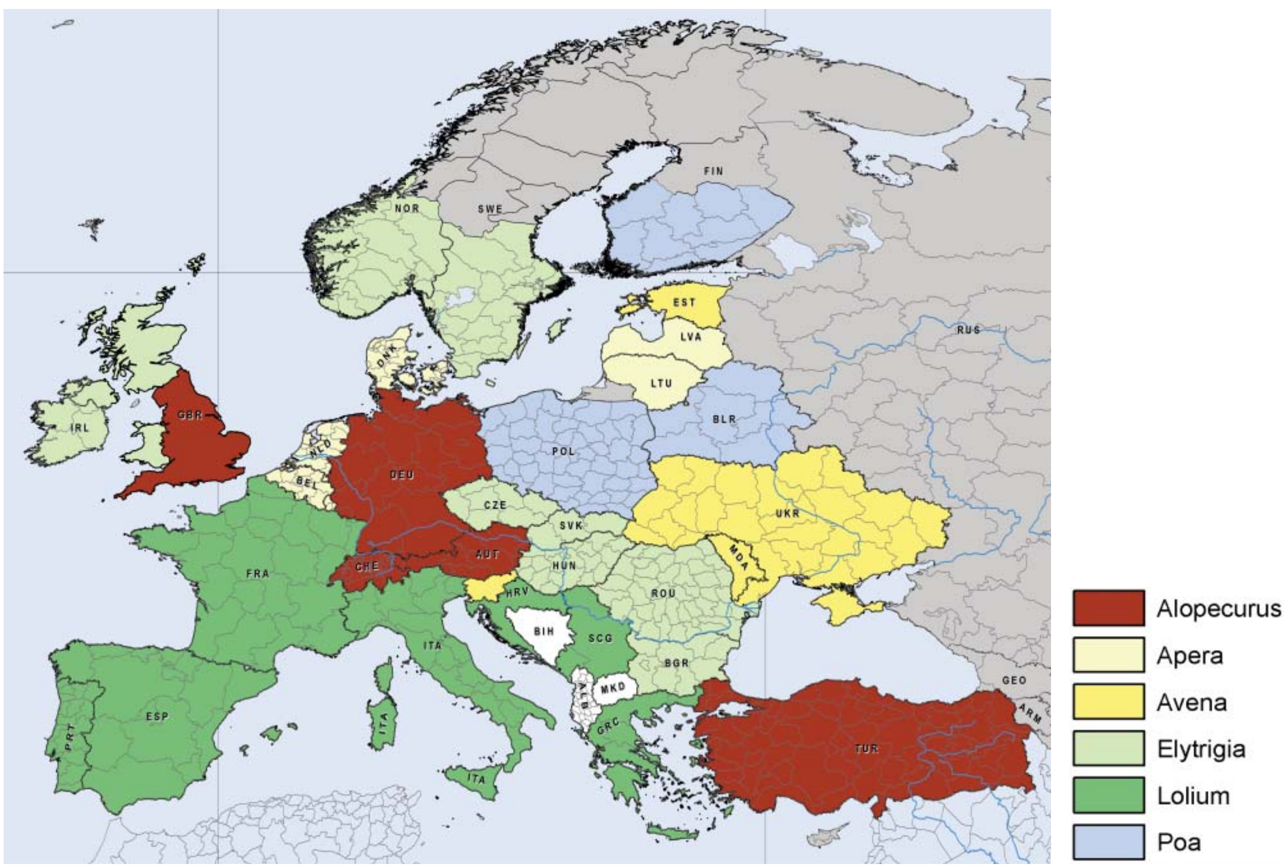

Figure 1.3 Average weed infestation in wheat, the second most frequent grasses.

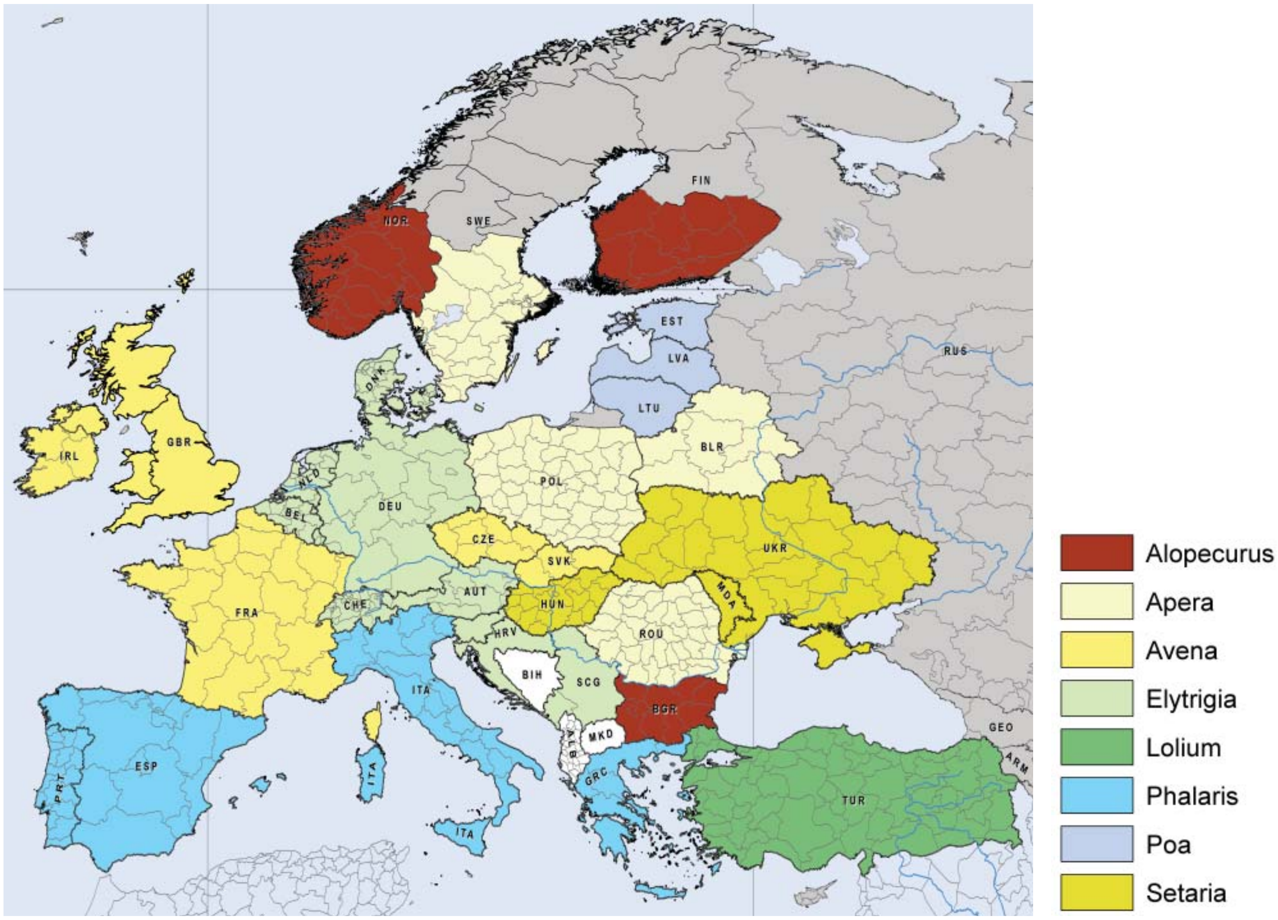

Figure 1.4 Average weed infestation in wheat, the third most frequent grasses. Note: The *Alopecurus* species in Scandinavia and Finland is *A. geniculatus*.

are rather frequent as additional grass weed species in southern and south-eastern Europe when it comes to the third most common grass weeds (Fig. 1.4).

Dicots

Winter wheat north of the Alps

The number of different dicot species in European wheat fields is usually much higher than the number of grass species. *Galium aparine* L. or cleavers, is one of the species that is regularly found in wheat fields of central and northern Europe (Fig. 1.5). The absolute number of individuals per field is usually not very high. Farmers, however, do not tolerate cleavers in their fields due to its biomass development, its strong competition with the crop and its negative influence on crop harvesting. *Stellaria media* (L.) Vill. is growing in many parts of Europe also. It is one of the most frequent species in Great Britain and Scandinavia. *Veronica* species (primarily *V. persica* and *V. hederifolia*) often escape herbicide treatments and are therefore found quite frequently in winter cereals (Fig. 1.6). *Tripleurosporum maritimum* (L.) W.D.J. Koch, *Anthemis*- and *Matricaria*-species are other common species in European winter wheat (all three genera are represented by 'Matricaria' in Figs 1.5 – 1.7). *Cirsium arvense* (L.) Scop. is a common perennial weed of eastern European countries with large low-tillage agricultural areas. This is also true for *Convolvulus arvensis* L (Fig. 1.7).

Wheat in the Mediterranean region

Poppy, *Papaver rhoeas* L., grows in many parts of Europe. This species appears to be the most frequent dicot weed in wheat of the Mediterranean area. An invasive species that has become of major importance in south-eastern Europe is *Ambrosia artemisiifolia* L.

Spring wheat weeds

Chenopodium album L. is a characteristic broadleaf weed of European spring wheat on both sides of the Alps (Figs 1.5 – 1.7). *Viola arvensis* Murray can often be found in the Baltic States and in Finland. *Thlaspi arvense* L. and *Galeopsis tetrahit* L. are also quite common species of spring wheat.

In some Mediterranean areas, it is rather difficult to decide which weeds are the most common ones due to strong climate contrasts within the same country. The growing conditions in the Çukurova region of Turkey and the Central Anatolian region are so different that weed spectra cannot easily be compared within the same crop. Also, borders between Europe and Asia change from time to time.

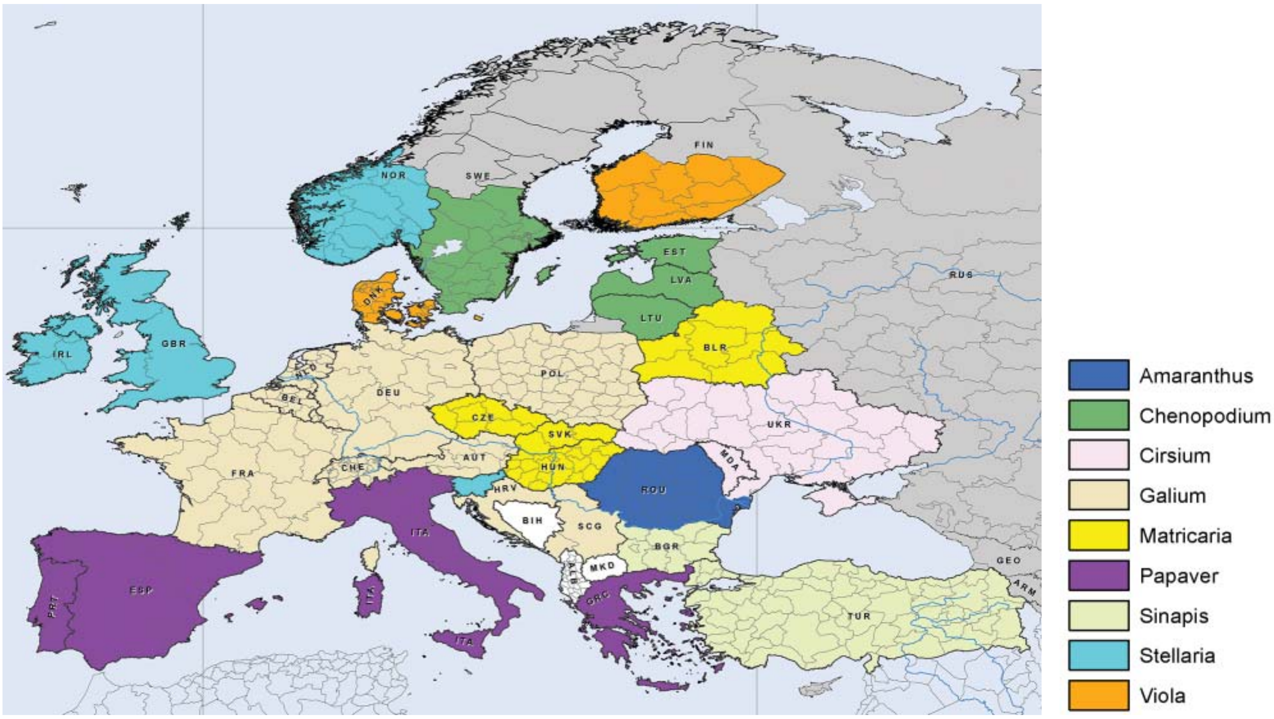

Figure 1.5 Average weed infestation in cereals, most frequent dicots.

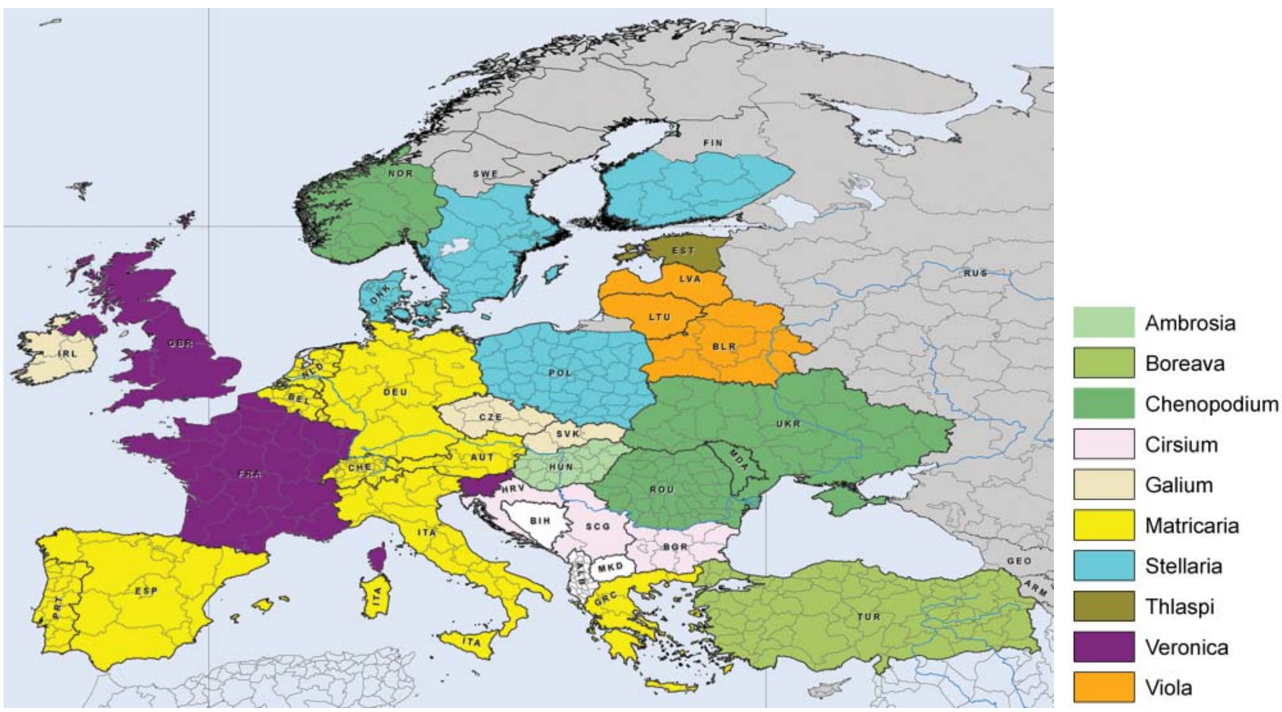

Figure 1.6 Average weed infestation in cereals, second most frequent dicots.

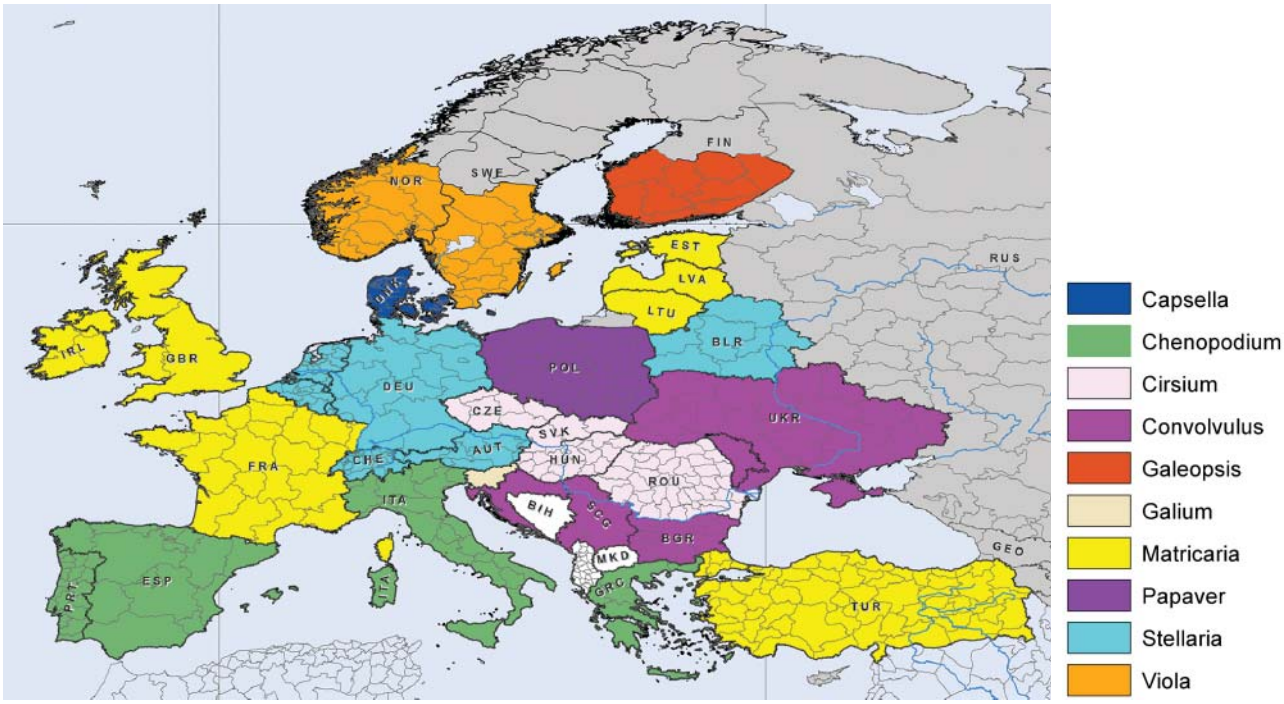

Figure 1.7 Average weed infestation in cereals, third most frequent dicots.

