CHAPTER 4

PRODUCTION, REGIONAL DISTRIBUTION OF CULTIVARS, AND AGRICULTURAL ASPECTS OF SOYBEAN IN INDIA

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1. INTRODUCTION AND HISTORICAL BACKGROUND

Soybean (*Glycine max* (L.) Merrill) has been one of the man's principle food plants for ages. Soybean has been cultivated since 2800 B.C. in China (more than 5000 years ago), which is also considered to be the center of origin for soybean. Soybean ranks first among the major oilseed crops of the world and has now found a prominent place in India. India is the fifth largest producer of soybean after the United States, Brazil, China, and Argentina (Table 1). Soybean cultivation in India started long ago but its successful cultivation has increased over last two decades. This increased cultivation has revolutionized the rural economy and improved the socio-economic status of farmers. Soybean farming made an unprecedented expansion in India between 1969 and 1996 when an annual growth rate of 15-20% was achieved. Presently, the area covered by soybean cultivation is around 5.7×10^6 hectares (ha) as recorded for the winter 2002-03 (SOPA Report, 2002-03). Soybean is grown mainly in Madhya Pradesh, Maharashtra, Rajasthan, and in small pockets in other states, like Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Uttaranchal, Gujarat, Karnataka, and Chhattisgarh. Despite being an exotic crop to India, soybean occupies a vital place in its agriculture, edible-oil economy, and foreign exchange. Tiwari *et al.* (1994) identified suitable soybean varieties for the non-traditional regions of India and demonstrated soybean to be a successful crop in northern, eastern, and southern regions of the country.

Soybean cultivation in the Indian subcontinent dates back to 1000 A.D. The crop was introduced from China through the 'silk route' in the Himalayan mountain ranges running across the Tibetan plateau and through the North-East regions (Assam). Around the same time, the crop was introduced to Central India from Japan, South

D. Werner and W. E. Newton (eds.), Nitrogen Fixation in Agriculture, Forestry, Ecology, and the Environment, 43-66.

Table 1. World Production of Soybeans.
Area in million hectare; Yield in tonnes/hectare; Production (Prod.) in million tonnes.
After Oilseed World Market and Trade (USDA, 1999) and Agriculture Statistics at a Glance, Director of Economic and Statistical Ministry of Agriculture, GOI (as given by Paroda, 1999).

Country	1996-1997			1997-1998			1998-1999		
	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield	Prod.
United States	25.55	2.53	64.84	27.97	2.62	74.22	28.66	2.62	75.03
Brazil	11.80	2.27	26.80	13.00	2.33	30.00	12.90	2.40	31.00
China	7.47	1.77	13.22	8.35	1.67	13.80	8.00	1.73	13.00
Argentina	6.20	1.81	11.20	7.10	2.35	16.00	7.40	2.53	18.70
India	5.23	0.99	5.20	5.86	1.15	6.72	6.30	0.90	5.70/5.90
European Union	0.34	3.44	1.15	0.46	3.37	1.44	0.54	3.26	1.74
Paraguay	1.20	2.25	2.70	1.20	2.23	2.90	1.25	2.64	3.30
Others	5.29	1.22	6.47	6.41	1.12	7.17	5.61	1.51	8.40
Total/(Average)	63.19	(2.08)	131.58	69.34	(2.19)	152.26	70.65	(2.23)	157.70

China and South-East Asia (Hymowitz and Kaizuma, 1981). Black-seeded soybean, under the names Bhatt, Bhatmash, or Kalitur, has since been cultivated for many years in the hilly areas of Assam, Bengal, Manipur, in the hills of Khasi and Naga, and at 6000 ft. elevation in the Kumaun regions as well as the Garhwal hills (Anonymous, 1956). Hooker (1879) clearly described soybean in his book "Flora of British India, Vol. II" and Williams (1932) mentioned the cultivation of soybean in his book "Flora India, Vol. II".

Between the years 1885-1904, attempts were made to cultivate soybean at Nagpur (Maharashtra), Madras (Tamil Nadu), Lahore (Former Punjab of undivided India), Bombay, Pune (Maharashtra), and Surat (Gujarat), but these attempts were not encouraging. However, the work carried out between 1910-1935 in Madhya Pradesh, Assam, Orissa, Bihar, Gujarat, and Uttar Pradesh paved the way for successful cultivation in India (Kaltenbach and Legros, 1936; Kale, 1936). A varietal trial, which was comprised of 33 varieties of Manchurian and Chinese origin, was conducted in 1933 and resulted in the establishment of soybean cultivation in Central India in 1936. Two varieties, "Otootan" (black seeded) and "Easy Cook" were promoted between 1935 and 1952 in addition to the country type (desi) Punjab white. Other varieties from the USA, *viz*., "Harbinsoy", "Chiquito", "George Washington", "Mammoth Yellow", and "Biloxi" were also evaluated (Tiwari *et al*., 1999).

In India, large-scale cultivation of soybean started in 1964, using yellow-seeded high-yielding soybean exotic varieties ("Bragg", "Clark-63", and "Lee") received from USA. They were tested at Jawaharlal Nehru Krishi Vishwa Vidhyalaya (JNKVV) Jabalpur, Madhya Pradesh, and almost concurrently at Govind Ballabh Pant (GBP) University of Agriculture and Technology, Pantnagar, Uttaranchal, under a major collaboration with the USA (Paroda, 1999). Subsequently, in the mid-seventies, cultivation practices that were suitable for Indian conditions (Saxena *et al*., 1971) and several new soybean varieties were introduced (Saxena and Pandey, 1971; Singh and Saxena, 1975). Since then, both the area cultivated and the production of soybean have increased until what was a marginal crop is now a major cash crop and is recognised as the miracle "golden bean" of the 20th century (Singh *et al.,* 2001*).*

2. ALL-INDIA AREA COVERAGE, PRODUCTIVITY, AND PRODUCTION OF SOYBEAN BETWEEN 1970-2003

Soybean has seen phenomenal growth in both area and production in India (Paroda, 1999). In 1970-71, soybean was grown on 32,000 ha with a production of 14,000 tonnes and a productivity of 426 kg/ha. The area of soybean cultivation, production, and productivity has gradually increased over the years. In 1977-78, a six-fold increase from 32,000 to 195,000 ha in cultivation area occurred with a thirteen-fold increase from 14,000 tonnes to 183,000 tonnes in production and a two-fold increase from 426 to 940 kg/ha in productivity. In 1987-88, the area of soybean cultivation increased almost eight times, to 1,543,000 ha with a significant increase in production, to 898,000 tonnes, however, productivity decreased significantly to 582 kg/ha. This rapid growth in area of soybean cultivation continued in the next decade. In 1997-98, the area under soybean cultivation increased to 5.99 x 10^6 ha and the

yield increased to 1,079 kg/ha, resulting in a record production of 6.463 x 10^6 tonnes (Agricultural Statistics at a Glance, 2001).

