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Production Systems, Constraints, and Research Priorities

P.K. Joshi
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P.K. Joshi[1]
N.P. Singh[2]
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R.V. Gerpacio[4]
P.L. Pingali[5]

IFAD

CIMMYT

1 National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi, India.
2 Indian Agricultural Research Institute (IARI), New Delhi, India.
3 Directorate of Maize Research (DMR), New Delhi, India.
4 International Maize and Wheat Improvement Center (CIMMYT), Laguna, Philippines.
5 Food and Agricultural Organization of the United Nations (FAO-UN), Rome, Italy.

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Abstract: Maize is a promising substitute crop allowing diversification from the rice-wheat system in the upland areas of India. The crop has high production potential, provided the available improved hybrids and composites reach the farming community. This study found that major biotic production constraints were *Echinocloa*, *Cynodon dactylon*, rats, and termites, which reduced maize production levels by more than 50%. Other important abiotic and biotic stresses listed in descending order of importance were: caterpillars, water stress, stem borers, weevils, zinc deficiency, rust, seed/seedling blight, cutworm, and leaf blight. Non-availability of improved seeds, inadequate input markets, ineffective technology dissemination, and lack of collective action were the principal socio-economic constraints.

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1. Introduction

1.1 Background

The last decade of the 20th century witnessed extensive economic reforms in India, which in turn saw growing stocks of surplus wheat and rice. This, however, came at an associated cost of degradation of both soil and water resources. At the global level, prices of these two leading cereals declined sharply, inducing the farming community to partly diversify agriculture to sustain and augment farm income and improve the quality of soil and water resources.

Maize is considered a promising option for diversifying agriculture in upland areas of India. It now ranks as the third most important food grain crop in India. The maize area has slowly expanded over the past few years to about 6.2 million ha (3.4% of the gross cropped area) in 1999/2000. Paroda and Kumar (2000) predicted that this area would grow further to meet future food, feed, and other demands, especially in view of the booming livestock and poultry producing sectors in the country. Since opportunities are limited for further expansion of maize area, future increases in maize supply will be achieved through the intensification and commercialization of current maize production systems.

The changing global scenario is compelling policy-makers to adhere to the regulations and obligations set by the World Trade Organization (WTO). The resulting new economic regime is expected to alter the economics of existing cropping systems, including maize, in terms of production, value added, and trade. The question often raised is how research and development efforts can efficiently contribute to intensifying maize production in upland areas while protecting the interests of poor maize producers. To answer the question, it is necessary to study and characterize maize production systems, and future policy and technology interventions need to be formulated accordingly. This study attempts to identify existing maize production constraints and explore future sources of intensification. More specifically, this study aims to: (1) characterize maize production systems in upland areas, (2) assess the historical performance of maize, (3) identify constraints limiting maize production, and (4) assess opportunities for maize intensification in the upland areas of India.

1.2 Characterization of Maize Production Environments

In India, maize is grown in a wide range of environments, extending from extreme semi-arid to sub-humid and humid regions. The crop is also very popular in the low- and mid-hill areas of the western and northeastern regions. Broadly, maize cultivation can be classified into two production environments: (1) traditional maize growing areas, including Bihar, Madhya Pradesh, Rajasthan, and Uttar Pradesh (BIMARU), and (2) non-traditional maize areas, including Karnataka and Andhra Pradesh (KAP). In traditional areas, the crop is often grown in marginal eco-regions, primarily as a subsistence crop to meet food needs. In contrast, maize in the non-traditional areas is grown for commercial purposes–i.e., mainly to meet the feed requirements of the booming poultry sector. Key indicators of development in these two contrasting production environments are given in Table 1. Low levels of literacy, income, and urbanization characterize traditional maize growing areas in the BIMARU states, where a large number of poverty-ridden people live. In contrast, the KAP states show low poverty levels, modest urbanization, and agricultural income above the national average.

To better understand maize production systems at the micro-level in traditional and non-traditional areas, rapid rural appraisal (RRA) surveys were conducted at selected locations using a three-stage stratified sampling scheme. During the first stage, three districts from each state were identified. The selected districts were among the top maize producing districts and represented major agro-ecological regions in the state (Figure 1). These included Begusarai, Munger, and Siwan in Bihar; Chindwara, Jhabua, and Mandsaur in

Table 1. Socio-economic and infrastructure development indicators in maize agro-ecological regions, India, 1999.

		Traditional maize growing areas				Non-traditional maize growing areas		
Indicators of development	**Units**	**Bihar**	**Madhya Pradesh**	**Rajasthan**	**Uttar Pradesh**	**Andhra Pradesh**	**Karnataka**	**All India**
Population†	millions	82.88	60.38	56.47	166.5	75.73	52.74	1027.01
Poverty‡	% population	42.60	37.43	15.28	31.15	15.77	20.04	26.10
Urbanization	% population	13.14	23.18	22.88	19.84	26.89	30.92	25.71
Literacy	% population	38.48	44.20	38.55	41.60	44.09	56.04	52.51
Electrification	% villages	70.71	94.23	85.42	75.81	99.92	98.51	85.95
Road length	Per 100 sq. km	50.53	47.59	38.01	67.94	58.27	75.09	66.11
Banks	Per 100,000 population	5.30	6.17	6.62	5.77	6.51	9.13	6.93
Credit to agriculture	Rs/capita¶	147.00	192.00	260.00	191.00	658.00	822.00	271.00
Agricultural production	Rs/ha¶	7,864.00	6,371.00	4,876.00	10,690.00	13,419.00	12,194.00	11,691.00
Average size of holding	ha	0.87	2.35	3.56	0.85	1.56	2.13	1.45
Irrigated area	% gross cropped area	43.67	22.53	28.25	63.91	43.67	23.57	36.86

Source: Center for Monitoring Indian Economy (2000) Profiles of districts, CMIE, New Delhi.
† Population is based on preliminary estimates for 2001.
‡ Poverty based on poverty data for 1997.
¶ US$ 1.00 = Indian Rs 44.00 (May 2004).

Madhya Pradesh; Banswara, Bhilwara, and Udaipur in Rajasthan; Behraich, Bulandshar, and Hardoi in Uttar Pradesh; Karimnagar, Mahboobnagar, and Nizamabad in Andhra Pradesh; and Belgaum, Chitradurga, and Dharwad in Karnataka. During the second stage, two blocks (sub-districts) from each selected district were chosen using the same criterion of larger maize area. For the third stage, two villages from each block were randomly selected for interacting with maize producers and conducting the RRA. In all, RRA was conducted in 72 villages across 18 selected districts and 6 states. A brief profile of selected districts with respect to agro-climate, and socio-economic and technological indicators is presented in Tables 2 and 3. The selected districts represented a wide range of agro-ecological regions delineated under the National Agricultural Research Project (Ghosh, 1991). Each agro-eco region is a homogenous and contiguous entity for better targeting research and technology transfer.

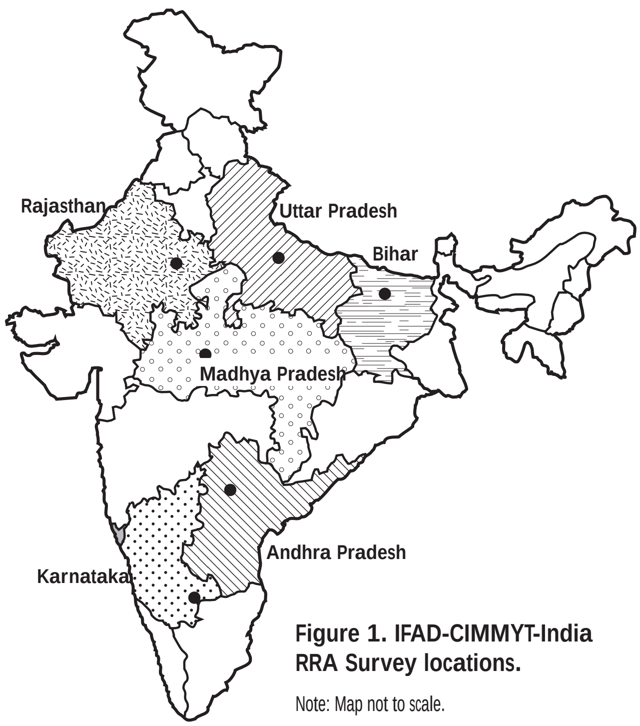

Figure 1. IFAD-CIMMYT-India RRA Survey locations.

Note: Map not to scale.

Maize in India is grown in diverse environments–from the cool, dry area of Chitradurga, Karnataka, to the warm, wet plateau of Chindwara, Madhya Pradesh. For the most part, landholdings are marginal (less than 1.0 ha) and small (between 1.0 and 2.0 ha), and use of inorganic fertilizers is extremely limited, with some exceptions in Andhra Pradesh (Table 3). The cost of agricultural outputs was highly variable among the selected districts but less than the national average (Rs. 11,691/ha or US$ 266/ha) in most districts surveyed. The area planted to hybrids also showed considerable variation. The non-traditional maize growing southern states had a perceptible presence of hybrids compared to the traditional northern states, especially in pockets of Madhya Pradesh and Rajasthan, where hybrid cultivation is at a significantly lower level. The value of agricultural output was extremely low in Munger and Begusarai districts in Bihar, Jhabua district in Madhya Pradesh, Bahraich district in Uttar Pradesh, Nizamabad in Andhra Pradesh, and Dharwad in Karnataka (Table 3). There are not enough employment and income-augmenting opportunities in either the farming or non-farming sectors. These indicators clearly reveal that farmers in maize growing areas are poor and waiting for a low-cost technological breakthrough.

Table 2. Salient agro-climatic features of selected districts, India, 2001.

State	District	Agro-ecological region	Mean annual rainfall (mm)	Tempe-rature (°C)	Topography†	Soil type (scientific)	Soil type (local)
Traditional maize growing states							
Bihar	Munger	South Bihar Alluvial Plain	1,110	8-35	Normal, Diara Belt	Alluvial heavy textured	Sandy loam, clayey
	Siwan	North West Alluvial Plain	1,211	7-36	Normal	Alluvial light textured	Loam, sandy loam
	Begusarai	North West Alluvial Plain	1,214	11-33	Normal, Diara Belt	Alluvial light textures	Loam, sandy loam
Madhya Pradesh	Chindwara	Satpura Plateau	700-1,400	11-36	Normal, hilly (Tamiya Block)	Black clay loam	Shallow medium black, gravelly, clayey
	Mandsaur	Malwa Plateau	800-1,200	8-38	Normal	Medium black	Medium black, sandy loam, clayey loam, sandy
	Jhabua	Jhabua	600-800	6-38	Hilly tract	Sandy loam to sandy clay loam	Red yellow,
Rajasthan	Banswara	Humid South Plain	880	3-45	Normal	Red, mixed red and black	Mixed red, black, calcareous
	Bhilwara	Sub-humid Southern Plain	700	2-46	Dry, normal	Lithosols, alluvial	Sandy, alluvial
	Udaipur	Sub-humid Southern Plain	700	2-46	Dry, normal, hilly	Lithosols, alluvial	Sandy, loam, alluvial
Uttar Pradesh	Behraich	North Eastern Plain	1470	5-44	Normal	Alluvial	Clay loam, sandy loam, loam
	Hardoi	Central Plain	885-1160	6-42	Normal uplands (eastern part)	Alluvial	Sandy loam, calcareous, clay loam
	Bulandshar	Western Plain	700	3-44	Normal, Doab between Ganga and Yamuna rivers	Alluvial	Loam, sandy clayey
Non-traditional maize growing states							
Andhra Pradesh	Mahboob-nagar	Northern Telangana	900-1150	13-42	Normal	Chalkas with small patches of laterite soils, loamy	Sandy loam, black cotton soil
	Karimnagar	Northern Telangana	900-1150	13-42	Normal	Chalkas with small patches of laterite soils, loamy	Sandy loam, black cotton soil
	Nizamabad	Scarce Rainfall Zone	500-750	17-40	Normal, dry soils	Chalkas, alfisols	Loam, clayey and sandy soil, black cotton soils
Karnataka	Chitradurga	Central Dry Zone	456-717	10-35	Normal	Chalkas, loamy	Red loam to deep black soils
	Dharwad	Northern Dry Zone	465-786	11-38	Ridges, undulating land	Granite, quartz, sand stone	Black clay medium and sandy soil
	Belgaum	Northern Dry Zone	465-786	12-40	Undulating land, plateau	Granite, quartz, sand stone	Black clay medium and sandy soil

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

† *Diara belt* is the shallow riverbed, submerged during the rainy season; crop cultivation is done only when rainwater recedes. *Doab area* is the land between the Ganga and the Yamuna rivers.