This is why a more detailed view of Turkish crops is presented in Chapter 2.

Maize

Growing conditions

European maize will only fully develop between spring and autumn due to its high temperature requirements and its cool weather sensitivity. Its high water requirements limit its growing areas to some extent also. In most northern parts of Europe, maize is not planted before April or May. The acreage of this crop has increased considerably in the past 20 years. One major reason for the success of maize in Europe is its short-season, early maturing varieties. Excellent weed control tools have also contributed to the relatively large acreage. Maize reacts very efficiently to nitrogen fertilizers such as manure from animal production and it is one of the most suitable crops for biogas production. Genetically engineered maize is only grown in Spain (129,000 ha in 2012; Clive 2012). This maize is insect-resistant.

Statistics

Maize was grown on 18.3 million ha in Europe in 2012 (EU27) compared with 13.4 million ha in 2002 (FAOSTAT). It is important to stress that a clear distinction in the data for green maize and grain maize is often not easy when using official data. Regional statistics can differ to some extent in comparison to globally compiled FAO data. According to the Deutsches Maiskomitee e.V. (the German Maize Committee) (www.maiskomitee.de/web/public/Fakten.aspx/Statistik/Europäische_Union), the proportion of harvested green maize to grain maize in the 16 most important maize-producing countries in the EU amounted to around 8 million ha (grain maize) vs. 5 million ha (silage maize) in 2007 and 9.4 million ha vs. 5.8 million ha in 2012 respectively.

Weeds

Monocots

Echinochloa crus-galli is by far the most widespread grass weed in European maize (Fig. 1.8). The second most frequent grass weeds are *Setaria* species, primarily *Setaria viridis* (L.) P. Beauv., *Setaria glauca* (L.) P. Beauv. syn. *Setaria lutescens* (Weigel) Hubbard. and *Setaria verticillata* (L.) P. Beauv (Figs 1.9 & 1.10). Andreasen and Streibig (2011) have noted recently that *Setaria viridis* and *Echinochloa* spp., C4 plants native to warmer climates, were able to gain footholds in the open maize crop. This is a species that had not previously succeeded in invading Scandinavian crops. *Sorghum halepense* (L.) Pers. and *Cynodon dactylon* grow primarily in the Mediterranean area due to their temperature requirements (Figs 1.8–1.10). Both species play a special role in the Çukurova region of Turkey.

Dicots

Chenopodium species, primarily *Chenopodium album* L. and *Chenopodium hybridum* L. can be found in most European maize fields (Fig. 1.11). *Convolvulus arvensis* is also rather widespread. It seems, however, to dominate especially in the Mediterranean area. *Amaranthus* species are very common weeds in maize fields, primarily *Amaranthus retroflexus* L. One species that has become a dominant weed problem in southern European countries – especially in some Balkan states – in recent years is *Ambrosia*

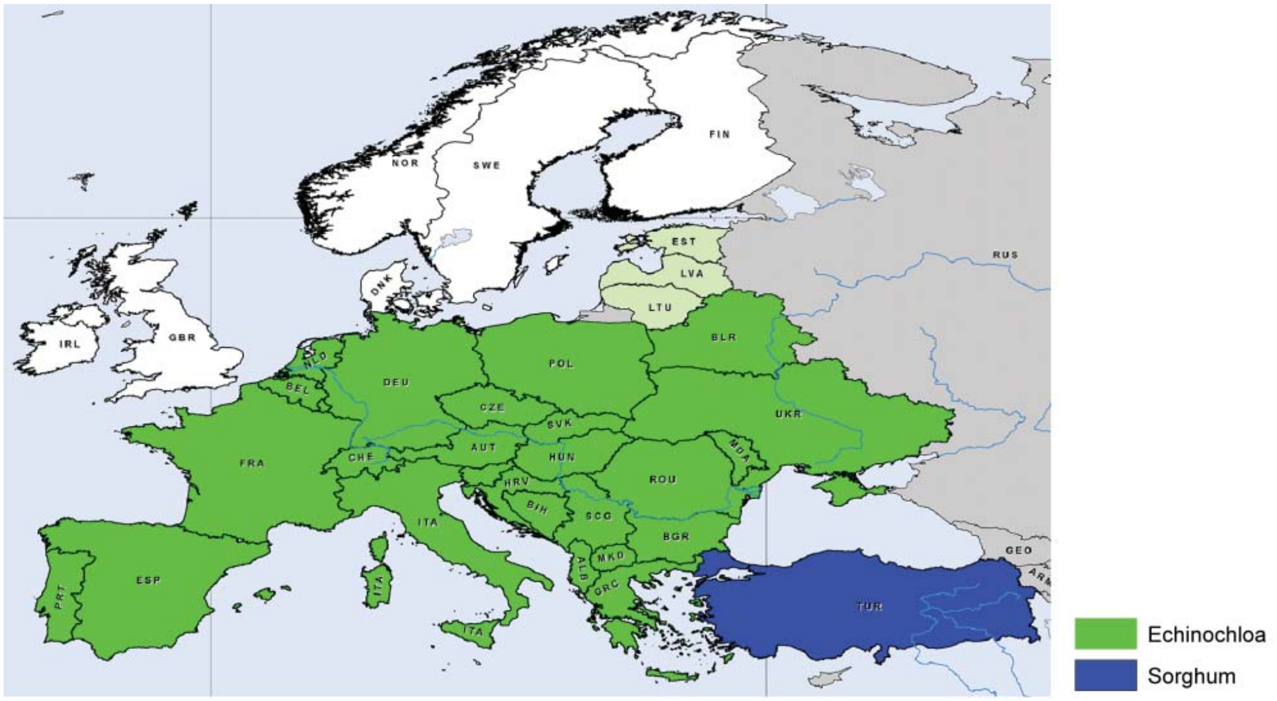

Figure 1.8 Average weed infestation in maize, most frequent grasses.

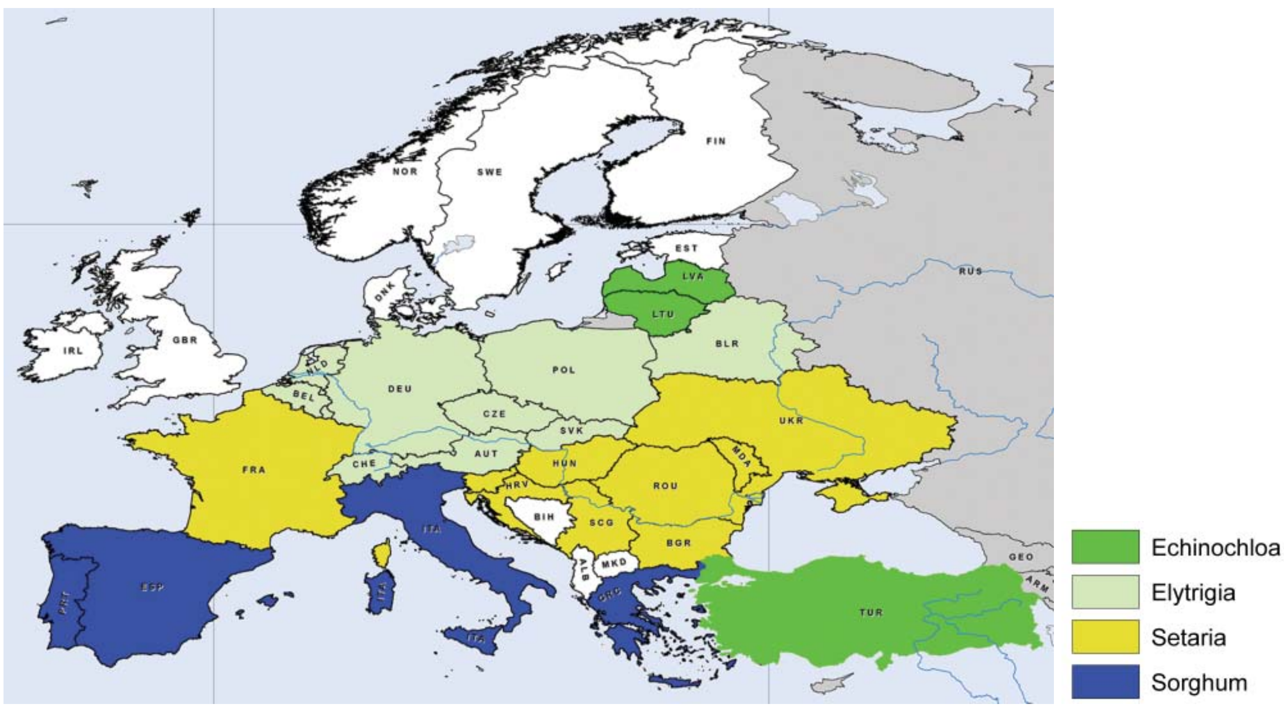

Figure 1.9 Average weed infestation in maize, second most frequent grasses.

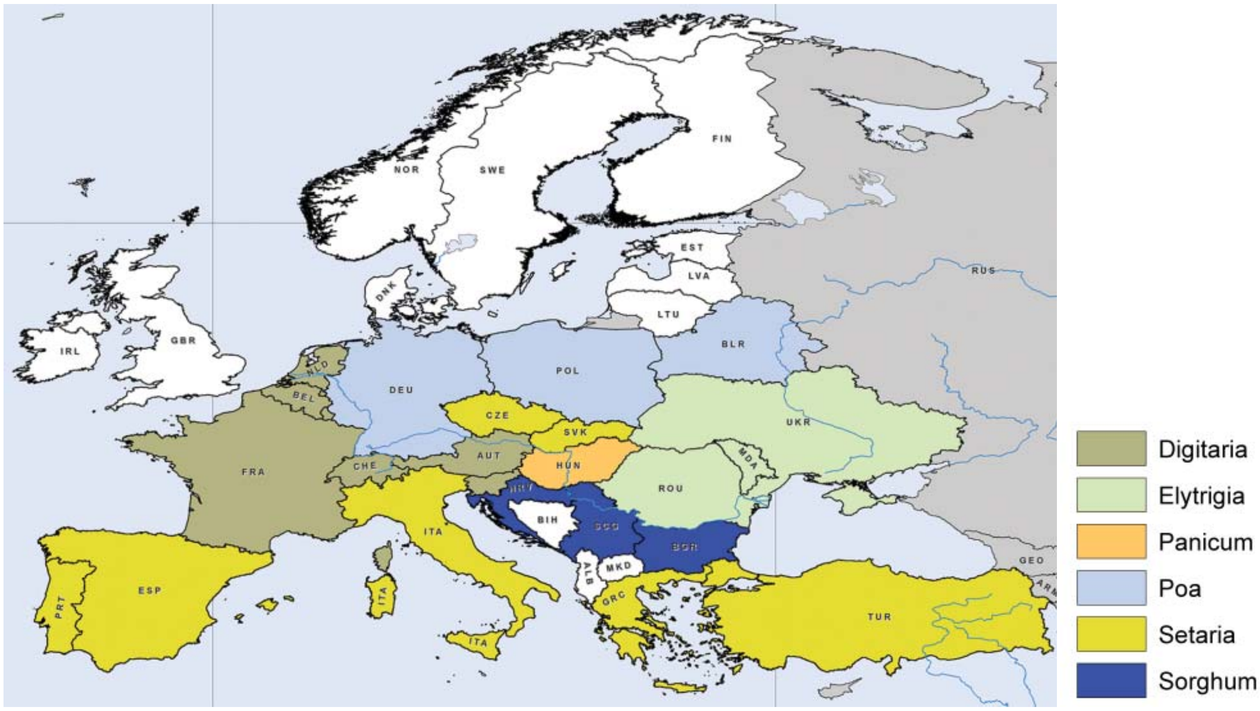

Figure 1.10 Average weed infestation in maize, third most frequent grasses.

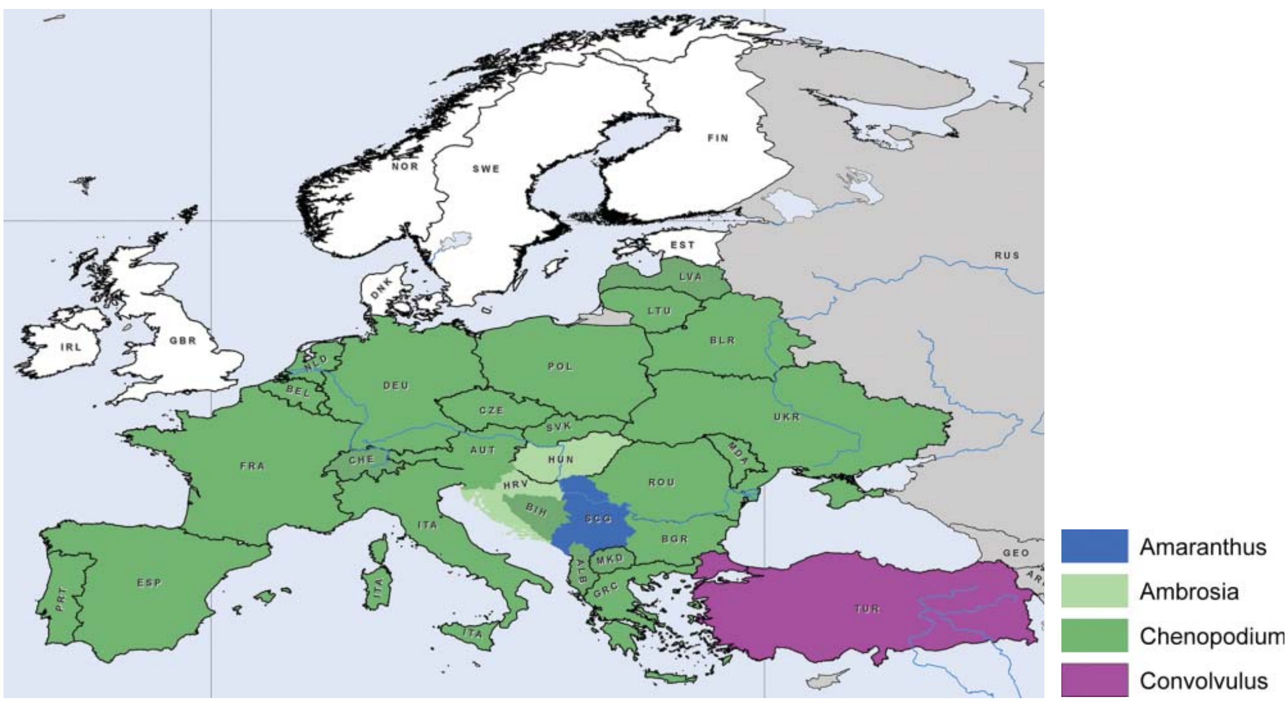

Figure 1.11 Average weed infestation in maize, most frequent dicots.

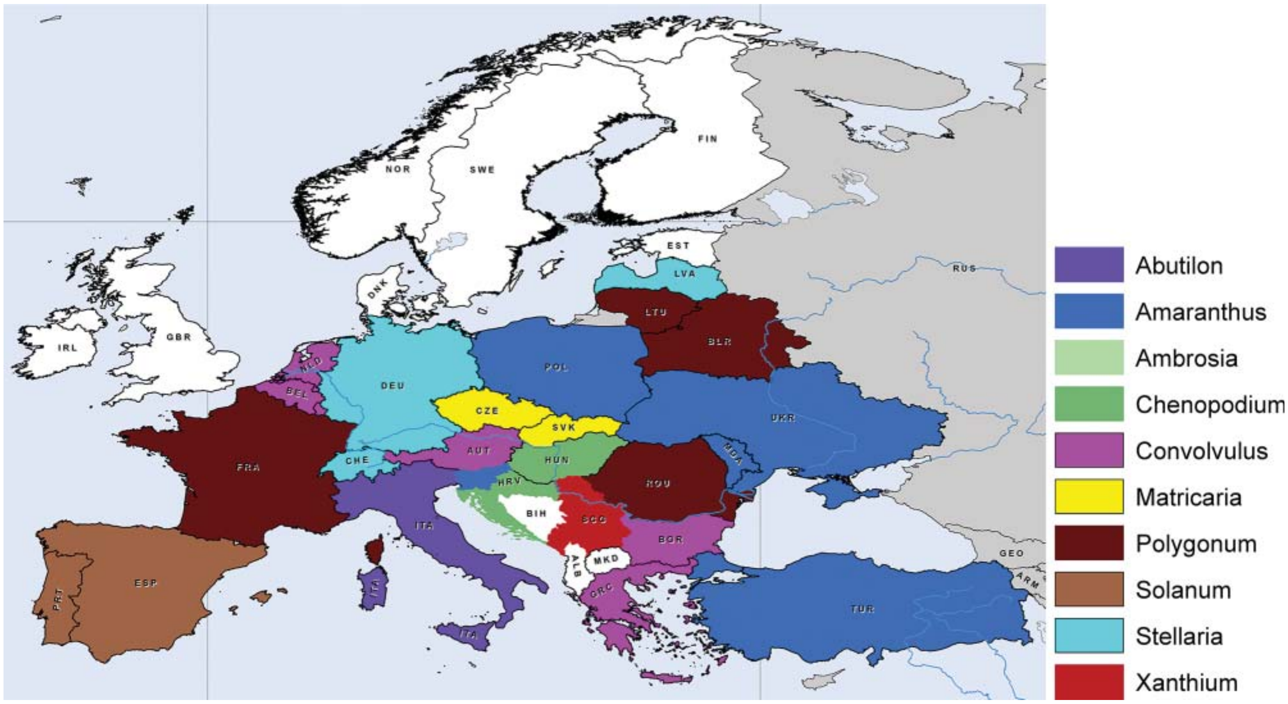

Figure 1.12 Average weed infestation in maize, second most frequent dicots.