During the winter season of 1999-2000, the area of soybean cultivation in India was only 5.645 x 10^6 ha, which was about 11.15 %, lower than in 1998-99 (SOPA Report, 2000 -01). In the subsequent two seasons, an increasing trend in the area of soybean cultivation occurred. During 2001-02, the area increased to 6.0021 x 10^6 ha, which is about 6.32% higher than in 1999-2000 and 3.27% higher than in 2000-01. In the next winter season (2002-03), a decrease of 5.44% in cultivation area was recorded. Production and productivity data for the last five seasons (1998-2003) reveal that a maximum productivity and production of 928 kg/ha and 5.90 x 10^6 tonnes, respectively, were recorded in the 1998-99 season. However, in the four subsequent growing seasons, a variable reduction in both productivity and production was recorded (Table 2).

3. ALL-INDIA STATE-WISE AREA COVERAGE, PRODUCTIVITY, AND PRODUCTION OF SOYBEAN

All-India state-wise area coverage of soybean during the winters of 1998 through 2003 are summarized in Table 2, which also indicates variability in area, production, and productivity in the different states of India. Area coverage, productivity, and production trends over the last five years are critically analysed below for three main soybean-producing states of the country.

3.1. Madhya Pradesh

In India, Madhya Pradesh is recognised as the “Soya state” because of its significant contribution in soybean production (70-80%). In Madhya Pradesh, area coverage, yield estimate, and production of soybean have shown a relatively decreasing trend during the last four seasons (1999-2003). The maxima in yield (945 kg/ha), production (4.18 x 10^6 tonnes) as well as of covered area (44.3 million ha) were all observed in 1998-99, whereas the minima in yield (855 kg/ha), production (3.28 x 10^6 tonnes), and covered area (38.3 million ha) all occurred in 2002-03 (SOPA Reports, 2002-03).

The sowing status of soybean for the year 2000-01 also revealed that, in the Mandsaur and Neemach districts, cotton and maize sowing was the alternative for soybean. Soybean cultivation at present occurs in the 45 districts of seven divisions of the state: Jabalpur, Sagar, Rewa, Indore, Ujjain, Gwalior, and Bhopal (Table 3).

3.2. Maharashtra

In the state of Maharashtra, area covered under soybean cultivation and production was rather variable during last five years (1998-2003). Data for the season 2002-03 indicated that area coverage and production were 1.22 x 10^6 ha and 1.215 x 10^6 tonnes, respectively, which were about 24% and 27.7%, respectively, higher in the previous season. Not much variability was observed in the yield of soybean over the last five years.

Table 2. All India State Wise Area Coverage and Yield Estimates of Soybeans during 1998-2003. Area (A) in 10^5 hectares; Productivity (Pdty) in kg/hectare; Production (Prod.) in 10^5 tonnes. After SOPA Reports (2000-2001; 2001-2002; and 2002-2003).

State (S No.)	1998-1999			1999-2000			2000-2001			2001-2002			2002-2003		
	A	Pdty	Prod	A	Pdty	Prod.	A	Pdty	Prod.	A	Pdty	Prod.	A	Pdty	Prod.
Madhya Pradesh (1)	44.3	945	41.8	38.8	916	35.53	40.3	926	37.30	42.4	920	38.93	38.4	855	32.79
Chhatisgarh (2)	-	-	-	-	-	-	-	-	-	0.54	560	0.30	-	-	-
Maharashtra (3)	10.9	958	10.4	11.3	940	10.62	10.2	980	10.02	9.82	970	9.52	12.2	998	12.15
Rajasthan (4)	6.17	870	5.37	4.84	738	3.57	6.24	800	4.950	6.54	740	4.84	4.17	712	2.967
Uttar Pradesh (5)	0.50	434	0.22	0.28	500	0.74	0.15	600	0.092	-	-	-	-	-	-
Karnataka (6)	0.75	555	0.42	0.40	500	0.20	0.65	535	0.350	-	-	-	-	-	-
Gujrat (7)	0.15	600	0.09	0.31	550	0.17	0.28	500	0.140	-	-	-	-	-	-
Andhra Pradesh (8)	0.22	1495	0.33	0.36	525	0.19	0.28	600	0.168	-	-	-	-	-	-
Other States (9)	0.63	540	0.34	0.15	530	0.08	0.02	525	0.010	0.75	550	0.41	2.06	-	1.798
Total/ Average*	63.5	928*	59.0	56.5	895*	50.50	58.1	912*	53.04	60.0	900*	54.00	56.8	876*	49.71

The sowing status in the state of Maharashtra, as provided in the SOPA Report (2000-01), shows that soybean cultivation is mainly in 29 districts of 7 divisions: Nagpur, Kolhapur, Amarawati, Nasik, Pune, Aurangabad and Latoor (Table 3).

Table 3. Major Soybean-Producing Divisions and Districts of Three States of India. After the SOPA Report (2002-03).

