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Soybean [*Glycine max* (L.) Merr.] is the leading oilseed crop produced and consumed in the world today. A native of Asia, the soybean was introduced into North America, Europe, then into South and Central America (Hymowitz, 2004, this publication). In each of these production areas, soybean has become a major economic crop.

Current world production of soybean far exceeds that of any other edible oilseed (Plate 1-1). The 176 million megagrams (Mg) of soybean produced in 2001 is 35% of the world total oilseed production. Oil palm (*Elaies guineensis* Jacq.) is second, with 26% of world oilseeds, and coconut (*Cocos nucifera* L.) comprises 10% of world production. Peanut (*Arachis hypogaea* L.), cottonseed (*Gossypium hirsutum* L.), and rapeseed (*Brassica napus* L.) each make up about 7% of world oilseeds. Sunflower (*Helianthus annuus* L.) is about 4%, and olive (*Olea europaea* L.) about 3% of world oilseed production.

Soybean has been the dominant oilseed produced since the 1960s (Smith and Huyser, 1987). Since 1985, world soybean production has increased by 75 million Mg (Plate 1-1). During this time, oil palm production has increased 90 million Mg, rapeseed production 15 million Mg, peanut production 15 million Mg, coconut production 12 million Mg, and sunflower about 8 million Mg. Cottonseed and sesame (*Sesamum indicum* L.) seed production have remained relatively unchanged since 1985.

### 1-1 WORLD SOYBEAN PRODUCTION

About 50 countries in the world grow soybean (Table 1-1). During the past half century, the USA has been the world's leading producer and, in 2000/2001, produced about 77 million Mg of soybean, or 45% of the world total (Plate 1-2). The two largest producers in South America are Brazil, with 35 million Mg (21% of world total) produced on 14 million ha, and Argentina with about 23 million Mg (14% of world total) produced on 9 million ha. The People's Republic of China, with 15 million Mg, (9% of world total) and India, with 5 million Mg, are the two largest soybean producers in Asia and the Middle East. Italy, with 0.9 million Mg, was the largest soybean producer in the European Union. The Russian Federation, with 0.3, and Yugoslavia, with 0.2 million Mg, produced most of the soybean in Eastern Europe.

Table 1-1. World soybean production in specified countries, 2000/2001.†

Country	Area	Yield	Production
	1 000 ha	Mg	1 000 Mg
North and Central America			
Canada	1 035	2.29	2 372
Guatemala	10	3.06	30
Mexico	72	1.66	119
Nicaragua	6	2.22	14
United States	29 423	2.61	76 862
South America			
Argentina	9 478	2.47	23 472
Bolivia	568	1.81	1 033
Brazil	13 788	2.55	35 205
Columbia	21	2.23	47
Ecuador	69	1.67	116
Paraguay	1 193	2.75	3 283
Uruguay	10	1.59	17
Europe			
Austria	16	2.10	33
Croatia	49	1.84	90
Hungary	26	1.78	48
France	99	2.57	254
Italy	246	3.65	894
Romania	54	1.42	70
Russian Federation	373	0.83	302
Ukraine	66	1.05	68
Yugoslavia	116	1.88	200
Africa			
Congo	25	0.48	24
Ethiopia	7	3.57	25
Nigeria	588	0.73	429
Rwanda	28	0.57	16
South Africa	111	1.57	173
Uganda	116	1.13	132
Zambia	13	2.31	30
Zimbabwe	62	2.13	132
Asia and the Middle East			
Burma	69	0.90	62
Cambodia	32	1.05	33
China, People's Republic of	9 003	1.72	15 431
India	6 076	0.88	5 342
Indonesia	774	1.21	940
Iran	90	1.56	140
Japan	124	1.92	238
Korea, Democratic People's	310	1.13	350
Korea, Republic of	82	1.41	115
Myanmar	111	0.95	105
Nepal	20	0.85	17
Thailand	228	1.43	324
Turkey	25	2.13	50
Viet Nam	127	1.20	153
Oceania			
Australia	55	1.89	104
World total	74 821	2.26	168 934

† Data from Food and Agricultural Organization of the United Nations, FAO Statistical tables, Agriculture, 2002.

### 1-1.1 Soybean Production in the USA

Soybean is grown in the eastern half of the North America, from coastal areas of the Gulf of Mexico north to southern Canada (Plate 1-3). These areas have adequate moisture to successfully produce the crop. Soybean production extends west in the USA to the Dakotas, Nebraska, Kansas, Oklahoma, and Texas. The western margins of profitable soybean production in these states have been extended with the use of irrigation.

Soybean is grown as a full-season, spring seeded crop throughout its production area in the USA. From 6 to 9% of the soybean hectareage is planted as a second crop, following winter wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), or winter canola, south of 35°N lat. The area planted to double crop soybean increases progressively farther south of 35°N. lat. In these areas, soybean is typically seeded in late June or early July, following fall seeded crops that are harvested in mid-June to early July. Early harvesting of high-moisture winter wheat increases successful production of soybean as a second crop.

