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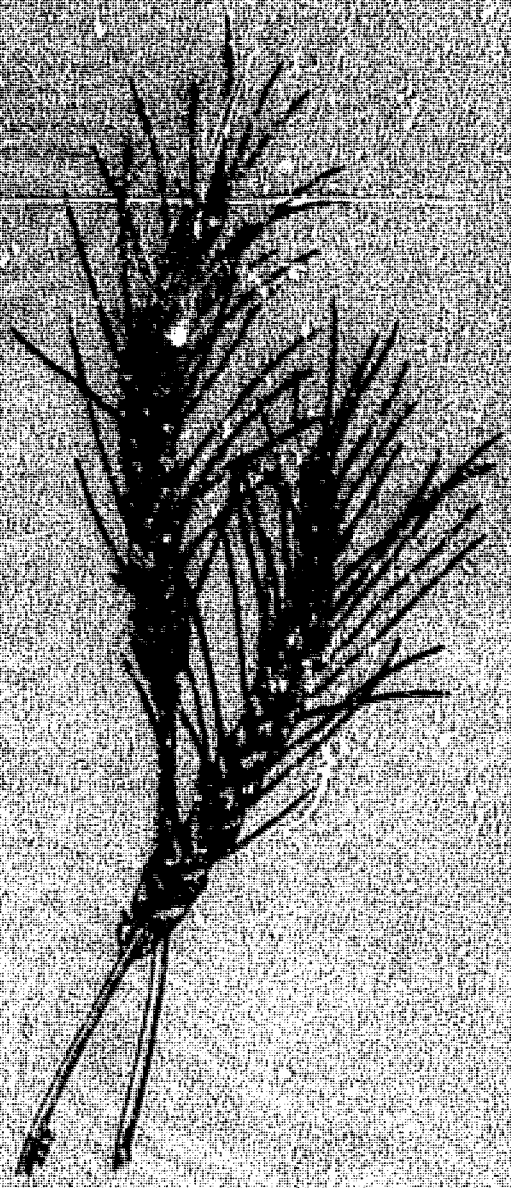

A Survey and Strategy for Collecting

GENETIC RESOURCES OF WHEAT

International Board for Plant Genetic Resources

THE GENETIC RESOURCES OF WHEAT
A SURVEY AND STRATEGIES FOR COLLECTING

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Preface

Among the world's crops, wheat is one of the most threatened by genetic erosion. A steady stream of improved cultivars is displacing the traditional landraces and reducing the genetic variability of the crop in the field.

Fortunately the collecting of wheat germplasm is of long standing, going back to the early years of this century and the explorations of such people as N.I. Vavilov and V.H. Harlan. This germplasm is dispersed among a number of collections however and it is necessary to get a coherent picture in order to set priorities for future work.

It is with this need in mind that this survey has been compiled. It is based upon reports presented to, and endorsed by the IBPGR Wheat Advisory Committee and the Board of Trustees of the IBPGR.

Inevitably some sources of information have not been found and others may have been misinterpreted. The IBPGR would be grateful for any additional information and comments.

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INTRODUCTION

Along with rice and maize, wheat is one of the three major crops in the world, both in terms of area planted and in terms of total production (almost 500 million tonnes in 1983). Since its inception in 1974 the IBPGR has, therefore, rated wheat as a first priority for collection.

Meetings have been held regularly to monitor the state and progress of wheat germplasm collecting. The first of these was the "IBPGR Symposium on Wheat Genetic Resources" held in Leningrad in 1975. Subsequently an IBPGR Advisory Committee on Wheat Genetic Resources, co-sponsored by the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), was established. This has met four times, twice in Rome in 1976 and 1978, once at CIMMYT, Mexico in 1981 and once at Kyoto, Japan in 1983, following the Sixth International Wheat Genetics Symposium.

At each of these meetings what was known about the material in collections and the progress of collecting missions has been reviewed. On the basis of this new recommendations have been made for further collecting. Summaries of missions that have collected wheat material that are known to the IBPGR can be found in the FAO/IBPGR Plant Genetic Resources Newsletters **37** (1979), **46** (1981) and **58** (1984). These show that since 1976 over 7000 samples of cultivated wheat and over 1500 samples of wild relatives have been collected. Other missions are known to have taken place, but details are not available.

Up to the third meeting of the Wheat Advisory Committee no general survey of wheat germplasm had been carried out and recommendations had been based upon the knowledge of individual committee members. For that meeting a report was prepared, subsequently published as "A World Survey of Wheat Genetic Resources" by R.P. Croston and J.T. Williams (1981). This summarized the contents of a number of major collections for the first time and directed attention to taxa and countries that were clearly under-collected.

The authors of that survey experienced and recognized a number of limitations. These included a lack of information from a number of collections; a number of listings that were clearly out of date; difficulties in assessing duplication among collections which leads to inflated estimates of the number of lines available; and a multiplicity of taxonomic systems which were not always used consistently within a collection.

The appointment of a wheat officer by the IBPGR has provided the opportunity to consider the problems outlined above in greater depth, and to go some way towards resolving them. More detailed and updated information on more collections is now available; account can be taken of missions that have occurred since 1980 and it has been possible to make progresss towards discounting duplicates. The problem of taxonomy is discussed below.

TAXONOMY

It is not the purpose of this survey to review the taxonomy of wheat and its wild relatives. Nevertheless it is necessary to adopt an approach that is relevant to wheat genetic resources, and enables the various systems of classification used by different collections to be reconciled. These problems were considered in depth by Croston and Williams (1981). The approach adopted here is similar with a tendency towards lumping rather than splitting as this enables data from different collections to be more easily merged. Thus, here 20 species of **Aegilops** are recognized and six of **Triticum**. Synonyms for these are listed in Appendix I.

Table 1 lists the species used here along with their genomes. These are the symbols recommended by Kimber and Sears (1983) to supercede those suggested by Kihara (1954). The revision arises from the development of more objective methods of treating chromosome pairing patterns at meiosis and better reflects the true genomic composition of these species. It also better indicates how the species might be used in breeding.

CULTIVATED MATERIAL

More or less detailed information on contents was available from the collections listed in Appendix II. To get a global picture of the amount of wheat germplasm the number of accessions of each species (where known) originating from each country were added together, discounting as far as possible any duplicates within and among collections. Supplementary data were obtained from miscellaneous reports (see Appendix III). This information is summarized for material originating from the countries of the Mediterranean; East Africa; South, Southwest and East Asia; and Latin America in Table 2.

This table is necessarily imprecise for two reasons. The first is that full details of a number of major collections, including those of the N.I. Vavilov Institute of Plant Industry in Leningrad and that of the Crop Germplasm Institute in Beijing, are currently unavailable. Secondly, although efforts have been made to discount duplication, some lines have almost certainly been counted twice. However this is not thought to be a major problem with materials from developing countries which tend to move among collections in large blocks and be identified by distinctive collectors' numbers.

The table is also incomplete. For some countries, e.g., Albania, Mongolia, there is simply insufficient information to make an estimate of what has been collected. With most of the developed countries the situation is different in that advanced cultivars and breeders' lines have become so dispersed among collections that tracing and discounting duplicates is virtually impossible, and so they have been excluded from this survey.

Given these shortcomings the table remains a useful guide. It includes most of those countries where landraces are still to be found, and hence those areas that merit consideration for further collecting. For most

Table 1. The genera **Aegilops** and **Triticum**, by ploidy and genome

Diploids		Tetraploids		Hexaploids	
AEGILOPS					
A. bicornis (Forsk.) Jaub. & Spach	S[b]	**A. columnaris** Zhuk.	UM	**A. crassa** (6x) Boiss.	DDM
A. caudata L.	C	**A. crassa** (4x) Boiss.	DM	**A. juvenalis** Thell.	DMU
A. comosa Sibth. & Sm.	M	**A. cylindrica** Host	CD	**A. triaristata** (6x) Willd.	UMUn
A. longissima Schweinf. & Muschl.	S[1]	**A. kotschyi** Boiss.	US[1]	**A. vavilovii** (Zhuk.) Chenn.	DMS
A. mutica Boiss.	Mt	**A. lorentii** Hochst.	UM		
A. speltoides Tausch	S	**A. ovata** L.	UM		
A. squarrosa L.	D	**A. triaristata** (4x) Willd.	UM		
A. umbellulata Zhuk.	U	**A. triuncialis** L.	UC		
A. uniaristata Vis.	Un	**A. ventricosa** Tausch.	DUn		
TRITICUM					
T. monococcum L. subsp. **boeoticum** (Boiss.) MK. subsp. **monococcum*** L.	A	**T. timopheevi** Zhuk. subsp. **araraticum** (Jakubz.) MK. subsp. **timopheevi*** Zhuk.	AG	**T. aestivum*** (L.) Thell.	ABD
T. urartu Tuman	A	**T. turgidum** (L.) Thell. subsp. **dicoccoides** (Korn.) Thell cultivars*	AB	**T. zhukovskyi*** Men. & Er.	AAG

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* Cultivated types (for **T. turgidum** it includes all the cultivated subspecies and convars)

Table 2. Summary of cultivars in collections

Country of origin	*Triticum turgidum* cultivars	*Triticum aestivum* cultivars	Minor species, mixtures and unknown	Total	Wheat area 1000s of ha. (1948-1952)	No. of ha. per sample
Afghanistan	99	3726	953	4778	2000	419
Algeria	50	40	387	477	1507	3159
Argentina	25	467	8	500	4487	8974
Bhutan		169		169	55[c]	325
Bolivia	2	5	85	92	36	391
Brazil	1	225		226	671	2969
Chile	15	757	2	774	791	1022
China	75	3601	8943	12619[a]	23049	1827
Colombia		48	13	61	173	2836
Cyprus	227	14	12	253	75	296
Egypt	350	393	130	873	605	693
Equador	5	41		46	54	1174
Ethiopia	1507	792	4642	6941	360	52
Greece	231	325	402	958	878	916
India	950	2597	14	3561	9290	2609
Iran	220	1619	10993	12832[b]	2080	162
Iraq	165	217	53	435	948	2179
Israel	130	124	9	263	34[d]	129
Italy	437	582	203	1222	4705	3850
Jordan	96	11	205	312	182	583
Korea		100		100	257	2570
Lebanon	22	22		44	70	1591
Libya	33	70	29	132	124	939
Mexico	53	541	2	596	604	1013
Morocco	248	260	4	512	1287	2514
Nepal		674	66	740	128	173
Pakistan	12	1688	17	1717	4218	2457
Paraguay		15		15	2	133
Peru		174		174	157	902
Portugal	314	550	37	901	698	775
Saudi Arabia	14	7	7	28	36	1286
Spain	191	854	26	1071	4156	3880
Sudan		61		61	13	213
Syria	682	70	330	1082	994	919
Tunisia	233	72	215	520	917	1763
Turkey	1661	3477	714	5852	4770	815
Uruguay	4	206		210	509	2424
Venezuela		10		10	10	1000
Yemen AR	6	71	66	143	14	98
Yemen PDR			50	50	2	40
Yugoslavia	178	2474	161	2813	1319	647
Total	8236	27149	28778	64163	72765	
Average						1134

countries the number of samples has been related to the wheat area before the advent of high-yielding cultivars. The number of hectares per sample so obtained shows, to some, extent how well countries are sampled in relation to each other.

Of the cultivated species only **Triticum turgidum** (largely durum wheat) and **T. aestivum** occur with any great frequency. Although durum wheat makes up only 8% of the world wheat crop (Srivastava 1983) it represents a higher proportion in these tables which include those regions where this species is most commonly cultivated.

Inspection of the original collection listings shows that the great majority of this material is landraces. Only a few countries such as India and Egypt have contributed a significant proportion of breeders' material and cultivars, but overall this amount is small.

A strategy for collecting

With around 60 000 samples of wheat landraces traceable on current data, it is clear that the remaining work is in the nature of filling in gaps. Table 3 lists the priorities for future collecting as decided by the fourth meeting of the IBPGR Wheat Advisory Committee in 1983, but some further revision is due in the light of new information. Jordan and Turkey are now thought to be adequately covered, and the Republic of Korea appears no longer to have landrace material. A number of the other countries are effectively closed for political reasons, or sufficient information to make assessments is lacking.