Madhya Pradesh		*Maharashtra*		*Rajasthan*
Division	*Districts*	*Division*	*Districts*	*Districts*
Bhopal	Bhopal Sehore Raisen Vidisha Betul Raigarh Hosangabad/Harda	Nagpur	Nagpur Wardha Chandrapur Bhandara Gadchiroli Gondia	Kota Bundi Baran Chittorgarh Udaipur Bhilwara Banswara Sawai Madhopur Jhalawar
Jabalpur	Jabalpur Katni Balaghat Chhindwara Mandla Dindori Seoni Narsinghpur	Kolhapur	Kolhapur Sangli Satara	
Sagar	Sagar Damoh Panna Tikamgarh Chattarpur	Amrawati	Amrawati Yevatmal Akola Washim Buldhana	
Rewa	Rewa Sidhi Satna Shadol Umaria	Nasik	Nasik Jalgaon Dhulia Nandurwar	
Indore	Indore Dhar Jhabua Khargone Badwani Khandwa	Pune	Pune Ahmednagar Solapur	

Ujjain	Ujjain	Aurangabad	Aurangabad
	Mandsour		Jalna
	Neemuch		Bid
	Ratlam		
	Dewas		
	Shajapur		
Gwalior	Gwalior	Latoor	Latoor
	Shivpuri		Osmanabad
	Guna		Parbhani
	Datia		Hingoli
	Murena		Nanded
	Sheopur kalan		
	Bhind		

3.3. Rajasthan

No soybean cultivation in Rajasthan was reported prior to 1952. The cultivation in Rajasthan was initiated in 1981-82 when 10^4 ha were planted (Agriculture in Rajasthan: Some facts, 2001). Both increases and decreases in the soybean cultivation area have occurred over the last five years. The area under cultivation in the years 1998-2003 varied as follows: 6.17×10^5 ha > 4.84×10^5 ha < 6.24×10^5 ha < 6.54×10^5 ha > 4.17×10^5 ha. Maximum yield (870 kg/ha) and production (5.4×10^5 tonnes) were recorded in 1998-99 and, in the subsequent years, a reduction in both yield and production was observed. The maximum decreases of 18.2% and 44.9% in the yield and production, respectively, were observed in 2002-03 as compared to 1998-99.

Soybean cultivation spreads over nine districts of Rajasthan: Kota, Bundi, Baran, Jhalawar, Chittor, Udaipur, Bhilwara, Banswara, and Sawai Madhopur. Of these, Kota and Bundi are the main soybean-producing districts of Rajasthan (Table 3; SOPA Report, 2000-01).

4. REGIONAL DISTRIBUTION OF SOYBEAN CULTIVARS

Under the soybean varietal development programme, intensive research has been conducted by various Universities and Research Institutes in India. These include: JNKVV, Jabalpur (Madhya Pradesh); National Research Center for Soybean (NRCS), Indore (Madhya Pradesh); GBP University of Agriculture and Technology, Pantnagar (Uttaranchal); Indian Council of Agricultural Research (ICAR), New Delhi; Indian Agricultural Research Institute (IARI), New Delhi; Punjab Agriculture University, Ludhiana (Punjab); Birsa Agriculture University, Ranchi (Bihar); Kalyani University, West Bengal; Gujarat Agriculture University, Gujarat, Punjab; Rao Agriculture University, Akola (Maharashtra); Banglore Agriculture University, Banglore (Karnataka); and Tamil Nadu Agriculture University, Coimbatore (Tamil Nadu). The yield, resistance towards pests and diseases, germinability, pod maturity time, improvement of germination, and lodging and shattering resistance were the major

targets. A good germplasm collection is maintained and evaluated at NRCS (Indore) to ensure their proper utilization in different zones of the country. From time to time over the last decade, improved varieties of soybean have been released for the different agro-climatic zones of the country. The released varieties consist of those of exotic as well as indigenous origin.

From the point of view of agroclimatic conditions and varietal suitability, different regions of India are grouped into five soybean zones. Bhatnagar and Tiwari (1990), Ram (1996) and Bhatnagar (2002) have tabulated the varieties suitable for these five different soybean zones (Tables 4, 5 and 6).

Table 4. Soybean Varieties Suitable for Different Zones of India.
After Bhatnagar and Tiwari (1990).

S. No.	Zone	Area covered	Suitable Varieties
1	Northern Hill zone	Himachal Pradesh and hills of Uttar Pradesh	Bragg, NRC-2, PK-262, PK-308, PK-327, PK-416, Pusa-16, Pusa-20, Pusa-24, Shilajeet, Shivalik, VL Soya-1, VL Soya-2, VL Soya-21, VL Soya-47 and Hara Soya.
2	Northern Plain zone	Punjab, Haryana, Delhi, North eastern plains of Uttar Pradesh and Western Bihar	Alankar, Ankur, Bragg, , PK-262, PK-308. PK-327, PK-416, PK-564, PK-1024, Pusa-16, Pusa-24, Shilajeet, SL-4 and SL-96.
3	Central zone	Madhya Pradesh, Bhundelkhand region of Uttar Pradesh, Rajasthan, Gujarat and Northern Orissa	Bragg, Durga, Gaurav, Gujarat Soya-1, Gujarat Soya-2, JS 80-21, JS 75-46, JS 71-05, JS-335, MACS-13, MACS-57, MACS-58, Monetta, NRC-2, NRC-12, NRC-7, NRC-37, PK-472, PK 71-21, UPSM-19 and Alankar.
4	Southern zone	Karnataka, Tamil Nadu, Andhra Pradesh, Kerala and Maharashtra	Co-1, Hardee, KHSb-2, MACS-124, Monetta, PK-471, PK-1029, PK-472, Pusa-37, Pusa-40, MACS-450 and LSB-1.
5	Northern Eastern zone	Assam, West Bengal, Bihar, Meghalaya, Sikkim, Arunachal Pradesh, Nagaland and Tripura	JS 80-21, Birsa Soya-1, Bragg, PK-472, Pusa-16, Pusa-22, Pusa-24 and MACS-124.

Description of 1979 germplasms in a published catalogue.
Recommendation of RSC 2 and RSC 3 for cultivation due to their resistance towards stem borer pests.
Enlistment of general characteristic features like germinability, resistance towards leaf shattering and various diseases of the four cultivars Ahilya-1 (NRC-2), Ahilya-2 (NRC-12), Ahilya-3 (NRC-7), Pooja (MAUS-2) and their suitability for cultivation in Himachal Pradesh, Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat.
Recommendation of four rust resistant varieties namely PK-1024, PK-1029, JS-80-21 and Ankur for cultivation in disease affected area of Central India and Maharashtra, Karnataka, Tamil Nadu and Kerala.
Data on an increase of 35% in the national yield in 1997-98 after adopting improved technology by farmers.

Table 5. Soybean Varieties Suitable for Different Zones from 1996.
After Ram (1996).