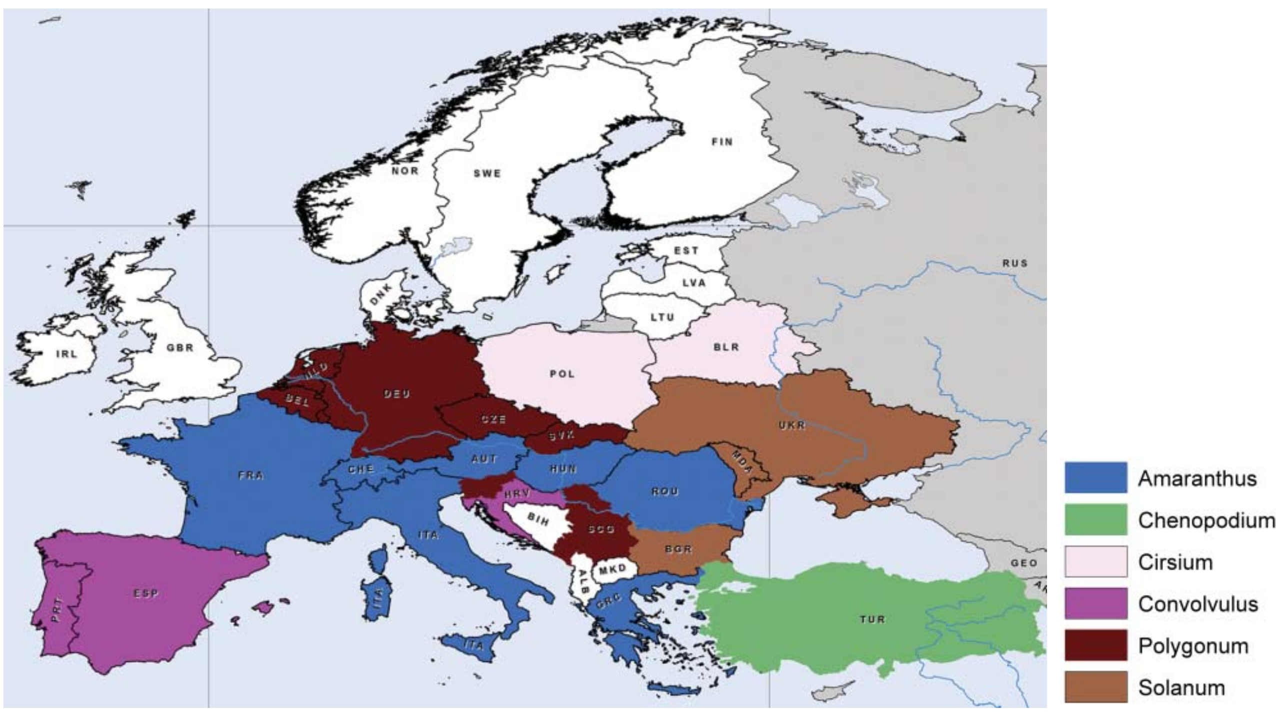

Figure 1.13 Average weed infestation in maize, third most frequent dicots.

artemisiifolia L. (Figs 1.11 & 1.12). *Xanthium strumarium* L. needs high temperatures for its development and grows preferably in Mediterranean countries such as Serbia (Fig. 1.13) and in the Çukurova region of Turkey. *Solanum nigrum* can be found quite frequently all over Europe. Some species of the genus *Solanum* prefer warm weather and are usually more common in southern European countries such as Spain (Fig. 1.12). There, *Abutilon theophrasti* is increasingly causing problems as an invasive species in maize (Recasens et al. 2005) similar to the situation in Italy.

A recent publication by Jensen et al. (2011) confirms some findings that were posted on the EWRS Weed Mapping WG website for maize from 2009 onwards.

Figure 1.14 Flowering oilseed rape near Frankfurt, Germany, 11 May 2012.

Figure 1.15 Volunteer cereals in oilseed rape near Frankfurt, Germany; 1 December 2012 – both suffering from frost.

Figure 1.16 *Tripleurospermum maritimum* in oilseed rape near Frankfurt, Germany, 7 June 2009.

Oilseed rape

Growing conditions

Most of European oilseed rape (Fig. 1.14) is grown as a winter crop. Spring rape is of minor importance. The winter crop is usually planted from August to September and harvested between June and July. Spring rape is sown during March and April; it is harvested between August and September.

Statistics

In 2010, oilseed rape was grown on 7 million ha arable land in Europe (EU27, source: USDA/FRS, February 2012), of which 1.5 million ha were found in France and Germany each, 0.9 million ha in Poland, and 0.6 million ha in the UK and in Romania respectively. The acreage of spring rape in Germany amounted to around 4000 ha only (www.ufop.de/3813.php).

Weeds

By far the most frequent monocot weeds in Europe are volunteer cereals (Figs 1.15 & 1.17), followed by blackgrass, silky bentgrass (Fig. 1.18) and couch or quack-grass (Fig. 1.19). *Tripleurospermum maritimum subsp. inodorum* (Merat) M. Laínz (synonym *Matricaria inodora* L.) (Fig. 1.16) is the most common dicot weed. The occurrence of lamb's quarters – *Chenopodium album* – is typical of spring rape, for example, in the Baltic States (Fig. 1.20). A number of weeds occurring in winter cereals are quite frequently found in oilseed rape also (*Alopecurus*, *Apera*, *Tripleurospermum*, *Galium*, *Viola*, *Stellaria*, for instance, Figs 1.21 & 1.22). *Cirsium arvense* as a perennial weed is not too common; where it occurs, however, it can cause severe damage to the crop (Fig. 1.23).

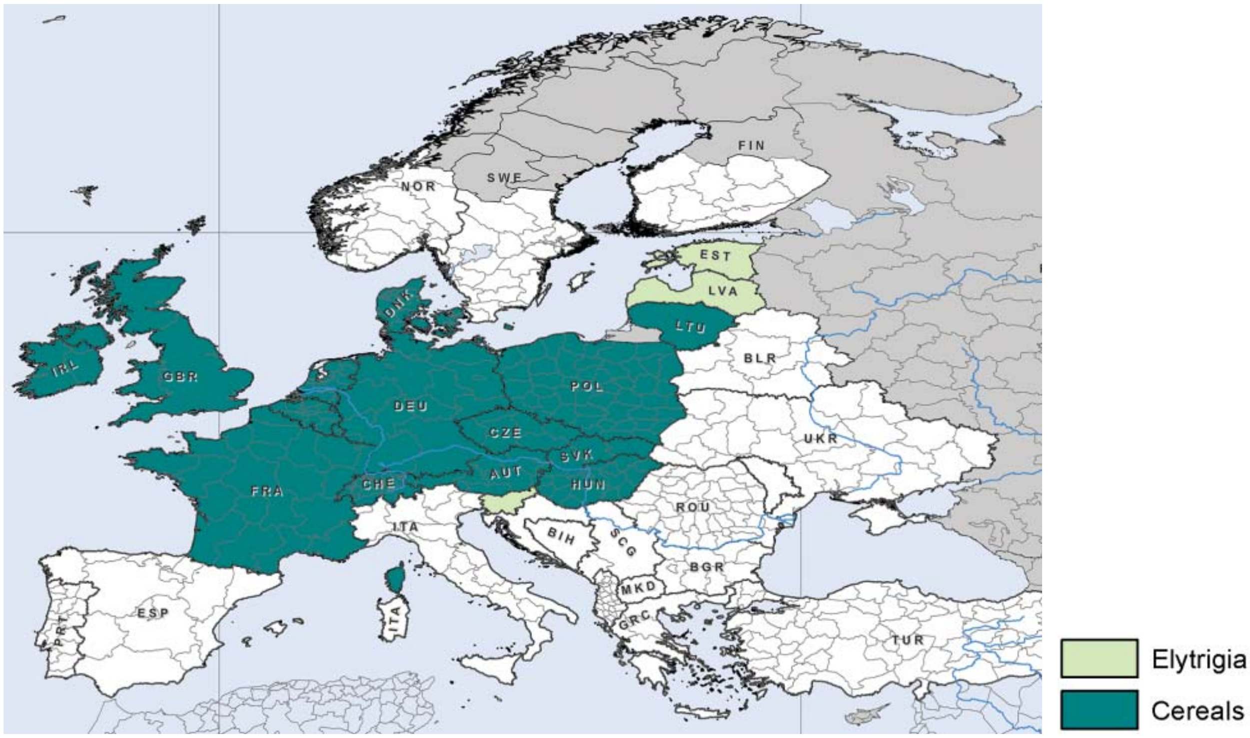

Figure 1.17 Average weed infestation in oilseed rape, most frequent monocots.

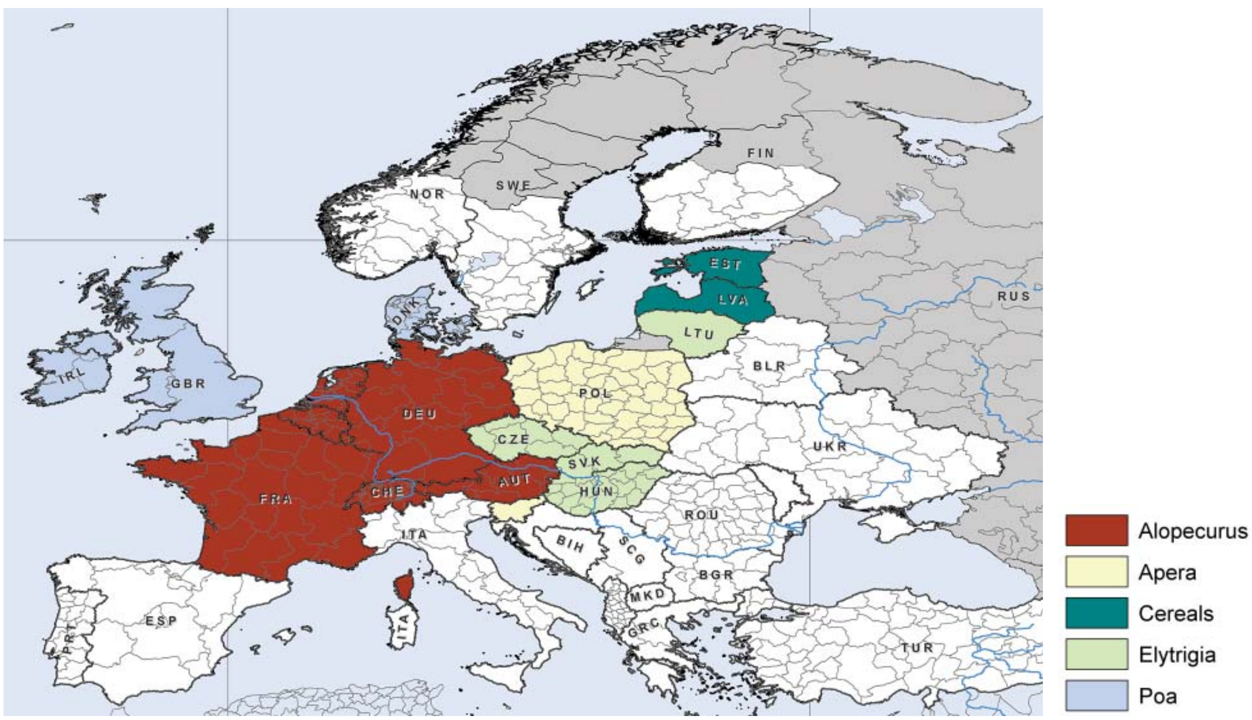

Figure 1.18 Average weed infestation in oilseed rape, second most frequent monocots.

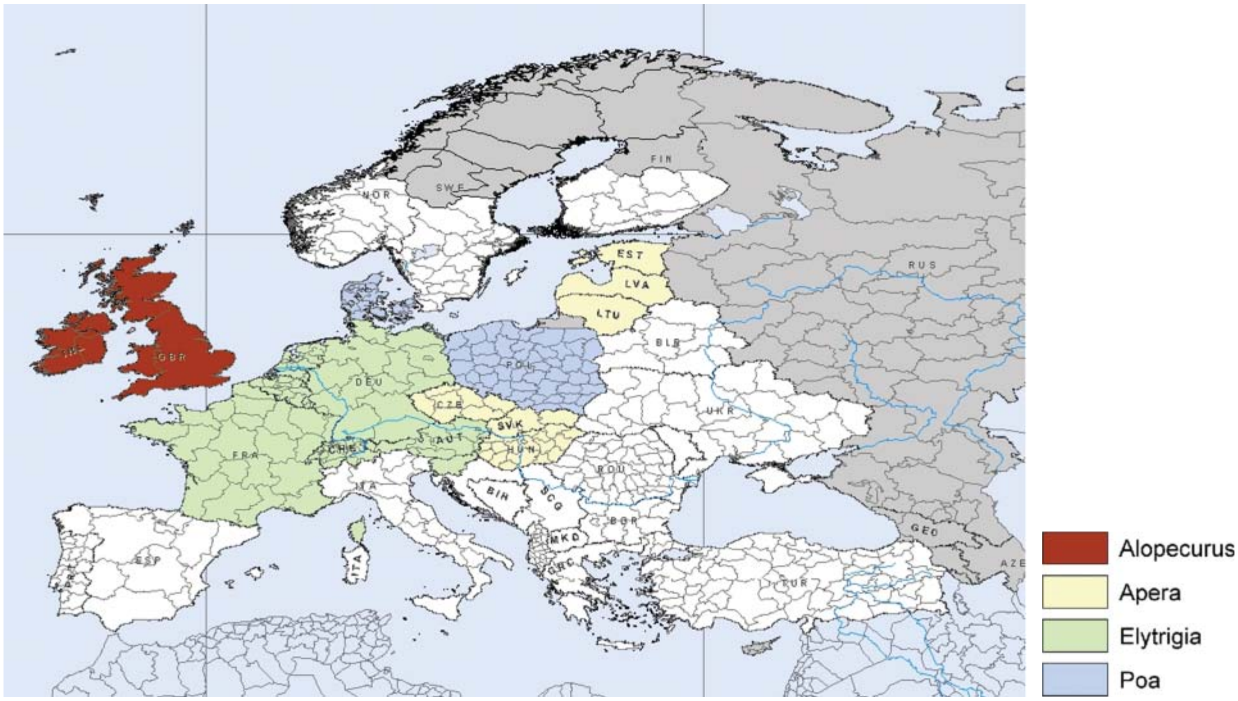

Figure 1.19 Average weed infestation in oilseed rape, third most frequent monocots.

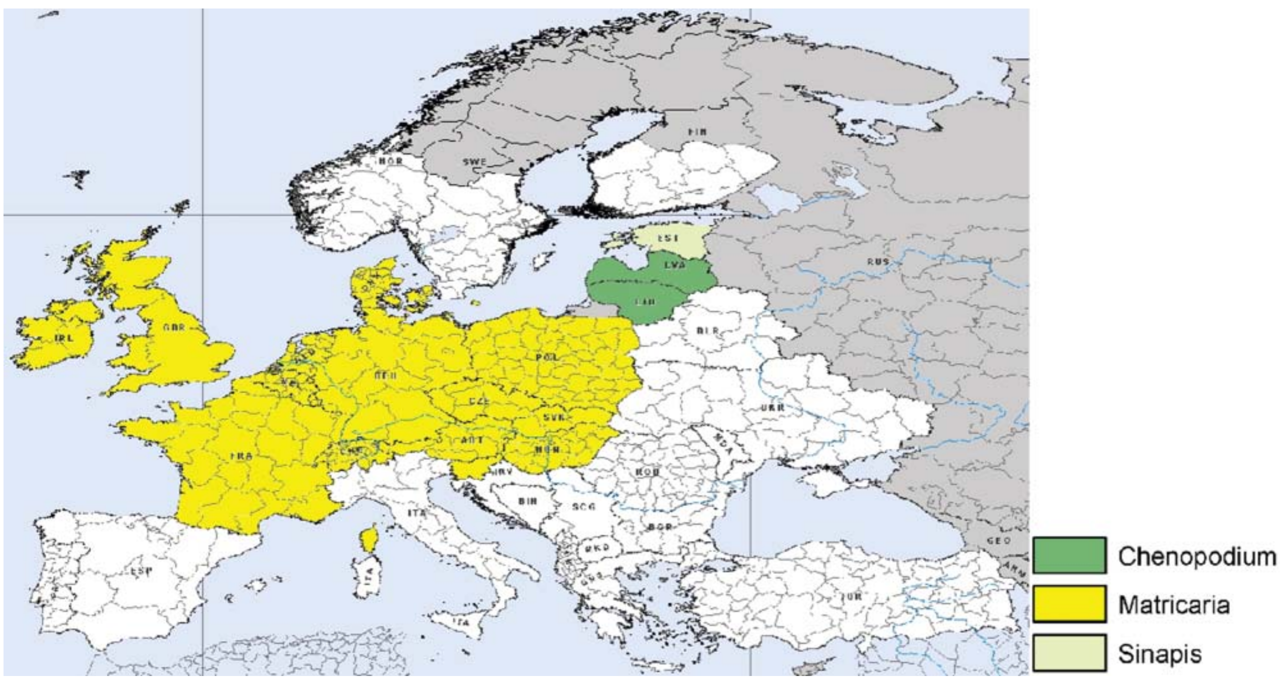

Figure 1.20 Average weed infestation in oilseed rape, most frequent dicots.