Therefore the current strategy is to concentrate IBPGR efforts on Morocco and the countries of the Arabian peninsula, while encouraging national and institute programmes to collect in other priority areas. When conditions permit, action will be taken in politically difficult areas.

In addition to the material listed above there may be some further 30 000 landrace samples yet to be traced, including old European landraces and material from a varlety of sources in the Vavilov collection. Additionally there are lines produced by breeders to be accounted for, upwards of 40 000 perhaps.

Whatever its shortcomings, the global collection of cultivars is clearly a huge resource for breedeers and any further collecting will be minor beside it. The emphasis now must shift towards the conservation and utilization of this germplasm.

Footnotes to Table 2.

a. There is good reason to think that this estimate is conservative.
b. This includes the equivalent of 10 000 landrace samples in short term store in Iran, but full details are not available.
c. Period 1962-1965
d. Period 1949-1952

Table 3. Priorities for future collecting of cultivated material as decided by the IBPGR Wheat Advisory Committee in 1983

Priority 1

Mediterranean	
Albania	
Algeria	Tindouf area
Morocco	Landraces seriously threatened
Yugoslavia	For **T. monococcum**
Southwest Asia	
Iraq	Sulaimaniya region only
Jordan	
Lebanon	
Oman	Mountainous areas
Saudi Arabia	Mountainous areas
Turkey	Areas of east and southeast
Yemen, Democratic	Mountainous areas
Central Asia	
Afghanistan	Areas as yet unexplored
Iran	Azerbaidzhan, Elburz mountains, Mashad
East Asia	
Korea, Rep. of	

Priority 2

Africa	
Ethiopia	Has an active, continuing national programme
Mozambique	Status of collection at INIA needs to be investigated
South Asia	
Bhutan	Collecting planned for 1984
Burma	Capture adaptive variability developed in that country since Indian wheats were introduced
Nepal	Western hill regions
East Asia	
China	Continuing programme at national level
South America	
Bolivia	Andean area
Brazil	
Colombia	Andean area
Ecuador	Andean area
Mexico	
Peru	Andean area
Venezuela	Andean area

Table 3. (cont.)

Regions thought to have been adequately collected
(Countries in brackets still have certain areas to be collected: see above)

Mediterranean		East Africa
Algeria	Libya	Sudan
Cyprus	Portugal	
Egypt	Spain	
Greece	Tunisia	
Italy	(Yugoslavia)	

Southwest & Central Asia	South Asia
(Iraq)	India
Israel	(Nepal)
Pakistan	
Syria	
(Turkey)	
Yemen AR	

Countries for which more information is needed

Korea, PDR	Mongolia	USSR

WILD SPECIES

As the collecting of cultivars approaches completion, more attention will need to be given to the wild species, a point stressed by the Consulatative Group on International Agricultural Research in 1983. The IBPGR Wheat Advisory Committee also agreed that there should be a more planned approach towards the further collecting of wild species. Accordingly this section summarizes the status of wild material in collections and proposes a strategy for future work.

Distribution

The distribution of the genus **Aegilops** extends in a broad band from the Atlantic coasts of Morocco, Portugal and Spain, through the Middle East and southern USSR to the western borders of China and Pakistan. Additionally **A. squarrosa** occurs as a weed in the Yellow River valley in China, and **A. cylindrica**, **A. ovata** and **A. triuncialis** as weeds over much of the USA.

The wild species of **Triticum** are more restricted, being more or less confined to the fertile crescent area of Iran, Iraq, Israel, Jordan, Lebanon, Syria, Turkey, and the USSR. Only **T. monococcum** subsp. **boeoticum** extends further, being found additionally throughout Greece and Turkey. In general terms the fertile crescent represents a kind of "centre of diversity" for the two genera, the ranges of 20 out of the 24 species lie within or overlap into this area.

Summary of material in collections

Bringing together information on the wild species has proven relatively uncomplicated. Much of the material has been gathered by two groups, missions from the University of Kyoto in Japan (for a review see Tanaka (1983)) and those made by Dr. B.L. Johnson and his associates at Riverside, California, USA. Material collected by missions from other institutes has been added to these two major groups, as well as a number of lines in other collections whose origins are often obscure.

The result of combining all this separate information is shown in Table 4. Because of the comparatively small number of samples involved, and the comparatively detailed documentation available on most of them, it is probable that most of the duplication among collections has been discounted. There may, however, be additional material in collections for which information is not currently available. It should be borne in mind that it has not been possible to take account of any errors in species identification nor in naming the country of origin. Accessions of species that appear to come from far outside their areas of distribution must be suspect.

It is fortunate that most of the locations where wild material has been collected are fairly precisely described. This has enabled the areas from which material has been collected to be plotted in some detail (see Appendix IV). Those areas marked as having been intensively collected

Table 4. Summary of wild **Triticum** and **Aegilops** materials in germplasm collections by species and country of origin

Country of origin	AEGILOPS species																					TRITICUM species			
	Unknown	bicornis	caudata	columnaris	comosa	crassa	cylindrica	juvenalis	kotschyi	longissima	lorentii	mutica	ovata	speltoides	squarrosa	triaristata	triuncialis	umbellulata	uniaristata	vavilovii	ventricosa	monococcum subsp. boeoticum	timopheevi subsp. araraticum	turgidum subsp. dicoccoides	urartu
Afghanistan	4	.	+	.	.	19	7	.	.	.	.	.	.	.	91	.	53	.	.	.	.	.	.	.	.
Algeria	11	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	+	.	.	.	.
Bulgaria	.	.	.	.	.	.	1	.	.	.	.	.	3	.	.	.	3	.	.	.	.	.	.	.	.
China	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.
Cyprus	166	.	+	.	.	.	.	.	5	.	.	.	3	.	.	.	2	.	.	.	.	.	.	.	.
Egypt	.	9	.	.	.	.	.	.	15	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
France	.	.	.	.	.	.	3	.	.	.	3	.	31	.	1	13	14	.	.	.	2	.	.	.	.
Greece	649	.	82	.	127	.	4	.	.	.	190	.	93	.	.	137	169	.	8	.	.	25	.	.	.
Hungary	.	.	+	.	.	.	+	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Iran	54	.	+	25	3	28	90	3	4	13	6	5	.	1	123	2	231	14	.	.	.	99	19	4	15
Iraq	7	.	12	2	.	23	7	14	28	.	36	.	4	104	+	48	167	65	.	1	.	442	508	42	3
Israel	.	5	+	.	.	1	+	.	31	49	1	.	6	26	.	.	.	.	.	+	.	1	.	1681	.
Italy	.	.	.	.	.	.	+	.	.	.	.	.	23	.	.	10	.	.	.	.	+	.	.	.	.
Jordan	.	.	.	.	.	.	.	.	105	9	.	.	13	1	.	.	.	.	.	11	+	.	.	1	.
Lebanon	11	.	+	.	.	+	.	.	7	+	.	.	2	+	.	.	.	.	.	+	.	14	.	50	102
Libya	1	+	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	+	.	.	.	.
Morocco	4	.	.	.	.	1	3	.	.	.	.	.	2	2	1	9	3	.	.	.	6	.	.	.	.
Pakistan	12	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	.	.	.	.	.	.	.	.
Portugal	.	.	.	.	.	.	.	.	.	.	.	.	135	.	.	17	92	.	.	.	.	.	.	.	.
Romania	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spain	.	.	.	.	.	.	.	.	.	.	.	.	90	.	.	3	65	.	.	.	9	.	.	.	.
Syria	5	.	8	15	+	19	1	+	40	10	36	.	42	32	1	.	35	8	.	14	.	3	.	20	9
Tunisia	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turkey	277	1	114	39	19	1	172	1	9	.	194	64	136	271	23	223	623	198	5	.	.	549	71	171	101
USSR	3	.	.	3	6	2	59	2	3	.	14	6	1	36	186	8	58	6	.	.	.	75	63	2	19
Yugoslavia	99	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Unknown	15	11	43	2	53	29	36	9	19	8	78	2	49	92	105	18	203	22	6	.	17	190	14	87	14
Total	1320	26	259	94	208	123	384	29	266	89	558	78	588	565	540	488	1719	313	19	26	34	1399	675	2058	263

+ The species is reported to occur in this country, but there is no record of it being collected.

reflect a subjective assessment of the comparative density of collecting sites. This is not the same as the density of samples from an area as it has been the practice of many missions to collect several, sometimes many, samples from a single site.

Generally it appears that the areas of collection match the published distributions (e.g., Dorofeev (1976), Eig (1929), Harlan and Zohary (1966), Johnson and Dhaliwal (1976), Tanaka (1983), Zeven and de Wet (1982)) moderately well, but that they differ considerably in detail. In some cases a species has been collected outside the supposed distribution, but in the main the distributions have not been adequately covered. There are a number of possible reasons for this: some areas are still unexplored; the occurrence of a species within its general area of distribution may be sporadic both in space and time; plants may have been immature or already have shattered when a mission was in the area; the distributions may, in part, be inaccurate.

Apparent discrepancies between Table 4 and Appendix IV may arise because of incomplete information on origin. Material where only the country of origin is known could be included in Table 4, but not in the maps.

In total there are about 12 000 accessions of wild species, making the wild relatives of wheat well represented when compared to other crops. Collecting has tended to concentrate in the Near East and Greece leaving many peripheral areas as yet unexplored.

Considerations for planning a strategy

1. Previous explorations:

The following areas appear to be comparatively well covered by previous missions - Greece, northern and western Iran, northern Iraq, Israel, southern Portugal and Spain, western and northern Syria, and much of Turkey. When plotting missions in these and other countries it is evident that most collecting has been carried out in the vicinities of the major road networks. Areas of North Africa, East Europe and southern USSR appear largely uncollected. In general there is little ecological information on the sites where these samples have been collected. Most missions have been short-term and an ecogeographical approach has not been used.

2. The status of material in collections:

All the material listed in Table 4 is thought still to be available. However, it is unclear how much is true population samples; probably the majority is not. It is known that more than one sample of a species has been collected at many sites, and listings strongly suggest that this has often been the result of splitting populations into morphotypes. In addition the standards of maintenance are often less than ideal, and this must have lead to a loss of within line variability.

3. The distribution of genetic variability:

Although the geographic distribution of some characters in some species has been studied, there is little **a priori** guidance as to where the most genetic variation might be found in any one species. However, as

species distributions are concentrated in northwest Iran, northern Iraq, Lebanon, Syria, and eastern Turkey, missions in these areas might be expected to collect more species than elsewhere.

4. Likely usage:

So far comparatively little use has been made of wild material, for although the techniques of gene transfer are well understood (see Feldman and Sears 1981), the work is time consuming. The lack of use also indicates, presumably, the availability of the required genetic variation in cultivated material. On the other hand breeders are showing an increased interest in crosses with these and other more distant genera such as **Agropyron** and **Hordeum.** Although characters, such as disease resistance, which are likely to be simply inherited are normally sought, some attention is also being paid to more complex characters such as salt tolerance and photosynthetic efficiency.

It is not possible to predict which species or populations will yield the most valuable contributions to wheat breeding. However it is possible to rank the species for ease of use, the order depending on how many genomes are shared with cultivated wheat. It would seem sensible to concentrate on those species carrying any of the A, B or D genomes, particularly the ancestral species **T. monococcum** subsp. **boeoticum, T. turgidum** subsp. **dicoccoides** and **A. squarrosa.** These will recombine with the chromosomes of wheat in a hybrid without the manipulation of the **Ph** gene or the use of irradiation. A second priority should go to those species of **Aegilops** carrying the S genome which will, in the absence of the **Ph** gene, pair with the B genome to some extent. Even when new methods of genetic manipulation become available it seems reasonable to assume that these species will remain the easiest to use.

Strategy for further collecting

With the points outlined above in mind the following strategy for the further collecting of wild species has been adopted.

1. Areas which are species poor, but which have been comparatively intensively collected, e.g., most of Greece, southern Portugal and Spain, will not receive priority for further collecting.