S. No	Zone	Area covered	Varieties recommended
1	Northern Hill zone	Himachal Pradesh and hills of Uttar Pradesh	Bragg, Lee, PK-262, PK-308, PK-327, PK-416, Pant Soybean-564, Pusa-16, Pusa-20, Shilajeet, Shivalik, VL Soybean-1 and VL Soybean-2
2	Northern Plain zone	Punjab, Haryana, Delhi, North Eastern plains of Uttar Pradesh and Western Bihar	Alankar, Ankur, Bragg, Clark-63, PK-262, PK-308. PK-327, PK-416, Pant Soybean-564, Pusa-16, Pusa-22, Pusa-24, Shilajeet, SL-4, and SL-96
3	Central zone	M.P, Bundelkhand region of Uttar Pradesh, Orissa, Rajasthan, Gujarat, Northern and western parts of Maharashtra.	Bragg, Clark-63, Durga, Gaurav, Gujarat Soybean-1, Gujarat Soybean-2, JS-2, JS-80-21, JS-75-46, JS-76-205, MACS-13, MACS-58, Monetta, PK-471, Pusa-16, Pusa-22 and T-49.
4	Southern zone	Karnataka, Tamil Nadu, Andhra Pradesh, Kerala and Southern parts of Maharashtra	Co-1, Davis, Hardee, Improved Palican, PHSb-2, Monetta, PK-471, Pusa-37 and Pusa-40
5	North-Eastern zone	Assam, West Bengal, Bihar and Meghalaya	Birsa Soybean-1, Pusa-16, Pusa-22, Pusa-24, Alankar and Bragg

In the year 2000, the Rajasthan Seed Corporation Ltd., Jaipur, determined the maturity period, yield, and other important characteristic features of three cultivars, namely JS-335, Ahilya (NRC-12), and Ahilya-1 (NRC-2), which were recommended for cultivation in Rajasthan. Culitvars, NRC-7, JS-335, JS 71-05, L129 and NRC 25, were susceptible to insects. NRC 33, which exhibited field resistance, was recommended as a source for insect resistance (Annual Report, DARE/ICAR, 2000-01). Shrivastava and Shrivastava (2001) have listed soybean varieties that are recommended for ten agro-climatic regions of Madhya Pradesh (Table 7) and fifteen other varieties have been described in terms of maturity period, yield, and other important characteristics, suitable for cultivation in Madhya Pradesh (Table 8). Similarly, Khare *et al*. (2000) tabulated soybean varieties, which are important for various agroclimatic zones of Madhya Pradesh (Table 9). Seven soybean varieties, along with their important agronomical characters for various areas of adaptation (Madhya Pradesh, Rajasthan, Uttar Pradesh and Andra Pradesh), were described in 2001-02 (see Table 10).

Khatri *et al*. (2002) have listed ten important pests along with the names of varieties showing resistance against specific pests that cause damage to soybeans (Table 11). Bhatnagar (2002) has tabulated 26 varieties of soybeans with their special characteristic features and duration of maturation (Table 12).

Table 6. Soybean Varieties Suitable for Different Agro-climatic Zones of India from 2002. After Bhatnagar (2002).

S.No.	Zone	Area covered	Suitable varieties
1	Northern hill zone	Himachal Pradesh and hills of Uttar Pradesh	Bragg, PK-262, PK-308, PK-327, PK-416, Pusa-16, Pusa-20, Pusa-24, Shilajeet, Shivalik, VL Soya-2 and NRC-2.
2	Northern plain zone	Punjab, Haryana, Delhi, Eastern plain zones of Uttar Pradesh and Western Bihar	Bragg, PK-262, PK-308, PK-327, PK-416, PK-564, Pusa-16, Pusa-24, Shilajeet, SL-2, SL-4, SL-96, PK-1024 and PK-1042.
3	Central zone	Madhya Pradesh, Bundelkhand region of Uttar Pradesh, Rajasthan and North Eastern Maharashtra	Bragg, JS 80-21, JS 75-46, JS 71-05, JS-335, Monetta, PK-472, Pusa-16, Pusa-24, Punjab-1, PK-416, NRC-2, NRC-12, NRC-7 and NRC-37.
4	Southern zone	Karnataka, Tamil Nadu, Andhra Pradesh, Kerala, and Southern region of Maharashtra	Co-1, Hardee, KHSB-2, KM-1, Monetta, PK-471, ADT-1, MACS-450, PK-472, MACS-58, PK-1029, MAUS-1, MAUS-2 and MACS-450.
5	North Eastern zone	Assam, West Bengal, Bihar, Meghalaya, Chhattisgarh and Orissa	Birsa Soybean-1 and Bragg in Bihar hills, Alankar, Bragg, PK-262, PK-472, Pusa-16, Pusa-24, and JS 80-21 in North-East region.

Table 7. Soybean Varieties Recommended for Different Agroclimatic Zones of Madhya Pradesh. After Shrivastava and Shrivastava (2001).

S. No.	Agroclimatic Zone	Varieties
1.	Plains of *Chhattisgarh	JS 72-280 (Durga), JS 80-21 and JS 335.
2.	Kamour plateau and satpura hills	JS 72-280, JS 72-44 (Gaurav), JS 75-46, JS 80-21, JS 335, JS 90-41, MACS 58 and PK 472.
3.	Plateau of Vindhya	Punjab-1, JS 72-44, JS 76-205, JS 80-21, PK-472.
4.	Central Narmada valley	JS 72-44, JS 72-280, JS 75-46, JS 76-205, JS 80-21, JS 90-41 and PK-472.
5.	Gird region	JS 80-21, JS-335.
6.	Bundelkhand region	JS 72-44, JS 72-280, JS 75-46, JS 76-205, JS 80-21, JS-335, JS 90-41 and PK-472.
7.	Satpura hills	Punjab-1, JS 75-46, JS 80-21, JS-335, JS 90-41, PK-472 and MACS-58.
8.	Malwa	JS 72-44, Punjab-1, JS 71-05, JS 76-205, JS 80-21, JS-335, JS 90-4, PK-472, Ahilya-1, Ahilya-2, Ahilya-3.
9.	Nimar valley	JS -335, JS 90-41.
10.	Jhabua hills	JS-335, JS 90-41.

* Chhattisgarh is separated from Madhya Pradesh as a new state.

Table 8. Developed Varieties for Soybean Cultivation in Madhya Pradesh. After Shrivastava and Shrivastava (2001).