Table 3. Salient socio-economic and technology adoption features in selected districts, India, 2001.

State	District	Agro-ecological region	Size of land holding (ha)	Gross cropped area (GCA) (000 ha)	Maize area (000 ha)	Maize area as % GCA†	Irrigated area to GCA†(%)	% area planted to HYVs‡	Fertilizer use (kg/ha)	Value of crop output (Rs§/ha)
Traditional maize growing states										
Bihar	Munger	South Bihar Alluvial Plain	0.71	186.0	44.6	23.9	40.5	na¶	48.7	3,407
	Siwan	North West Alluvial Plain	0.68	274.9	27.0	9.8	51.8	na	37.8	7,018
	Begusarai	North West Alluvial Plain	0.50	198.7	78.0	39.3	48.8	na	142.4	5,312
Madhya Pradesh	Chindwara	Satpura Plateau	2.00	593.4	50.2	8.5	14.0	98.0	25.6	7,709
	Mandsaur	Malwa Plateau	2.53	831.0	90.5	10.9	24.2	25.0	51.5	8,062
	Jhabua	Jhabua	2.12	459.0	104.7	22.8	13.3	38.0	21.7	3,595
Rajasthan	Banswara	Humid South Plain	1.65	339.7	113.4	33.4	24.2	65.0	55.3	4,466
	Bhilwara	Sub-humid Southern Plain	2.02	532.6	170.5	32.1	41.5	58.4	46.3	7,025
	Udaipur	Sub-humid Southern Plain	1.62	375.7	157.9	42.1	33.3	53.4	25.2	5,317
Uttar Pradesh	Behraich	North Eastern Plain	0.87	698.5	400.3	57.3	19.9	82.6	38.9	5,541
	Hardoi	Central Plain	0.89	329.5	52.9	16.1	60.4	60.3	45.9	8,972
	Bulandshar	Western Plain	1.23	281.7	100.4	35.6	95.8	94.2	93.8	10,247
Non-traditional maize growing states										
Andhra Pradesh	Mahboob-nagar	Northern Telangana	2.23	703.0	46.6	9.8	67.4	85.4	197.2	11,618
	Karimnagar	Northern Telangana	1.30	476.0	97.6	28.8	94.4	76.5	224.8	13,049
	Nizamabad	Scarce rainfall zone	1.30	338.0	62.8	8.9	25.1	90.5	71.9	4,854
Karnataka	Chitradurga	Central dry zone	2.44	694.1	110.0	15.8	23.9	95.5	78.3	14,852
	Dharwad	Northern dry zone	2.90	1,331.3	112.2	8.4	13.8	82.6	50.3	3,563
	Belgaum	Northern dry zone	2.38	1,015.2	88.6	8.7	32.8	78.8	64.4	10,194

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

† GCA = Gross cropped area.

‡ HYVs = High yielding varieties.

§ US$ 1.00 = Indian Rs. 44.00 (May 2004).

¶ na = not applicable.

2. Maize Production Trends and Systems

2.1 Maize Production Trends

Production of cereals other than rice and wheat stagnated during the 1980s and declined marginally during the 1990s (Table 4). During these two decades, maize performed better than other important coarse cereals (barley, sorghum, and pearl millet). Production of maize continued to increase and reached 11.5 million tons in 1999/2000, from a mere 4.1 million tons in 1960/61 and 7.5 million tons in 1970/71 (Figure 2), mainly due to a notable rise in its yield levels. Maize yields went up from 1.1 t/ha in the triennium average ending (TE) 1981/82 to 1.7 t/ha in TE 1998/99. The maize area also gradually expanded from about 4.4 million ha in TE 1960/61 to 5.9 million ha in TE 1980/81 and 6.2 million ha in TE 1998/99 (Table 5 and Figure 3).

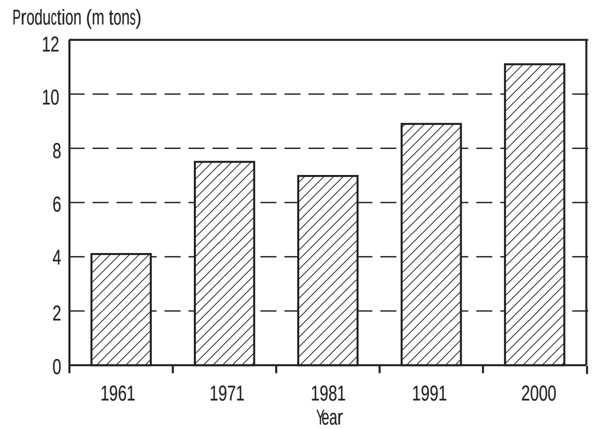

Figure 2. Maize production in India, 1961/2000.

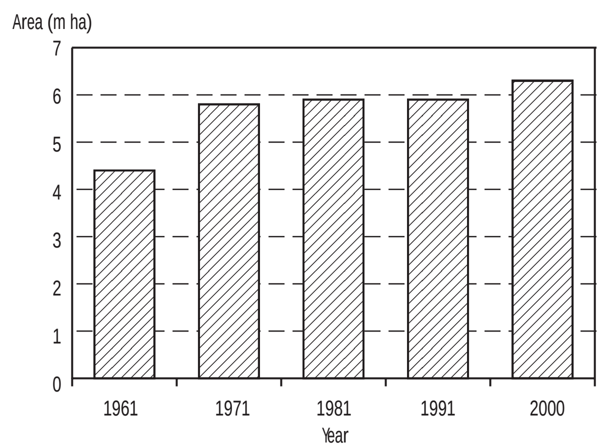

Figure 3. Maize area in India, 1961/2000.

Table 4. Annual compound growth rates (%) of area, production, and yield of maize, coarse cereals, and food grains in India.

	1981-90			1991-99		
Commodity	**Production**	**Area**	**Yield**	**Production**	**Area**	**Yield**
Rice	3.62	0.41	3.19	1.90	0.62	1.27
Wheat	3.57	0.46	3.10	3.81	1.67	2.11
Maize	1.89	-0.20	2.09	2.55	0.84	1.69
Coarse cereals	0.40	-1.34	1.62	1.48	-0.54	-0.08
Food grains	2.85	-0.23	2.74	1.94	-0.17	1.52

Source: Directorate of Economics and Statistics, Ministry of Agriculture, GOI (various issues).

Table 5. Maize production, area, and yield in selected states of India.

	Production (000 tons)			Area (000 ha)			Yield (kg/ha)		
State	**†TE 1981**	**TE 1991**	**TE 1999**	**TE 1981**	**TE 1991**	**TE 1999**	**TE 1981**	**TE 1991**	**TE 1999**
Traditional maize growing states									
Bihar	807.9	1,172.6	1,371.8	854.1	684.8	718.6	946.7	1,709.0	1,897.7
Madhya Pradesh	674.7	1,185.7	1,075.4	772.6	877.8	843.9	873.3	1,350.0	1,276.0
Rajasthan	704.9	1,128.6	1,090.2	899.5	958.8	946.1	780.0	1,176.7	1,151.0
Uttar Pradesh	936.4	1,394.2	1,372.6	1,183.6	1,100.5	1,013.7	792.3	1,263.3	1,336.7
Non-traditional maize growing states									
Karnataka	392.0	733.6	1,643.3	149.0	261.5	528.6	2,630.9	2,805.6	3,108.7
Andhra Pradesh	583.8	456.6	1,216.0	314.1	308.3	400.5	1,858.8	1,481.2	3,036.2
All India	**6,485.7**	**8,892.4**	**10,754.4**	**5,887.0**	**8,892.9**	**6,221.5**	**1,100.0**	**1,530.0**	**1,730.0**

Source: Derived from Center for Monitoring Indian Economy (2000) - agriculture, CMIE, New Delhi.

† TE: Triennium average ending.

This is a clear indication that maize is gradually spreading to new areas and, to some extent, also replacing barley, sorghum, and pearl millet as a feed and fodder crop.

During 2001-02, as much as 70% of the maize grown in India was cultivated in six states (Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Rajasthan, and Uttar Pradesh). In 1999/2000, the national average maize yield (1.8 t/ha) was far behind the world average of 4.86 t/ha. During this period, the average maize yield on about 45% of the total maize area in India was less than 1.5 t/ha, and on only 15% was it slightly more than 3 t/ha. Lower yields and higher production costs in India, as compared to other countries, made maize non-competitive on the international market. In a globally competitive environment, maize yields in India need to increase to protect the maize producer.

In 1999/2000, maize yield levels across states ranged from less than 1.5 t/ha in Madhya Pradesh, Rajasthan, and Uttar Pradesh to more than 3 t/ha in Andhra Pradesh, Karnataka, and West Bengal (Figure 4). In Bihar, where a sizable area of maize was cultivated under irrigation, yield levels were still low, approaching 2 t/ha. These four traditional maize growing states (Bihar, Madhya Pradesh, Rajasthan, and Uttar Pradesh) have huge potential to raise maize production through increasing yield levels and intensifying cultivation in upland areas, provided that existing constraints are alleviated. In 1998/99, these states accounted for nearly 60% of the total maize area and about 40% of total production in India. An increase in average maize yields of about 25% in these states would result in additional maize production equal to more than 1 million tons throughout the country. In contrast, the non-traditional maize growing states of Andhra Pradesh and Karnataka account for 26% of total maize production and cover only 15% of the area, mainly due to high productivity. The study covered both of these contrasting production environments.

Maize area, production, and yield levels in the surveyed states are given in Table 5, and their periodical growth rates in Table 6. Maize in the non-traditional states performed impressively during the 1990s. Maize production increased annually at a rate of 9.25% in Andhra Pradesh and 11.66% in Karnataka, primarily due to area expansion and higher yields (Table 6). Maize production in Karnataka increased from 392,000 tons in TE 1981 to 1.643 million tons in TE 1999. This state ranked first in maize production in TE 1999, although it had ranked sixth in TE 1981 and fifth in TE 1991. Similarly, maize production in Andhra Pradesh jumped substantially, from 584,000 tons in TE 1981 to 1.216 million tons in TE 1999. In both these non-traditional maize growing states, maize yields were significantly higher than in traditional maize growing areas. Egg and maize production followed similar trends in Karnataka and Andhra Pradesh (Figures 5 and 6), showing close linkages between maize production and the poultry sector.