2. Exploration of the areas as yet uncollected or only partially collected is to be encouraged on an opportunist basis. Collecting in North Africa is a priority for IBPGR support, and the IBPGR will encourage national programmes to collect in Bulgaria, southern France, the whole of Italy, northern Portugal, Romania, northern Spain, southern USSR and Yugoslavia unless material from these areas is already in collections for which information is currently not available.

3. The IBPGR will actively support further collecting in the species-rich area of Southwest Asia. Although much of this area is comparatively well explored, it does contain all the wild species of **Triticum** and most of the **Aegilops** species carrying the D and S genomes.

Future field work in this area should, as far as possible, aim to collect away from the major roads where previous missions have been.

Planning should be carried out on an ecogeographic basis to identify differing environments in terms of temperatures, rainfall, soils and/or bedrock, and vegetation. Collecting in areas that contrast in these respects is likely to capture more genetic diversity, at least for any adaptive characters. Such planning can, of course, only identify general areas for collecting and the selection of sites must be done in the field. This means that personnel should expect to spend extended periods of time planning both away from and in the field, and in the collecting itself.

In terms of species there is probably a need for more **T. turgidum** subsp. **dicoccoides** from every country except Israel, and all other **Triticum** species from all countries where they occur. But since many of the areas where these species appear to have been under-collected are well collected for **Aegilops**, it must be assumed that the occurrence of the wild **Triticum** species can be sporadic and increasing the number of samples from these areas may not be easy.

In the case of **Aegilops** an increase in the number of samples from any of these countries would be worthwhile, although the rarity of some species may make this difficult. **A. squarrosa** is something of a special case as its distribution extends eastward into western China. Further collecting over the whole of its range on a coarse grid basis will be needed when the political situations allow.

4. It is not possible to collect the whole genetic variation of these wild species, nor is it necessary to attempt this whilst they still appear unthreatened in the wild. The aim should be to collect sufficient variability for the breeder to use.

To this end, it is suggested that a practical objective would be to collect a further 1000 populations of **Triticum** species and 500 of **Aegilops** carrying the D genome from Southwest Asia. These should be large populations from as wide a range of environments as possible. Along with existing material, future collections from outside this region and collections of other species of **Aegilops** when encountered, this should satisfy the foreseeable needs of breeders.

A NOTE ON POST COLLECTION WORK

Although this document is concerned with planning future collecting, it should not be forgotten that proper storage and maintenance of this material is needed if the value of this work is not to be lost. It is very likely that much material in collections has already suffered considerable genetic erosion due to small population sizes in store which, along with inadequate storage conditions, necessitates frequent regeneration and leads to genetic drift.

To make further collecting of the wild relatives worthwhile it is necessary to tackle this and other aspects of post collection work.

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APPENDIX I

Synonyms used in this survey

Species used here	is equivalent to or includes
AEGILOPS	
A. bicornis (Forsk.) Jaub. & Spach	**T. bicorne** (Forsk.)
A. caudata L.	**A. markgrafii** Greuter, **T. caudatum** (L.) Godr. & Gren, **T. dichasians** (Zhuk.) Bowden
A. columnaris Zhuk.	**T. columnare** (Zhuk.) Morris & Sears
A. comosa Sibth. & Sm.	**A. heldreichii** Holzm., **T. comosum** (Sibth. & Sm.) Richter
A. crassa Bioss.	**T. crassum** (Boiss.) Aitch. & Hemsel
A. cylindrica Host	**T. cylindricum** Ces., Pass. & Gib
A. juvenalis (Thell.) Eig	**A. turcomanica** Rosh., **T. juvenale** Thell, **T. turcomanicum** (Rosh.) Bowden
A. kotschyi Boiss	**A. peregrina** (Hack.) Maire & Weill., **A. variabilis** Eig., **T. kotschyi** (Boiss.) Bowden, **T. peregrinum** Hack. & Fraser
A. longissima Schweinf. & Muschl.	**A. searsii** Feld & Kis., **A. sharonensis** Eig, **T. longissimum** (Schweinf. & Muschl.) Bowden, **T. searsii** Feld. & Kis.
A. lorentii Hochst.	**A. biuncialis** Vis., **T. machrochaetum** (Schuttl. & Huet) Richter
A. mutica Boiss	**Ambylopyrum muticum** (Boiss.) Eig, **T. muticum** (Boiss.) Hack., **T. tripsacoides** (Jaub. & Spach) Bowden
A. ovata L.	**A. geniculata** Roth., **T. ovatum** (L.) Raspail
A. speltoides Tausch	**A. aucheri** Boiss., **A. liguistica** (Savign.) Coss., **T. speltoides** (Tausch) Gren. ex Richt.
A. squarrosa L.	**A. tauschii** Coss., **T. aegilops** P. Beauv. ex R. & S., **T. squarrosum** (L.) Raspail
A. triaristata Willd.	**A. neglecta** Req. ex Bertool., **A. recta** (Zhuk.) Chenn., **T. triaristatum** (Willd.) Godr. & Gren.

A. triuncialis L.	**A. bushirica** Rosch, **T. triunciale** (L.) Raspail
A. umbellulata Zhuk.	**T. umbellulatum** (Zhuk.) Bowden
A. uniaristata Vis.	**T. uniaristatum** (Vis.) Richter
A. vavilovii (Zhuk.) Chenn.	**A. crassa** Boiss. subsp. **palaestina** Eig., **A. crassa** subsp. **vavilovii** Zhuk., **T. syriacum** Bowden
A. ventricosa Tausch	**T. ventricosum** Ces., Pass & Gib.

TRITICUM

T. aestivum (L.) Thell.	**T. compactum** Host, **T. macha** Dek. & Men., **T. spelta** L., **T. sphaerococcum** Perc., **T. vavilovii** (Tuman.) Jakubz., **T. vulgare** Host
T. monococcum L.	
subsp. **boeoticum** (Boiss.) MK.	**T. boeoticum** Boiss, **T. sativum** Aschers., **T. spontoneum** Flaksb., **T. thaoudar** Reut. in Bourg ex Hausskn.
subsp. **monococcum** L.	
T. timopheevi Zhuk.	
subsp. **araraticum** (Jakubz.) MK.	**T. araraticum** Jakubz.
subsp. **timopheevi** Zhuk.	
T. turgidum (L.) Thell.	
subsp. **dicoccoides** (Korn.) Thell.	**T. dicoccoides** (Korn. ex Aschers. & Graebn.) Schweinf.
cultivars	**T. abyssinicum** (Vav.) Flaksb., **T. aethiopicum** Jakubz., **T. carthlicum** Nevski, **T. dicoccon** Schrank, **T. dicoccum** Shubl., **T. durum** Desf., **T. georgicum** Dek., **T. ispahanicum** Heslot, **T. orientale** Perc., **T. paleocolchicum** Men., **T. persicum** Vav., **T. polonicum** L., **T. pyrimidale** Perc., **T. turanicum** Jakubz.,
T. urartu Tuman.	
T. zhukovskyi Men. & Er.	

APPENDIX II

List of centres holding major collections from which data were analyzed in this report

Australia	Australian Wheat Collection New South Wales Department of Agriculture Private Mail Bag 944 Tamworth NSW 2340
Cyprus	Agricultural Research Institute (ARI) Nicosia
Czechoslovakia	Department of Genetic Resources Institute of Genetics and Plant Breeding 16106 Prague 6 - Ruzyne 507
Ethiopia	Plant Genetic Resources Center P.O. Box 30726 Addis Ababa
Germany, D.R.	Zentralinstitut für Genetik und Kulturpflanzenforschung Correnstrasse 3 4325 Gatersleben
Germany, F.R.	Institut für Pflanzenbau und Pflanzenzüchtung Bundesforschungsanstalt für Landwirtschaft Braunschweig-Völkenrode (FAL) Bundesallee 50 D-3300 Braunschweig
India	National Bureau of Plant Genetic Resources (NBPGR) Indian Agricultural Research Institute (IARI) Campus 110012 New Delhi
Italy	Istituto del Germoplasma del CNR Via G. Amendola 165/A 70126 Bari
Japan	Plant Germplasm Institute Faculty of Agriculture Kyoto University Mukoshi Kyoto 617

Japan	National Institute of Agricultural Sciences Division of Genetics Seed Storage Laboratory Kannondai 3.1.1. Yakabe - machi Tsukuba - gun Ibarakai - ken 300-21
Pakistan	Pakistan Agricultural Research Council National Agricultural Research Centre P.O. National Health Laboratories National Park Road Islamabad
Turkey	Aegean Regional Agricultural Research Institute (ARARI) P.O. Box 9 Menemen Izmir
UK	Plant Breeding Institute Maris Lane Trumpington Cambridge CB2 2LQ
USA	Wheat Germplasm Collection University of California, Riverside Riverside, CA 92521
USA	U.S. National Small Grain Collection, Building 046, BARC-West US Department of Agriculture Beltsville, MD 20705

APPENDIX III

Additional sources of information

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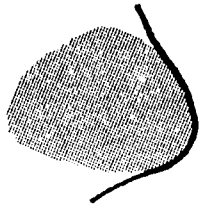
APPENDIX IV

The distribution of collections of the wild relatives of wheat

Limits of areas from which these species have been collected



Areas of comparatively intense collection in terms of sites

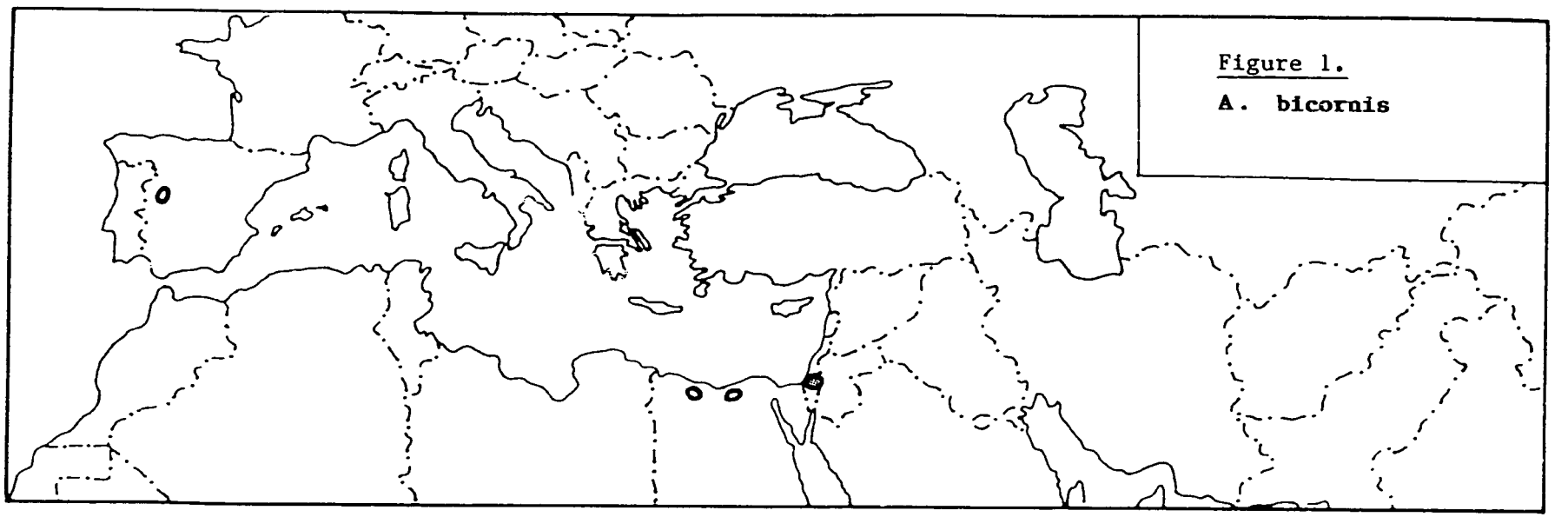


Figure 1.