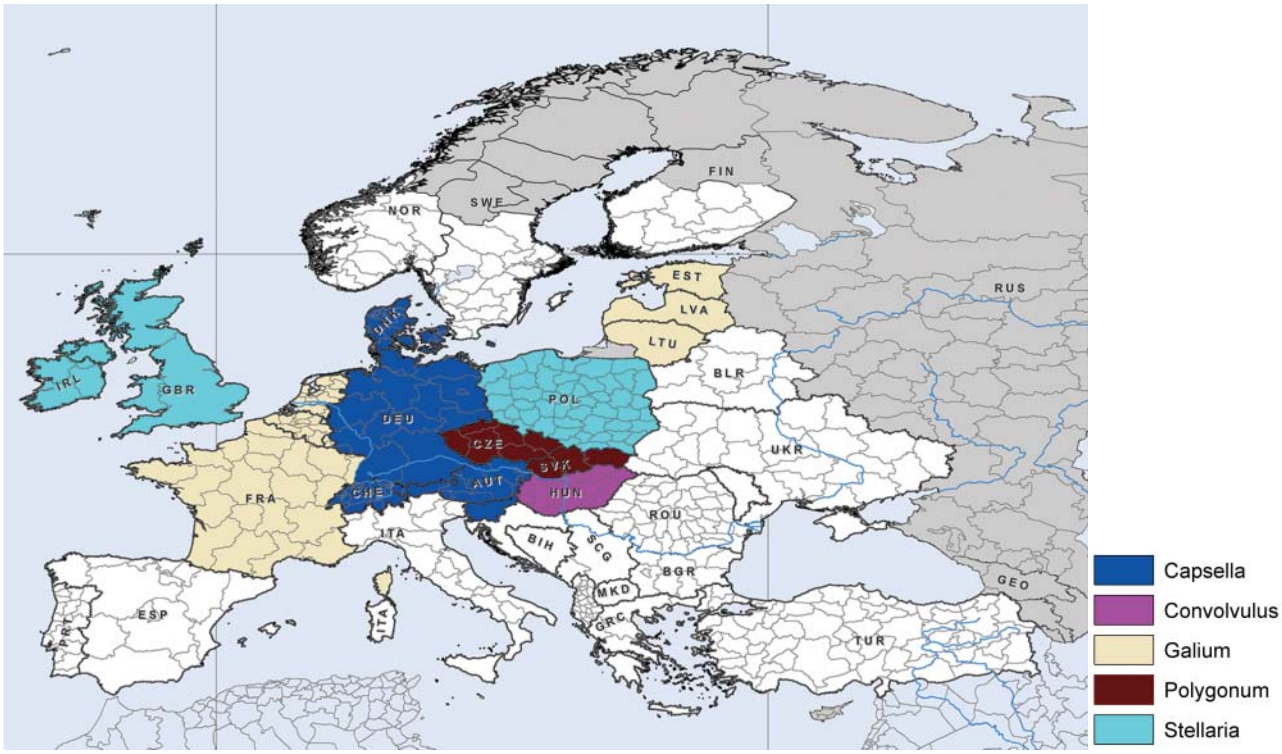

Figure 1.21 Average weed infestation in oilseed rape, second most frequent dicots.

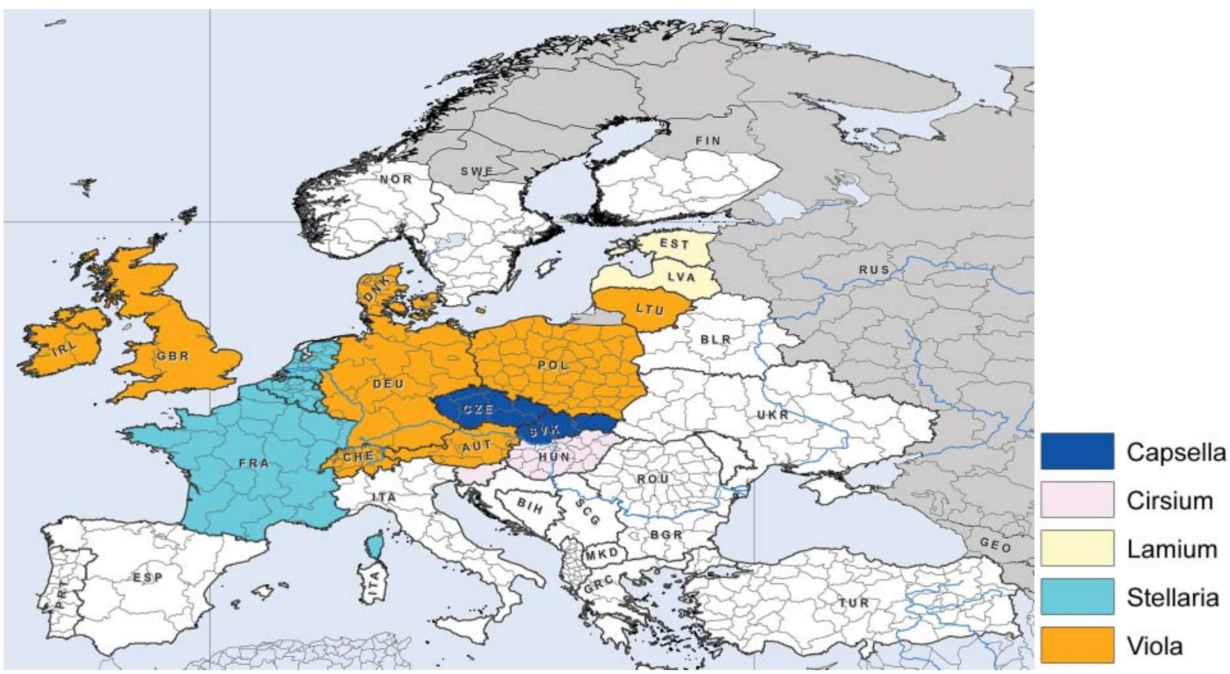

Figure 1.22 Average weed infestation in oilseed rape, third most frequent dicots.

Figure 1.23 *Cirsium arvense* in an oilseed rape field in southern Germany, 21 June 2012.

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CHAPTER 2

Asia

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Introduction

The three most important crops in Asia are rice (145.3 million ha), wheat (100.9 million ha) and maize (57.6 million ha) according to FAOSTAT (2012 data, area harvested).

There are several overviews describing the management of major crops in Asia. First, there are detailed CIMMYT overviews on maize production in Asia such as one by Meng et al. (2006) for China. Another one analyzes the situation in India (Joshi et al. 2005). Similar CIMMYT reports exist for wheat and rice (e.g. one by Reynolds et al. 2008 and one by Hobbs & Morris 1996). The wheat planting situation in China is documented from time to time by the USDA Foreign Agricultural Service (e.g. Sandene 2006).

Around 30-year-old crop monographs by Ciba-Geigy provide an idea on what weed infestations in Asia looked like in the past (e.g. Häfliger 1979). The weed infestation in India is described by another historical overview by Ambasht (1982).

Rice

Growing conditions

Rice is grown in different management systems. It can be dry seeded, wet seeded, broadcast incorporated, drilled or transplanted (Fig. 2.1). Lowland rice is usually cultivated in paddies with levees (Fig. 2.3); upland rice grows on rain-fed soil without levees. Paddies are drained one to two weeks before harvest to improve grain filling and to reduce the amount of water in the straw (Fig. 2.2). Two subspecies of rice dominate the market in Asia and in the Americas: long-grain indica rice and short-grain japonica rice.

There are three seasons for growing rice in India:

- the early *kharif* season with planting from March to May and harvest from June to October;
- the mid-*kharif* season with planting from June to October and harvest from November to February
- the *rabi* season with planting from November to February and harvest from March to June.

In some regions of India, two crops of rice are harvested per year.

In China, different rice growing periods are also common:

- The early rice of southern provinces is planted from February to April and harvested in June and July.
- The intermediate rice crop is planted between March and June; it is harvested in October and November.
- In the northern provinces, rice is planted between April and June. It is harvested in September and October.
- As in India, two rice crops can be harvested in some parts of China.

For a list of growing periods in some provinces, see Kang et al. (2002).

In many Asian areas, rice may be rotated with, for example, wheat or maize.

Pakistan is the home of Basmati rice, which is characterized by a sweet fragrance ‘aroma’, a long grain and of premium quality. Basmati varieties are grown in the core rice-growing area of Pakistan called the ‘Kalar tract’ which includes a few districts (Gujranwala, Hafiz Abad, Sheikhupura, Lahore, Sialkot, Narowal, Mandi Bahauddin) of the Punjab province. Coarse grain varieties of indica rice type are grown in the rest of the Punjab, in Sindh province, Khyber Pakhtunkhwa and parts of Balochistan province. Japonica rice types are grown in the cold regions, including the Swat valley. Rice nursery sowing in Pakistan starts in the last decade of May and continues until the 20th of June. One-month-old nursery rice is then transplanted to the puddle-covered, levelled and flooded fields. The crop is harvested in October and November. Coarse grain varieties have a shorter crop duration. They are sown and harvested earlier than the Basmati varieties. Dry direct seeding of rice is gaining popularity due to water shortages. Water shortages have led to the cultivation of rice as a dry direct seeded crop (DDS) instead of the conventional flooded method (CFM) in many Asian countries such as Pakistan, India, the Philippines and China. This cropping change has led to the prevalence of some weeds in DDS rice which usually do not germinate in rice that follows the CFM. The most important examples are *Trianthema portulacastarum* L. (Jabran et al. 2012) and *Cynodan dactylon*.

Statistics

According to FAOSTAT (2010 data, area harvested), the following approximate acreages were used for rice cultivation: India 37 million

Atlas of Weed Mapping, First Edition. Edited by Hansjörg Krähmer.

Figure 2.1 Transplanted paddy rice near Yuki, Japan.

Figure 2.2 Rice near Yuki, Japan before harvest.

ha, China 30 million ha, Indonesia 13 million ha, Thailand 11 million ha, and Vietnam 7.5 million ha.

Weeds

Monocot weed species prevail in rice fields. The weed spectra may differ to some extent from country to country and from growing system to growing system. There are, however, a few dominant weeds which can be found all over the world. The most common weed genus in rice is *Echinochloa* (Rao 2011). More than 20 *Echinochloa* species are known but only a few play a role as weeds. Three or four species may cause major problems: *Echinochloa crus-galli* (L.) P. Beauv., *Echinochloa colona* (L.) Link, *E. oryzicola* (Vasinger) Vasinger syn. *E. phyllopogon* (Stapf) Koso-Pol. and *E. glabrescens* Munro ex Hook. f. Annual and perennial *Cyperus* species follow *Echinochloa* in frequency. A few weed species can be ranked in third position: e.g. *Fimbristylis miliacea* (L.) Vahl or *Monochoria vaginalis* (Burm. f.) C. Presl ex Kunth. Weedy rice may cause serious problems also. *Ludwigia* species and *Ipomoea* species are rather common as dicot weeds in Asia. More details about rice weeds can be found in Chapters 16 (Rice weed belts) and 35 (Weeds in rice). There, some literature on weed resistance in rice is also discussed.

Figure 2.3 Rice research at the IRRI near Manila, the Philippines.

Wheat

Growing conditions

In Asia, wheat is grown under very different environmental conditions. Large spring wheat areas in Russia and Kazakhstan are characterized by a typical continental climate similar to wheat areas in the Canadian provinces. Rain-fed wheat prevails. There are around 1.3 million hectares of irrigated wheat in Kazakhstan. There, spring wheat is planted in May and harvested between late August and October. Most wheat in China, India and Pakistan, however, is irrigated wheat. In China, winter wheat is grown on the North China Plain and in central China (Sandene 2006). Planting starts in September, and the crop is harvested in June. Spring wheat is grown in the north-eastern temperate provinces, in parts of Inner Mongolia, in parts of Ninxia, Gansu and Qinghai. In the Indo-Gangetic plain, wheat is rotated with rice, maize or with cotton in most cases. India produces wheat primarily in the winter time (in the cool *rabi* season) and primarily in the northern states near the River Ganges (humid, subtropical climate). Some spring wheat is grown in the Northern Hills Zone where the crop is planted in April or May and harvested from September to November. In total, India is subdivided in six wheat-growing zones (Narang & Virmani 2001). Most wheat is grown in the North Western Plains Zone (~11million ha), in the North Eastern Plains Zone (~9 million ha) and in the Central Zone (~5 million ha) as described by Singh (2008). The season lasts usually from October/November to March/April. Most wheat fields in India are irrigated (>80%; Chatrath et al. 2008). In Pakistan, wheat is planted between October and December, that is, also in the *rabi* season and harvested in April or May. The optimum period is 1–20 November. All wheat varieties grown in the *rabi* season are actually spring wheat varieties grown in winter, similar to wheat in the Mediterranean area, in Australia, Argentina and in many parts of the USA. Pakistani wheat can be found in the vicinity of the River Indus. The major wheat areas of Pakistan are located in the provinces of Punjab (6–7 million ha) and Sindh (~1million ha), according to Raza (2011). The climatic conditions in the Pakistan wheat-growing areas can show extreme differences. Annual rainfall within the Punjab province can vary between 150 and 1500 mm (Naeem et al. 1995).

Elevation above sea level also plays a major role. In the Middle East, Iran, Iraq and Turkey are the countries with the highest wheat acreages. In Iran, wheat is grown in mountain areas at altitudes up to 2000 m above sea level. In the irrigated wheat area, four regions are distinguished (Kamali & Duveiller 2008):

- the Northern Warm and Humid Zone – 0.2 million ha, spring wheat cultivars, altitude below 800 m;
- the Southern Warm and Dry Zone – 0.7 million ha, spring wheat cultivars, altitude below 500 m;
- the Temperate Zone – 0.8 million ha, spring and winter wheat cultivars, altitude around 1000 m;
- the Cold Zone, 0.9 million ha, winter wheat cultivars, altitude above 1000 m.

More than 4 million ha are rain-fed.

Some maps for Turkey have already been shown in the European section. Küçüközdemir et al. (2008) have provided an overview on the Turkish wheat-growing areas and practices. Around 75% of the acreage is planted with winter wheat, 25% is planted with spring wheat. About 1.5 million hectares are irrigated, the rest is rain-fed. Winter wheat is grown in Central Anatolia and in the eastern parts of Turkey. A considerable acreage in Turkey is planted with spring wheat forms in autumn, as in many other Mediterranean areas. The winter crop is usually planted in October and harvested between July and August.

Statistics

By far the largest wheat-growing areas of the world are located in Asia. According to FAOSTAT (2010 data), wheat was harvested in India on 28.5 million ha, in China on 24.3 million ha, in the Russian Federation on 21.6 million ha, in Kazakhstan on 13.1 million ha, in Pakistan on 9.1 million ha, and in Iran on 7 million ha. The wheat area in Turkey amounts to around 8 million ha (USDA/ FAS, February 2011).

Weeds

Russia and Kazakhstan

Spring wheat

Similar to weed communities in the Canadian Prairies, wild oats (mainly *Avena fatua*, Fig. 2.4) and foxtails (e.g. *Setaria viridis*, Fig. 2.5) as monocot weeds are the dominant weeds in the large wheat-growing areas in Russia and Kazakhstan. *Sonchus* species, for example, *Sonchus arvensis* (perennial sowthistle, Fig. 2.6), *Chenopodium album* (lamb's quarters, Fig. 2.7), *Cirsium arvense* (Canada thistle), *Descurainia sophia* (flixweed), *Fallopia convolvulus* (wild buckwheat) and *Convolvulus arvensis* (field bindweed) are quite common weeds in the huge Asian and Eurasian wheat areas (Agroatlas; Spaar & Schuhmann 2000; Bayer CropScience data).

Winter wheat

Winter wheat grows in some areas where winters are not too severe, for example in regions north of the Caucasus. There, *Alopecurus* species and *Galium aparine* are quite frequent weeds (Figs 2.4 & 2.7).

China

Rice

Some local weed data are available for rice in China.

- *Liaoning*: Song et al.2009
- *Hubei*: Chang et al. 2009.

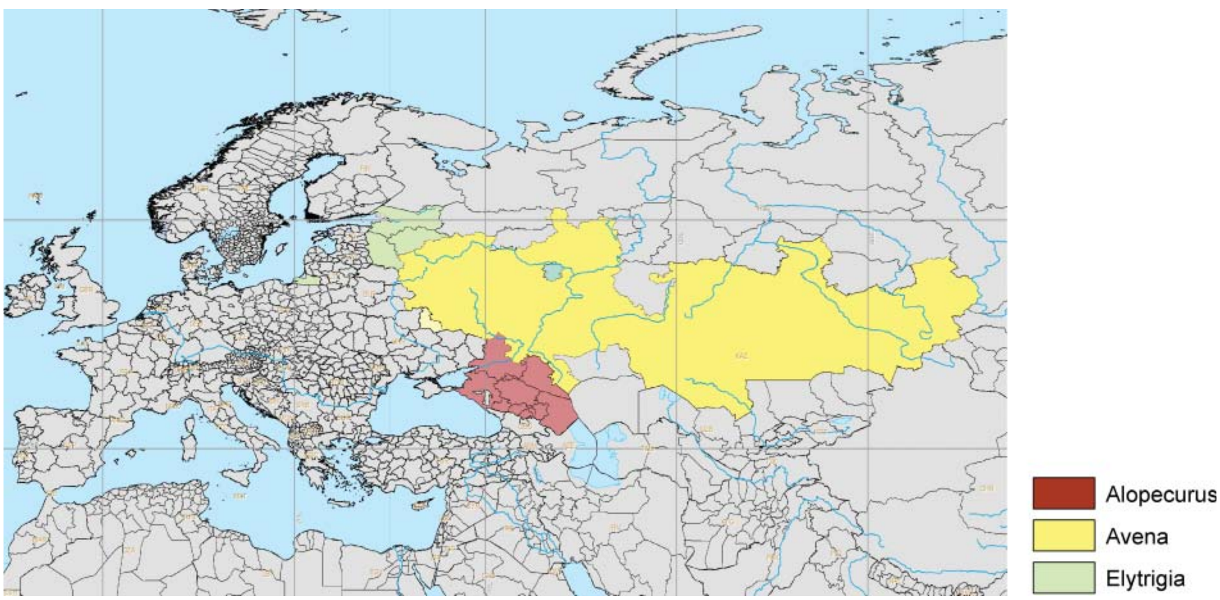

Figure 2.4 Average weed infestation in wheat of the Russian Federation, most frequent grasses.