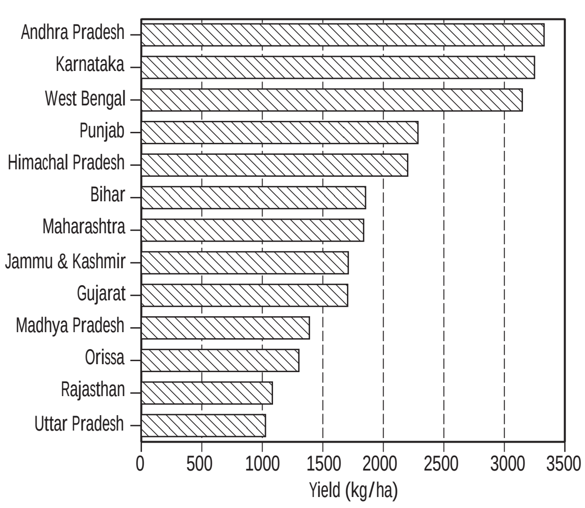

Figure 4. Maize yields in different states of India, 1999.

Table 6. Annual compound growth rates (%) of maize in selected states of India.

State	Period	Annual compound growth rate Production	Area	Yield
Bihar	1971-80	-1.26	-0.50	-0.77
	1981-90	2.67	-3.02	5.86
	1990-99	2.10	0.57	1.52
	1971-99	1.79	-1.11	2.93
Madhya Pradesh	1971-80	1.06	2.51	-1.43
	1981-90	5.07	1.28	3.73
	1990-99	-0.71	-0.78	0.11
	1971-99	3.24	1.44	1.77
Uttar Pradesh	1971-80	-4.71	-3.25	-1.51
	1981-90	4.95	-0.10	5.05
	1990-99	-1.19	-1.24	-0.06
	1971-99	1.29	-1.29	2.63
Rajasthan	1971-80	-1.93	0.61	-2.52
	1981-90	0.99	0.02	1.01
	1990-99	0.55	-0.29	0.80
	1971-99	2.00	0.90	1.10
Andhra Pradesh	1971-80	5.54	1.35	4.14
	1981-90	-0.07	-1.28	1.23
	1990-99	9.25	3.50	5.56
	1971-99	4.31	0.76	3.52
Karnataka	1971-80	0.12	3.98	-3.72
	1981-90	7.25	6.39	0.81
	1990-99	11.66	9.85	1.65
	1971-99	5.36	5.46	-0.10
India	1971-80	-0.63	-0.13	-0.47
	1981-90	1.89	-0.20	2.09
	1991-99	2.55	0.84	1.69
	1971-99	2.22	0.17	2.06

Source: Directorate of Economics and Statistics, Ministry of Agriculture, GOI (various issues).

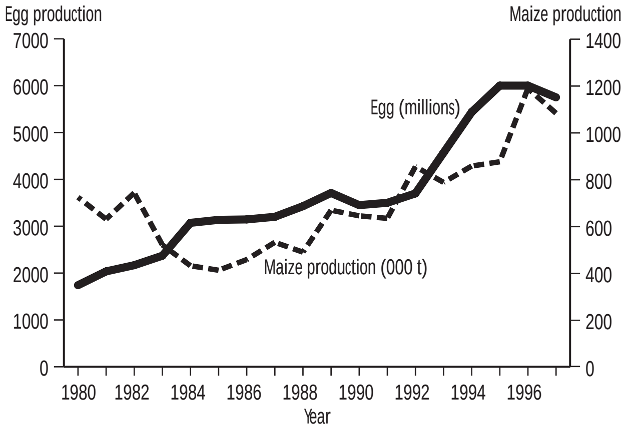

Figure 5. Egg and maize production in Andhra Pradesh, 1980/97.

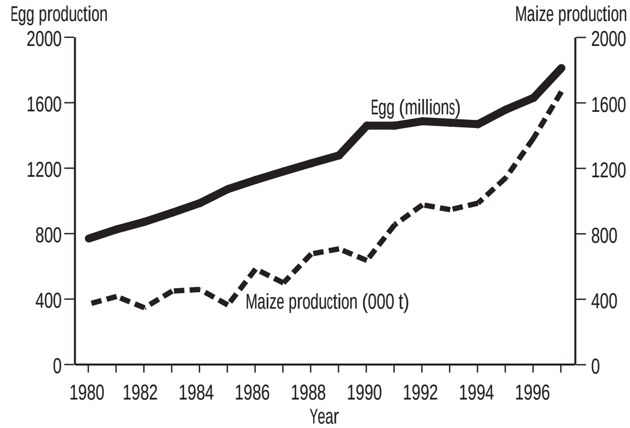

Figure 6. Egg and maize production in Karnataka, 1980/97.

In contrast, maize performed quite dismally in traditional growing areas (BIMARU states), although better in some than in others. During the 1990s, maize production increased in Bihar, declined in Madhya Pradesh and Uttar Pradesh, and stagnated in Rajasthan (Table 5). In TE 1998/99, Bihar's maize production (about 1.4 million tons) accounted for about 44% of the total maize area and contributed 68% of total production in India. Production grew by about 2.1% annually during 1990/99, largely due to yield increases as farmers increasingly cultivated improved cultivars and used inorganic fertilizers. In Uttar Pradesh and Madhya Pradesh, however, the area under maize decreased, and Rajasthan yield levels fell during the same period.

2.2 Maize Production Systems

2.2.1 Adoption of improved varieties

At about 60% of the total maize area in 1997/98, adoption of improved maize cultivars at the national level was relatively lower than that for rice (74%) and wheat (85%). In the study sites, there is a contrast between the traditional and non-traditional maize growing areas with respect to adoption of improved cultivars. In non-traditional areas the entire maize area is planted to hybrids (Table 7), for which seed replacement is high (75-90%). In these areas, maize is a commercial crop, and farmers intend to make a profit using the available improved technologies in their maize production.

Table 7. Season-wise area under different maize cultivars (as % of total maize area) in selected states of India, 2001.

State	District	Agro-ecological region	Rainy season area			Winter season area			Area under recycled seed	
			Local	Composite	Hybrids	Local	Composite	Hybrids	Rainy	Winter
Traditional maize growing states										
Bihar	Munger	South Bihar Alluvial Plain	75	25	0	0	0	100	100	10
	Siwan	North West Alluvial Plain	50	25	25	0	40	60	100	10
	Begusarai	North West Alluvial Plain	10	20	0	5	15	80	75	15
Madhya Pradesh	Chindwara	Satpura Plateau	75	25	0	50	25	25	100	100
	Mandsaur	Malwa Plateau	40	50	10	50	40	10	80	75
	Jhabua	Jhabua	75	20	5	75	20	5	100	100
Rajasthan	Banswara	Humid South Plain	60	25	15	4	6	90	80	40
	Bhilwara	Sub-humid Southern Plain	94	3	1	<1	<1	<1	90	<1
	Udaipur	Sub-humid Southern Plain	90	6	4	<1	<1	<1	90	<1
Uttar Pradesh	Behraich	North Eastern Plain	50	40	10	10	15	75	90	75
	Hardoi	Central Plain	70	20	10	10	80	10	90	90
	Bulandshar	Western Plain	20	30	50	nc[†]	nc	nc	40	<1
Non-traditional maize growing states										
Andhra Pradesh	Mahboobnagar	Northern Telangana	nc	nc	100	nc	nc	nc	5	nc
	Karimnagar	Northern Telangana	nc	nc	100	nc	nc	nc	25	nc
	Nizamabad	Scarce rainfall zone	nc	nc	100	nc	nc	nc	nc	nc
Karna-taka	Chitradurga	Central dry zone	nc	nc	100	nc	nc	nc	nc	nc
	Dharwad	Northern dry zone	nc	nc	100	nc	nc	nc	nc	nc
	Belgaum	Northern dry zone	nc	nc	100	nc	nc	nc	10	nc

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
[†] nc = not cultivated.

In the traditional maize growing areas, most farmers still grow local maize varieties during the rainy season (Table 7 and Figure 7), and seed replacement is very low. Composite varieties are also spreading, but their adoption is sporadic and limited to 25% of the maize area. Because of the high risk of surface waterlogging, hybrids are not very popular in the study domain during the rainy season, except in Bulandsahar district in Uttar Pradesh. Meanwhile, during the winter season, hybrids followed by composite varieties are widely cultivated in all the selected districts of Bihar, Banswara district in Rajasthan, and Behraich district in Uttar Pradesh (Figure 8). Winter maize is gaining importance because the crop is invariably grown with less risk under assured irrigation and complemented by best management practices, giving higher yields and more income than rainy season maize. In Bihar, for example, winter maize yield levels were much higher (2.6 t/ha) than rainy season yields of only 960 kg/ha. Thus farmers often use hybrids or composites during the winter season, and farm-saved local variety seed during the rainy season. Hybrids of Pioneer, Cargill, Ganga-Kaveri, and Bioseeds are popular during the winter season in Bihar. A complete list of popular cultivars in the study sites is given in Appendix 1.

In Madhya Pradesh, Rajasthan, and Uttar Pradesh, most farmers are not aware of available improved cultivars, and/or believe that improved cultivars may not suit their cropping system. For example, farmers prefer short-duration cultivars of about 70 days over hybrids maturing in 80-85 days because: (1) the high probability of terminal drought, which adversely affects crop yields, and (2) the high watch-and-ward requirement to protect the crop from bird damage, for which collective action by all maize producers is needed.

2.2.2 Crop rotation and calendar

Important crop rotations that include maize are listed in Appendix 2. Maize is most commonly grown in rotation with wheat in traditional areas and with chickpea in non-traditional areas. The most popular rotations are rice-wheat in Bihar, rice-wheat or pearl millet-wheat in Uttar Pradesh, soybean-wheat in Madhya Pradesh, pearl millet-wheat or groundnut-wheat in Rajasthan, and pearl millet-chickpea in Andhra Pradesh and Karnataka. Intercropping of maize with black gram, green gram, or vegetables is also common during the rainy season. In the most harsh, fragile, and rainfed environments maize-fallow is customarily practiced, as was evident in the Jhabua district of Madhya Pradesh.

Since maize is largely grown under rainfed conditions during the rainy season, the crop is sown after the onset of the monsoon. Sowing time ranges from the first fortnight of June to the first fortnight of July, depending upon the onset of the monsoon (Appendix 3). The crop is invariably harvested before the first fortnight in September. During the winter season, maize is sown in favorable and irrigated environments, usually in the month of November. In Uttar Pradesh, planting is sometimes delayed until the first fortnight in December, when the crop is rotated with short-cycle potato. Winter maize is harvested in the month of March, the exact date depending on the maturity of the selected cultivars.

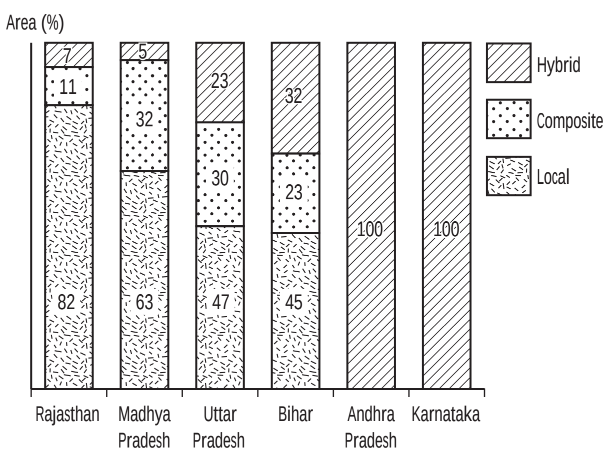

Figure 7. Area under different maize cultivars during the rainy season.