Soybean production in the USA increased by 49% since 1985, from 51 to 76 million Mg (Table 1-2). During this time, area planted to soybean increased only 14%, from 25.6 to 29.3 million ha. Seed yields for the entire country increased 28%, from 1.98 to 2.53 Mg ha<sup>-1</sup>. Leading soybean-producing states are Iowa (13.0 million Mg), Illinois (12.4 million Mg), Minnesota (7.9 million Mg), and Indiana (6.9 million Mg), all in the North-Central USA.

Soybean production in all the North-Central states averaged 67 million Mg during 2000/2002, about 82% of the total for the USA (Table 1-2). This is a change from 15 yr ago when North-Central states produced 71% of the U.S. soybean crop. Since 1985, soybean production decreased in all the southern states except Arkansas and Oklahoma. The decrease in production was due primarily to a decrease in area planted to soybean, from 7.6 million ha in 1983/1985 to 3.7 million ha in 2000/2002.

Production increased in all the North-Central states, with the greatest increases in Iowa, Illinois, Minnesota, Nebraska, and South Dakota (Table 1-2). The increased production is due to increases in both area planted and yields per unit area. States with the greatest increases in area planted are South Dakota (1264 thousand ha), Iowa (1044 thousand ha), Nebraska (970 thousand ha), Minnesota (864 thousand ha), and Illinois (586 thousand ha). Those states with the greatest increases in seed yields since 1985 are Kentucky (0.72 Mg ha<sup>-1</sup>), Missouri and Nebraska (0.69 Mg ha<sup>-1</sup>), and Indiana and Iowa (0.65 Mg ha<sup>-1</sup>).

### 1-1.2 Soybean Production in Brazil

Brazil is the second largest soybean producer in the world, and the largest producer in South America. Initially introduced into southern Brazil, the soybean opened the Cerrados to agriculture, and more recently contributed to an expanding agriculture in the Northeast (Portugal, 1999). Soybean was first produced on a commercial scale in the state of Rio Grande do Sul, using adapted U.S. cultivars. Production in Brazil increased from 0.5 million Mg in 1964/1965 to 31 million Mg in 1998/1999. During this time, seed yields increased from 1.20 to 2.40 Mg ha<sup>-1</sup>. Initially, production was confined to the southern states of Rio Grande do Sul, Santa

Table 1-2. Area, yield, and production of soybean by states in the USA, mean of 1983/1985 and 2000/2002.†

State	Area harvested		Yield		Production	
	1983/1985	2000/2002	1983/1985	2000/2002	1983/1985	2000/2002
	— 1 000 ha —		— Mg —		— 1 000 Mg —	
<b>Northern states</b>						
Delaware	100	82‡	1.86	2.33	186	193
Illinois	3 652	4 238	2.32	2.91	8 477	12 367
Indiana	1 721	2 259	2.40	3.05	4 155	6 890
Iowa	3 306	4 350	2.34	2.99	7 744	13 029
Kansas	610	1 056	1.44	1.70	870	1 814
Kentucky	557	484	1.79	2.51	986	1 216
Maryland	163	207	1.95	2.31	319	480
Michigan	447	823	2.05	2.33	912	1 913
Minnesota	2 002	2 866	2.20	2.76	4 401	7 900
Missouri	2 115	1 962	1.68	2.37	3 560	4 673
Nebraska	942	1 912	2.03	2.72	1 909	5 225
New Jersey	53	39	1.97	2.15	105	84
New York	--	60	--	2.15	--	129
North Dakota	237	858	1.70	2.23	400	1 920
Ohio	1 473	1 840	2.46	2.58	3 661	4 741
Pennsylvania	67	156	2.11	2.35	144	369
South Dakota	488	1 752	1.83	2.17	890	3 818
Wisconsin	154	606	2.20	2.67	339	1 614
<b>Southern states</b>						
Alabama	526	57	1.52	1.77	786	102
Arkansas	1 538	1 201	1.59	2.07	2 449	2 479
Florida	117	4	1.68	1.08	196	5
Georgia	749	59	1.46	1.64	1 082	97
Louisiana	964	299	1.67	2.02	1 626	596
Mississippi	1 203	556	1.57	1.99	1 874	1 090
North Carolina	693	540	1.55	1.94	1 077	1 051
Oklahoma	86	111	1.32	1.39	113	155
South Carolina	560	173	1.27	1.41	708	244
Tennessee	712	446	1.64	2.04	1 134	908
Texas	151	98	1.71	1.81	260	178
Virginia	275	192	1.58	2.13	442	410
West Virginia	--	6	--	1.99	--	13
<b>USA</b>	<b>25 662</b>	<b>29 296</b>	<b>1.98</b>	<b>2.53</b>	<b>50 809</b>	<b>75 711</b>

† Data from USDA, NASS, 2002.

‡ Values in italics indicate a decline in mean value from 1983/1985 to 2000/2002.