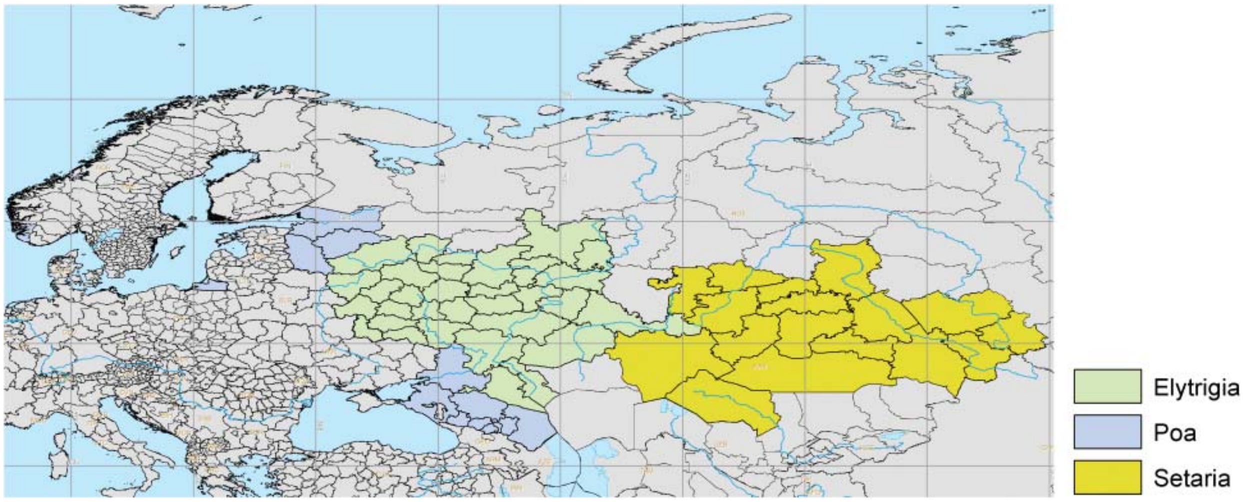

Figure 2.5 Average weed infestation in wheat of the Russian Federation, second most frequent grasses.

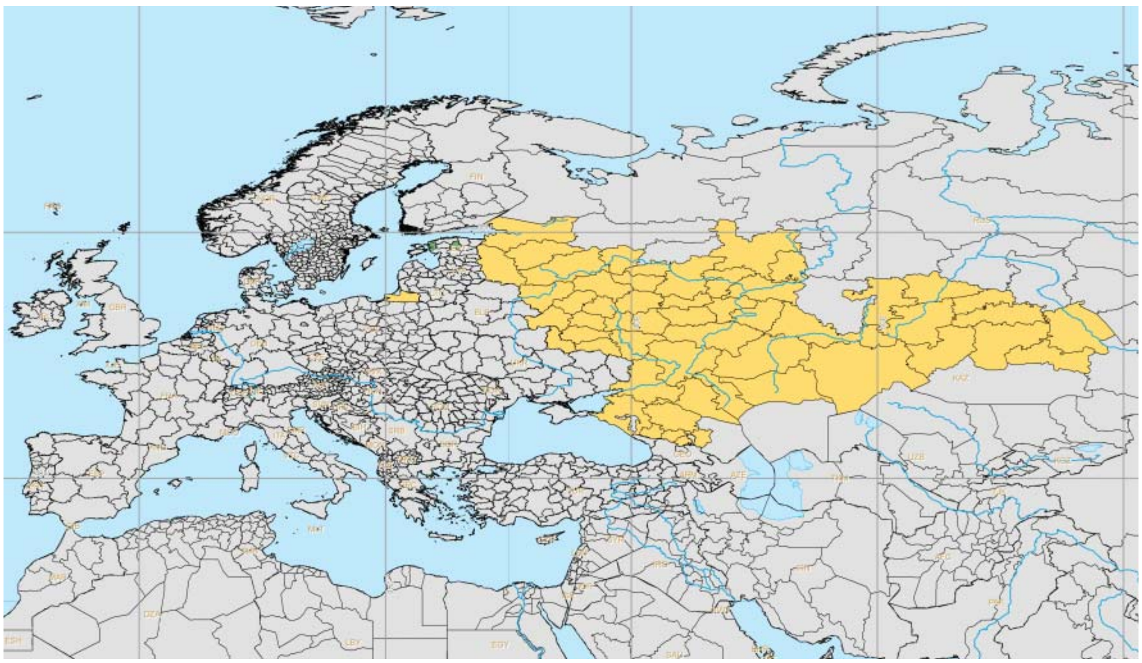

Figure 2.6 Average weed infestation in wheat of the Russian Federation, distribution of *Sonchus arvensis* as the most frequent cereal weed in the Russian Federation.

We will, however, discuss rice weeds in different contexts so refer to Chapters 16 and 35 for more details.

Wheat

By far the greatest number of publications from China exists for weeds in wheat so that the situation in single provinces could be depicted with some certainty. For most articles, abstracts were used which already contain the essential weed spectra in summarized form:

- *Heilongjiang*: Wang et al. 2000, Liu et al. 2004
- *Nei Menggu*: Lu et al. 2006, Zhang et al. 2006a
- *Beijing*: Menegat et al. 2013
- *Hebei*: Su et al. 1988, Cai et al. 2001, Hun et al. 2008, Hun et al. 2009, Hun et al. 2011, Zhang et al. 2007
- *Shanxi*: Zhang et al. 2007, Anon 2010
- *Qinghai*: Wei et al. 2011, Weng et al. 2011
- *Gansu*: Xie & Chen 1992
- *Henan*: Zheng & Wang 2004
- *Anhui*: Qiang & Liu 1990, Qiang & Li 1996, Qiang 2005
- *Jiangsu*: Wang & Qiang 2002, Chen et al. 2006
- *Hubei*: Zhang et al. 1998
- *Zejiang*: Shuiliang et al. 1998
- *Guizhou*: Chen 2008

Data on oilseed rape support in some respects the data on wheat:

- *Anhui*: Huang et al. 2007

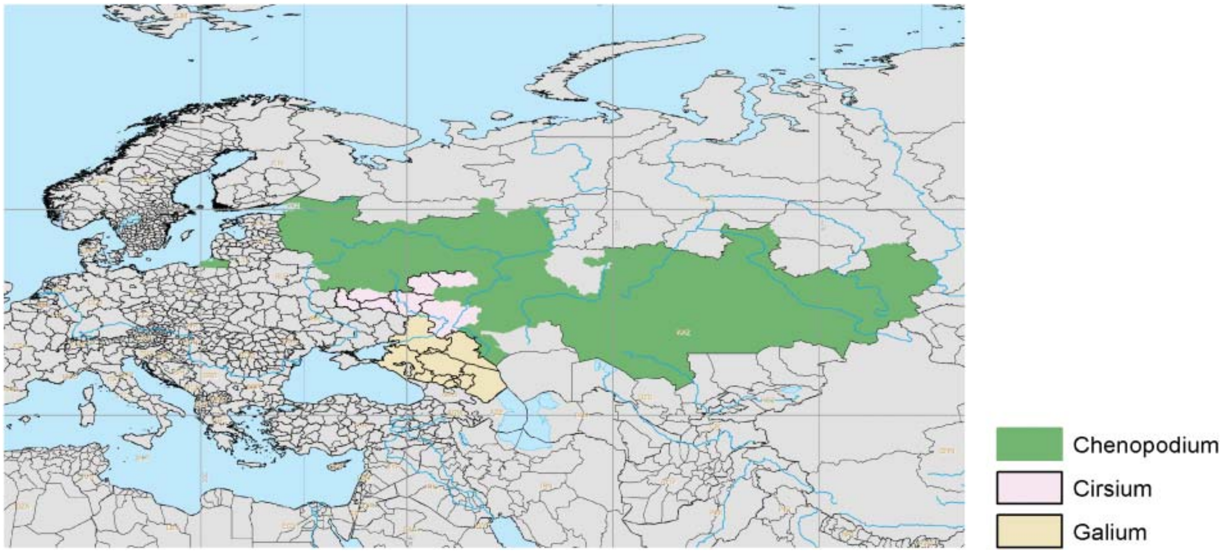

Figure 2.7 Average weed infestation in wheat of the Russian Federation, second most frequent dicots.

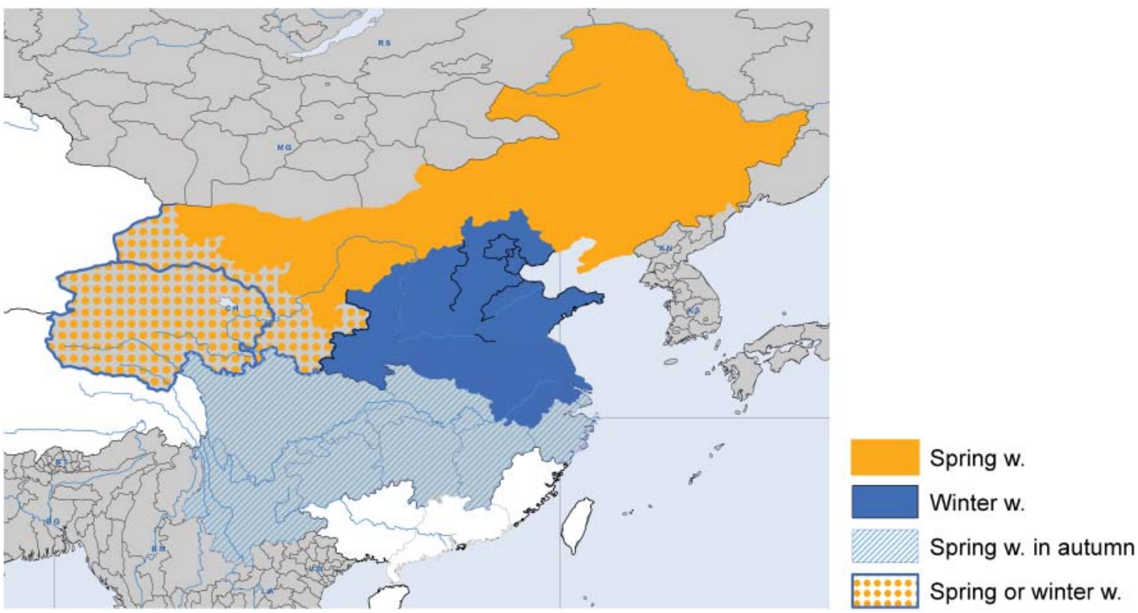

Figure 2.8 Distribution of spring and winter wheat in China.

Some supporting background was derived from herbicide testing in different parts of China:

- Cui et al. 2008, 2011
- Cheng & Ni, 2013.

General overviews on weeds in China are also helpful:

- Zhang 2003

Weed infestation depends to some extent on growing periods. Where temperatures allow it, winter cereals are grown.

Figure 2.8 shows the distribution of spring and winter wheat varieties in China according to He et al. (2010). Winter wheat with the highest yields is grown in the North China Plain. Spring wheat planted in autumn is primarily grown in subtropical areas. Spring wheat can usually be found in Inner Mongolia and in the most northern Chinese provinces.

Winter wheat

The weed infestations of winter wheat in many Chinese areas appear rather similar to some European fields at first glance: *Alopecurus* species play a major role (Figs 2.9 & 2.10) and *Galium aparine*. The prevailing monocot species are, however, *Alopecurus aequalis* Sobol. and *Alopecurus japonicus* Steud., *Bromus* species, e.g. *Bromus japonicus* Thunb. are other relatively frequent grass weeds. *Aegilops tauschii* Coss. and *Poa annua* L. belong to the second most frequent grass species (Fig. 2.9). *Galium aparine* L. is one of the prevalent dicot species (Fig. 2.11) where winter wheat is grown in winter. *Descurainia sophia* (L.) Schur. (Fig. 2.12) and various *Polygonum* species are, however, also rather common. This makes weed spectra

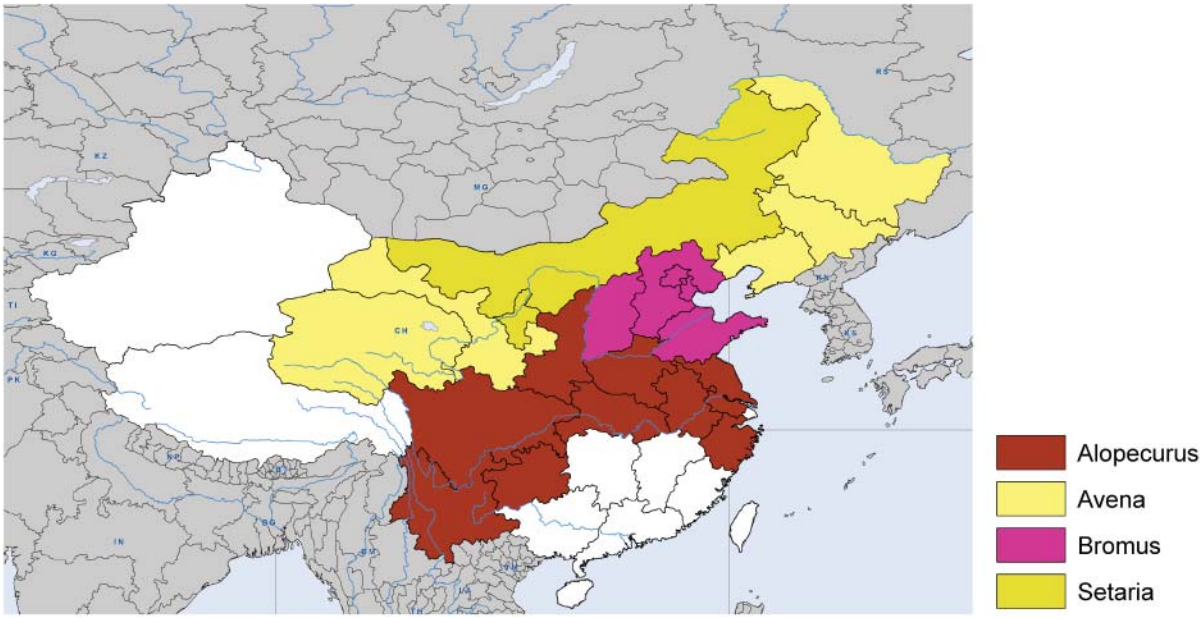

Figure 2.9 Average weed infestation in Chinese wheat, most frequent grasses.

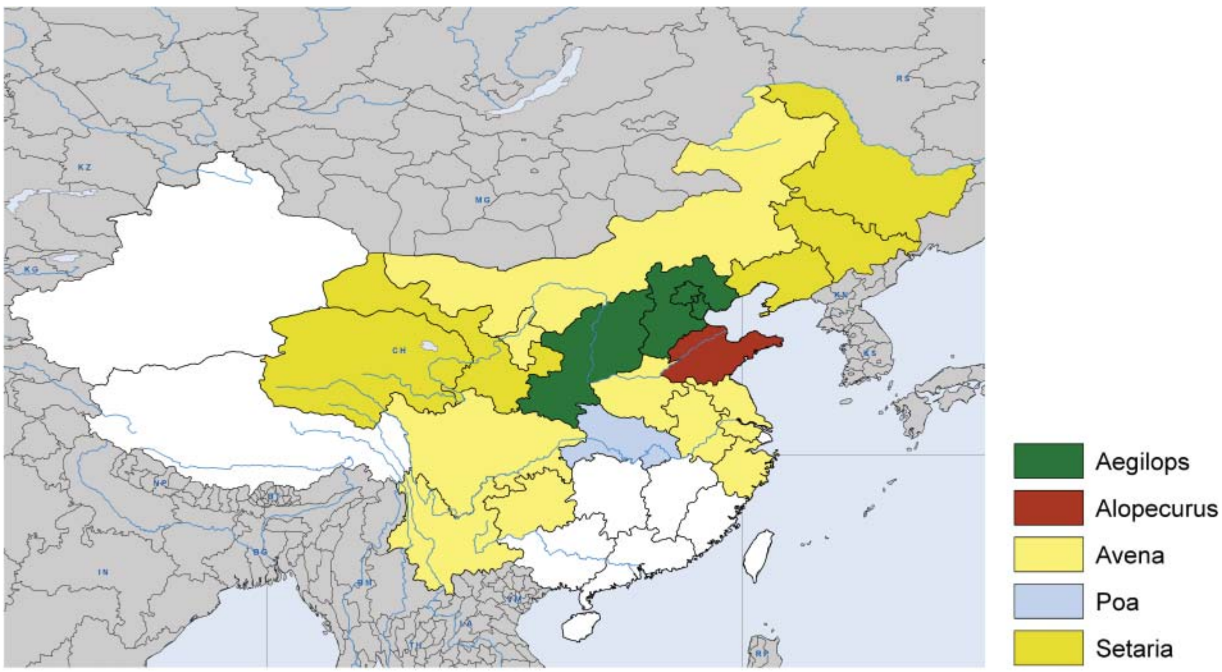

Figure 2.10 Average weed infestation in Chinese wheat, second most frequent grasses.

more similar to some North American and Russian cereal-growing areas. Qiang (2005) demonstrates the importance of crop rotation for weed infestations for the Anhui province. In areas where rice is grown, *Alopecurus aequalis* and *Alopecurus japonicus* are frequent in wheat as a rotational crop. In drier regions, *Avena fatua* is the dominating grass weed. *Galium aparine* can, however, be found in both areas.