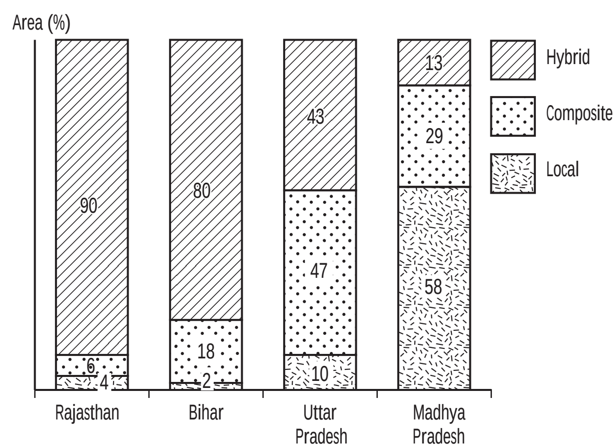

Figure 8. Area under different maize cultivars during the winter season.

2.2.3 Land and crop management practices

Most maize cultivation operations in India are performed in a traditional mode (Table 8), but some are gradually being modified. For example, line-sowing is gradually becoming more widespread than the traditional broadcasting method in most study sites, and bullocks and tractors are mostly used for land preparation. Also, improved soil conservation practices are being promoted by state governments and adopted by farmers. In contrast, in Chindwara, Madhya Pradesh, and Bhilwara, Rajasthan, farmers were applying only age-old traditional soil conservation methods such as raised bunds around the fields. Farmers in Munger and Begusarai in Bihar, Bulandshar in Uttar Pradesh, Chitradurga in Karnataka, and Nizamabad in Andhra Pradesh have replaced animals with tractors for land preparation. In other areas where the size of landholdings is declining, the small farmers now also hire tractors for land preparation. Evidence showed that the share of machines is gradually growing and that of bullocks declining. The Comprehensive Cost of Cultivation Scheme (Government of India 2000) report revealed that for rainy season maize production, the share of machinery use in operational costs increased marginally, from 2.6% in 1990/91 to 4% in 1996/97 in Madhya Pradesh and from 5% to 9% in Uttar Pradesh during the same periods (Table 9). In Andhra Pradesh, about 7% of total operational costs were due to machine use in 1996/97. In Rajasthan, this value reached just 2% in 1996/97, from a negligible share in 1990/91. The share of animal power in operational costs was 27% in Madhya Pradesh, 16% in Rajasthan, 8% in Uttar Pradesh, and 11% in Andhra Pradesh.

Weeding and other crop care/management practices are considered to be the most important factors affecting maize production. Weeds are ranked as the worst production constraint and can devastate the crop if not properly managed. Weeding and other crop management operations are performed twice. No chemicals are currently used for weed control, nor are they likely to be, given prevailing wage rates and existing unemployment in rural areas. Alternative innovative agronomic practices for weed management could be quickly adopted. Family labor, particularly women, performs most crop management operations. The opportunity cost of women and other farm laborers is extremely low. With some exceptions, not much labor is hired for maize production. If the chemical method of weed control were to be accepted, it would probably be in Uttar Pradesh, where a large share of labor is hired for different operations.

Harvesting is also done manually by both men and women, although women participate more than men at this stage. Shelling is generally performed manually, mostly by men, although mechanical shellers are also used in Munger, Begusarai, and Bahraich. Before shelling, ears are generally sorted for seed, home consumption, animal feed, and marketing. Thickly filled and long ears are separated for next year's seed. Women are largely responsible for storing the seed. The participation of women in maize production was found to be quite high. Although women do not have a key role in decision-making processes, they contribute significantly to raising maize production levels. Their contribution to sowing (particularly line-sowing), weeding, harvesting, and storing seed is enormous.

Table 8. Existing cultural practices for maize cultivation in selected states of India, 2001.

State	District	Land preparation method	Sowing/planting method	Soil conservation method	Crop care operations
Traditional maize growing areas					
Bihar	Munger	Machine	Broadcasting, Line	Traditional, Improved	Manual
	Siwan	Animal, Machine	Line	Traditional, Improved	Manual
	Begusarai	Machine	Broadcasting, Line	Traditional, Improved	Manual†
Madhya Pradesh	Chindwara	Animal, Machine	Broadcasting, Line	Traditional	Manual
	Mandsaur	Animal, Machine	Broadcasting, Line	Traditional, Improved	Manual
	Jhabua	Animal, Machine	Broadcasting, Line	Traditional, Improved	Manual
Uttar Pradesh	Behraich	Animal, Machine	Broadcasting, Line	Traditional, Improved	Manual
	Hardoi	Animal, Machine	Broadcasting, Line	Traditional, Improved	Manual
	Bulandshar	Machine	Broadcasting, Line (minimal)	Traditional, Improved	Manual
Rajasthan	Banswara	Animal, Machine	Broadcasting, Line	Traditional, Improved	Manual
	Bhilwara	Animal, Machine (minimal)	Broadcasting, Line	Traditional	Manual
	Udaipur	Animal, Machine	Broadcasting, Line	Traditional, Improved	Manual
Non-traditional maize growing areas					
Andhra Pradesh	Mahboobnagar	Machine, Animal	Line	Traditional, Improved	Manual
	Karimnagar	Machine, Animal	Line, Broadcast	Traditional, Improved	Manual
	Nizamabad	Machine	Line	Traditional, Improved,	Manual
Karnataka	Chitradurga	Machine, Animal	Line	Traditional, Improved	Manual
	Dharwad	Machine, Animal	Line	Traditional, Improved	Manual
	Belgaum	Animal, Machine	Line	Traditional, Improved	Manual

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
† Defoliation is also practiced in the winter season.

Table 9. Cost of maize production (Rs/ha†) in selected states of India, 1996/97.‡

	Traditional maize growing area		Non-traditional maize area	
Input	Madhya Pradesh	Rajasthan	Uttar Pradesh	Andhra Pradesh
Seed	136.13	172.70	111.00	476.96
	(3.42)	*(2.66)*	*(2.16)*	*(5.73)*
Fertilizer	263.43	611.32	435.94	1308.40
	(6.61)	*(9.42)*	*(8.47)*	*(15.71)*
Manure	101.83	481.09	99.23	329.84
	(2.56)	*(7.42)*	*(1.93)*	*(3.96)*
Insecticide	0.00	0.00	0.00	83.12
	(0.00)	*(0.00)*	*(0.00)*	*(0.99)*
Irrigation	0.63	15.17	104.86	159.12
	(0.02)	*(0.23)*	*(2.04)*	*(1.92)*
Human labor	2184.34	3952.13	3422.06	4294.22
	(54.82)	*(60.93)*	*(66.46)*	*(51.57)*
Animal power	1068.00	1042.42	422.81	924.57
	(26.80)	*(16.07)*	*(8.21)*	*(11.10)*
Machine	158.39	129.87	481.59	552.61
	(3.98)	*(2.00)*	*(9.35)*	*(6.64)*
Interest on working capital	71.66	81.83	71.33	198.48
	(1.80)	*(1.26)*	*(1.39)*	*(2.38)*
Total operational costs	3982.41	6486.53	5148.82	8327.39
	(100.00)	*(100.00)*	*(100.00)*	*(100.00)*
All paid up costs (Cost A) (Rs/kg)	254.11	180.45	173.82	263.48
Cost A + imputed value of family labor and bullock labor (Cost B) (Rs/kg)	410.19	278.67	330.39	425.64
Cost B + imputed rental value of owned land + cost of owned capital (Cost C) (Rs/kg)	571.14	499.32	523.29	495.96

Source: Cost of Cultivation of Principal Crops, Government of India, 2000.
† US$ 1.00 = Indian Rs.44.00 (May 2004).
‡ Figures in parentheses indicate % of total operational costs.

2.2.4 Input use and levels

Resource use patterns in maize production in the districts included in this study are presented in Tables 10 to 12 and Tables 13a to 13c. Average seed use levels are higher in winter season maize than rainy season maize (Table 10). Hybrid seed use was also higher than for local/traditional varieties and composites. Local/traditional seed use ranged from 6.0 to 10.0 kg/ha, while hybrid seed use ranged from 7.0 to 14.5 kg/ha in traditional maize growing areas in the rainy season. In the non-traditional maize growing areas, hybrid seed use ranged from 12.5 to 16.0 kg/ha, and local/traditional varieties and composites were not cultivated. Seed use in the winter season ranged from 8.0 to 10.0 kg/ha, except in the Banswara district of Rajasthan, where seed use was 14.0 kg/ha. The use of other inputs (nutrients and organic manures) is higher in areas where maize is grown as a commercial crop. For example, input use levels (particularly nutrients, organic manure, and pesticides) are relatively higher in Bihar, Andhra Pradesh, and Karnataka than in other regions (Table 11). All these districts have a sizable marketed surplus, between 60 and 95%. On the other hand, input use is very low in Jhabua district, where tribal populations predominate and maize is grown for subsistence. Application of nitrogenous and phosphate fertilizers is negligible, and zinc and pesticide use is uncommon. Farmers in this district also use meager quantities of farmyard manure (FYM).

Table 10. Average seed use (kg/ha) of different maize cultivars by season in selected states of India, 2001.

		Rainy season			Winter season		
State	District	Local	Composite	Hybrids	Local	Composite	Hybrids
Traditional maize growing states							
Bihar	Munger	8.0	8.0	10.0	8.0	9.0	10.0
	Siwan	6.0	6.0	8.0	7.0	7.0	9.0
	Begusarai	7.0	7.0	8.0	7.0	8.0	9.0
Madhya Pradesh	Chindwara	7.5	7.5	8.5	8.0	8.0	9.0
	Mandsaur	6.0	6.0	7.5	6.0	6.0	8.0
	Jhabua	6.0	6.0	7.0	6.0	6.0	7.0
Uttar Pradesh	Behraich	8.0	8.0	11.0	8.0	8.0	11.0
	Hardoi	8.0	8.0	10.0	8.0	8.0	10.0
	Bulandsahar	10.0	12.0	14.5	—-†	—-	—-
Rajasthan	Banswara	8.0	9.0	12.0	9.0	10.0	14.0
	Bhilwara	6.0	8.0	12.0	—-	—-	—-
	Udaipur	7.0	8.0	12.0	—-	—-	—-
Non-traditional maize growing states							
Andhra Pradesh	Mahboobnagar	—-	—-	15.0	—-	—-	—-
	Karimnagar	—-	—-	15.0	—-	—-	—-
	Nizamabad	—-	—-	16.0 (sole crop)	—-	—-	10.0 (intercrop)
Karnataka	Chitradurga	—-	—-	15.0	—-	—-	—-
	Dharwad	—-	—-	12.5	—-	—-	—-
	Belgaum	—-	—-	12.5	—-	—-	—-

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
† —- = not cultivated.