Catarina, Parana, and Sao Paulo. The use of U.S. cultivars, adapted to production in the southern USA, limited successful production to these areas. New cultivars were developed that were adapted to production in lower latitudes. During the 1980s, production expanded in the Cerrado area of the states of Minas Gerais, Mato Grosso do Sul, Mato Grosso, Goias, Bahia, and Maranhao.

The use of improved production technology has contributed to the expansion of profitable soybean production in Brazil. Empresa Brasileira de Pesquisa Agropecuaria (Embrapa) scientists have developed cultivars with increased yield potential, with resistance to pathogens that limited yields, and that are adapted to tropical production areas. The use of reduced tillage, correction of soil acidity, and improved seed quality have all contributed to increased productivity.

### 1-1.3 Soybean Production in Argentina

Argentina is the second largest producer of soybean in South America. The first planting of soybean in Argentina was in 1862 (Larreche and Firpo Brenta, 1999). During the 1970s, when soybean hectareage expanded rapidly, there was a marked increase in production. Production increased rapidly subsequent to the 1970s, from 1.4 million Mg in 1976/1977 to 19.9 million Mg in 1998/1999. Soybean cultivars in Maturity Groups III to IX, depending upon latitude, are grown from 23 to 39°S lat. Most of the production (85%) is in the Pampean provinces of Sante Fe, Cordoba, and Buenos Aires.

About 65% of the soybean produced in Argentina is grown as a full-season crop, the remaining 35% is double cropped with wheat. Most of the seeding is done using minimum or no tillage. Soybean is commonly rotated with corn (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench], grassland, peanut, and less commonly with sunflower, oat (*Avena sativa* L.), and flax (*Linum usitatissimum* L.).

Factors that contributed to increased soybean production in Argentina are the end of an export ban on oilseeds in the mid-1970s, and exemptions of soybean from an export tax in the early 1990s. This gave producers access to increasing international prices. The adoption of double-cropping soybean after wheat, and the use of minimum and no-tillage production systems also contributed to increases in productivity. Investments in storage and transportation systems, including updating port structures and road and railway networks provided the infrastructure essential to successfully market the crop.

### 1-1.4 Soybean Production in China

China has always been the major producer of soybean in Asia. Soybean production in China increased from 7.5 million Mg in 1978 to 15 million Mg in 1999 (Lu and Wang, 1999). Yields increased from 1.06 Mg ha<sup>-1</sup> in 1978 to 1.83 Mg ha<sup>-1</sup> in 1999. The largest production areas in China are in the provinces of Heilongjiang, Liaoning, and Inner Mongolia. Soybean is spring seeded in these areas and grown as a full-season crop. Production in these areas is about 45% of the total for the country. About 30% of the soybean crop is produced in the provinces of Henan, Shandong, Hebei, and Anhui, where soybean is seeded in the summer as a second crop following winter wheat. About 25% of the crop is produced in southern China, south of the Yangtze River. Here, soybean may be seeded in the spring, or in the summer or fall following a rice crop.

Increases in soybean yields are attributed to improved cultivars, increased application of fertilizers, better pest control, and improved cultural practices. Mechanized tillage is practiced on about 40% of the soybean production area. Machine harvesting is done on only about 20% of the soybean area. Domestic consumption of soy foods is increasing as the standard of living of the Chinese increases.

### 1-1.5 Soybean Production in India

India ranks second in soybean production in Asia, and fifth in world production. The rapid expansion of soybean hectareage and increase in production oc-

curred since the 1980s (Paroda, 1999). In 1969, only 3000 ha of soybean were grown. From 1970/1971 to 1980/1981, area increased from 0.03 to 0.61 million ha. During the next decade, area increased to 2.56 million ha, and by 1998/1999 to 6.3 million ha. Total production increased from 0.44 million Mg in 1980/1981 to the current 6 million Mg in 1998/1999. Predominant soybean-growing states are Madhya Pradesh, Maharashtra, and Rajasthan.

Initial large-scale production of soybean in India during the 1960s was based on southern U.S. cultivars, including Bragg, Lee, etc., that were adapted to production areas in India. The rapid expansion of soybean area in the 1970s was due to increased research and development, the establishment of soybean oil extraction plants in central India, and the availability of fallow land during the rainy season.

Soybean is generally grown as a rainy season crop under normal rainfall conditions. Soybean is grown as a single crop following wheat or chickpea (*Cicer arietinum* L.), or in a multiple cropping system of soybean/wheat/chickpea. Inter-cropping soybean with corn, sorghum, sugarcane (*Saccharum officinarum* L.), and millet [*Pennisetum americanum* (L.) K. Schum] have become profitable production systems. Soybean has replaced some less profitable crops, including sorghum and some millets, and in some areas is replacing cotton.

Of the 6 million Mg of soybean produced, 5% is used for food and feed, 10% for seed, and 85% for oil extraction. Soybean contributes about 8% of the edible oil consumed in India. Most of the meal is exported. Efforts are underway to in-

Table 1-3. Soybean exports and imports by selected areas and countries, 2-yr means, 1985/1986 to 1999/2000.