A. bicornis

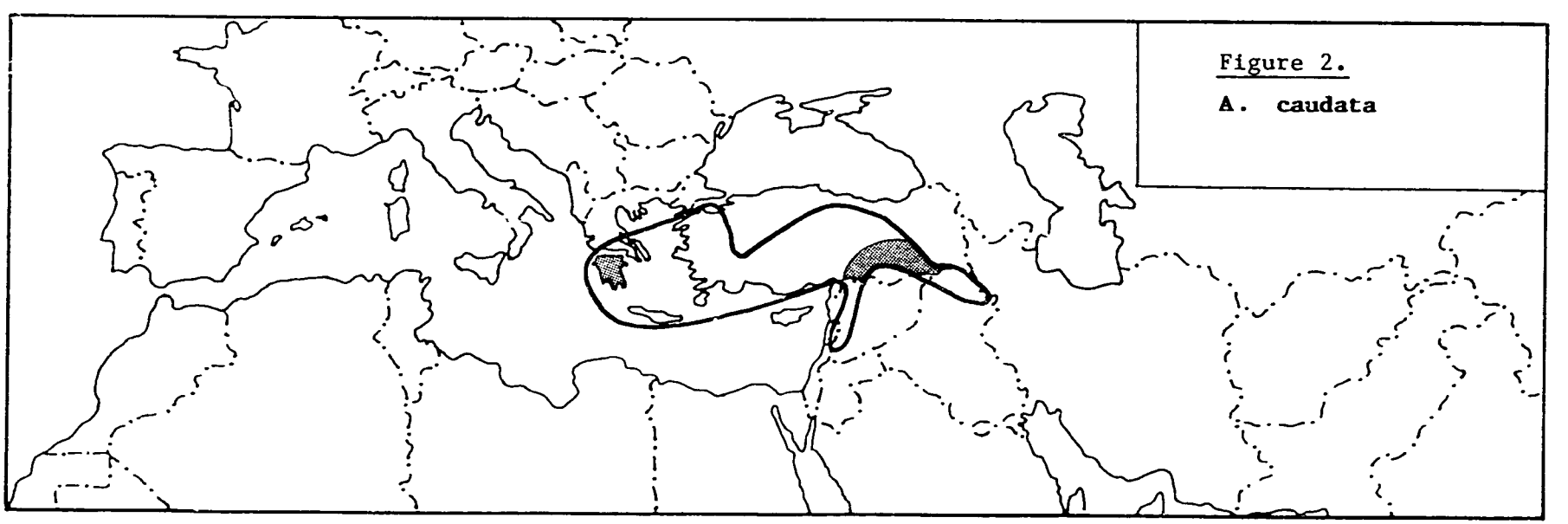


Figure 2.

A. caudata

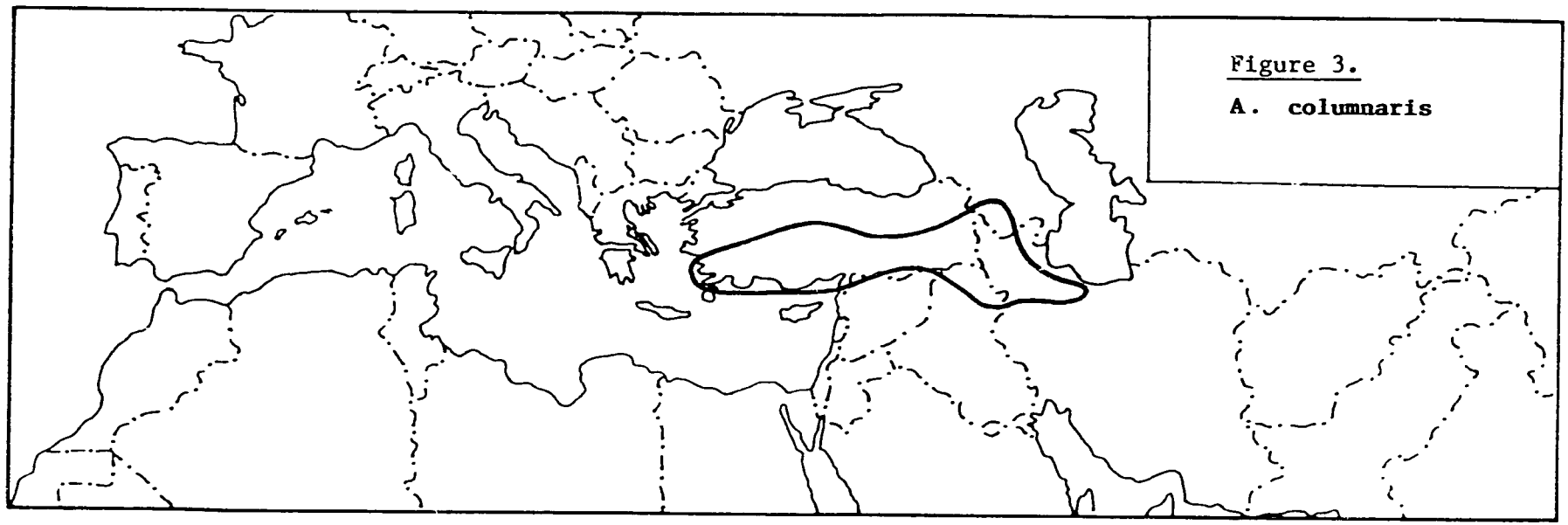


Figure 3.

A. columnaris

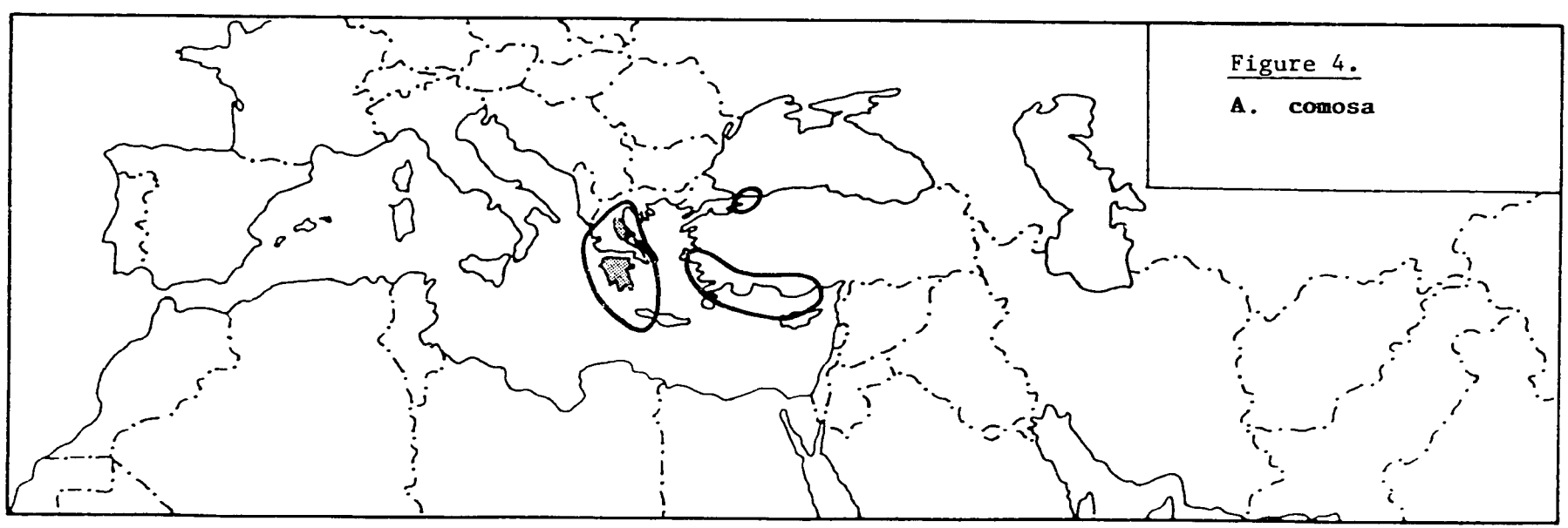


Figure 4.