Survey results show that maize is a labor-intensive crop. Labor accounts for half the total cost of maize cultivation and was as high as 70% in Jhabua district for composite maize (Table 12). Tribal populations are predominant in the district, and agriculture is completely at the subsistence level. Farm operations are most commonly carried out by family members, though hired labor is also used in weeding and harvesting. In traditional maize growing areas, production of local/traditional maize varieties required 29-83 person-days/ha of family labor, while that of hybrids required 24-69 person-days/ha. The involvement of both family and hired labor was higher in non-traditional hybrid maize

Table 11. Input use for maize production in selected states of India, 2001.

State	District	Seed (kg / ha)	Nitrogen (kg / ha)	Phosphorus (kg / ha)	Potassium (kg / ha)	Zinc (kg / ha)	Farmyard manure(qtl / ha)	Pesticide (kg / ha)
Traditional maize growing states								
Bihar	Munger	8.7	55.0	23.0	3.5	0.0	17.5	5.0
	Siwan	7.7	33.4	13.8	2.1	10.0	13.5	2.5
	Begusarai	7.3	76.6	32.2	4.2	6.0	15.5	6.5
Madhya Pradesh	Chindwara	8.3	30.2	18.4	2.8	0.0	11.0	2.0
	Mandsaur	6.7	41.7	18.4	0.0	0.0	13.5	2.5
	Jhabua	6.3	16.0	11.5	0.0	0.0	7.0	0.0
Uttar Pradesh	Behraich	10.7	33.0	11.5	0.0	0.0	7.5	2.0
	Hardoi	11.3	44.0	0.0	0.0	0.0	6.5	0.0
	Bulandshar	14.7	66.0	27.6	0.0	0.0	9.0	2.0
Rajasthan	Banswara	10.0	65.0	30.0	4.0	0.0	9.0	2.0
	Bhilwara	8.5	40.0	19.0	0.3	0.0	3.5	0.0
	Udaipur	9.0	45.0	20.0	0.5	0.0	4.5	0.0
Non-traditional maize growing states								
Andhra Pradesh	Mahboobnagar	12.5	110.0	40.0	5.0	0.0	12.5	3.0
	Karimnagar	12.0	100.0	40.0	5.0	0.0	15.0	2.0
	Nizamabad	14.0	150.0	50.0	10.0	0.0	20.0	4.5
Karnataka	Chitradurga	14.0	75.0	28.0	5.0	0.0	20.0	2.0
	Dharwad	12.5	50.0	25.0	3.0	0.0	15.0	1.5
	Belgaum	13.0	60.0	25.0	3.0	0.0	15.0	1.5

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

Table 12. Use of family and hired labor (person-days / ha) in maize production by type of cultivar in selected states of India, 2001. [†]

		Local varieties			Composites			Hybrids		
State	District	Family	Hired	Total	Family	Hired	Total	Family	Hired	Total
Traditional maize growing states										
Bihar	Munger	46.51	36.17	82.69	46.44	39.06	85.50	38.71	30.17	68.94
		(27.90)	(21.70)	(49.60)	(29.00)	(24.40)	(53.40)	(27.20)	(21.20)	(48.44)
	Siwan	29.50	54.48	83.98	29.56	54.48	84.04	24.63	45.42	70.00
		(16.30)	(30.10)	(46.40)	(17.20)	(31.70)	(48.90)	(16.00)	(29.50)	(45.47)
	Begusarai	64.76	66.01	130.77	64.70	65.89	130.83	53.87	54.96	108.96
		(25.90)	(26.40)	(52.30)	(27.20)	(27.70)	(55.00)	(24.80)	(25.30)	(50.16)
Madhya Pradesh	Jhabua	68.50	0.00	68.51	68.50	0.00	68.50	57.08	0.00	57.08
		(69.10)	(0.00)	(69.10)	(69.90)	(0.00)	(69.90)	(67.90)	(0.00)	(67.91)
	Mandsaur	83.29	26.56	109.86	82.95	26.55	109.50	69.15	22.13	91.25
		(43.90)	(14.00)	(57.90)	(45.30)	(14.50)	(59.80)	(42.80)	(13.70)	(56.48)
	Chindwara	70.09	46.00	116.11	69.91	46.06	115.96	58.36	38.28	96.65
		(32.30)	(21.20)	(53.60)	(34.00)	(22.40)	(56.40)	(31.10)	(20.40)	(51.51)
Rajasthan	Banswara	64.65	66.06	130.73	64.67	66.01	130.67	54.01	55.06	108.96
		(27.50)	(28.10)	(55.60)	(28.90)	(29.50)	(58.40)	(25.70)	(26.20)	(51.85)
	Bhilwara	46.51	36.17	82.85	46.47	36.26	82.73	38.74	30.27	68.96
		(29.70)	(23.10)	(52.90)	(31.40)	(24.50)	(55.90)	(28.80)	(22.50)	(51.26)
	Udaipur	74.42	46.40	121.05	74.42	46.48	121.10	61.99	38.84	100.82
		(34.80)	(21.70)	(56.60)	(36.50)	(22.80)	(59.40)	(33.20)	(20.80)	(54.00)
Uttar Pradesh	Behraich	76.06	58.40	134.47	76.08	58.40	134.48	63.39	48.78	112.09
		(31.00)	(23.80)	(54.80)	(32.70)	(25.10)	(57.80)	(29.50)	(22.70)	(52.16)
	Hardoi	74.49	46.58	121.07	74.42	46.48	121.10	61.99	38.84	100.82
		(34.70)	(21.70)	(56.40)	(36.50)	(22.80)	(59.40)	(33.20)	(20.80)	(54.00)
	Bulandshar	52.11	78.93	131.05	51.91	79.06	130.96	43.27	65.80	109.22
		(20.60)	(31.20)	(51.80)	(21.80)	(33.20)	(55.00)	(19.40)	(29.50)	(49.00)
Non-traditional maize growing states										
Andhra Pradesh	Nizamabad	—-[‡]	—-	—-	—-	—-	—-	62.74	63.02	125.73
								(22.40)	(22.50)	(44.89)
	Karimnagar	—-	—-	—-	—-	—-	—-	70.40	46.66	117.08
								(34.10)	(22.60)	(56.71)
	Mahboobnagar	—-	—-	—-	—-	—-	—-	63.32	45.01	108.33
								(33.20)	(23.60)	(56.80)
Karnataka	Chitradurga	—-	—-	—-	—-	—-	—-	68.78	60.00	128.76
								(27.40)	(23.90)	(51.29)
	Dharwad	—-	—-	—-	—-	—-	—-	61.75	45.28	106.88
								(28.50)	(20.90)	(49.33)
	Belgaum	—-	—-	—-	—-	—-	—-	52.36	56.33	115.36
								(30.55)	(21.20)	(51.70)

Source: IFAD-CIMMYT-India RRA Surveys, 2001. [†] Figures in parentheses indicate % of total operational costs. [‡] —- = not cultivated.

growing areas due to better commercial orientation. Wage rates and availability of family labor determined the extent of involvement of hired labor for different farming operations.

Tables 13a to 13c provide resource use patterns for local/traditional, composite, and hybrid maize production in India. Levels of machine power (tractors) and animal power (bullock) use are similar across the

Table 13a. Resource use pattern in maize production (local varieties) in selected traditional maize growing states of India, 2001.[†]

State	District	Labor(person-days/ha)	Bullock (pair-days/ha)	Tractor (hrs/ha)	Seed (kg/ha)	Fertilizer (kg/ha)	Farmyard manure (t/ha)	Irrigation (hrs/ha)	Interest on capital (16% p.a)	Rental value of owned land(Rs/ha)
Bihar	Munger	82.69	1.50	15.60	13.33	131.71	2.17	8.16	208.4	1,000.32
		(49.60)	(2.70)	(11.20)	(1.60)	(7.90)	(3.90)	(4.90)	(2.50)	(12.00)
	Siwan	83.98	1.50	18.70	12.67	132.13	2.66	9.05	253.4	1,312.25
		(46.40)	(2.50)	(12.40)	(1.40)	(7.30)	(4.40)	(5.00)	(2.80)	(14.50)
	Begusarai	130.77	2.00	24.20	13.75	187.53	0.50	11.50	287.55	1,500.24
		(52.30)	(2.40)	(11.60)	(1.10)	(7.50)	(0.60)	(4.60)	(2.30)	(12.00)
Madhya Pradesh	Jhabua	68.51	3.00	0.00	5.95	0.00	3.17	0.00	0.00	437.21
		(69.10)	(9.10)	(0.00)	(1.20)	(0.00)	(9.60)	(0.00)	(0.00)	(8.82)
	Mandsaur	109.86	3.98	10.30	13.28	75.89	3.86	5.69	123.33	1,005.62
		(57.90)	(6.30)	(6.50)	(1.40)	(4.00)	(6.10)	(3.00)	(1.30)	(10.60)
	Chindwara	116.11	2.96	13.70	15.16	158.13	4.04	14.93	249.11	855.65
		(53.60)	(4.10)	(7.60)	(1.40)	(7.30)	(5.60)	(6.90)	(2.30)	(7.90)
Rajasthan	Banswara	130.73	3.68	19.90	10.58	188.09	2.98	11.52	282.14	793.53
		(55.60)	(4.70)	(10.20)	(0.90)	(8.00)	(3.80)	(4.90)	(2.40)	(6.75)
	Bhilwara	82.85	2.14	13.90	10.18	131.56	2.14	8.3	211.44	532.51
		(52.90)	(4.10)	(10.70)	(1.30)	(8.40)	(4.10)	(5.30)	(2.70)	(6.80)
	Udaipur	121.05	3.63	14.90	9.62	160.39	2.99	10.49	224.55	793.42
		(56.60)	(5.10)	(8.40)	(0.90)	(7.50)	(4.20)	(4.90)	(2.10)	(7.42)
Uttar Pradesh	Behraich	134.47	3.18	19.20	12.27	203.66	3.35	12.02	282.18	911.58
		(54.80)	(3.90)	(9.40)	(1.00)	(8.30)	(4.10)	(4.90)	(2.30)	(7.43)
	Hardoi	121.07	3.65	15.00	13.95	161.01	3.00	10.51	225.42	793.24
		(56.40)	(5.10)	(8.40)	(1.30)	(7.50)	(4.20)	(4.90)	(2.10)	(7.39)
	Bulandshar	131.05	0.00	26.40	15.18	237.82	3.96	14.93	278.3	1,186.57
		(51.80)	(0.00)	(12.50)	(1.20)	(9.40)	(4.70)	(5.90)	(2.20)	(9.38)

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † Figures in parentheses indicate % of total operational costs.