Country or area	1985/ 1986	1987/ 1988	1989/ 1990	1991/ 1992	1993/ 1994	1995/ 1996	1997/ 1998	1999/ 2000
1 000 Mg								
<b>Exports</b>								
North and Central America	19 623	19 818	15 524	18 985	19 262	24 966	24 087	25 997
USA	19 472	19 614	15 328	18 746	18 819	24 400	23 380	25 171
Canada	151	204	196	239	440	565	704	824
South America	5 820	5 788	7 688	7 709	8 873	7 476	12 710	15 958
Argentina	2 774	1 740	1 831	3 774	2 669	2 302	1 666	3 594
Bolivia	8	23	74	92	130	238	208	198
Brazil	2 346	2 810	4 348	2 873	4 792	3 570	8 808	10 217
Paraguay	670	1 176	1 406	943	1 274	1 364	2 024	1 922
Europe	129	320	336	484	629	610	1 644	1 463
Belgium-Luxembourg	12	46	26	26	26	51	76	26
France	2	32	22	14	18	33	28	22
Italy	<1	8	25	44	2	6	30	10
Netherlands	100	204	234	320	462	404	1 267	1 190
Romania	<1	<1	<1	<1	<1	<1	42	41
Russian Federation	--	--	--	22	42	60	75	32
Asia	1 338	1 704	1 190	978	646	367	271	375
China	1 252	1 594	1 094	884	602	284	178	208
India	8	3	1	<1	<1	1	6	42
Malaysia	2	4	6	13	14	17	19	51
Viet Nam	42	49	36	26	3	41	38	38
World total	26 913	27 634	24 746	28 162	29 452	33 434	38 762	43 836

(continued on next page)

crease the development and acceptance of soy-based food products. This would increase the domestic consumption of soybean as a rich source of protein.

## 1-2 WORLD TRADE IN SOYBEAN, SOYBEAN OIL, AND SOYBEAN MEAL

### 1-2.1 World Trade in Soybean

Soybean is a major commodity traded in world markets (Sonka et al., 2004, this publication). Of the 170 million Mg of soybean produced in 2000/2001, about 44 million Mg, or 24% of the crop enters world trade. The major soybean-producing countries are also the main exporters of soybean (Table 1-3). The USA is the leading exporter of soybean, followed by Brazil, Argentina, and Paraguay.

Table 1-3. Continued.

Country or area	1985/ 1986	1987/ 1988	1989/ 1990	1991/ 1992	1993/ 1994	1995/ 1996	1997/ 1998	1999/ 2000
1 000 Mg								
<b>Imports</b>								
North and Central America	1 485	1 466	1 571	2 301	2 904	3 148	4 138	4 864
Canada	196	154	233	114	132	87	189	406
Mexico	1 160	1 080	1 004	1 795	2 334	2 640	3 450	4 026
USA	--	--	--	--	143	114	222	118
South America	506	668	162	602	836	1 301	2 268	1 689
Brazil	234	273	40	378	544	908	1 139	694
Columbia	87	198	49	100	155	188	190	256
Venezuela	164	172	65	103	122	188	179	166
Europe	14 220	14 936	13 536	14 868	14 120	16 121	16 973	17 046
Belgium-Luxembourg	1 402	1 422	1 092	1 266	1 141	1 233	1 351	1 225
Finland	134	174	144	146	125	159	166	138
France	569	528	325	451	508	704	680	524
Germany	3 002	3 087	2 629	3 044	3 192	2 822	3 283	4 029
Greece	148	184	256	280	293	227	272	264
Italy	1 412	849	719	930	1 350	1 082	811	767
Netherlands	2 853	3 578	3 540	3 994	3 530	4 856	5 150	5 128
Norway	303	299	294	234	112	316	283	387
Portugal	843	870	786	735	581	802	575	613
Romania	310	372	246	199	74	81	42	8
Russian Federation	--	--	--	117	158	33	7	124
Spain	2 173	2 390	2 374	2 488	2 068	2 589	2 950	2 804
United Kingdom	592	625	692	634	686	834	1 007	837
Yugoslavia	224	254	219	100	55	68	105	48
Asia	8 751	9 375	8 950	9 804	10 692	12 080	14 938	21 138
China	1 750	2 240	1 901	2 157	2 489	3 337	5 414	9 697
Indonesia	330	376	466	684	763	677	480	1 290
Israel	432	402	374	412	523	468	547	586
Japan	4 864	4 741	4 514	4 528	4 881	4 842	4 904	4 856
Korea, Republic of	927	1 072	1 035	1 170	1 158	1 469	1 491	1 466
Malaysia	229	322	423	533	490	441	482	565
Thailand	0	16	2	96	72	311	778	1 164
Africa	55	74	92	174	268	356	412	450
World total	26 462	27 978	25 034	28 195	28 876	33 094	38 769	45 199

† Data from Food and Agricultural Organization of the United Nations, 1988 to 1998 and 2002.