A. comosa

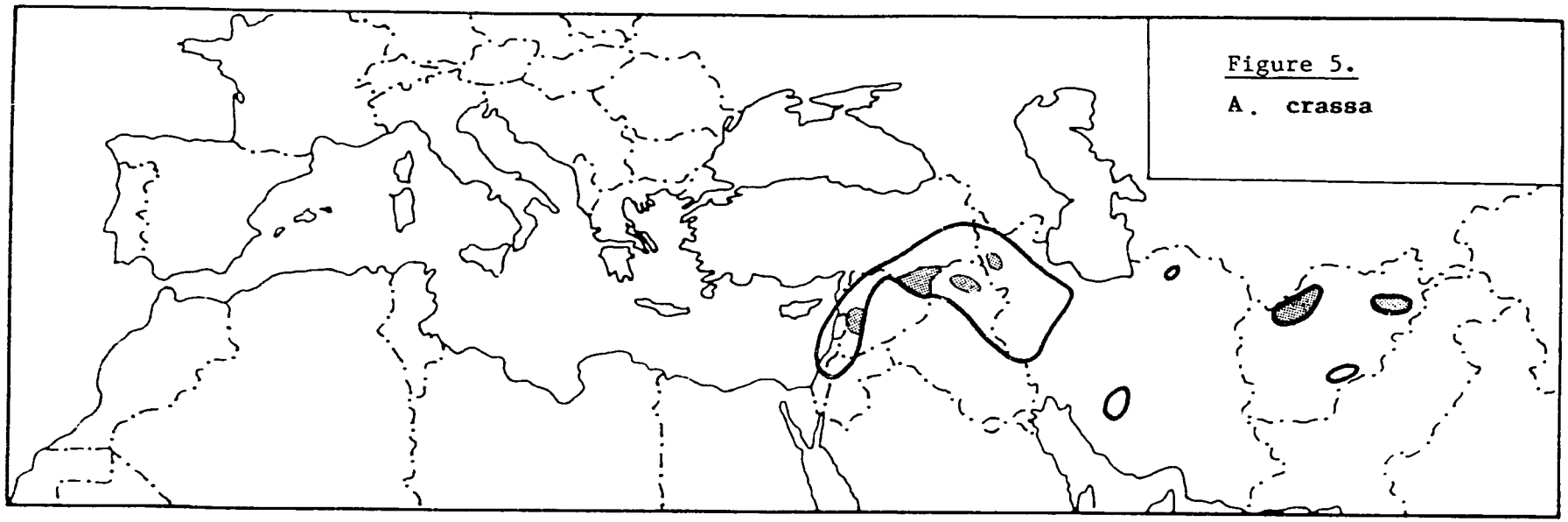


Figure 5.
A. crassa

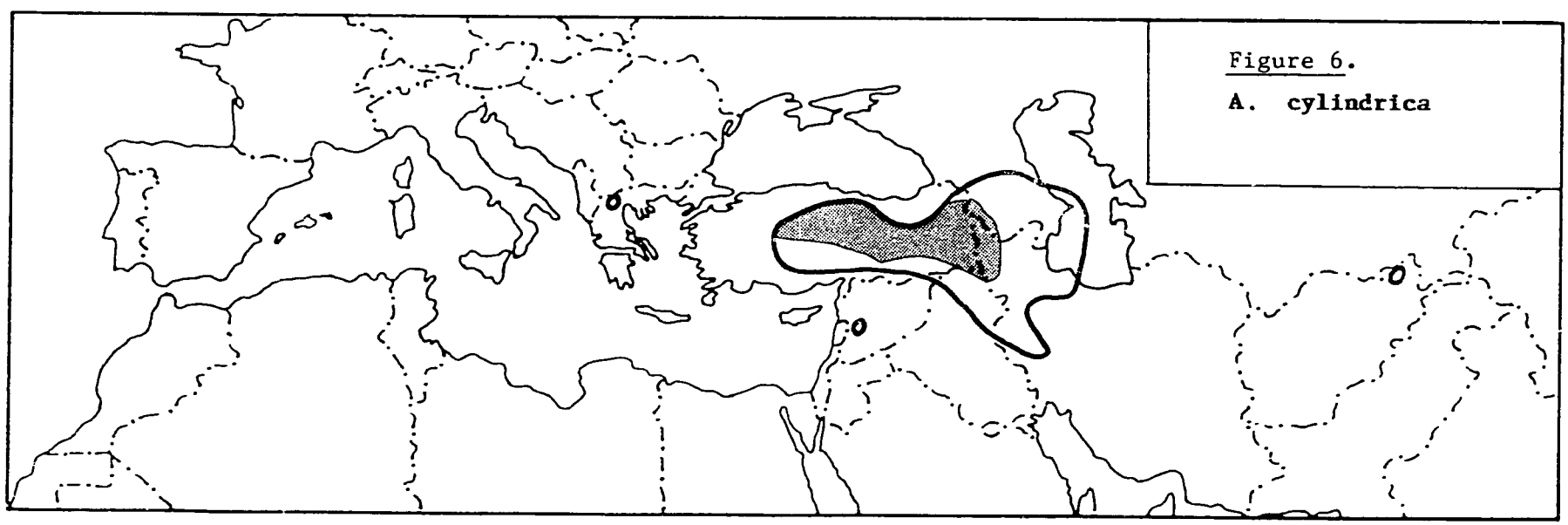


Figure 6.
A. cylindrica

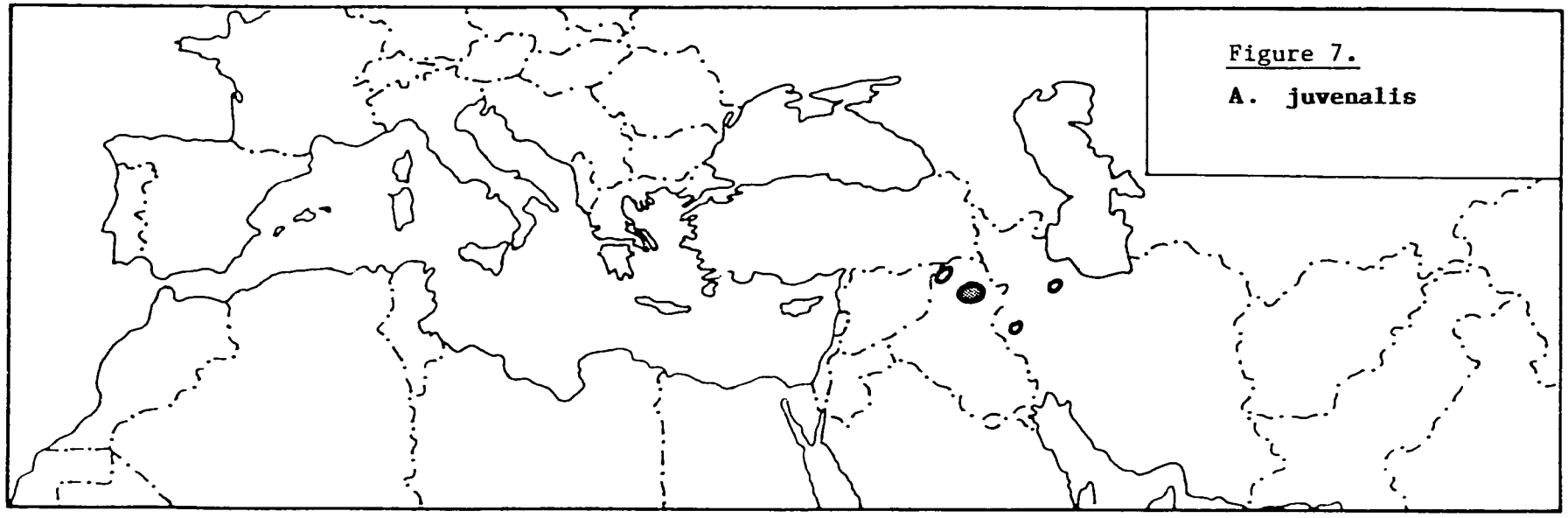


Figure 7.

A. juvenalis

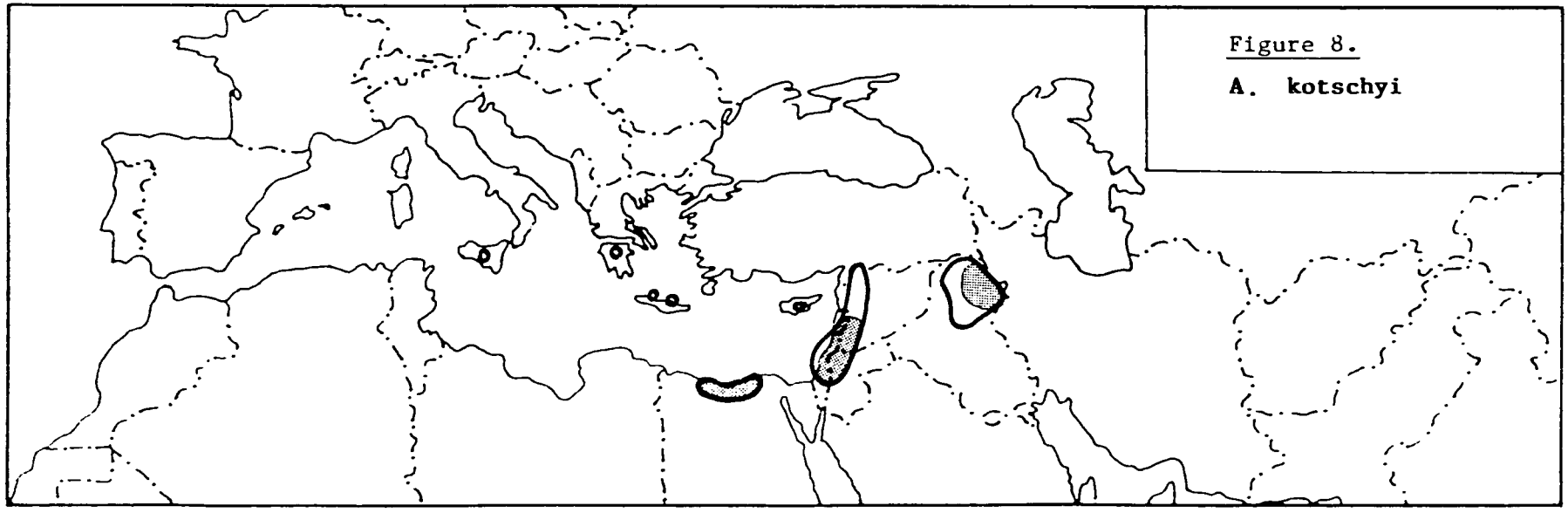


Figure 8.

A. kotschyi

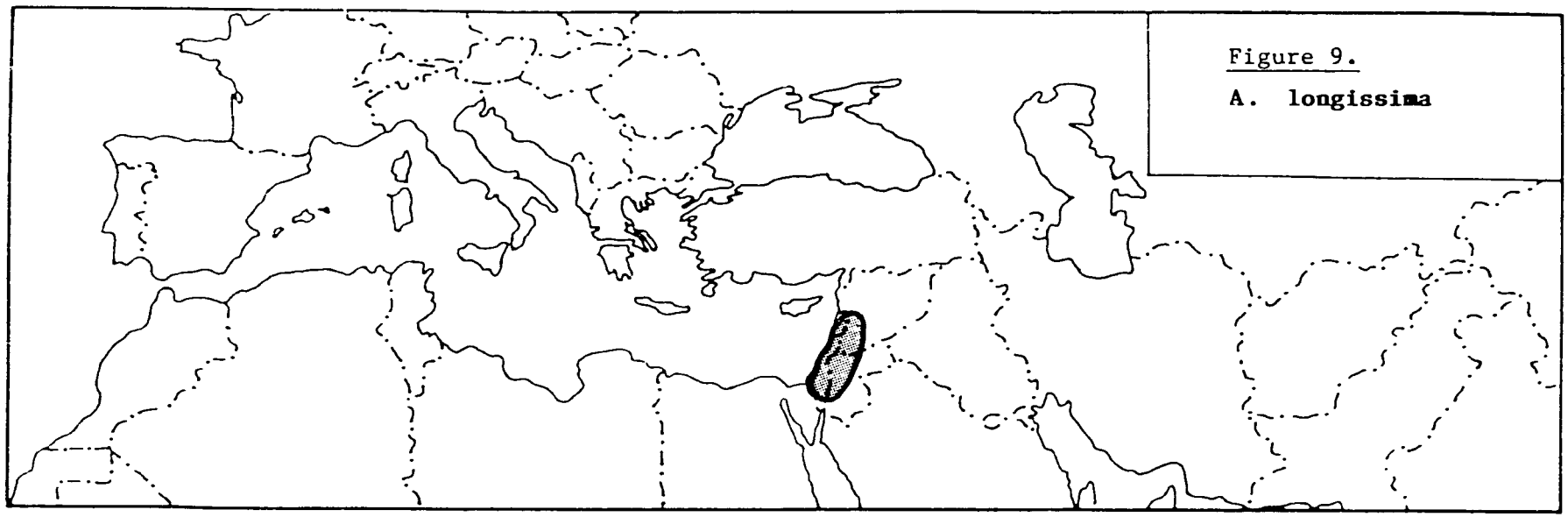


Figure 9.

A. longissima

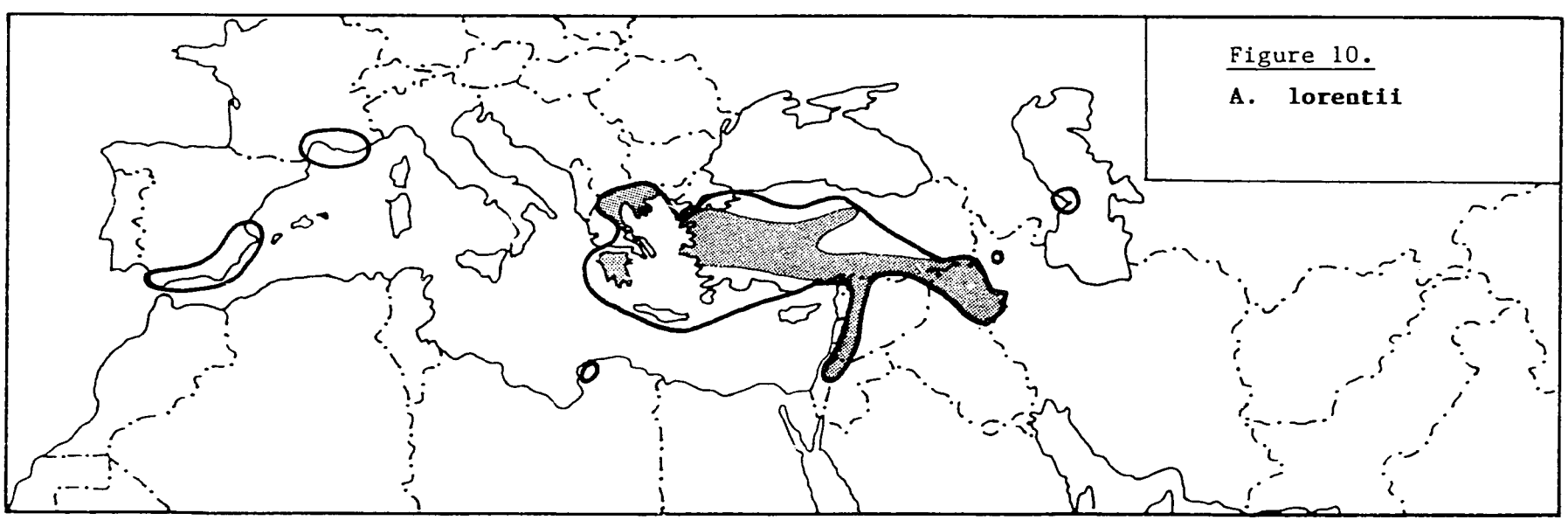


Figure 10.