Table 13b. Resource use patterns in maize production (composite maize) in selected traditional maize growing states of India, 2001.[†]

State	District	Labor(person-days/ha)	Bullock (pair-days/ha)	Tractor (hrs/ha)	Seed (kg/ha)	Fertilizer (kg/ha)	Farmyard manure (t/ha)	Irrigation (hrs/ha)	Interest on capital (16% p.a)	Rental value of owned land(Rs/ha)
Bihar	Munger	85.50	1.49	15.61	8.40	65.64	2.19	8.32	216.16	999.94
		(53.40)	(2.80)	(11.70)	(2.10)	(4.10)	(4.10)	(5.20)	(2.70)	(12.49)
	Siwan	84.04	1.48	18.76	7.73	67.03	2.69	8.94	249.22	1,312.30
		(48.90)	(2.60)	(13.10)	(1.80)	(3.90)	(4.70)	(5.20)	(2.90)	(15.27)
	Begusarai	130.83	1.98	24.18	12.48	92.77	3.01	11.42	285.45	1,499.83
		(55.00)	(2.50)	(12.20)	(2.10)	(3.90)	(3.80)	(4.80)	(2.40)	(12.61)
Madhya Pradesh	Jhabua	68.50	3.00	0.00	7.59	0.00	3.17	0.00	0.00	437.57
		(69.90)	(9.20)	(0.00)	(3.10)	(0.00)	(9.70)	(0.00)	(0.00)	(8.93)
	Mandsaur	109.50	4.02	10.37	8.69	38.45	3.84	5.69	128.18	999.83
		(59.80)	(6.60)	(6.80)	(1.90)	(2.10)	(6.30)	(3.10)	(1.40)	(10.92)
	Chindwara	115.96	3.01	13.70	11.30	80.19	3.98	15.01	246.74	844.07
		(56.40)	(4.40)	(8.00)	(2.20)	(3.90)	(5.80)	(7.30)	(2.40)	(8.21)
Rajasthan	Banswara	130.67	3.65	19.95	17.34	93.97	2.98	11.41	290.88	793.22
		(58.40)	(4.90)	(10.70)	(3.10)	(4.20)	(4.00)	(5.10)	(2.60)	(7.09)
	Bhilwara	82.73	2.17	13.93	18.87	66.60	2.17	6.29	214.60	531.32
		(55.90)	(4.40)	(11.30)	(5.10)	(4.50)	(4.40)	(5.60)	(2.90)	(7.18)
	Udaipur	121.10	3.66	14.95	16.31	79.51	2.99	10.61	224.26	793.09
		(59.40)	(5.40)	(8.80)	(3.20)	(3.90)	(4.40)	(5.20)	(2.20)	(7.78)
Uttar Pradesh	Behraich	134.48	3.17	19.19	18.61	102.37	3.34	12.09	290.85	912.10
		(57.80)	(4.10)	(9.90)	(3.20)	(4.40)	(4.30)	(5.20)	(2.50)	(7.84)
	Hardoi	121.10	3.66	14.95	15.29	79.51	2.99	10.60	224.26	794.11
		(59.40)	(5.40)	(8.80)	(3.00)	(3.90)	(4.40)	(5.20)	(2.20)	(7.79)
	Bulandshar	130.96	0.00	26.19	18.45	119.06	3.97	15.00	273.83	1,187.02
		(55.00)	(0.00)	(13.20)	(3.10)	(5.00)	(5.00)	(6.30)	(2.30)	(9.97)

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † Figures in parentheses indicate % of total operational costs.

different types of maize varieties grown. However, maize production in some areas, such as Jhabua and Mandsaur in Madhya Pradesh, Hardoi in Uttar Pradesh, and Udaipur and Bhilwara in Rajasthan, was much less mechanized as compared to the Bulandshar district of Uttar Pradesh, where average tractor power use was 26.4 machine-hours/ha, and animal power use was negligible. In terms of the share of total operational costs, that of machine power ranged from 7% (10.3 machine-hours/ha) to 13% (26.2 machine-hours/ha).

Overall, current input use in Indian maize production is far below recommended levels. Inorganic fertilizers are applied with the use of improved cultivars and irrigation. In the Jhabua district of Madhya Pradesh, where farmers are very poor, maize is grown in marginal rainfed environments, not fertilized at all, and grown only for subsistence. Across the surveyed districts/states, fertilizer use in maize production ranged from 38.4 kg/ha in Hardoi, Uttar Pradesh, to 329.4 kg/ha in Nizamabad, Andhra Pradesh. Maize farmers also commonly applied farmyard manure, varying from 500 kg/ha for local/traditional varieties in Begusarai, Bihar, to 5.7 t/ha for hybrid production in Nizamabad, Andhra Pradesh. The use of fertilizers and FYM was higher in the non-traditional hybrid maize growing areas. The availability and use of FYM varied from one household to another, depending mainly on the number of farm animals reared at home. Since most farmers continue to grow local/traditional cultivars under rainfed conditions, the use of other material inputs is also low. As such, there is enough scope for raising nutrient use across all maize types in all study sites, to increase maize production levels in India.

Table 13c. Resource use pattern in maize production (hybrid varieties) in selected traditional and non-traditional maize growing states of India, 2001.†

State	District	Labor(person-days/ha)	Bullock (pair-days/ha)	Tractor (hrs/ha)	Seed (kg/ha)	Fertilizer (kg/ha)	Farmyard manure (t/ha)	Irrigation (hrs/ha)	Interest on capital (16% p.a)	Rental value of owned land(Rs/ha)
Traditional maize-growing areas										
Bihar	Munger	68.94	1.48	15.65	6.83	133.22	2.16	8.20	213.50	1,000.03
		(48.44)	(2.60)	(11.00)	(4.00)	(7.80)	(3.80)	(4.80)	(2.50)	(11.71)
	Siwan	70.00	1.47	18.78	6.28	133.02	2.65	9.05	249.42	1,312.72
		(45.47)	(2.40)	(12.20)	(3.40)	(7.20)	(4.30)	(4.90)	(2.70)	(14.21)
	Begusarai	108.96	1.99	24.11	13.55	187.68	3.04	11.40	286.74	1,500.21
		(50.16)	(2.30)	(11.10)	(5.20)	(7.20)	(3.50)	(4.40)	(2.20)	(11.51)
Madhya Pradesh	Jhabua	57.08	2.99	0.00	2.92	0.00	3.16	0.00	0.00	437.31
		(67.91)	(8.90)	(0.00)	(2.90)	(0.00)	(9.40)	(0.00)	(0.00)	(8.67)
	Mandsaur	91.25	4.00	10.34	6.78	77.55	3.81	5.80	126.02	1,000.42
		(56.48)	(6.20)	(6.40)	(3.50)	(4.00)	(5.90)	(3.00)	(1.30)	(10.32)
	Chindwara	96.65	3.00	13.69	9.00	159.87	3.98	15.10	247.69	968.27
		(51.51)	(4.00)	(7.30)	(4.00)	(7.10)	(5.30)	(6.70)	(2.20)	(8.60)
Rajasthan	Banswara	108.96	3.69	19.96	19.16	186.61	3.03	11.60	290.00	793.10
		(51.85)	(4.40)	(9.50)	(7.60)	(7.40)	(3.60)	(4.60)	(2.30)	(6.29)
	Bhilwara	68.96	2.15	13.99	6.78	132.38	2.15	8.23	209.87	531.13
		(51.26)	(4.00)	(10.40)	(4.20)	(8.20)	(4.00)	(5.10)	(2.60)	(6.58)
	Udaipur	100.82	3.65	14.93	12.09	159.08	2.99	10.53	224.06	793.17
		(54.00)	(4.90)	(8.00)	(5.40)	(7.10)	(4.00)	(4.70)	(2.00)	(7.08)
Uttar Pradesh	Behraich	112.09	3.18	19.12	14.95	203.72	3.35	12.12	283.66	911.60
		(52.16)	(3.70)	(8.90)	(5.80)	(7.90)	(3.90)	(4.70)	(2.20)	(7.07)
	Hardoi	100.82	3.65	14.93	12.09	159.08	2.99	10.53	224.06	793.17
		(54.00)	(4.90)	(8.00)	(5.40)	(7.10)	(4.00)	(4.70)	(2.00)	(7.08)
	Bulandshar	109.22	0.00	26.30	17.38	238.07	4.01	14.98	280.87	1,187.70
		(49.00)	(0.00)	(11.80)	(6.50)	(8.90)	(4.50)	(5.60)	(2.10)	(8.88)
Non-traditional maize-growing areas										
Andhra Pradesh	Nizamabad	125.73	0.00	28.85	24.87	329.39	5.71	22.18	420.15	1,749.50
		(44.89)	(0.00)	(10.30)	(7.40)	(9.80)	(5.10)	(6.60)	(2.50)	(10.41)
	Karimnagar	117.08	1.65	15.89	16.35	141.22	3.79	6.44	235.37	1,186.77
		(56.71)	(2.00)	(7.70)	(6.60)	(5.70)	(4.60)	(2.60)	(1.90)	(9.58)
	Mahbobnagar	108.33	1.83	10.49	16.93	119.01	2.98	8.93	366.20	937.26
		(56.80)	(2.40)	(5.50)	(7.40)	(5.20)	(3.90)	(3.90)	(3.20)	(8.19)
Karnataka	Chitradurga	128.76	0.00	23.34	23.19	247.03	5.32	21.99	316.32	905.28
		(51.29)	(0.00)	(9.30)	(7.70)	(8.20)	(5.30)	(7.30)	(2.10)	(6.01)
	Dharwad	106.88	2.86	16.68	15.60	215.80	4.59	13.92	234.00	1,313.00
		(49.33)	(3.30)	(7.70)	(6.00)	(8.30)	(5.30)	(5.20)	(1.80)	(10.10)
	Belgaum	98.35	2.33	18.56	20.36	220.65	3.87	16.52	201.36	1,300.12
		(51.70)	(3.60)	(6.70)	(6.30)	(9.30)	(4.50)	(4.10)	(2.30)	(7.85)

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † Figures in parentheses indicate % of total operational costs.

2.2.5 Yield levels

Hybrid yields are substantially higher than yields of composites and local/traditional cultivars. On average, hybrid yield levels were 2 to 3 times higher than those of local varieties and 1.5 times higher than those of composites. In the 1999/2000 rainy season, average yields of local varieties ranged from 1.5 to 2.0 t/ha in Bihar, 1.0 to 1.5 t/ha in Madhya Pradesh, 0.9 to 1.4 t/ha in Rajasthan, and 1.4 to 1.8 t/ha in Uttar Pradesh (Table 14). In the case of composite varieties, average yields ranged from 2.4 to 3.0 t/ha in Bihar, 1.2 to 1.8 t/ha in Madhya Pradesh, 1.2 to 1.8 t/ha in Rajasthan, and 1.8 to 2.2 t/ha in Uttar Pradesh. These levels are comparable to national average yields, but are lower than the global average of 4.86 t/ha. Clearly, hybrids could potentially increase maize production in India. Hybrid maize yields during the rainy season in Andhra Pradesh and Karnataka (3.2-3.8 t/ha) were lower than those in Bihar (5.0-6.5 t/ha).

Maize yields during the winter season were higher than yields during the rainy season. On average, the difference was up to 1.0 t/ha for hybrids and 0.5 t/ha for local varieties. Bihar, where about 32% of total maize area is planted to hybrids, achieved considerably higher yields from hybrids during the winter season, ranging between 5.5 and 6.5 t/ha in Munger district, 6.0 to 7.0 t/ha in Siwan district, and 6.0 to 9.0 t/ha in Begusarai district (Table 14). During winter, maize enjoys a favorable environment of cooler temperatures and higher solar radiation, is less affected by insects pests, and thereby yields better.

In Bihar, winter maize is generally cultivated on *diara* lands, which are river flood plains considered most fertile. These lands are used for cultivation only during the winter season, after the river water has receded. Yield levels on *diara* lands are comparable to those in the principal maize growing countries, namely China (4.7 t/ha) and the USA (8.6 t/ha). It was also observed that hybrids (mainly from the private sector) outperform composites in selected sites. Farmers in the study sites reported that local and composite cultivars tend to yield below their potential because of: (1) low seed replacement, (2) poor seed quality, and (3) non-effectiveness of the recommended package of practices. A well-established and effective seed sector would help farmers to access new hybrids and thereby increase maize production.