S. No.	Name of Variety	Maturation Period and Yield	Specific Properties
		(A). Early maturing	
1	Punjab–1	90-98 days, 1.8-2.0 t/ha	High seed germinability
2	JS-71-05	90-97 days, 2.0-2.4 t/ha	Resistant to pod dehiscence
3	JS-335	95-100 days, 2.5-3.0 t/ha	High seed germinability (80%) and high yield
4	JS 90-41	87-98 days, 2.5-3.0 t/ha	Four seeded pods
5	NRC-7 (Ahilya-3)	90-99 days, 2.5-3.5 t/ha	Resistant to various bacterial and viral diseases
6	NRC-12 (Ahilya-2)	96-99 days, 2.5-3.0 t/ha	Resistant to leaf blight and tolerant to YMV.
		(B). Medium maturing	
7	Gaurav (JS 72-44)	106 days, 2.0-2.5 t/ha	Resistant to bacterial pustule and pod blight.
8	Durga (JS 72-280)	102 days, 2.0-2.6 t/ha	High germinability (80%)
9	MACS-13	106-108 days, 2.0-2.6 t/ha	Resistant to YMV and high germinability (80%)
10	JS 75-46	106 days, 2.0-3.0 t/ha	Resistant to pod shattering.
11	JS 76-205	104 days, 2.0-2.5 t/ha	Highest germinability.
12	PK 472	104-106 days, 2.0-3.0 t/ha	Resistant to bacterial pustule, YMV and Rhizoctonia.
13	MACS-58	106-108 days, 2.2-2.6 t/ha	Resistant to YMV and leaf spot.
14	JS 80-81	106 days, 2.2-3.0 t/ha	High germinability and resistant to leaf eating insect.
15	NRC-2 (Ahilya-1)	103-106 days, 25-30 Qui/ha	Resistant to various fungal and bacterial diseases.

Table 9. Soybean Notified Varieties Recommended for Different Agroclimatic Zones of Madhya Pradesh.
After Khare et al. (2000).

S.No.	Agroclimatic Zone	Varieties
I.	Plains of Chhatisgarh	JS 72-280 (Durga), JS 80-21 and JS-335.
II.	Plateau of Baster	JS 80-21, JS–335
III.	Northern hills of Chhatisgarh	JS 80-21, JS–335
IV.	Kamour plateau and Satpura hills	JS 72-280, JS 72-44 (Gaurav), JS 75-46, JS 80-21, JS-335, JS 90-41, MACS 58 and PK-472.
V.	Plateau of Vindhya	Punjab-1, JS 75-46, JS 76-205, JS 80-21, PK-472.
VI.	Central Narmada valley	JS 72-280, JS 75-46, JS 76-205, JS 80-21, JS-335, JS 90-41 and PK- 472.
VII.	Gird region	JS 80-21, JS-335.
VIII.	Bundelkhand region	JS 72-280, JS 75-46, JS 76-205, JS 80-21, JS-335, JS 90-41 and PK-472.
IX.	Satpura hills	Punjab-1, JS 75-46, JS 80-21, JS-335, JS 90-41, PK-472 and MACS-58.
X.	Malwa	Punjab-1, JS71-05, JS 76-205, JS 80-21, JS-335, JS 90-4, PK- 472, Ahilya-1, Ahilya-2, Ahilya-3.
XI.	Nimar valley	JS-335, JS 90-41.
XII.	Jhabua hills	JS-335, JS 90-41.

Table 10. Soybean Varieties Notified in 2000-01.
After Annual Report, DARE/ICAR (2000-01).

Variety	Area of Adaptation	Yield Potential (t/ha)	Remarks
A. Central Releases			
NRCS-37 (Ahilya-4)	Madhya Pradesh, Rajasthan, and Uttar Pradesh	1.8-2.0	Resistant to pod shattering and good germination, early maturity

MAUS-47 (Parbhani Sona)	Maharashtra, Madhya Pradesh, and Rajasthan	1.5-1.8	Culinary purpose
Himso-1563 (Hara Soya)	Maharashtra, Madhya Pradesh, and Rajasthan	1.5-2.0	Culinary purpose
B. State Releases			
Indira Soya-9	Madhya Pradesh	1.5-1.8	Moderately resistant to rust, medium in maturity
MAUC-32	Maharashtra	1.8-2.0	Medium duration
Pant Soy 1092	Uttar Pradesh	_	Resistant to YMV, medium duration
LBS-1	Andhra Pradesh	1.2-1.5	Medium duration

Table 11. Insect-resistant Varieties of Soybean. After Khatri et al. (2002).

S. No.	Common and Scientific Name of Insect	Resistant Varieties
1	Stem fly (*Melanagromyza sojae*)	TAS 1-3-5-2, MAQS-14, SL-459, MACS-617, MACS-716, DSB-I, MACC-124, MACS-534, JS (SH) 90-91, JS 90-35, MAUM-47, JS (SH) 91-33, MAUS 92-3, CO-1, DS 93-39-2, RSC-2, RSC-3, TAS-41, SACS-428, JS-335, JS (SH) 88-86, MACS-380 and MACS-396
2	Girdle beetle (*Obereopsis brevis*)	PK-1162, JS-335
3	Green Semi looper worm *(Chrysodeixis acuta)*	NRC-34, JS (SH) 89-48, MAUS-33, DSB-1, RAC-1, RAC-2, NRC-3, JS 90-9, UGM-52, NRC-12
4	Brown Semi looper worm *(Gisonia gema)*	DSB-1, RCS- 1 and NRC-12, NRC-7, RAC-3, NRC-34
5	Leaf borer insect (*Billonmbata sabsesivella*)	NRC-37, JS (HS) 89-48, MACS-124, MACS 92-47, SL-414, NRC-39, JS71-05, DS 93-35-2, UGM-52, JS-335, MAUS-610, MACS-716, TAS-41, MAUS-33, MAUS-31, JS 92-2, MACS-44

6	Leaf folding caterpillar (*Hedylepta indica)*	HRMSO-1564
7	Tobacco caterpillar (*Spodoptera litura*.)	MRMSO-1564, JS90-41, UGM-52, SL-459, DSK 93-204-101
8	Bean stink bug (*Challiopsis* sp.)	NRC-36, NRC-39, BLS-2
9	Mahu (*Aphis* sp.)	JS-335, JS-7105, JS-88-66, SL-79, CO-2, PK-1092
10	White fly (*Bemisia tabaci*)	PK-1241, JS-91-4, PK-1189, PK-1180, PK-1162, PK-1158, BRAG SL-317, SL-452, SL-443, SL-450, PK-416, SL-427, PKB-25, SL-457, PK-1042, PK-1135.