Exports of soybean have changed since 1985. In 1985/1986, U.S. exports were 72% of the world total, and exports from South America represented 22% of the world total. Since then, South America has gradually increased soybean exports, and these now represent 36% of the world total. Brazil and Argentina account for 23 and 8%, respectively, of current world soybean exports. In recent years, exports from the USA have increased, but not as rapidly as those from South America, and now are 57% of the world total. Asian exports, primarily from China, have decreased from 1.3 million Mg in 1985/1986 to 0.2 million Mg in 1999/2000.

Soybean has been exported primarily to Europe and Asia. European imports have increased slightly, from 14.2 million Mt in 1985/1986 to 17.0 million Mt in 1999/2000. Imports have been relatively stable among the European countries during this period.

Imports of soybean into Asia have increased considerably since 1985, from 8.8 million Mg in 1985/1986 to 21.1 million Mg in 1999/2000. Japanese imports have been relatively stable, at about 4.9 million Mg, during this period. China has shown the greatest increase in imports of the Asian countries. Chinese imports increased from 1.8 million Mg in 1985/1986 to 9.7 million Mt in 1999/2000. During this same period, Chinese soybean exports decreased from 1.2 to 0.2 million Mg. Thailand became a significant importer of soybean, increasing imports from 0 to 1.2 million Mg since 1985.

Mexico has become the largest soybean importer in the Americas, with imports increasing from 1.2 to 4.0 million Mg from 1985/1986 to 1999/2000.

World trade in soybean has been affected by the widespread production of transgenic soybean cultivars (Parrott and Clemente, 2004, this publication). Currently, about 68% of the U.S. soybean hectareage is planted to soybean resistant to glyphosate, a herbicide with wide spectrum weed control. Glyphosate resistance was incorporated into soybean using genetic transformation, and this genetic modification resulted in widespread concerns about the nutritional value of transgenic soybean cultivars. Most of the soybean grown in the USA and Argentina are glyphosate resistant, and the decrease in exports from these countries in 1997/1998 may be a reflection of concerns about consuming transgenic soybean (Table 1-3.). Current trends indicate that the reluctance to import and consume transgenic soybean with glyphosate resistance have been alleviated.

### 1-2.2 World Trade in Soybean Oil and Meal

Argentina and Brazil are the two largest exporters of soybean oil, followed by the USA (Table 1-4). Asian countries are the largest importers of soybean oil, with China, India, and Iran the major importers. European countries, with alternative sources of edible oil, imported much less soybean oil than Asian countries. African countries, including Egypt, Morocco, and Tunisia, have increased soybean oil imports significantly over the past 15 yr.

The major soybean-producing countries are the major exporters of soybean meal (Table 1-5). North and South America combined, export nearly 80% of the world's soybean meal. Europe, Germany, and the Netherlands, major importers of soybean, are the leading exporters of soybean meal. India has replaced China as the primary exporter of soybean meal in Asia.

Europe is the major importer of soybean meal, utilizing about half of the world's imports. France has consistently been the largest European importer over the past 15 yr. Other large soybean meal importers in Europe include Belgium-Luxembourg, Denmark, Germany, Italy, and Spain. Soybean meal in Europe is used primarily in livestock rations.

Asia is second to Europe as the largest soybean meal importer. China and Thailand are the largest soybean meal importers in Asia. Indonesia, Japan, and the Republic of Korea, the Philippines, and Thailand have each increased imports to about 1000 Mg of soybean meal annually. Canada and Mexico are the major importers of soybean meal in North and Central America.

### 1-3 WORLD PRODUCTION TRENDS

Modest increases in soybean production can be expected in the USA over the next 10 yr. Eighty-seven percent of the U.S. crop is produced in the North-Central states. In this area, corn and soybean are typically alternated in a 2-yr rotation on the same land. Because corn is an important grain crop in the North-Central states, it is not anticipated that soybean will replace corn, but that the corn-soybean sequence will continue. Area planted to soybean in the North-Central states was about 21 million ha, slightly less than the 22 million ha planted to corn. This suggests only a 5% potential increase for soybean acreage in the corn-soybean rotation. There are limited opportunities for soybean to replace other major crops in this area.

Area planted to soybean in the southern USA has decreased about 3 million ha since 1985. If this area were again planted to soybean, it would represent about a 10% increase in total U.S. soybean area of production.

Area of soybean production in China is expected to increase very slightly, to about 9 million ha over the next 10 to 20 yr (Lu and Wang, 1999). Land resources that could be committed to soybean are extremely limited. Yields per hectare are anticipated to increase to 2.00 to 2.40 Mg ha<sup>-1</sup>, for a total production of about 20 million Mg. Soybean production will be consumed domestically, to meet increasing demand for soy foods and livestock feeds.