Table 14. Yield (t/ha) of different types of maize cultivars in selected states of India, 2001.

State	District	Rainy season			Winter season		
		Local	Composite	Hybrids	Local	Composite	Hybrids
Traditional maize growing states							
Bihar	Munger	1.50	2.40	5.00	2.00	2.85	6.00
	Siwan	1.60	2.50	5.50	2.25	3.20	6.50
	Begusarai	2.00	3.00	6.50	3.00	3.50	7.50
Madhya Pradesh	Chindwara	1.20	1.60	2.50	1.40	1.85	3.00
	Mandsaur	1.50	1.80	3.00	1.75	2.00	3.25
	Jhabua	1.00	1.20	2.00	1.25	1.65	2.50
Uttar Pradesh	Behraich	1.80	2.20	3.60	2.00	2.40	4.50
	Hardoi	1.40	1.80	2.50	1.60	2.20	3.60
	Bulandsahar	1.57	2.07	3.00	—-[†]	—-	—-
Rajasthan	Banswara	1.40	1.80	2.80	1.60	2.00	3.60
	Bhilwara	0.90	1.20	1.60	—-	—-	—-
	Udaipur	1.20	1.40	2.00	—-	—-	—-
Non-traditional maize growing states							
Andhra Pradesh	Mahboobnagar	—-	—-	3.75	—-	—-	—-
	Karimnagar	—-	—-	3.50	—-	—-	—-
	Nizamabad	—-	—-	6.50 (60-70,000 green ears)	—-	—-	—-
Karnataka	Chitradurga	—-	—-	3.80	—-	—-	—-
	Dharwad	—-	—-	3.50	—-	—-	—-
	Belgaum	—-	—-	3.25	—-	—-	—-

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
[†] —- = not cultivated.

2.2.6 Economics of maize production

The economics of maize production for local varieties, composites, and hybrids is presented in Tables 15a, 15b, and 15c, respectively. As expected, the cost of producing hybrid maize was higher than for local varieties and composites (Table 15a). On average, the cost of hybrid maize production was approximately 7% higher than that of local varieties, and 12% higher than that of composites. The net profit over the sum of all paid up costs, plus the imputed value of family labor and family bullock labor, plus the imputed rental value of owned land and the cost of owned capital (cost C) was much higher for hybrids than for local varieties and composites (Table 15b). In all districts of the traditional maize growing BIMARU states, except in Jhabua, Madhya Pradesh, and Bhilwara in Rajasthan, farmers were incurring losses by growing local maize varieties. Returns over all paid costs (cost A) were positive in all districts, except for production of local varieties in Chindwara, Madhya Pradesh, Banswara in Rajasthan, and Hardoi and Bulandshar in Uttar Pradesh.

The unit cost of production shows the efficiency of production. It was noted that the unit cost of hybrid production, due to significantly higher yield levels, was much lower than that of composites and local varieties (Table 15c). The most efficient hybrid producing districts were Munger and Siwan in Bihar. Jhabua, which grows maize for subsistence, has the lowest unit cost of hybrid production, when all paid up costs and imputed value of family labor and family bullock labor are considered. The unit cost of production was higher in traditional maize growing areas, except in Bihar, where the moisture regime and climatic conditions favor wide adoption of improved cultivars and higher maize yields.

Table 15a. Cost of cultivation (Rs/ha[†]) of various maize cultivars in selected states of India, 2001.

		Local maize varieties			Composite maize varieties			Hybrid maize varieties		
State	District	Cost C	Cost B	Cost A	Cost C	Cost B	Cost A	Cost C	Cost B	Cost A
Traditional maize growing states										
Bihar	Munger	8,336	6,011	5,011	8,006	5,852	4,852	8,540	6,003	5,215
	Siwan	9,050	7,575	6,262	8,594	7,275	5,963	9,238	7,512	6,450
	Begusarai	12,502	9,265	7,765	11,894	8,906	7,406	13,034	9,510	8,297
Madhya Pradesh	Jhabua	4,957	1,532	1,095	4,900	1,625	1,188	5,044	1,819	1,181
	Mandsaur	9,487	5,337	4,337	9,156	5,178	4,178	9,694	5,419	4,544
	Chindwara	10,831	7,331	6,487	10,281	7,008	6,164	11,259	7,509	6,790
Rajasthan	Banswara	11,756	8,519	7,725	11,188	8,300	7,506	12,609	9,084	8,578
	Bhilwara	7,831	5,506	4,975	7,400	5,450	4,919	8,072	5,534	5,215
	Udaipur	10,693	6,969	6,175	10,194	6,794	6,000	11,203	7,253	6,684
Uttar Pradesh	Behraich	12,269	8,469	7,556	11,634	8,209	7,297	12,894	8,806	8,181
	Hardoi	10,734	7,009	6,215	10,194	6,773	5,980	11,203	7,253	6,684
	Bulandshar	12,650	10,050	8,862	11,906	9,681	8,494	13,375	10,500	9,587
Non-traditional maize growing states										
Andhra Pradesh	Nizamabad	—-[‡]	—-	—-	—-	—-	—-	16,806	12,619	11,294
	Karimnagar	—-	—-	—-	—-	—-	—-	12,388	7,925	6,975
	Mahboobnagar	—-	—-	—-	—-	—-	—-	11,444	7,281	6,706
Karnataka	Chitradurga	—-	—-	—-	—-	—-	—-	15,063	10,625	10,031
	Dharwad	—-	—-	—-	—-	—-	—-	13,000	9,062	7,987
	Belgaum	—-	—-	—-	—-	—-	—-	14,520	9,142	8,500

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
[†] US$ 1.00 = Indian Rs. 44.00 (May 2004).
[‡] —- = not cultivated.
Note: Farm gate prices were used to compute the data. Cost A: All paid up costs; Cost B: Cost A+ imputed value of family labor and family bullock labor; Cost C: Cost B+ imputed rental value of owned land + cost of owned capital.

Table 15b. Net returns over cost (Rs/ha[†]) of various maize cultivars in selected states of India, 2001.

		Local maize varieties			Composite maize varieties			Hybrid maize varieties		
State	District	Cost C	Cost B	Cost A	Cost C	Cost B	Cost A	Cost C	Cost B	Cost A
Traditional maize growing states										
Bihar	Munger	114	2,439	3,439	3,369	5,523	6,523	7,385	9,920	10,710
	Siwan	-290	1,185	2,488	4,181	5,500	6,812	7,553	9,278	10,340
	Begusarai	-3152	85	1,585	6	2,994	4,494	5,326	8,851	10,063
Madhya Pradesh	Jhabua	1088	4,513	4,950	4,000	7,675	8,113	6,116	9,541	9,979
	Mandsaur	-2817	1,332	2,332	44	4,022	5,022	5,946	10,221	11,096
	Chindwara	-5738	-2,238	-1,395	-2,036	1,237	2,081	866	4,616	5,334
Rajasthan	Banswara	-5381	-2,144	-1,350	-2,688	200	994	3,966	7,491	7,997
	Bhilwara	1594	3,919	4,450	4,850	6,800	7,331	6,778	9,316	9,634
	Udaipur	-494	3,231	4,025	1,450	4,850	5,644	4,522	8,472	9,041
Uttar Pradesh	Behraich	-4684	-884	29	-3,024	401	1,313	5,966	10,054	10,679
	Hardoi	-5554	-1,848	-1,055	-2,454	967	1,760	-883	3,067	3,636
	Bulandshar	-6500	-3,900	-2,712	-2,066	159	1,346	1,385	4,260	5,173
Non-traditional maize growing areas										
Andhra Pradesh	Nizamabad	—-[‡]	—-	—-	—-	—-	—-	9,319	13,506	14,831
	Karimnagar	—-	—-	—-	—-	—-	—-	12,788	17,250	18,200
	Mahboobnagar	—-	—-	—-	—-	—-	—-	11,356	15,519	16,084
Karnataka	Chitradurga	—-	—-	—-	—-	—-	—-	10,113	14,550	15,144
	Dharwad	—-	—-	—-	—-	—-	—-	10,750	14,688	15,763
	Belgaum	—-	—-	—-	—-	—-	—-	10,268	15,366	15,361

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
[†] US$ 1.00 = Indian Rs. 44.00 (May 2004).
[‡] —- = not cultivated.
Note: Farm gate prices were used to compute the data. Cost A: All paid up costs; Cost B: Cost A+ imputed value of family labor and family bullock labor; Cost C: Cost B+ imputed rental value of owned land + cost of owned capital.

Efficient maize producing zones were delineated based on the unit cost of production (Figure 9). It was noted that all selected maize growing districts in Uttar Pradesh, Chindwara and Mandsaur in Madhya Pradesh, and Banswara in Rajasthan were inefficient when cultivating local varieties because of poor yield levels. Maize production in Begusarai in Bihar and Bhilwara and Udaipur in Rajasthan was borderline in terms of efficiency. The remaining districts were efficient maize producers. Introduction of hybrids changed the scenario. Only Chindwara in Madhya Pradesh and Hardoi in Uttar Pradesh were inefficient (Figure 10). Therefore, strong seed sector and technology dissemination mechanisms need to be developed to achieve widespread use of improved technologies and hybrids.

Table 15c. Unit cost of production (Rs/kg†) of various cultivars in selected states of India, 2001.

		Local maize varieties			Composite maize varieties			Hybrid maize varieties		
State	District	Cost C	Cost B	Cost A	Cost C	Cost B	Cost A	Cost C	Cost B	Cost A
Traditional maize growing states										
Bihar	Munger	3.21	2.31	1.93	2.16	1.58	1.31	1.74	1.23	1.06
	Siwan	3.93	3.29	2.72	2.69	2.27	1.86	2.00	1.63	1.40
	Begusarai	4.57	3.39	2.84	3.21	2.41	2.00	2.41	1.76	1.54
Madhya Pradesh	Jhabua	3.54	1.09	0.78	2.45	0.81	0.59	2.10	0.67	0.49
	Mandsaur	6.90	3.90	3.20	4.58	2.59	2.09	2.85	1.59	1.34
	Chindwara	10.40	7.10	6.30	6.05	4.12	3.63	4.50	3.00	2.72
Rajasthan	Banswara	7.84	5.68	5.15	5.59	4.15	3.75	3.23	2.33	2.20
	Bhilwara	3.70	2.60	2.30	2.64	1.95	1.76	2.45	1.68	1.58
	Udaipur	4.45	2.90	2.57	3.77	2.51	2.22	3.03	1.96	1.81
Uttar Pradesh	Behraich	7.00	5.00	4.00	5.54	3.90	3.47	2.80	1.91	1.78
	Hardoi	8.95	5.84	5.18	5.66	3.76	3.32	4.67	3.02	2.78
	Bulandshar	9.04	7.18	6.33	4.91	4.03	3.54	3.71	2.92	2.66
Non-traditional maize growing areas										
Andhra Pradesh	Nizamabad	—-‡	—-	—-	—-	—-	—-	3.06	2.29	2.05
	Karimnagar	—-	—-	—-	—-	—-	—-	2.34	1.49	1.32
	Mahboobnagar	—-	—-	—-	—-	—-	—-	2.38	1.52	1.39
Karnataka	Chitradurga	—-	—-	—-	—-	—-	—-	2.84	2.00	1.89
	Dharwad	—-	—-	—-	—-	—-	—-	2.60	1.81	1.60
	Belgaum	—-	—-	—-	—-	—-	—-	2.71	1.83	1.26

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

† US$ 1.00 = Indian Rs. 44.00 (May 2004).