Spring wheat

Wild oats (*Avena fatua)* and *Setaria* species belong to the most widespread species in Chinese spring wheat (Fig. 2.9). *Chenopodium* species, especially *Chenopodium album*, and *Fallopia convolvulus* (L.) Löve are the dominating dicot species (Fig. 2.11). The weed spectrum is very similar to the major Canadian and eastern Russian ones.

India, Nepal and Pakistan

Maps for wheat in India, Nepal and Pakistan were prepared based on regional weed literature.

India

- *Jammu and Kashmir*: Dangwal et al. 2010a & 2010b
- *Punjab*: Erenstein, 2009, Singh et al. 2012

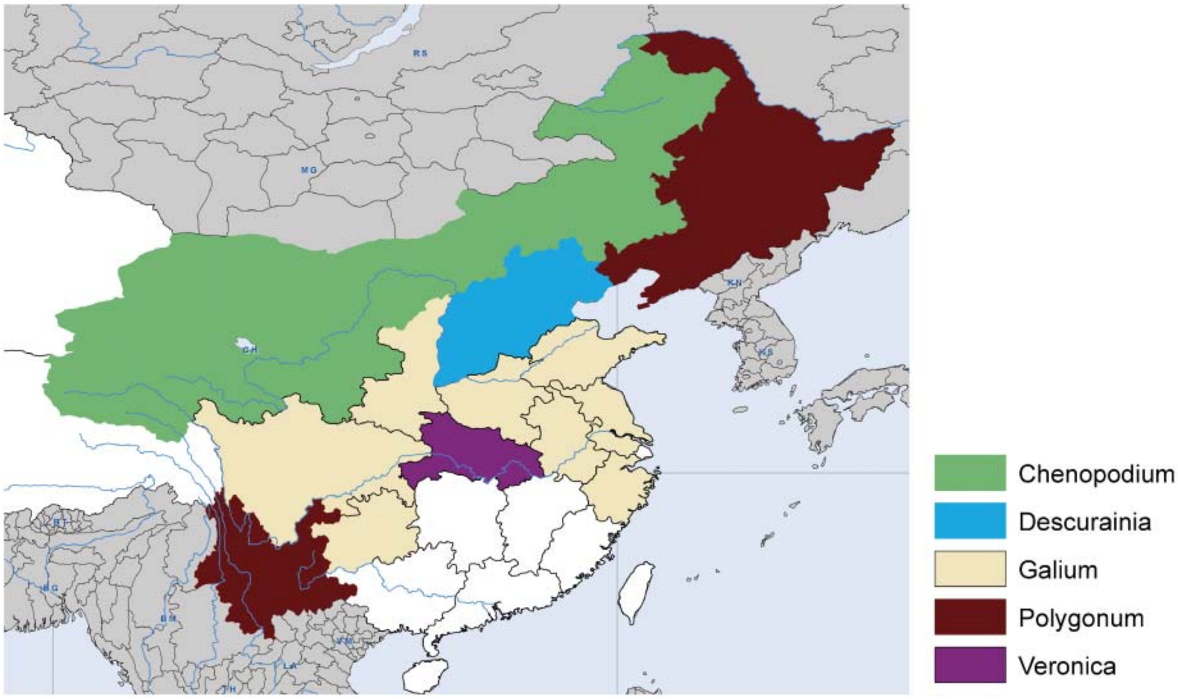

Figure 2.11 Average weed infestation in Chinese wheat, most frequent dicots.

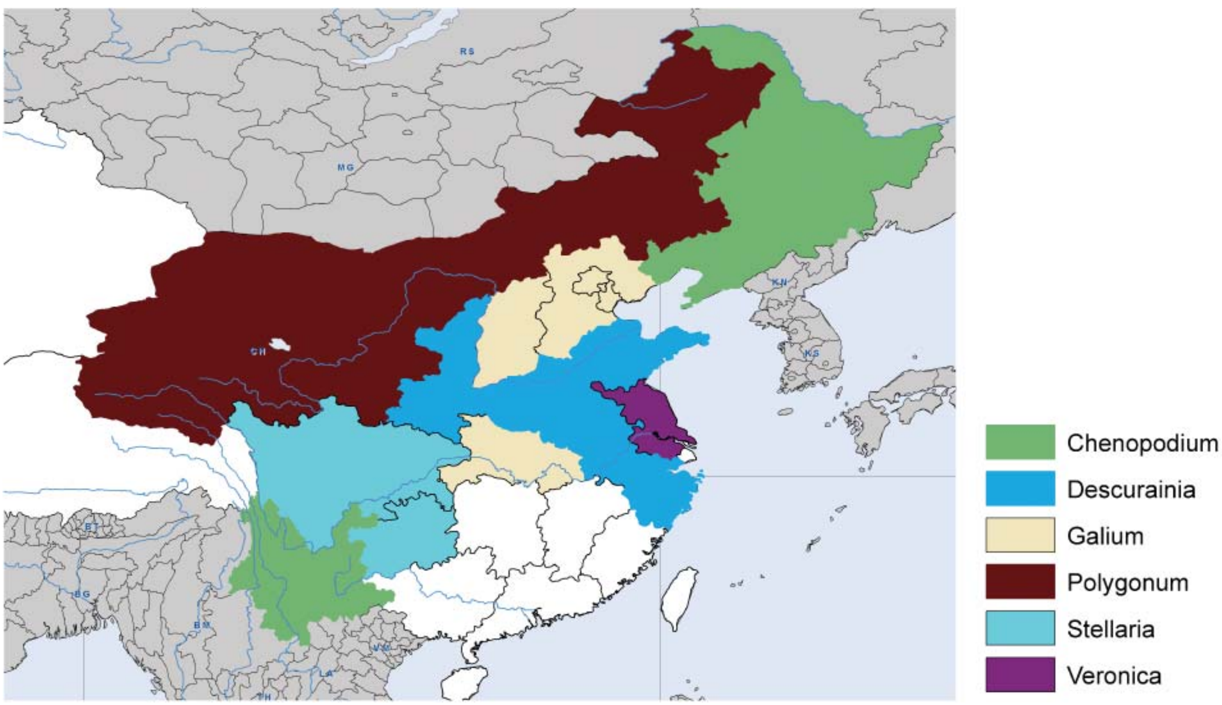

Figure 2.12 Average weed infestation in Chinese wheat, second most frequent dicots.

- *Himachal Pradesh*: Kumar et al. 2005b
- *Uttarakhand*: Pandey et al. 1998, Gupta et al. 2008
- *Haryana*: Singh et al. 1995, Yadav & Malik 2005, Chhokar et al. 2006, Chhokar et al. 2008, Bir et al. 2010
- *Rajasthan*: Porwal & Gupta 1992
- *Uttar Pradesh*: Hobbs et al. 1992, Kumar & Agarwal 2010, Mishra et al. 2011
- *Gujarat*: Bhaskar & Vyas 1988

General overviews on Indian weeds in wheat:

- Mayee et al. 2008

Nepal

- Ranjit et al. 2003 & 2006

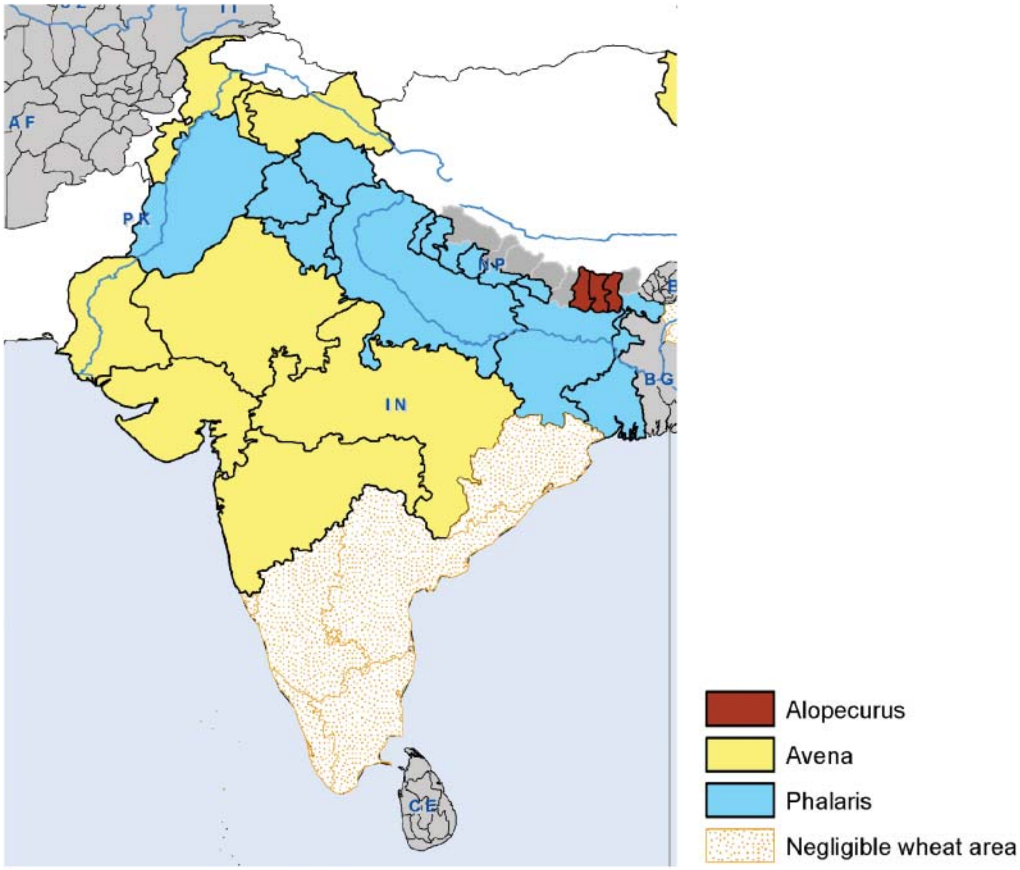

Figure 2.13 Average weed infestation in Indian, Nepalese and Pakistani wheat, most frequent grasses.

Pakistan

- *Khyber Pakhunkthwa*: Hussain et al. 2007
- *Punjab*: Naeem et al. 1995, Siddiqui et al. 2001, 2004, 2010; Ashiq et al. 2007; Muhammad et al. 2009; Qurehshi et al. 2009; Waheed et al. 2009
- *Sindh*: Jakhar et al. 2005, Kazi et al. 2007, Memon et al. 2011

General overviews of weeds in Pakistan were published by Ahmad and Shaikh (2003).

Phalaris minor and wild oats (*Avena* – complex, *A. fatua*. *A. ludoviciana*, *A. sterilis*) are the most frequent grass species of wheat in the Indo-Gangetic plain (Figs 2.13 & 2.14). Singh et al. published a review on *Phalaris minor* in 1999. Chauhan et al. (2012) claim that this weed came from Mexico to India. The drastic spread of this weed after the Green Revolution in the late 1960s was usually associated with the introduction of dwarf wheat varieties, improved irrigation and fertilizer use (Vincent & Quirke 2002). I. and S. Kaushik (2009) stress, however, that the occurrence of *P. minor* in India had already been reported in 1896 and in 1945. Chauhan et al. (2012) elaborate on the characteristics of the rice-wheat production system and mention a number of weed species associated with its management. *Cynodon dactylon* (L.) Pers. may become a problem on some sites from time to time (Fig. 2.14). In Pakistan, it is primarily found on field borders, less often within fields. *Poa annua* can be a rather common weed as well. In the colder mountain areas, *Alopecurus* species, e.g. *Alopecurus nepalensis* Trin. Ex Steud. and *Alopecurus aequalis* can frequently be observed (e.g. Ranjit et al. 2003 & 2006 or Siddiqui 2004).

The dicot weed spectra may vary depending on the amount of rainfall or on irrigation (Gupta et al. 2008). *Chenopodium* species, especially *Chenopodium album*, occur almost everywhere (Figs 2.15 & 2.16). Specialities of Indian and Pakistan wheat are some leguminous weed species such as *Melilotus indicus* (L.) All. or *Melilotus albus* Medik. and special knotweeds such as *Polygonum plebejum* R. Br. At higher altitudes, *Galium aparine* can be rather frequent, for example, in the Khyber Pakhunkthwa province of Pakistan (the former NWFP), as described by Hussain et al. (2007). *Spergula arvensis* L. is a common weed of wheat in the Pakistan Sindh province. *Anagallis arvensis* is a quite common weed in the whole Indo-Gangetic cropping area.

Iran

The basis of maps for Iran is a number of publications in various journals:

- *East Azerbaijan*: Baghestani et al. 2007, Hassannejad & Ghafarbi, 2013, Hassannejad & Ghisvandi, 2013
- *West Azerbaijan*: Baghestani et al. 2009
- *Zanjan*: Kakhki et al. 2013
- *Golestan*: Younesabadi et al. 2006, Zand et al. 2010
- *Semnan*: Baghestani et al. 2007
- *Razavi Khorasan*: Gherekhloo et al. 2010
- *Alborz*: Baghestani et al. 2006a & 2006b, Ashrafi et al. 2009, 2010, Zand et al. 2010
- *Tehran*: Zand et al. 2010
- *Lorestan*: Khourgami et al. 2011

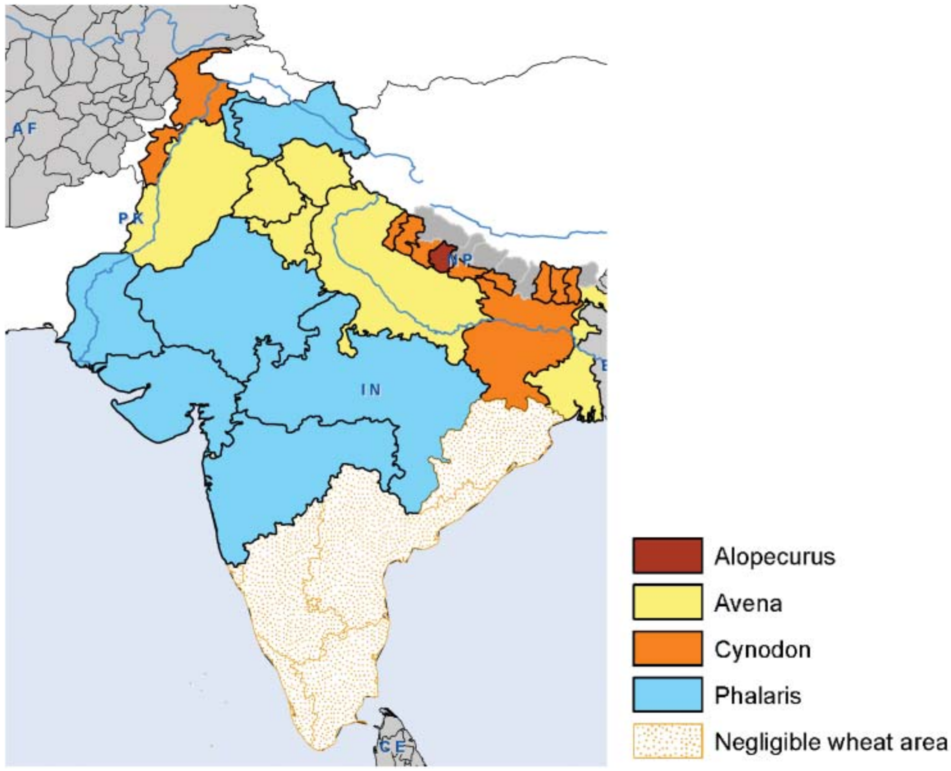

Figure 2.14 Average weed infestation in Indian, Nepalese and Pakistani in wheat, second most frequent grasses.

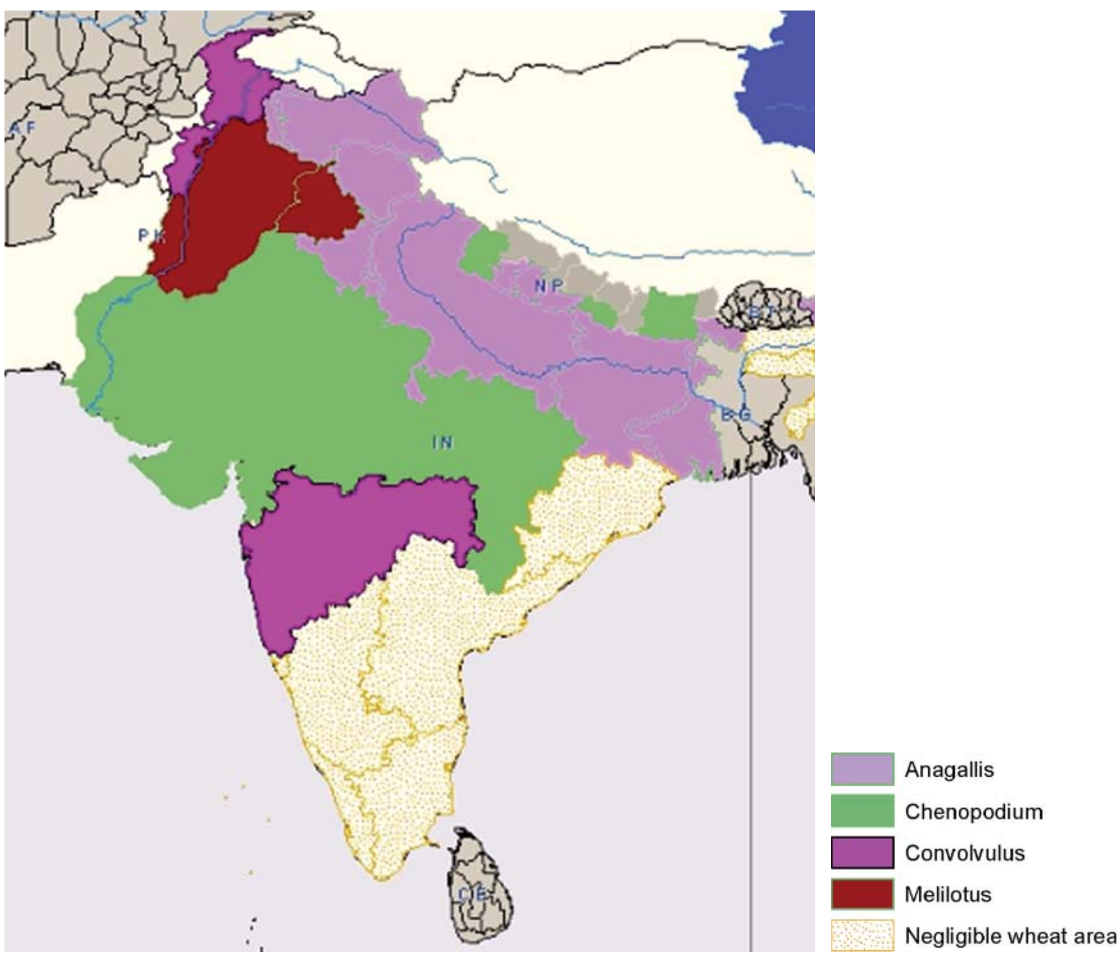

Figure 2.15 Average weed infestation in Indian, Nepalese and Pakistani in wheat, most frequent dicots.