Soybean area in Argentina is expected to increase to 8 million ha by 2010 (Larache and Firpo Brenta, 1999). Use of improved cultural practices could increase yields to an estimated 3.10 Mg ha<sup>-1</sup> by the year 2005. It is anticipated that much of the increased production will be exported.

Brazil has the greatest potential in the world for increased soybean production (Portugal, 1999). The Cerrados, or savannas, has a potential 80 million ha of land that can be used for grain production. Successful expansion of soybean into this area is dependent upon several factors. These include (i) growth in national income in major importing countries, (ii) the construction of crushing plants, and location of these plants, (iii) availability and price of competing vegetable oil products, (iv) the production in, and government policies of, major competing countries, and (v) improvement of transportation and storage facilities, with decreased costs. Currently, most of the Brazilian soybean crop is exported, and this trend is expected to continue.

Table 1-4. Soybean oil exports and imports by selected areas and countries, 2-yr means, 1985/1986 to 1999/2000.†

Country or area	1985/ 1986	1987/ 1988	1989/ 1990	1991/ 1992	1993/ 1994	1995/ 1996	1997/ 1998	1999/ 2000
1 000 Mg								
<b>Exports</b>								
North and Central America	564	759	629	609	788	865	1 267	794
USA	558	756	622	602	748	799	1 218	732
Canada	6	2	2	4	17	28	33	38
South America	1 306	1 718	1 764	1 961	2 692	3 106	3 542	4 550
Argentina	622	868	903	1 283	1 437	1 403	2 110	2 998
Bolivia	<1	1	6	8	19	56	92	128
Brazil	676	834	843	616	1 140	1 548	1 243	1 312
Paraguay	10	15	14	54	94	97	96	95
Europe	1 315	1 302	1 199	1 229	982	1 216	1 570	1 670
Belgium-Luxembourg	180	163	159	138	110	106	179	114
France	95	66	66	98	62	99	91	60
Germany	212	212	176	189	188	205	358	454
Greece	38	33	24	17	18	12	12	16
Italy	78	53	74	121	60	25	28	33
Netherlands	304	353	418	426	356	422	479	492
Portugal	90	36	19	30	22	73	63	43
Spain	288	330	218	178	114	219	270	214
Asia	61	184	161	132	236	445	1 024	605
China	1	6	17	8	46	113	373	46
Indonesia	--	--	31	23	32	6	14	<1
Iran	--	--	--	--	8	108	118	218
Malaysia	28	62	34	38	68	107	152	158
Singapore	19	98	65	50	48	54	33	32
World total	3 248	3 966	3 755	3 938	4 702	5 638	7 408	7 632

(continued on next page)

The area planted to soybean is expanding in India, and is expected to increase to 10 million ha by the year 2010 (Parada, 1999). Yields are expected to increase from the current 1.25 to 1.5 Mg ha<sup>-1</sup> by 2010. Soybean oil is largely consumed domestically, with the meal exported. Domestic consumption of soybean and soy products is likely to increase during the next 10 yr.

#### 1-4 POTENTIAL CHANGES IN SEED YIELDS

World average soybean yields were 1.83 Mg ha<sup>-1</sup> for the period 1983/1985 and 2.26 Mg ha<sup>-1</sup> for the period 1997/1999. This is a yield increase of 0.425 Mg ha<sup>-1</sup> over a 15-yr period, or 0.028 Mg ha<sup>-1</sup> yr<sup>-1</sup>. If this rate of yield increase can be sustained, it would make a major contribution to world soybean production over the next 10 yr.

Estimates of U.S. seed yield increases for soybean during the past 60 yr provide optimistic evidence for continued increases in productivity for the future. Specht et al. (1999) determined that soybean yields in the USA have increased 0.0232 Mg ha<sup>-1</sup> yr<sup>-1</sup> from 1924 to 1997. Rates of yield improvement of publicly developed elite

Table 1-4. Continued.