A. lorentii

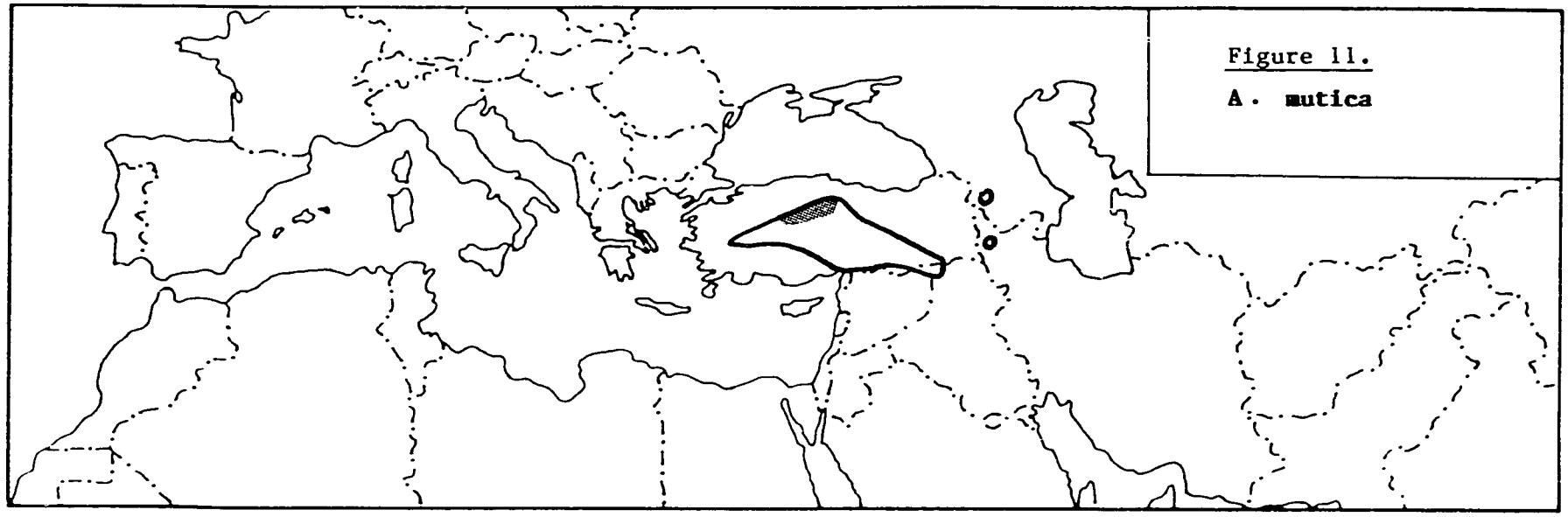


Figure 11.
A. mutica

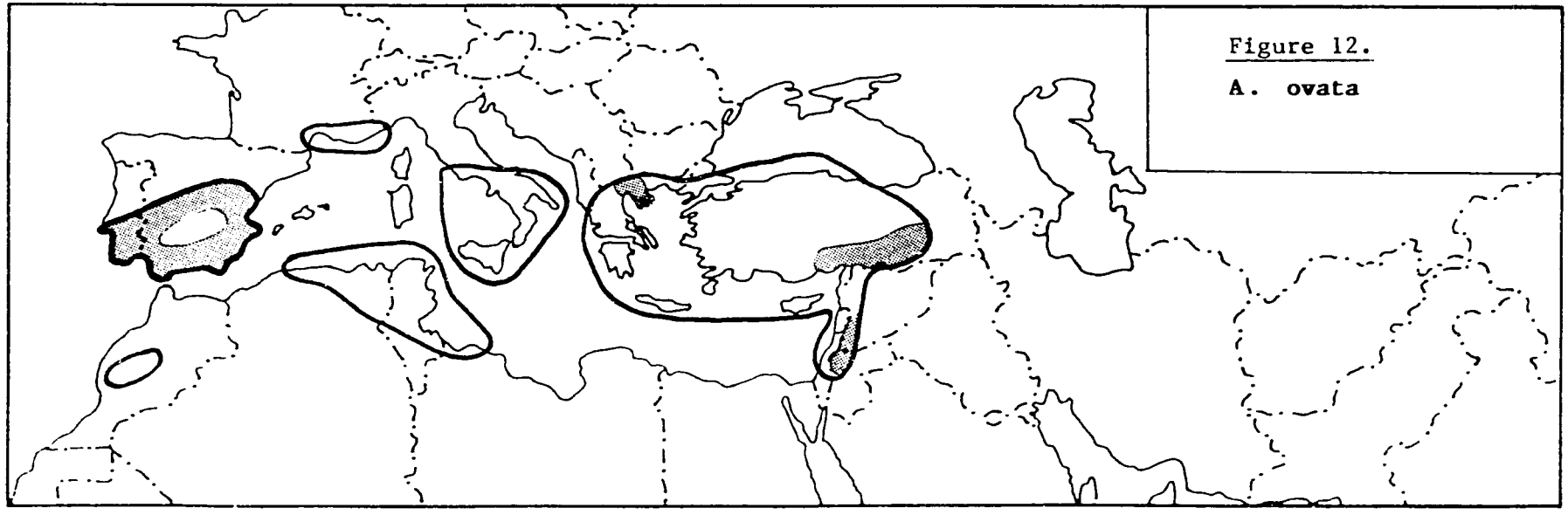


Figure 12.
A. ovata

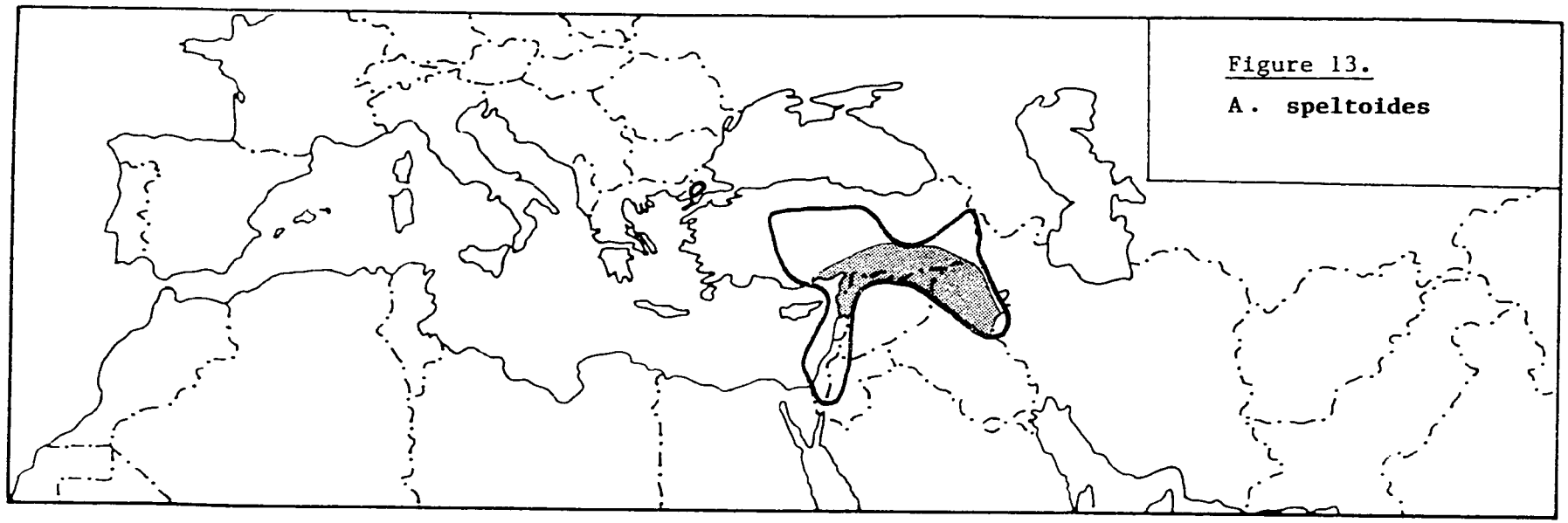


Figure 13.

A. speltoides

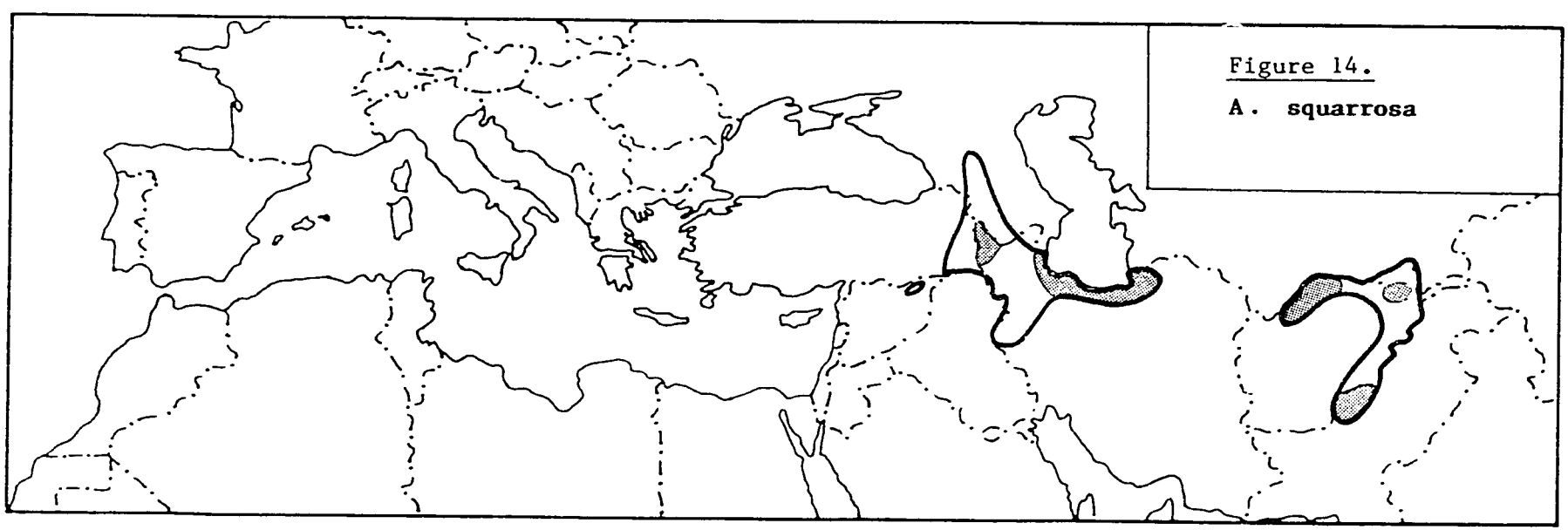


Figure 14.

A. squarrosa

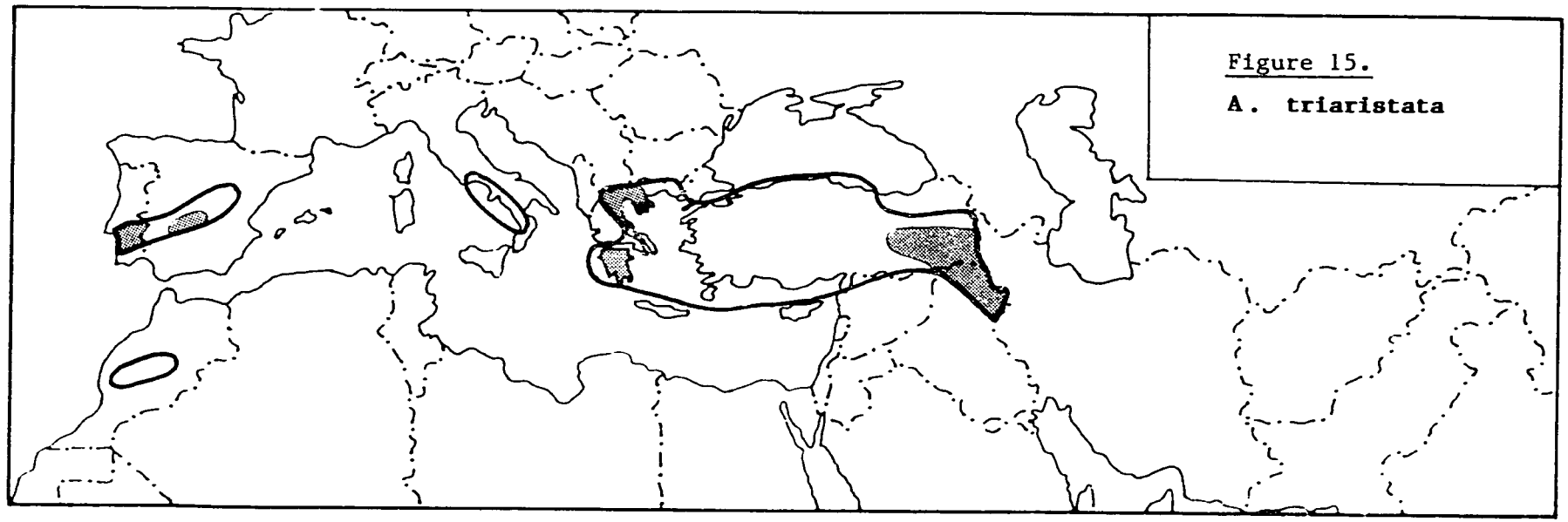


Figure 15.