Table 12. Improved Varieties of Soybean in India.
After Bhatnagar (2002)

S. No.	Variety	Duration Day	Specific Features
1	Ahilya-1 (NRC-2)	103-106	Early maturity, White flower, Yellow seed, Good germination, Limited growth. Best for Malwa plateau and North hills region.
2	Ahilya-2 (NRC-12)	96-99	Purple flower, Yellow seed, Brown hilum, Resistant to Bacterial pustule, Bacterial blight, YMV, GMV, *Rhizoctonia* aerial blight. Best for Bhundelkhund region.
3	Ahilya-3 (NRC-7)	90-99	Limited growth, Purple flower, Yellow seed, Gray hair, Large seed, Early maturity, Resistant to pests and diseases. Best for Madhya Pradesh.
4	Ahilya-4 (NRC-37)	96-101	White flower, Brown hairs, Yellow seed, Light dark brown hilum, Erect growth, Collar rot, Bacterial pustule resistant. Resistant to blight disease of pods and buds, Resistant to stem fly and Leaf minor.

5	CO-2	75-80	Limited growth, Purple flower, deep leaves, yellow seed, Tolerant to YMV and Leafminor. Best for Tamil Nadu.
6	Durga (JS 72-208)	102-105	White flower, Yellow seed, Early maturity and improve variety, Good germination, Resistant to bacterial pustule. Best for Kharif in M.P. and for Rabi in Chhattisgarh.
7	JS 71-05	94-96	Early maturity, Purple flower, Brown hair, Yellow seed, Black hilum, Dwarf determinate 35-40 cms height, Large seeds. Best for Malwa plateau of Madhya Pradesh.
8	JS-335	98-102	Purple flower, Yellow seed, Good germination, Semi-determinate, Tolerance to pod dehiscence, Resistant to bacterial pustules, Blight or *Alternaria* blight. Tolerance to GMV, Stem fly, High yielding variety. Best for Bhundelkhund.
9	JS-80-21	95-109	Purple flower, Yellow seed, good germination, Tolerant to defoliators, Bacterial pustules. Best for central region, North East region and Chhattisgarh.
10	Sneha (KB-79)	85-93	Limited growth, Purple flower, gray hairs, Yellow seeds, Brown hilum, Tolerance to many diseases. Best for Karnataka.
11	MACKS - 13	90-102	Purple flower, Yellow seeds, Good germination, tolerance to bacterial pustules, Viral disease and defoliators. Best for central region of India.
12	MACKS-58	95-105	Purple flower, Yellow seed, Tall plant, Tolerant to Bacterial pustule and leaf spot, YMV. Best for central region.

13	MACKS-124	90-105	Purple flower, Semi-Determinate. Best for southern region and Chhattisgarh.
14	MACKS-450	90-95	Purple flower, Medium height, Semi-Determinate, Yellow seed, Black hilum, Resistant to YMV and different diseases, Moderate resistant to stem fly and Insect pest. Best for southern region.
15	Pooja (MAUS-2)	102-110	Limited growth, Gray hair, Yellow seed, Brown hilum, Resistant to dehiscence of pods. Best for Maharashtra and Southern region.
16	PK-262	120-125	White flower, gray hair, Yellow seed, Brown hilum, Tolerant to YMV and Bacterial pustules. Best for Northern and North Plain region.
17	PK-416	100-109	White flower, Yellow seed, Resistant to Bacterial pustules and YMV, Tolerant to *Rhizoctonia*. Best for Northern region and Madhya Pradesh.
18	PK-472	100-105	White flower, Yellow seed, Deep green plant, Resistant to YMV, Leaf spot and Bacterial diseases. Best for Madhya Pradesh.
19	PK-564	105-115	Whit flower, Yellow seed, Deep brown flower hilum, Limited growth, Strong plant, Resistant to YMV and bacterial pustules, Tolerance to *Rhizoctonia*. Best for Northern region.
20	PK-1024	115-118	White flower, Small leaves, Limited growth, Yellow seed, Brown hilum, Resistant to pod dehiscence, tolerant to rust disease. Best for Northern region.
21	PK-1029	90-95	White flower, Limited growth, Broad green leaves, Yellow seeds, Black hilum and soybean rust disease. Best for Southern region.
22	PK-1042	110-119	Limited growth, White flower, Yellow seed, and Brown hilum, Resistant to pods dehiscence. Best for Northern plain region.
23	PUSA-16	100-105 (Plains), 110-120 (Hills)	Purple flower, Yellow seed, Good germination, Resistant to Rhizoctonia, Bacterial pustules, YMV and Insect pests.

24	Shivalik	120-125	White flower, Light milky hair, Yellow seed, Deep brown hilum, Resistant to middle height (90-100 cms) Yellow mosaic. Best for Himachal Pradesh.
25	VL Soya -2	104-116	Purple flower, Light white hair, Black hilum, Light colour pods. Best for Northern hills.
26	VL Soya -21	120-122	Limited growth, White flower, Brown hair, Yellow seed, Brown hilum, Good germination, Resistant to Bacterial pustules and Cercospora leaf spot.

5. REGIONAL AGRICULTURAL ASPECTS OF SOBEAN CULTIVATION

Soybean, the main winter season crop of India, has wide adaptability to various agro-climatic conditions and can be fitted to all climatic systems (both rain-fed and irrigated). Production and productivity of soybeans sown in various agricultural regions of India depend basically upon rainfall, temperature, sowing, quality of soil, selection of suitable varieties for a specific agro-climatic region, control of diseases, fertilizer management, crop rotation, and intercropping.

The following sections summarize and critically analyse the important agricultural aspects of soybean cultivation in India.

5.1. Environmental Factors

During the soybean cultivation period (June-September), the situation with regards to the monsoon varies in different soybean-growing states of the country. Good rains occur up to the middle of July in most parts of the soybean belt. Rains may appear in the first week of August and may continue until the third week of August. Scattered rains also occur in September. Rainfall generally seizes after the second week of September, which is a very important period for pod filling and development. Most of the soybean cultivation in India depends upon rainfall. In the rain-fed areas, maximum cultivation is completed in two phases, *i.e*., early sown phase (between the second and third week of June) and timely sown phase (third week of June to the second week of July). As an exception, sometimes early sowing has been reported in the second week of May, as was done in Maharashtra in 2001-02. Timely sowing of soybean, which is accomplished by the arrival of the monsoon at the right time, provides optimum soil moisture for seed germination. Early sowing of the crop invariably gives a good yield, as reported in Maharashtra in winter 2000-01 (SOPA Report, 2001-02).