Country or area	1985/ 1986	1987/ 1988	1989/ 1990	1991/ 1992	1993/ 1994	1995/ 1996	1997/ 1998	1999/ 2000
1 000 Mg								
<b>Imports</b>								
North and Central America	190	336	220	277	321	388	430	480
Dominican Rep.	42	62	76	85	81	82	95	106
Mexico	43	57	68	61	82	73	101	110
USA	21	156	15	1	36	56	28	41
South America	413	310	295	440	651	627	774	708
Brazil	152	52	30	95	200	186	187	132
Chile	56	32	56	69	97	93	77	48
Columbia	56	43	37	32	71	103	117	144
Ecuador	29	18	27	37	36	43	63	61
Peru	43	74	45	80	108	74	162	99
Venezuela	68	84	94	119	133	125	159	216
Europe	733	718	731	862	722	626	867	1 050
Belgium-Luxembourg	59	66	87	105	78	83	135	226
Denmark	37	40	45	50	32	36	37	30
France	85	73	72	74	69	65	64	44
Germany	144	138	148	142	126	103	45	50
Netherlands	39	35	36	25	19	21	143	124
Poland	46	52	41	52	93	74	107	86
Russian Federation	--	--	--	224	30	22	76	283
Sweden	66	72	82	66	52	37	29	27
United Kingdom	127	168	106	145	79	72	82	28
Asia	1 356	2 014	2 013	1 540	2 032	3 278	3 921	3 962
Bangladesh	60	226	186	262	145	426	484	670
China	108	279	478	278	579	1 398	1 063	604
Egypt	18	16	<1	<1	39	94	66	176
India	303	348	28	42	34	61	243	596
Iran	430	295	600	334	542	478	378	760
Korea, Republic of	<1	<1	5	34	22	49	61	136
Malaysia	2	56	37	27	24	50	118	98
Pakistan	217	375	364	216	222	199	222	267
Singapore	24	109	36	48	58	69	44	53
Turkey	92	164	145	137	185	124	159	163
Africa	315	334	337	420	722	666	669	940
Algeria	<1	1	3	55	178	59	41	12
Egypt	18	19	1	--	39	94	66	176
Morocco	96	98	109	119	168	157	142	272
Senegal	8	1	<1	1	33	32	83	90
Tunisia	52	63	86	81	129	126	131	134
World total	3 218	3 884	3 848	3 678	4 416	5 642	6 706	7 178

† Data from Food and Agricultural Organization of the United Nations, 1988 to 1998 and 2002.

breeding lines in the northern USA averaged 0.030 Mg ha<sup>-1</sup> yr<sup>-1</sup>, or about 1% per year over a 60-yr period (Wilcox, 2001). Data from various studies demonstrated that rates of yield increases have been greater in recent than in earlier years, indicating no yield plateaus have been reached in the genetic improvement of yield potential (Specht et al., 1999; Voldeng et al., 1997; Wilcox, 2001).

Table 1-5. Soybean meal exports and imports by selected areas and countries 2-yr means 1985/1986 to 1999/2000.†

Country or area	1985/ 1986	1987/ 1988	1989/ 1990	1991/ 1992	1993/ 1994	1995/ 1996	1997/ 1998	1999/ 2000
1 000 Mg								
<b>Exports</b>								
North America	5 339	6 156	4 513	5 550	4 631	5 200	7 130	6 126
USA	5 337	6 127	4 468	5 473	4 549	5 099	7 041	6 030
Canada	1	11	1	28	25	45	63	61
South America	10 860	12 369	14 385	14 555	17 035	18 728	20 828	23 922
Argentina	2 974	4 294	4 761	6 251	6 646	6 656	9 732	13 010
Bolivia	17	23	68	99	110	267	463	590
Brazil	7 782	7 965	9 027	8 019	10 029	11 413	10 230	9 910
Paraguay	82	78	62	177	250	370	400	389
Europe	4 406	4 303	3 935	3 532	4 306	4 262	5 130	5 475
Belgium-Luxembourg	1 033	844	786	696	907	793	989	966
France	12	16	12	9	8	12	33	44
Germany	1 148	1 300	869	1 074	1 078	968	1 376	1 218
Italy	128	100	75	84	42	24	26	140
Netherlands	1 541	1 703	1 733	1 918	2 038	2 138	2 267	2 550
Norway	151	147	132	135	67	177	148	152
Portugal	164	101	99	96	27	18	13	54
Spain	193	31	15	12	24	44	130	145
Asia	1 624	2 704	2 980	3 178	3 131	3 329	2 999	2 562
China	1 045	2 060	1 885	1 508	758	485	19	21
India	531	592	854	1 645	2 343	2 787	2 852	2 328
World total	22 274	25 194	26 220	27 460	29 186	31 588	35 114	38 108
<b>Imports</b>								
North and Central America	1 085	1 217	1 364	1 628	1 722	1 819	1 746	2 008
Canada	586	652	571	621	688	748	744	819
Cuba	202	173	223	186	227	229	212	176
Dominican Republic	64	89	101	146	215	240	254	330
Guatemala	30	47	42	44	56	93	114	144
Mexico	70	137	303	402	293	216	79	225
South America	609	1 032	505	803	946	1 359	1 904	2 136
Brazil	--	--	--	--	<1	64	238	88
Chile	29	53	52	117	127	203	318	462
Columbia	4	6	1	54	197	349	436	426
Ecuador	--	1	2	8	4	37	139	140
Peru	72	153	75	93	156	225	277	442
Venezuela	504	814	374	525	435	447	452	526

(continued on next page)

## 1-5 SUMMARY

Soybean is the major oilseed produced and consumed in the world today. The USA is currently the largest producer of soybean, followed by Brazil, Argentina, the People's Republic of China, and India. Production in the USA is primarily in the North-Central states, where the highest seed yields are attained. The largest producing countries export the greatest amounts of soybean, meal, and oil. Europe and Asia are the major importers of soybean, soy meal, and soy oil.