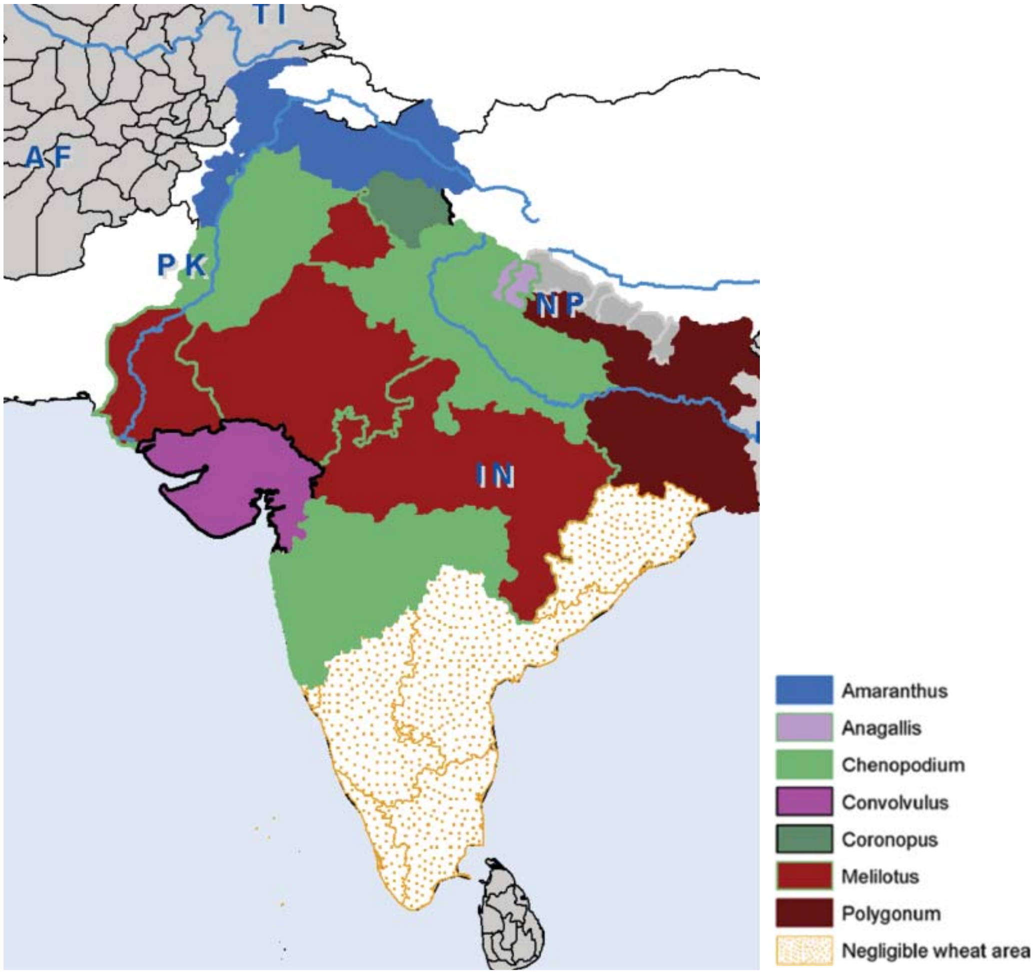

Figure 2.16 Average weed infestation in Indian, Nepalese and Pakistani in wheat, second most frequent dicots.

- *Khorasan*: Rassam et al. 2011
- *Khuzestan*: Sheibani & Ghadiri 2012, Hesammi & Lorzadeh 2011, Zand et al. 2010
- *Chaharmahal and Bakhtiari*: Esehaghbeygi et al. 2011
- *Yazd*: Baghestani et al. 2009
- *Fars*: Baghestani et al. 2007, Zand et al. 2010

Hübl and Holzner (1982) published agro-ecological data for Iran in the 1980s which are presumably more precise and more detailed than the ones presented in our atlas. Their publication refers, however, primarily to plant associations and does not indicate which weeds were the most common in those days. In contrast, we try to select single species and we mark them as the most frequent ones based on the data we have today. Hübl and Holzner (1982) already stress that vast areas of Iran have to be irrigated in order to secure yields. In some areas, the average annual precipitation amounts to less than 100 mm, such as in the Yazd province (Modarres 2006). Many articles have been published since Hübl's and Holzner's overview. Some of them are listed at the end of this chapter in the literature section for Iran. Figure 2.17 shows a rough overview of the cereal-growing areas in this country. The following maps (Figs 2.18–2.21) were designed along province lines and do not match the cereal-growing area in Fig. 2.17. In some provinces, the cereal areas are very small, such as in the Kerman or Yazd provinces (Ghadiryanfar et al. 2009). But even there (Baghestani

Figure 2.17 Major cereal-growing (wheat and barley) areas in Iran. Source: Adapted from a map by the U. S. Central Intelligence Agency, via Wikimedia Commons.

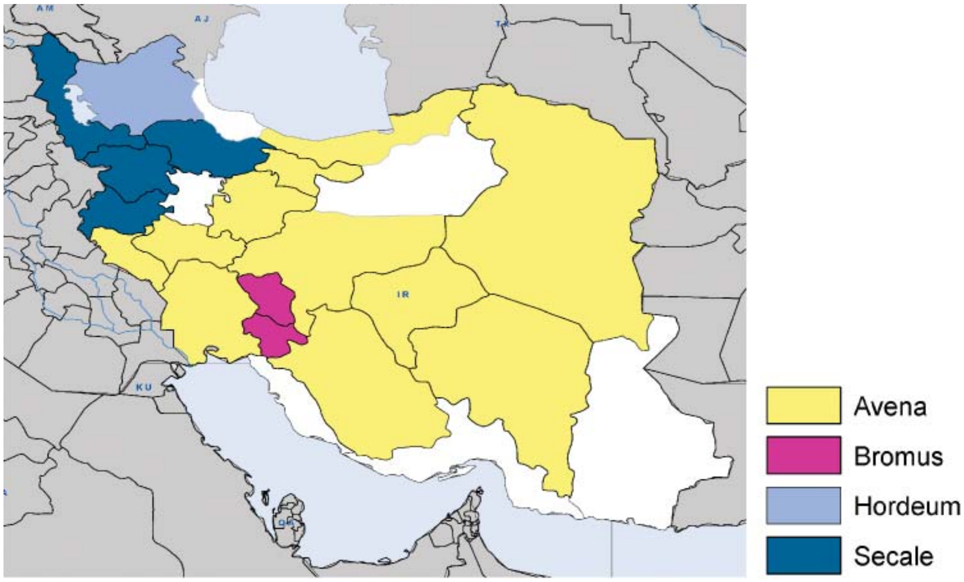

Figure 2.18 Most frequent monocot weeds in Iranian cereals.

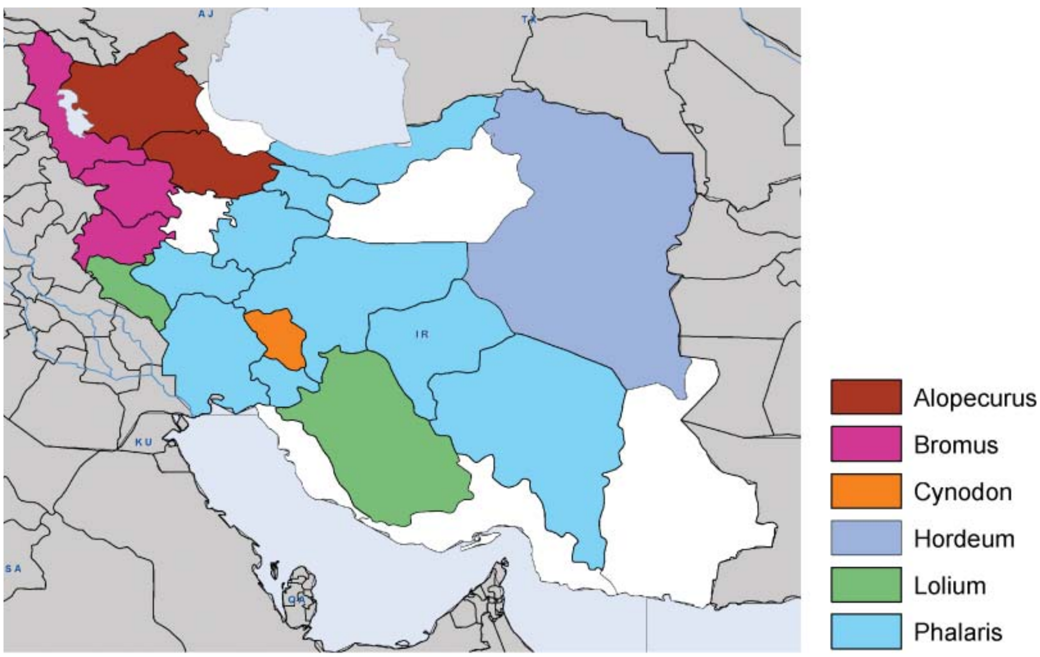

Figure 2.19 Second most frequent monocot weeds in Iranian cereals.

et al. 2009; Far 2012) typical dominating weeds such as *Avena ludoviciana* or *Descurainia sophia* can be found. In principle, *Avena fatua* and *Avena ludoviciana* Durieu syn *Avena sterilis* L. appear to be the most widespread grass weeds in Iranian cereals (Fig. 2.18). *Hordeum spontaneum* K. Koch – actually *Hordeum vulgare* subsp. *spontaneum* – and *Secale cereale* L. can be problem weeds in some areas, *Hordeum murinum* L. is also reported as a weed of parts of Iran. A widespread species in Iranian wheat is *Phalaris minor* (Fig. 2.19). Representatives of the genus *Setaria* such as *S. faberi* and *S. verticillata* may be found from time to time. A number of dicot weed species rare to Northern Europe may grow in Iran regularly such as *Caucalis* or *Scandix*-species. Weed distribution in Iran is – as elsewhere – dependent on crop management principles, as Rassam et al. (2011) describe. A few species are rather specific to some areas such as *Eremopyrum bonaepartis* (Spreng.) Nevski, a grass weed or the dicot *Acroptilon repens* (L.) DC, which was brought to the USA in the nineteenth century as an invasive species (Russian knapweed). Both can be found in East Azerbaijan where they are rather common (Hassannejad & Ghafarbi 2013). Black-grass, *Alopecurus myosuroides*, is common in West Azerbaijan and in Zanjan (Fig. 2.19). *Chenopodium album* as a globally distributed dicot weed is widespread in Iran also (Fig. 2.20). The altitude at

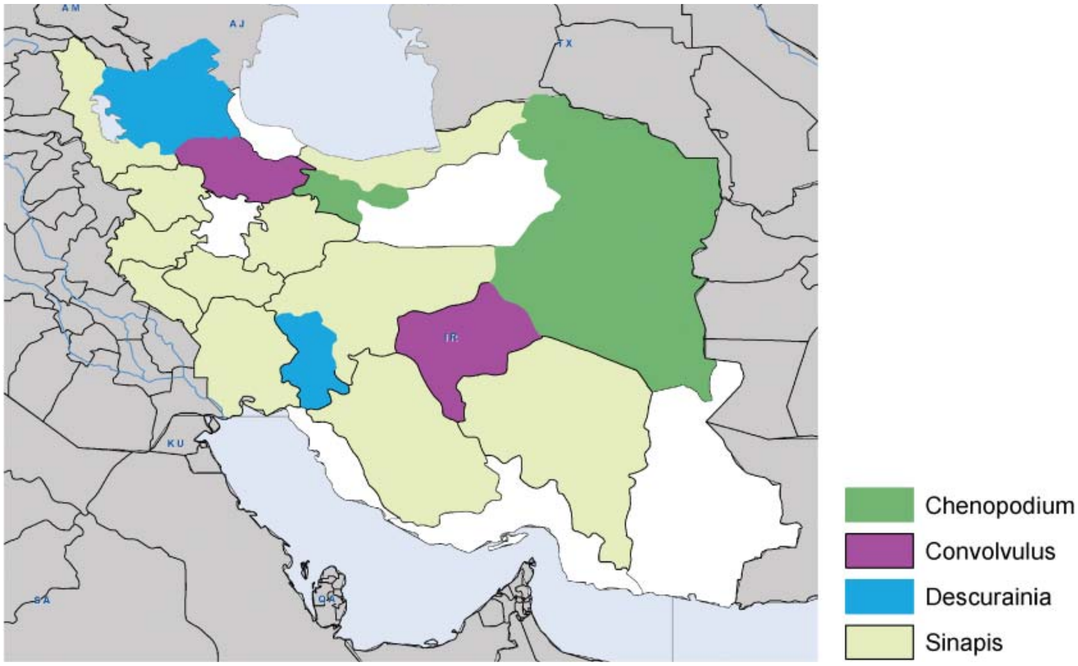

Figure 2.20 Most frequent dicot weeds in Iranian cereals.

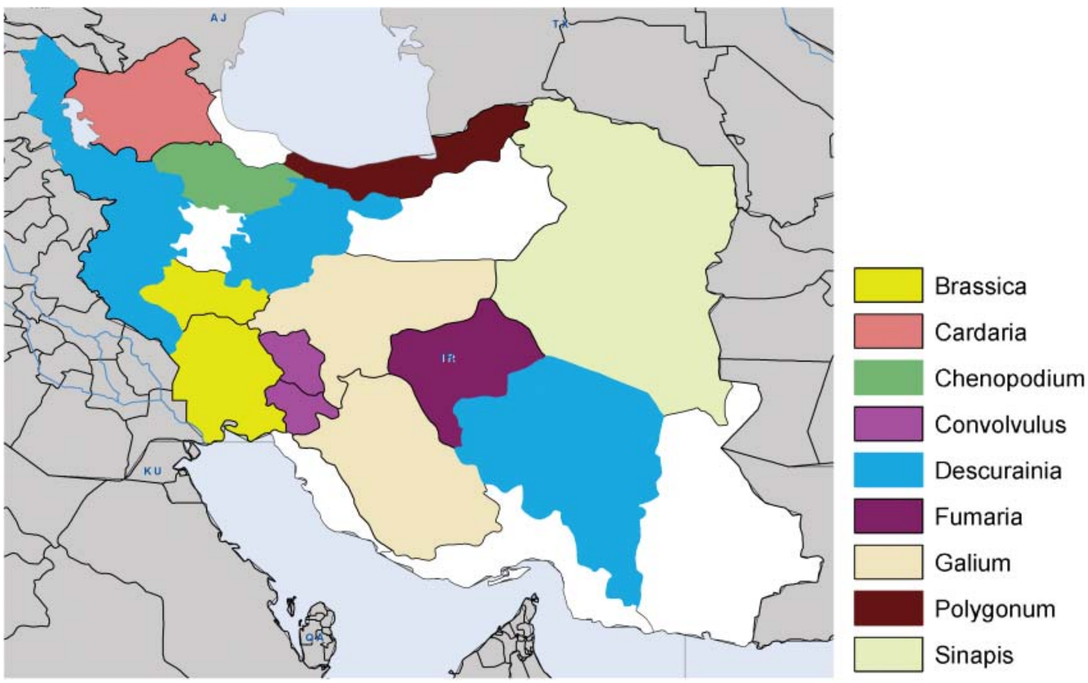

Figure 2.21 Second most frequent dicot weeds in Iranian cereals.

which wheat is grown has a great influence on the weed spectra due to the associated climate. In areas with lower elevation and high summer temperatures, *Xanthium* species may occur, whereas *Galium aparine* and *Descurainia sophia* are typical of higher elevations with cold winters (Figs 2.20 & 2.21). *D. sophia* is also a characteristic weed of some northern American states (see Fig. 3.13) and of elevated agricultural land in China (Fig. 2.12). It is quite common in steppe areas of the former Soviet Union (www.agroatlas.ru/en/content/weeds/Descurainia_Sophia/map/). Due to its drought tolerance, it is a typical global weed with habitats in Europe and northern Africa also. It is of Eurasian origin and was brought to North America in the 1800s (Howard 2003). There, it has spread rather quickly as an invasive species (see also Chapters 13 and 20).