The late arrival of the monsoon means both less rainfall and late sowing, which leads to the formation of undersized grains and less yield. Scattered rains in September can improve crop prospects (SOPA Report, 2000-01). Assessment of rainfall amounts for the recent years, 2000-2002, for the three main soybean-growing states of India, Madhya Pradesh, Maharashtra, and Rajasthan, indicates the rainfall

range at Division/District headquarters as well as the average state rainfall (Table 13).

While discussing the rainfall status and requirement for the cultivation of soybean in different regions of Madhya Pradesh, Mehta and Shrivastava (2002) have pointed out that the cultivation is done in North-west Madhya Pradesh with the average rainfall of *ca*. 800 mm and in South-east Madhya Pradesh with the average rainfall of 600 mm. It is worthwhile to note that the amount of rainfall varies in each monsoon season and, as a consequence, all of normal, excess, deficient and scanty rainfall have been recorded in different years for different regions (SOPA Report, 2001-02).

Table 13. Rainfall Status in Madhya Pradesh and Maharashtrain 2002, and Rajasthan in 2000. After SOPA Report (2002-03) and Agriculture in Rajasthan: Some Facts (2001).

Madyapradesh		
Divisions	Rainfall Range (mm)	Average (mm)
Jabalpur	723-1456	942
Sagar	662-868	700
Rewa	435-1060	690
Indore	505-998	670
Ujjain	291-645	659
Gwalior	168-609	417
Bhopal	566-1318	844
State Avg.	479-993	703
Maharashtra		
Nagpur	782-1223	917
Kolhapur	250-1458	862
Amaravati	600-1293	894
Nasik	504-898	694
Pune	366-601	445
Aurangabad	572-758	639
Latoor	443-1106	744
State Avg.	502-1048	742

Rajasthan - *Rainfall from June 2000 to September2000*

Districts	Av. Rain fall (Normal; mm)	Av. Rain fall (Actual; mm)
Kota	698	585
Bundi	726	529
Baran	822	814
Jhalawar	801	638
Chittor	792	486
Udaipur	596	391
Bhilwara	642	440
Banswara	903	545
Swai Madhopur	828	475
State Avg.	531	365

The optimum air temperature for seed germination is 30°C (20°C soil temperature) and temperatures above 40°C stop germination (Shrivastava *et al*., 2002). A temperature range of 25°C-28°C is found to be suitable for soybean growth. Even an increase of 2°C from the threshold temperature (29°C) causes a reduction in yield (Burke and Evett, 1999).

5.2. Quality of the Cropping Field Soil

Cultivation of soybean is done in the well-drained, black loamy soil with a pH between 7.0-7.5 (Bhatnagar, 2002). Very light, sandy, acidic and alkaline soils are not suitable for this crop. In Madhya Pradesh, the soya state of the country, soybean is being cultivated in different soil types, such as shallow-black to dark-black soil (Malwa), medium-black (Vindhyan plateau), dark-black (Central Narmada valley), light-black loamy and silty loam (Satpura plateau), sandy loam to heavy-black (Kamour plateau), red-black mixed (Bhundelkhund), mixed red-black and alluvial (Gird region), and shallow-black (Nimar valley) (Shrivastava and Shrivastava, 2001; Mehta and Shrivastava, 2002). Seeds are sown in the soil at a depth of 2.5-3.0 cm, at a distance of 10-15 cm, and in rows maintaining 45 cm distance between two adjacent rows (Shrivastava *et al.,* 2002).

5.3. Insect Pests, Diseases, and their Control Measures

One of the reasons for the reduced soybean productivity is the increase in diseases caused by various organisms. Various researchers have provided an account of important diseases of soybean and their control measures.

Singh *et al.* (1988) detailed the insect pests of soybeans in India, and then Singh and Singh (1989) classified and described the soybean pests and their control measures. The names and symptoms of the important diseases caused by fungi (seed rot, leaf spot, blight, root and stem diseases), bacteria (soybean rust, bacterial spot), and viruses (YMV), along with their control measures, have been reported by Khare *et al.* (2000). Pests that can spoil the cultivation of soybean due to their attack on different plant parts at different stages of growth have been described (Khatri *et al.,* 2002; Shrivastava *et al*., 2002; see Table 14). In addition to insect-pest diseases, Khatri *et al.* (2002) also pointed out six main diseases of soybean caused by viruses (Yellow Mosaic Virus), fungi (*Macrofomina* sp.*, Cercospora* sp.*, Colletotrichum slycence, Rhizoctonia solani, Focopsora pachyrhiza)* and bacteria *(Xanthomonas phaseoli* var. *sojans*). Shrivastava *et al.* (2002), while listing the breeding objectives for soybeans, have pointed out that, with the increase of soybean-cultivation area, diseases are also spreading. Furthermore, out of forty diseases reported to occur in different soybean-growing regions of the country, seven fungal, two viral, eighteen pest, and one bacterial disease have been highlighted by them as being of economic importance.

Biological and chemical treatments are recommended for the control of insects, fungal, bacterial, and viral diseases. The biopesticide (*Bacillus bassiana*) was found effective in controlling major diseases caused by insects (Annual Report,

DARE/ICAR, 1999-00). Khatri *et al.* (2002) have reported that the use of Nuclear Polyhedrosis Virus (NPV) reduces the number of tobacco caterpillars when sprayed with water.

Table 14. Major Insect Pests of Soybean in India.
After Khatri et al. (2002) and Shrivastava et al. (2002).