Production potential for soybean in the future should easily meet demands for soy products. Brazil is the country with the greatest potential for expanding area

Table 1-5. Continued.

Country or area	1985/ 1986	1987/ 1988	1989/ 1990	1991/ 1992	1993/ 1994	1995/ 1996	1997/ 1998	1999/ 2000
1 000 Mg								
<b>Imports</b>								
Europe	17 856	17 059	16 208	16 073	18 440	17 848	17 850	21 625
Austria	475	467	447	461	455	443	493	474
Belgium-Luxembourg	884	721	811	731	1 071	1 025	1 122	1 320
Bulgaria	390	487	319	123	68	74	52	54
Czechoslovak	413	455	264	400	300	395	404	438
Denmark	1 317	1 318	1 254	1 323	1 432	1 459	1 454	1 554
France	3 616	3 322	3 232	3 492	3 619	3 482	3 550	4 082
Germany	3 367	2 928	2 641	2 194	1 951	1 669	1 814	1 904
Hungary	610	636	649	405	446	527	608	676
Ireland	189	179	182	205	292	279	311	282
Italy	1 396	1 408	1 248	1 425	1 695	1 857	1 849	2 220
Netherlands	1 571	1 198	1 085	852	1 251	1 161	572	1 610
Poland	898	1 051	755	480	506	793	842	868
Romania	64	50	32	183	203	214	131	95
Russian Federation	--	--	--	--	496	92	118	284
Spain	1 115	1 134	1 324	1 653	1 927	1 707	1 742	2 474
Sweden	136	166	150	114	192	292	279	333
United Kingdom	1 205	1 221	1 126	1 292	1 456	1 497	1 354	1 452
Asia	2 116	2 983	3 313	4 746	5 588	7 726	11 022	9 558
China	4	8	47	130	130	973	3 607	587
Indonesia	241	165	60	182	430	812	769	1 084
Iran	243	306	338	481	457	653	446	440
Japan	182	405	542	870	860	795	839	812
Korea Rep.	117	319	466	562	654	1 070	831	1 142
Malaysia	164	157	141	251	383	582	533	584
Philippines	295	457	581	635	739	665	942	806
Saudi Arabia	170	271	248	312	362	432	542	524
Thailand	349	233	256	531	751	740	1 230	1 315
Turkey	2	42	66	235	240	282	378	530
Africa	815	941	1 023	900	1 026	1 040	1 540	2 040
Algeria	229	363	408	288	242	216	222	332
Egypt	280	264	218	294	415	372	590	858
South Africa	53	42	126	73	91	185	359	394
Tunisia	53	70	125	134	147	147	219	250
World total	22 902	26 189	25 814	27 089	27 864	30 007	34 211	37 461

†Data from Food and Agricultural Organization of the United Nations, 1988 to 1998 and 2002.

of soybean production. Seed yields of soybean have increased about 1% per year in major soybean-producing countries. There is no indication that this rate of increase will decrease in the future.

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## 2

Vegetative Morphology<sup>1</sup>

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The soybean [*Glycine max* (L.) Merr.] is an annual plant 75 to 125 cm in height (Shibles et al., 1974). It may be sparsely or densely branched, depending on cultivar and growing conditions. First-order branching of the main stem is most common; second-order branching is rare (Dzikowski, 1936). Intrinsic genetic factors and environmental effects (e.g., daylength, spacing, and soil fertility) affect branching. The possible branching variations are shown in Fig. 2–1.

The root system is best described as diffuse. It consists of a taproot, which usually cannot be distinguished from other roots of similar diameter, and a large number of secondary roots which in turn support several orders of smaller roots. In addition, multibranched adventitious roots emerge from the lower portion of the hypocotyl. The first bacterial root nodules are visible about 10 d after planting and at maturity the root system is extensively nodulated (Fig. 2–2).

The horizontal and vertical extent of the root system varies depending on cultural conditions. The taproot may reach a depth of 200 cm, and the side roots a length of 250 cm, in plants grown singly in an open field (Dzikowski, 1936), but the root system is less extensive under typical competitive conditions in field plantings. Mitchell and Russell (1971) and Raper and Barber (1970) showed that soybean grown under normal field conditions lacks a distinct taproot. Most lateral roots emerge from the upper 10 to 15 cm of the taproot and remain more-or-less horizontal but some extend obliquely to a depth of 40 to 75 cm, then turn steeply downward, sometimes reaching 180 cm. In the confined area of a rhizotron compartment, varieties differed in rates of growth, but all produced roots capable of reaching the bottom (217 cm) of each compartment (Kaspar et al., 1978). Under almost all conditions, however, most of the roots remained in the upper 15 cm of soil.

There are disadvantages to all extant methods of estimating the total root system (Bohm et al., 1975). An accurate three-dimensional reconstruction of the root system as it exists in the soil is perhaps impossible to attain.

<sup>1</sup> This chapter is reprinted from Chapter 3 of *Soybeans: Improvement, Production, and Uses*, 2nd ed. 1987.