A. triaristata

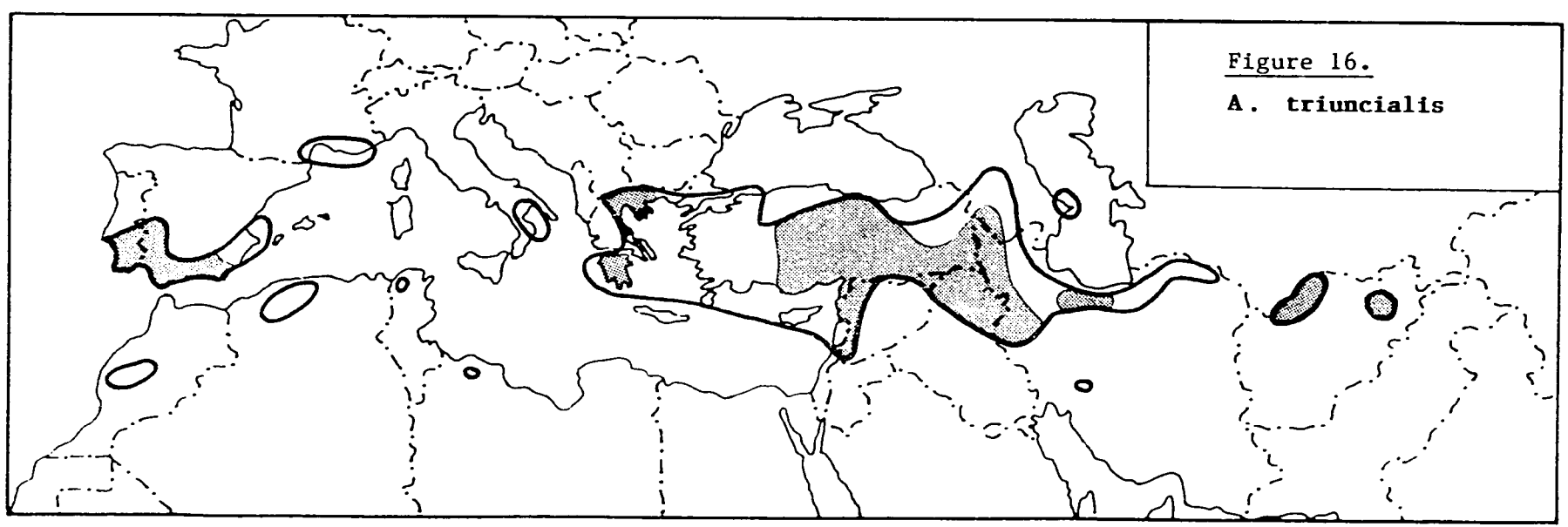


Figure 16.

A. triuncialis

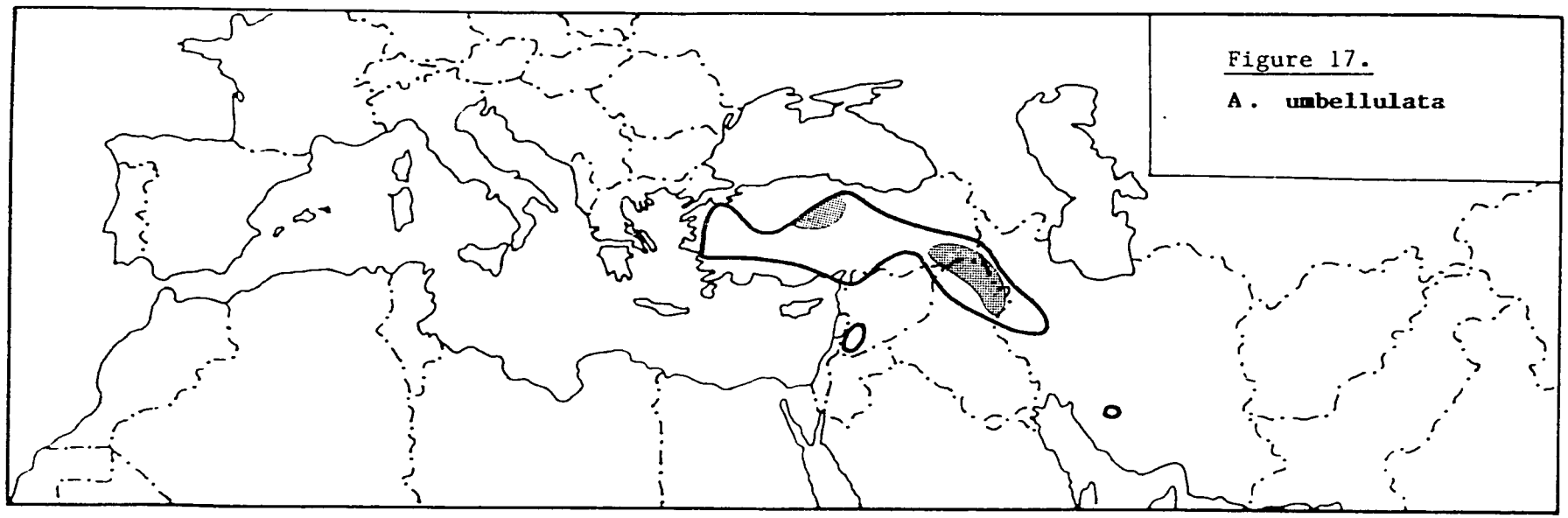


Figure 17.

A. umbellulata

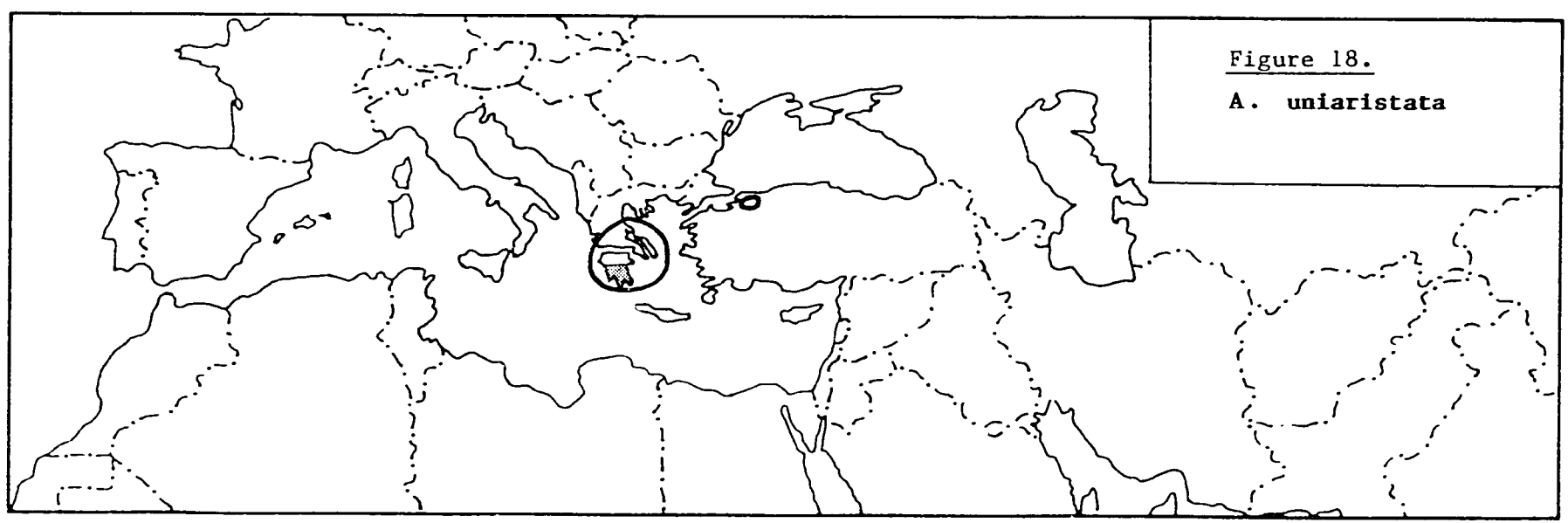


Figure 18.

A. uniaristata

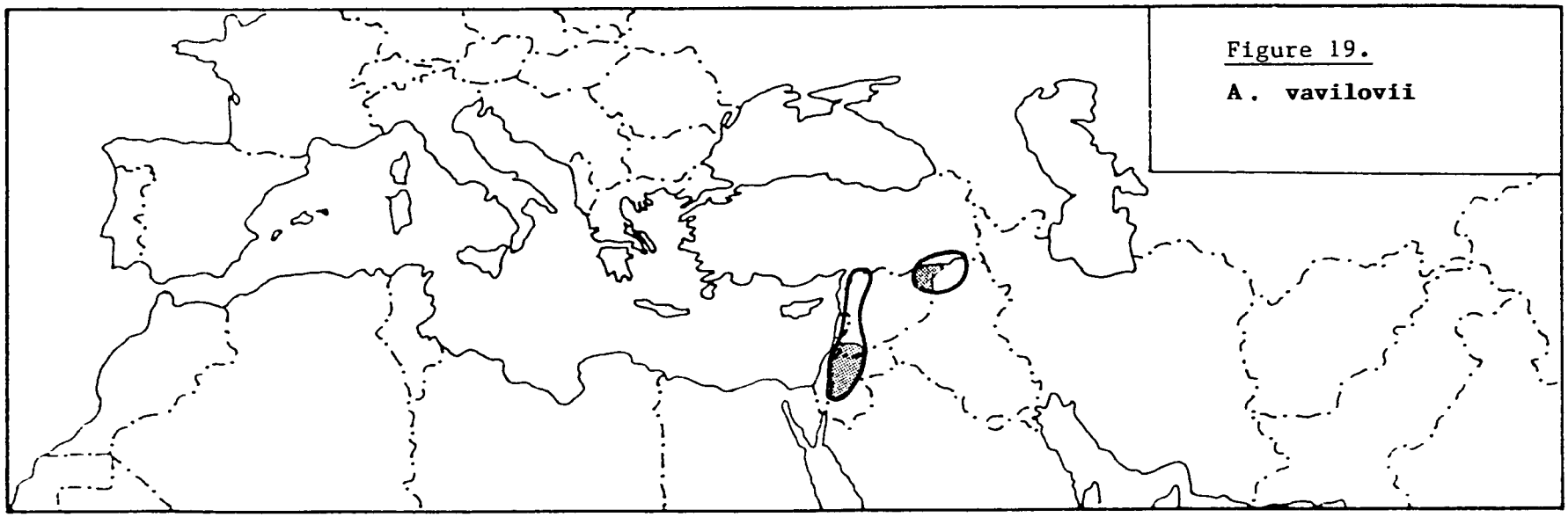


Figure 19.