Turkey

Some results for Turkey have already been presented in Chapter 1 (Europe). There, no regional details were discussed. Here, we try

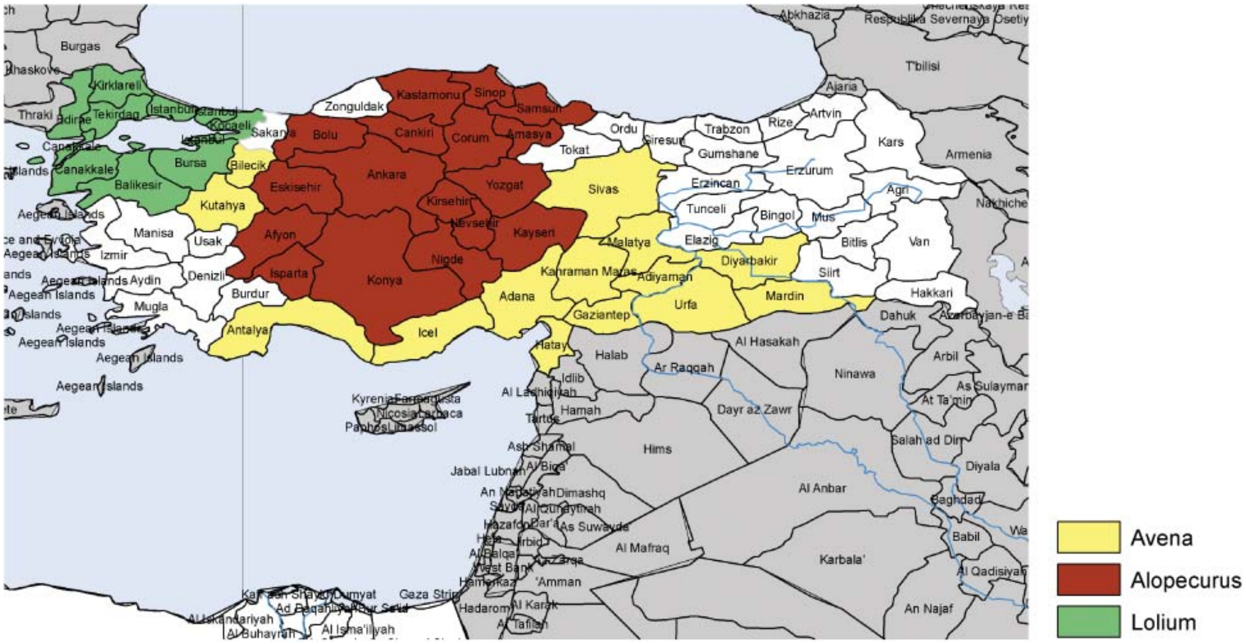

Figure 2.22 Most frequent monocot weeds in Turkish cereals.

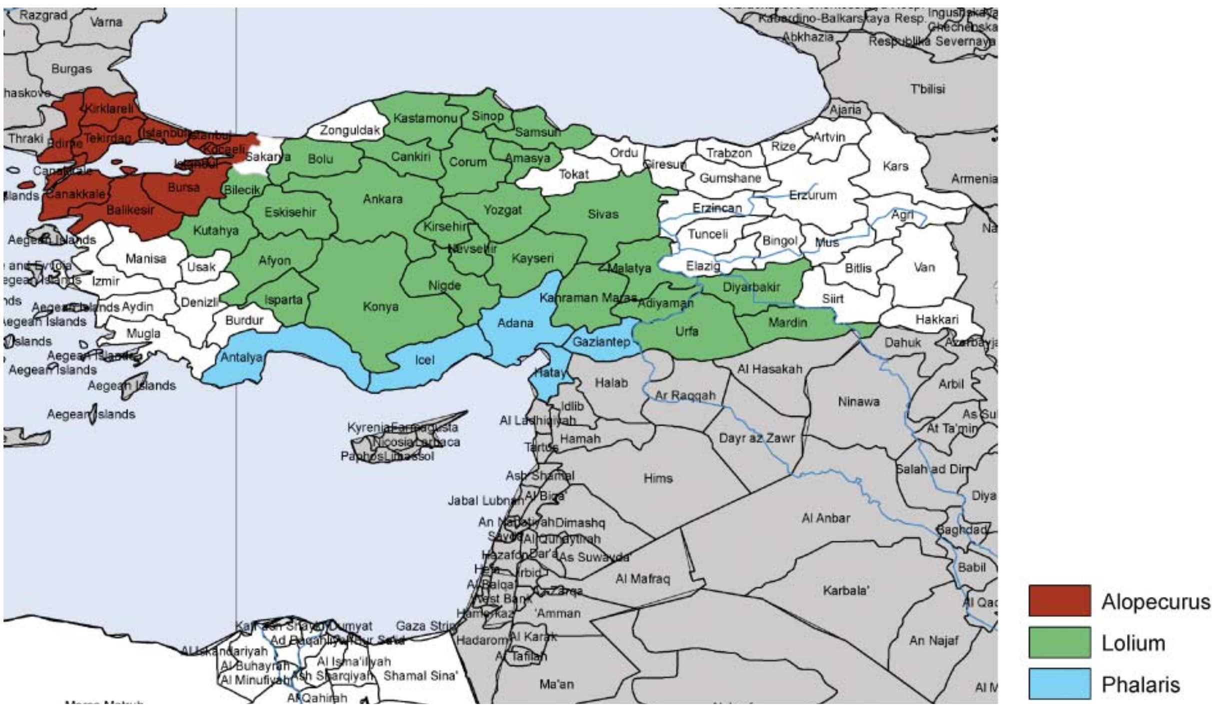

Figure 2.23 Second most frequent monocot weeds in Turkish cereals.

to demonstrate that a more detailed analysis can change a country view considerably. As already mentioned, the following maps were developed in cooperation with Turkish scientists, for example, with Professor H. Mennan (Samsun), Professor N. Uygur and Professor S. Uygur.

Aegilops cylindrica, *Alopecurus myosuroides*, *Avena sterilis*, *Bromus spp.*, *Lolium spp.* and *Phalaris spp.* belong to the most frequent grass weeds in Turkish wheat (Türkseven et al. 2009; Dikici & Dündar 2006; Mennan et al. 2003: Mennan & Zandstra 2003; e.g. Figs 2.22 – 2.24). *Bifora radians*, *Boreava orientalis*, *Sinapis arvensis*, *Tripleurospermum maritimum*, *Vicia spp.* and *Cirsium arvense* are among the most frequent dicot weeds (Figs 2.25 – 2.27). The *Galium* species that can be found in Turkish wheat fields are *Galium aparine* and *Galium tricornutum* Dandy, the latter species, has become rare in northern European countries within the last century. It is, however, still quite common in the USA and grows in different Mediterranean areas also (e.g. Royo-Esnal et al. 2012). The weed spectra at the higher altitudes of the Central Anatolian plains

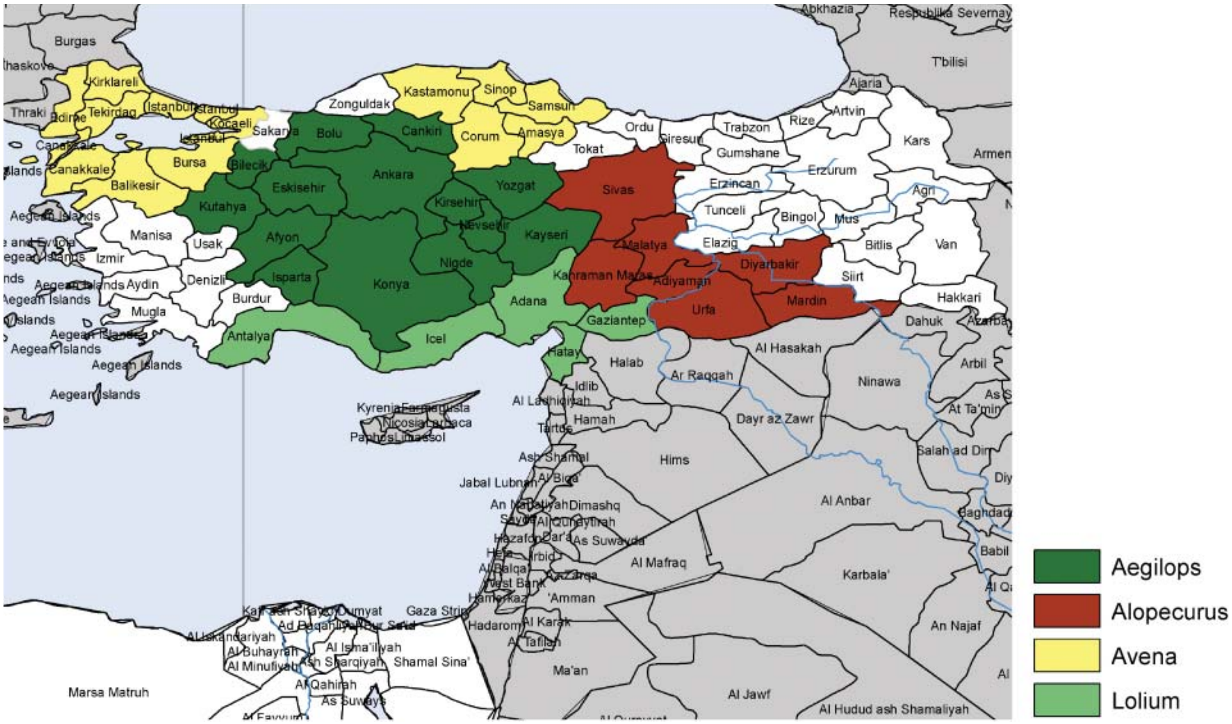

Figure 2.24 Third most frequent monocot weeds in Turkish cereals.

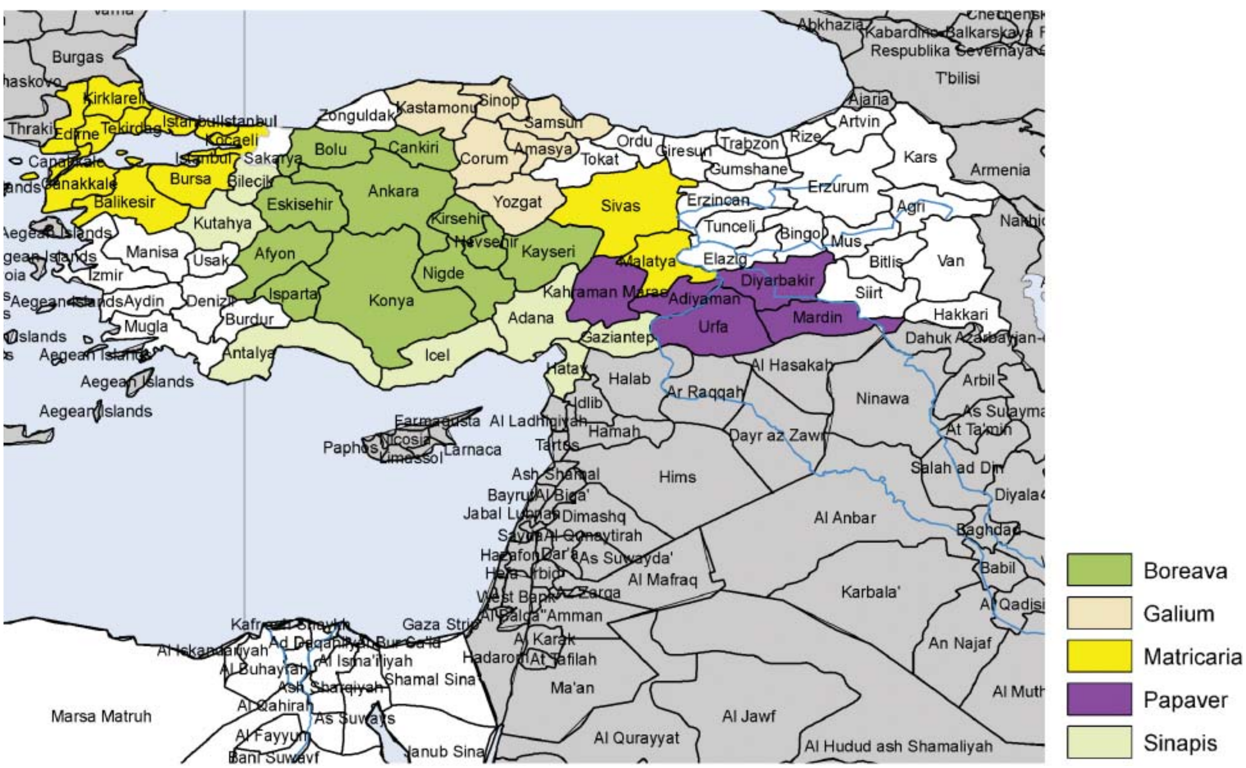

Figure 2.25 Most frequent dicot weeds in Turkish cereals.

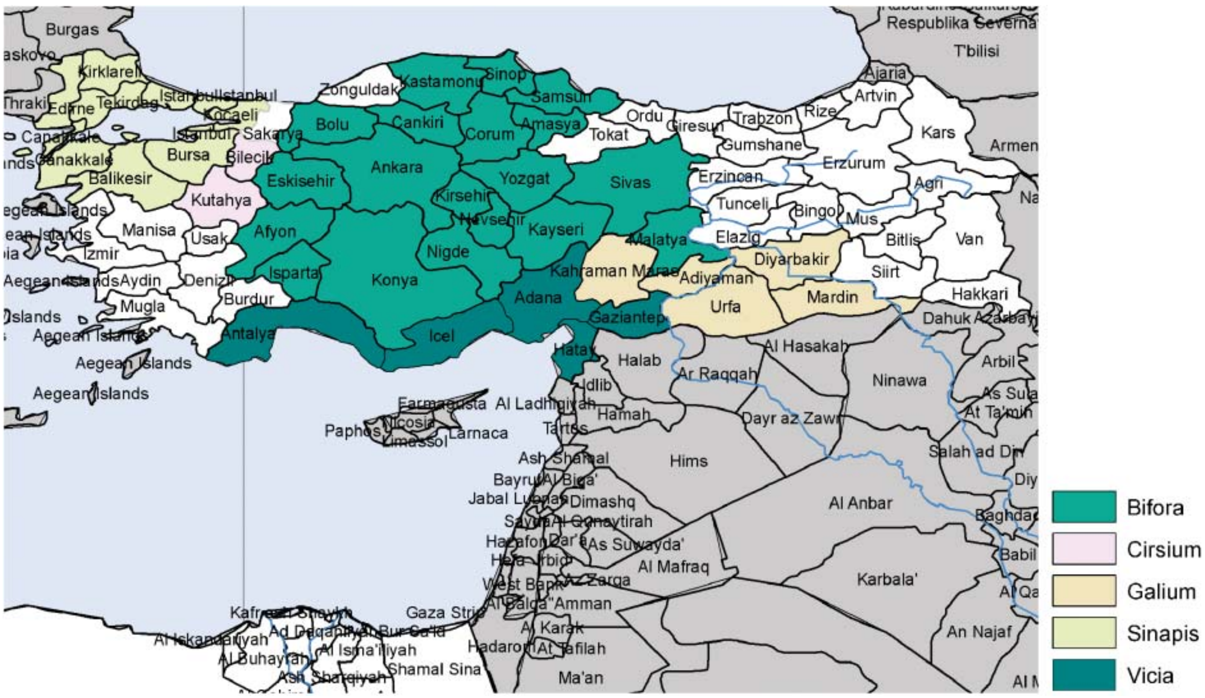

Figure 2.26 Second most frequent dicot weeds in Turkish cereals.

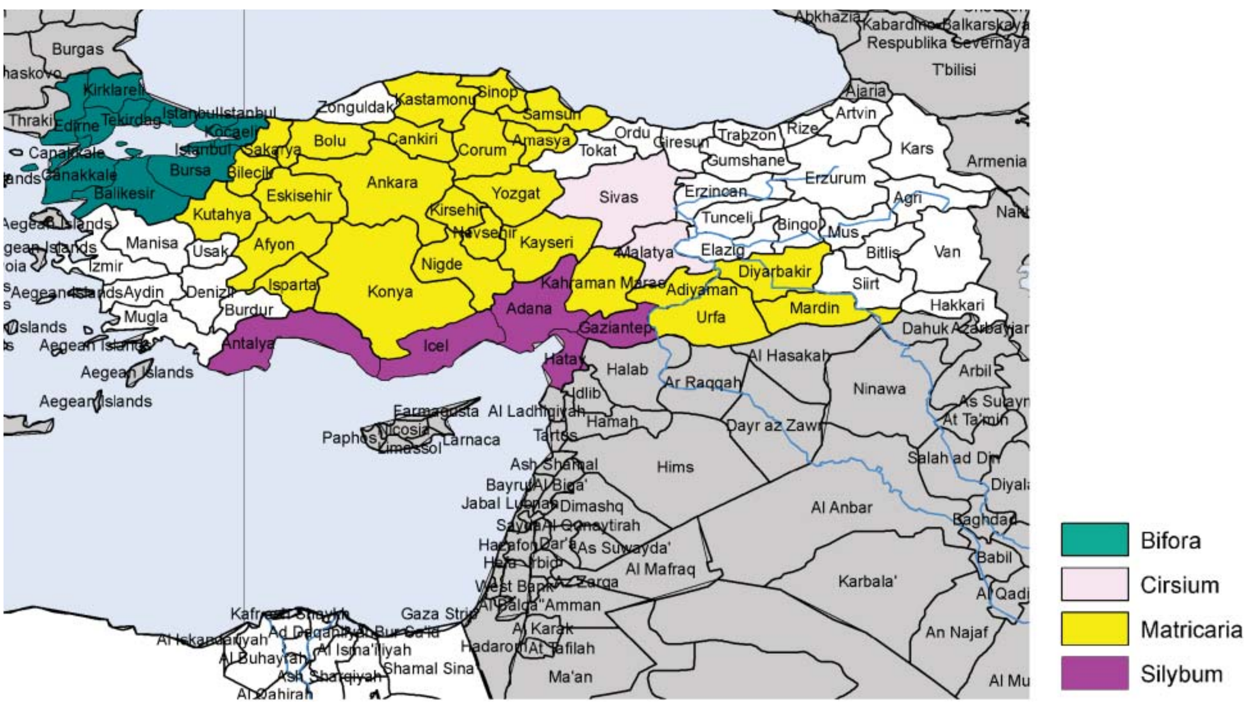

Figure 2.27 Third most frequent dicot weeds in Turkish cereals.