Common Name	Scientific Name	Damaged plant Parts & Symptoms
A. Seedling insects		
Blue beetle	*Cneorane* sp.	Cotyledonary leaves
Field cricket	*Gryllus* sp.	Seed and seedling
Seed maggot	*Delia platura*	Seedling root
Cut worms	*Agrotis ipsilon*	Cotyledonary leaves Seed and seedling
B. Stem borer pests		
Stem fly	*Melanagromyza sojae*	Yellow stem, stunted growth of leaves
Girdle beetle	*Obereopsis brevis*	Hollow stem, stem loss on maturation
C. Foliage feeder insects		
Green semi looper	*Chrysodeixis acuta*	Chlorophyll loss, low yield
Brown striped semi looper	*Mocis undata* *Aproaerema modicella*	Cut leaf margins Reduced growth
Leaf minor caterpillar	*Spodoptera litura*	Cut leaf margins
Tobacco caterpillar	*Spodoptera exigua*	Stuck leaves, cause holes
Linseed caterpillar	*Spilosoma obliqua*	Chlorophyll loss, low yield
Bihar hairy caterpillar	*Amsacta moorei*	Reduced growth, leaf loss
Red hairy caterpillar	*Helicoverpa armigera*	Leaf deformation
Gram pod borer	*Scopula remotataguence*	60-80% leaf loss, cause holes
Looper larva	*Hedylepta indica*	Cut leaf margins
Leaf folding caterpillar		Leaf loss
D. Sap suckers		
White fly	*Bemisia tabaci*	Cause Yellow leaves
Green jassids	*Empoasca terminalis*	Shrunk pods
Thrips	*Caliothrips indicus*	Spread yellow mosaic viral disease
Green stink bug	*Nezara viridula*	Yellow leaves
Brown bug	*Riptortus pedestris*	Shrunk pods

From time to time, various chemicals have been recommended for the control of soybean diseases. For pest diseases, these include Forate, Quinolphos, Aldosulfon, Methylparathion, Thymathaxam 70 (WS), Chloropyrifos 20 EC, or Ethian 50 EC; for fungal diseases, they include Indofill M 45, Bloytox 50, Hexaconezol 5 EC, or Propeconezol 5 EC; and for viral diseases, Mancojeb or Thiram + Carbendazim have been recommended (Annual Report, DARE/ICAR, 1997-98; Khare *et al*., 2000; Shrivastava and Shrivastava, 2001; Bhatnagar, 2002; Khatri *et al*., 2002).

5.4. Soybean Weeds and their Control Measures

Weeds and their management during soybean cultivation is a major problem and a cause of productivity loss. Weed species infesting soybean vary according to the agro-climatic region. The main weed species associated with soybeans, as reported by various researchers, are *Cyperus rotundus, Echinochloa colonum, Digitaria sanguinalis, Phyllanthus maderaspatensis, Acalypha indica, Anotis montholoni, Dactyloctenium aegyptium, Commelina benghalensis, Saccharum spontaneum, and Phyllanthus niruri (*Lokras *et al.,* 1987*;* Sharma *et al*., 1991; Singh *et al.*, 1991; Prabhakar *et al.*, 1992; Upadhyaya *et al.*, 1995; Jain *et al.*, 1998). Mehta and Shrivastava (2002) have found that weeds not only reduce production but also cause the spread of various insect pests.

Hand weeding has been adopted by farmers as the most effective control measure in the soybean-cultivated fields. Weed control is performed manually after a period of 20-25 days (Kurchania and Bhalla, 1999; Shrivastava and Shrivastava, 2001; Mehta and Shrivastava, 2002). Vyas *et al*. (1999) reported that the application of Alachlor as a pre-emergence measure resulted in better weed control and higher grain yield. Further, both Imazethapyr and Propaquizafop have shown promise for controlling weeds after their emergence (Annual Report, DARE/ICAR, 2000). Khare *et al*. (2000) and Shrivastava and Shrivastava (2001) have listed for soybean the herbicides to be applied before sowing (Fluchoralin, Metachlore), after sowing but before germination (Alachlore, Pendymethylin, Acetachlore, Metachlore), and on a standing crop (Imazethapyr).

5.5. Fertilizers

Cow dung and compost fertilizer are used for maintenance of agricultural land for soybean cultivation. Khare *et al*. (2000) pointed out that soil characteristics are maintained, if 10-15 tonnes/ha compost is applied every third year. In general, nitrogen (20 kg/ha), phosphate (60-80 kg/ha), and potash (20 kg/ha) is applied at the time of sowing (Shrivastava and Shrivastava, 2001; Mehta and Shrivatava, 2002; Bhatnagar, 2002). Shrivastava and Shrivastava (2001) suggested that leguminous crops require higher sulfur concentrations compared to cereal crops. Therefore, sulfur-containing fertilizers, like ammonium sulfate, super phosphate, and gypsum, are used for soybean cultivation. Mehta and Shrivastava (2002) have noted that the addition of zinc sulfate to zinc-deficient soil and gypsum to sulfur-deficient soil is necessary to maintain soybean productivity.

5.6. Intercropping and Crop Rotation

By adopting intercropping in the farming of soybeans, higher production can be achieved as compared to other crops. Patra and Chatterjee (1986), Prasad and Shrivatava (1991), and Jagtap *et al.* (1993) reported higher yields and return under soybean-based intercropping systems than with soybean alone. Crop rotation also helps in weed control (Kurchania and Bhalla, 1999). Soybean intercropping provides

safe production under unfavorable climatic conditions (Mehta and Shrivastava, 2002). Important intercropping combinations that are beneficial for different soybean-growing regions of Madhya Pradesh have been recommended by Mehta and Shrivastava (2002), with the Soybean-plus-Arhar (*Cajanus cajan*) intercropping system found to be most beneficial in terms of production.

Either soybean-plus-wheat or soybean-plus-chickpea are the major crop rotations, although other crops are also planted after soybeans (Shrivastava *et al.,* 2002; see Table 15). In different agro-climatic regions, sowing of wheat or chickpea or pea or sunflower after soybean cultivation can result in much higher production, but the benefit depends on irrigation facilities (Mehta and Shrivastava, 2002). Although Chui and Shibles (1884) noted reduced yields of soybeans after intercropping with maize, Shrivastava *et al*. (2002) indicated that intercropping of soybean with maize (*Zea mays*), as well as with pigeonpea (*Cajanus cajan*), jowar (*Sorghum vulgare*), fingermillet (*Elusine corocana*), or sugarcane (*Saccharum officinarum*), is beneficial. Goswami (2000) also reported that the soybean-plus-maize intercropping system is productive.

Table 15. Major Intercropping Systems involving Soybean in India.

Region	Intercropping System
Malwa plateau	Soybean-plus-Maize (*Zea mays*) (4:2) or Soybean-plus-Arhar (*Cajanus cajan*) (4:2)
Kamour plateau	Soybean-plus-Arhar (*Cajanus cajan*) (4:2)
Vindhyan Plateau	Soybean-plus-Jowar (*Sorghum vulgare*)(4:2)

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