A. vavilovii

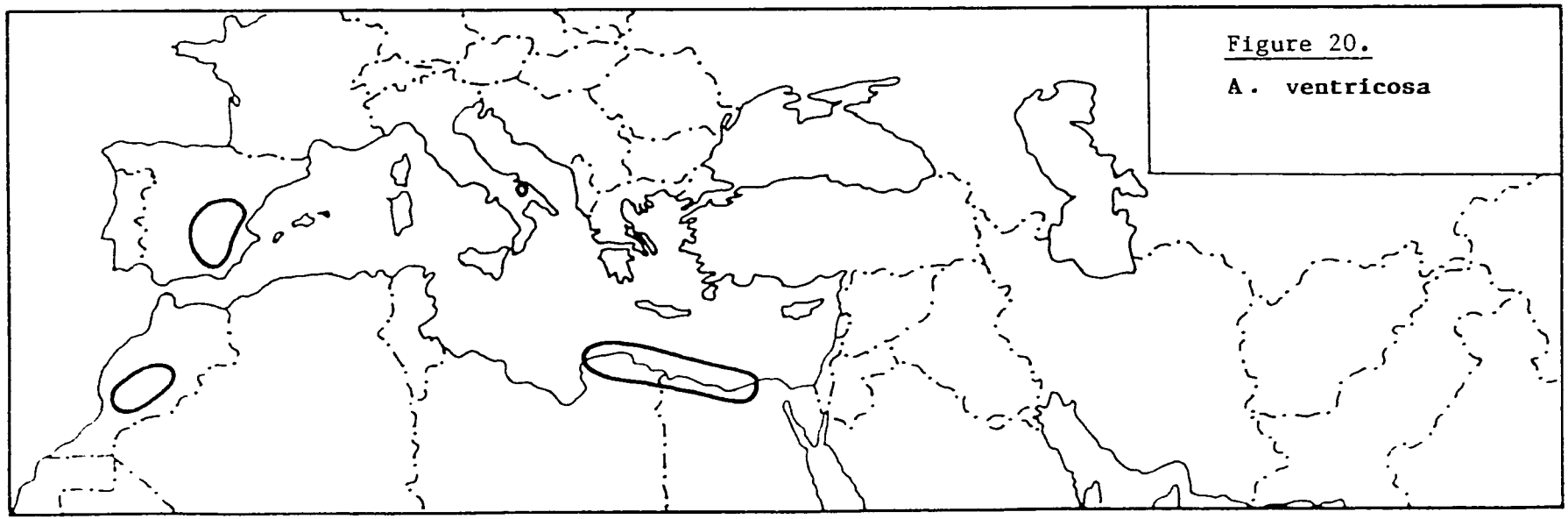


Figure 20.

A. ventricosa

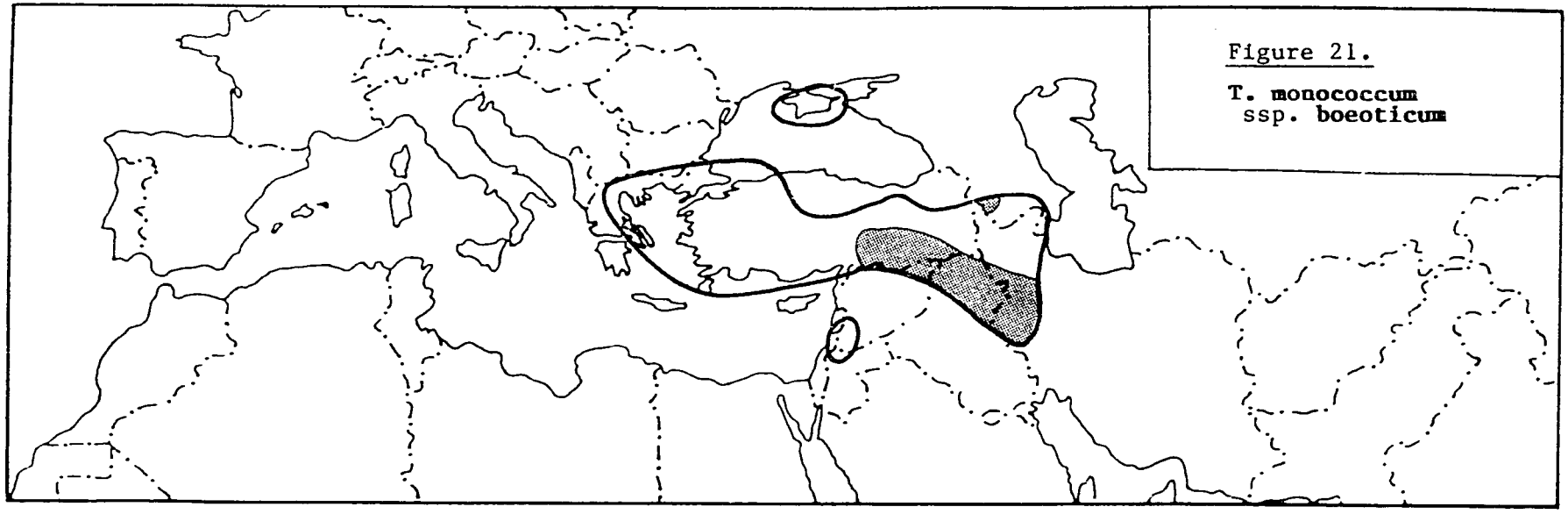


Figure 21.

T. monococcum ssp. boeoticum

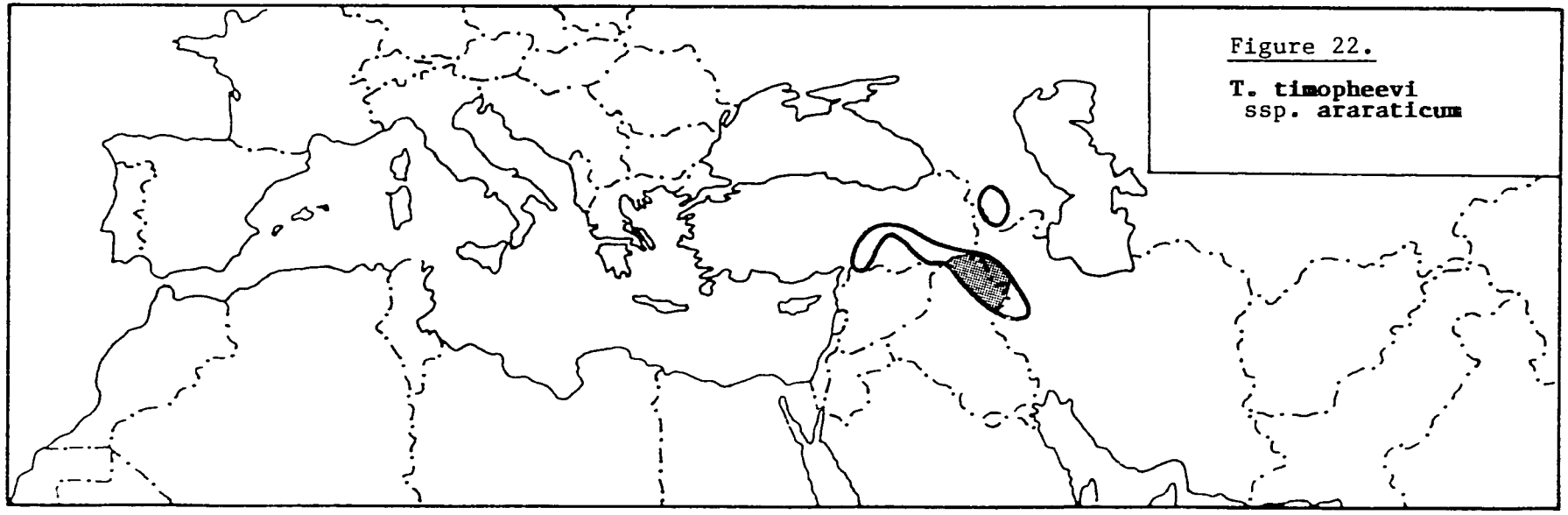


Figure 22.

T. timopheevi ssp. araraticum

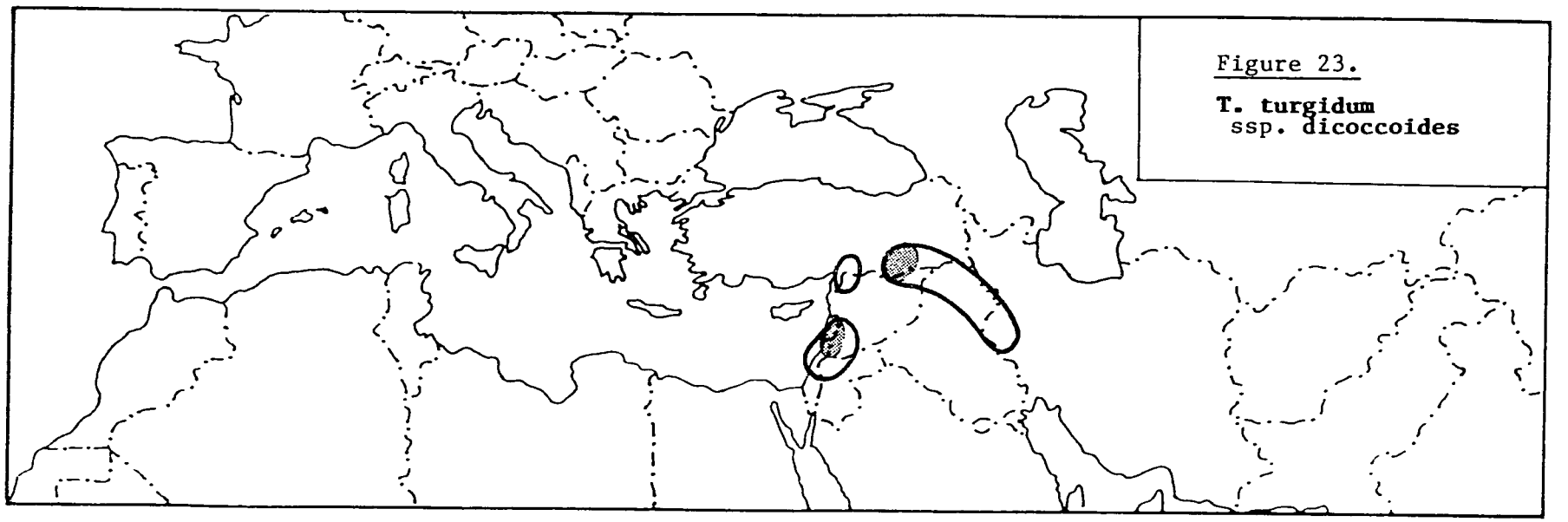


Figure 23.

T. turgidum ssp. dicoccoides

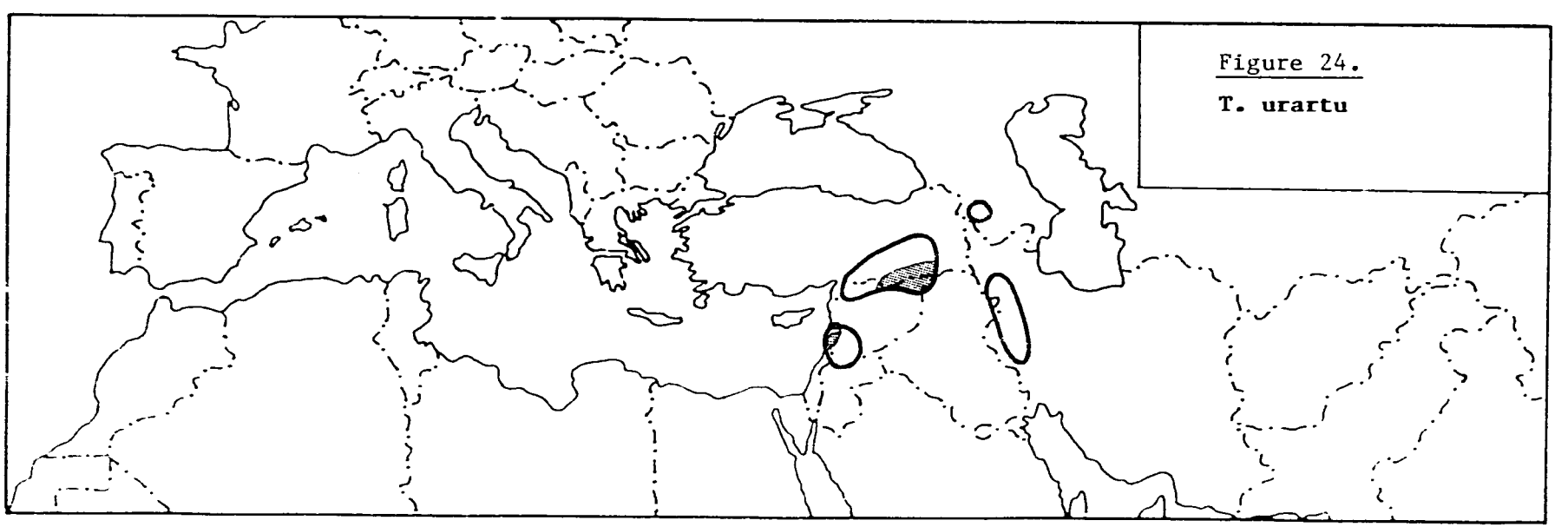


Figure 24.

T. urartu