‡ —- = not cultivated.

Note: Farm gate prices were used to compute the data. Cost A: All paid up costs; Cost B: Cost A+ imputed value of family labor and family bullock labor; Cost C: Cost B+ imputed rental value of owned land + cost of owned capital.

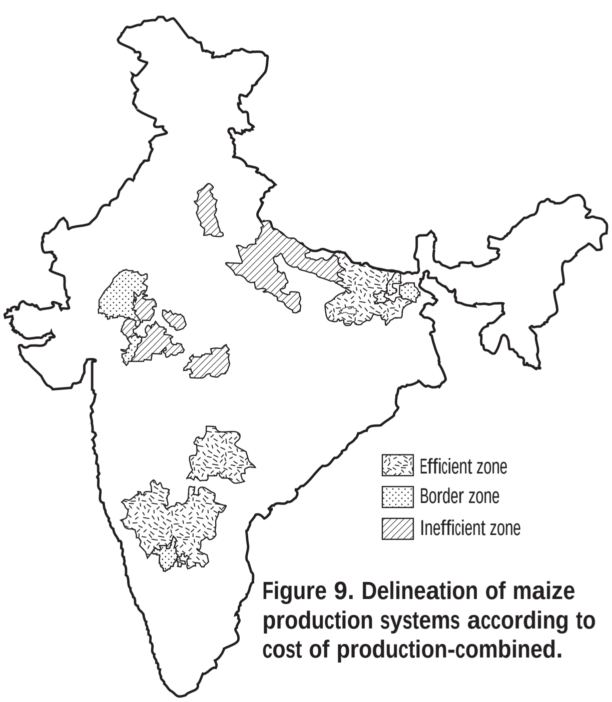

Figure 9. Delineation of maize production systems according to cost of production-combined.

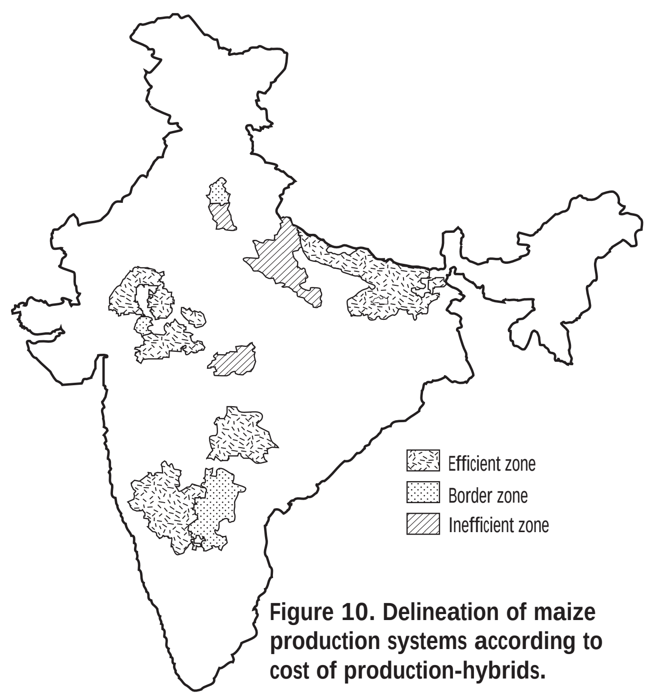

Figure 10. Delineation of maize production systems according to cost of production-hybrids.

Regions were grouped into four categories based on yield levels and unit cost of production: (1) low-yield and high-cost, (2) high-yield and high-cost, (3) low-yield and low-cost, and (4) high-yield and low-cost (Table 16). The most favorable region combines high-yield and low-cost, while low-yield and high-cost identify the most undesirable regions. It should be noted that about one-third of the maize area is characterized as high-yield and low-cost. Most non-traditional maize growing areas and, to some extent, Bihar fall into this category. Another extreme situation, low-yield and low-cost, is found in Jhabua district in Madhya Pradesh, where yields are very low and the unit cost of production is also low.

Technology and policy solutions to maize productivity constraints would not be the same for different categories within the table. While new research frontiers to raise yield levels would be the possible strategy in the high-yield and low-cost group, strong technology dissemination programs would be the prerequisite for low-yield and low-cost areas (Table 16). Low-yield and high-cost regions call for alleviating biotic and abiotic constraints. Low yields may be due to biotic and abiotic constraints, and farmers may incur costs while trying to minimize their losses. The fourth area, characterized as high-yield and high-cost, needs resource-saving technologies to reduce costs and enhance input use efficiency.

Table 16. Maize area (%) and possible strategies for improving production efficiency, by yield and production cost category, India, 2001. †

Attribute		Maize yield level			
		Low (less than 3 t/ha)		High (more than 4 t/ha)	
		Rainy season	Winter season	Rainy season	Winter season
Production cost	**High**	Chindwara Mandsaur Jhabua	Chindwara Mandsaur Jhabua	Munger Siwan Karimnagar Mehboobnaga Dharwad	Munger Siwan
		Alleviation of abiotic and biotic constraints (41%)		***Resource saving strategies (22%)***	
	Low	Hardoi Banswara Bhilwara Udaipur Belgaum	Hardoi Banswara	Begusarai Behraich Bulandshar Nizamabad Chitradurga	Begusarai Behraich
		Technology dissemination strategies (4%)		***New yield frontiers (33%)***	

† Figures in parentheses are the estimated proportions of maize area in each category.

2.2.7 Post-harvest practices and product/by-product utilization patterns

The important post-production/post-harvest operations for maize are drying, grain (and seed) storage, shelling, and milling. Despite technological advances, solar drying, not mechanical drying, is commonly practiced across the study areas. With large proportions of production aimed for the market, all surveyed states (except Madhya Pradesh, Rajasthan, and the Hardoi district of Uttar Pradesh) have improved storage facilities that prevent grain damage from ground- or rainwater, insect pests, and excessive heat. These facilities consist of bins with thatched roofs or brick roofs, and ferro-cement bins. Conventional storage methods include cribs, and open and closed mud-plastered baskets. In Rajasthan, maize is stored in thatched-roof cribs. In general, the type of storage structure depends largely on the farmer's financial status. The introduction of high-yielding hybrids called for modern, improved storage facilities. Local maize varieties, which have several husk layers tightly covering the ear, have some protection against common insects. Hybrids, with shorter, loose husks, do not have the same protection.

In general, shelling is still done conventionally in the field or in home backyards. In conventional shelling, grains are removed from the cobs either by beating them on the ground or having animals walk over them. Milling, on the other hand, is done mechanically in all study areas, except Jhabua, Madhya Pradesh, where it is still done conventionally, i.e., flour is milled from maize grains using a hand-held stone mill, which virtually all households in the village own.

With few exceptions, more than 50% of all maize produced in both traditional and non-traditional maize growing areas is marketed (Table 17). Traditional maize growing areas marketed up to 80% of their produce, while the marketed surplus in non-traditional areas was as high as 96%. In contrast, the marketable surplus is a mere 33% in Jhabua, Madhya Pradesh, and 35% in Bhilwara, Rajasthan.

Farmers in non-traditional maize growing areas, as well as in Bihar and Uttar Pradesh, grow maize for commercial purposes, i.e., a large portion is sold on the market. In contrast, the crop is important for household food security in traditional maize growing areas, where a significant portion is consumed as food, especially in poorer districts. Maize consumption as food, however, has gradually declined over time, due to the availability of cheaper rice and wheat in fair price shops. Also, 2-5% of all maize produced is eaten as green ears, particularly in Nizamabad, Andhra Pradesh. Green ears have become popular in urban areas and fetch high prices. A quick maize crop for green ears earns high profits, provides green fodder for animals, and clears land for subsequent crops. These advantages can be realized provided there is a good market close to the village. Unfortunately, the maize production environment has a poor network of markets and very low levels of urbanization. Contract farming prevails in states where maize and allied industries have flourished in the past, especially in southern India. Such arrangements may also help ensure better returns to maize growers in other states/regions.

Dry, shelled cobs are used as fuel. Green leaves and stems, from thinning the maize crop, are used as animal fodder. Maize grain is often fed to dairy cattle, whose milk yield is reported to increase by 20-25% if fed maize grain. Maize gives higher conversion of dry substance to milk, meat, and eggs as compared to other cereals. Maize grain is either fed directly to animals or is dried, milled, and mixed with other ingredients.

Farmers are unaware of other uses of maize and its products. Nor are they familiar with specialty maize types and products such as baby corn, sweet corn, popcorn, corn oil, and corn syrup. If these alternative maize types and products could be introduced in conjunction with assured markets and agro-processing industries, this would go a long way towards improving livelihoods of poor maize producers.

Table 17. Maize utilization and marketing (% of total maize production) in selected states of India, 2001.

		Retained for home utilization				
State	**District**	**Grain consumption**	**Green ear**	**Animal feed**	**Wastage**	**Marketed surplus**
Traditional maize growing states						
Bihar	Munger	10	2	5	3	80
	Siwan	10	2	10	3	75
	Begusarai	20	5	10	5	60
Madhya Pradesh	Chindwara	40	3	5	5	47
	Mandsaur	30	2	5	5	52
	Jhabua	55	5	2	5	33
Uttar Pradesh	Behraich	19	2	5	2	74
	Hardoi	20	2	5	3	70
	Bulandsahar	30	3	5	2	60
Rajasthan	Banswara	30	2	5	3	60
	Bhilwara	60	2	1	2	35
	Udaipur	45	2	1	2	50
Non-traditional maize growing states						
Andhra Pradesh	Mahboobnagar	0	2	3	1	94
	Karimnagar	0	2	2	2	94
	Nizamabad	0	1	2	1	94+2 (green ear)
Karnataka	Chitradurga	0	2	1	1	96
	Dharwad	1	2	1	1	95
	Belgaum	1	2	1	1	95

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

3. Maize Production Constraints

3.1 Biotic and Abiotic Constraints

Compared to most cereals, maize faces fewer biotic and abiotic constraints to production. Weeds are the major problem during the rainy season. Farmers reported that, in the absence of appropriate crop management practices, weed damage to the maize crop may be as high as 50-75%. Most farmers control weeds and perform almost all crop management operations twice. *Cynodon dactylon* and *Echinocloa* are important weeds in all study sites. *Amaranthus* and *Achyranthes aspera* are also found in Madhya Pradesh and *Cyprus rotendrus* in Andhra Pradesh and Karnataka (Table 18).

Among the insect pests, caterpillars (*Amsacta moorei*), stem borers (*Chilo partellus*), and termites (*Odontotermes obesus*) seriously affect plant growth and maize production in all the study sites. Rats also severely damage maize ears in all the areas. Weevils (*Cylas formicaricus*) and cutworms (*Agrotis ipsilon*) are found in Bihar; jassids (*Amrasca biguttula*), aphids (*Rhopalosiphum maidis*), moths (*Plutella maculipennis*) and white grubs (*Lachnosterna consanguinea*) in Madhya Pradesh; grasshoppers (*Hieroglyphus nigrorepletus*) and white grubs (*Lachnosterna consanguinea*) in Rajasthan; and pink borers (*Chilo zonellus*) and termites (*Odontotermes obesus*) in Andhra Pradesh and Karnataka. Among diseases, rust (*Puccinia sorghi*) is common in all the sites. *Xanthomonas* spp. is reported in Bihar and downy mildew (*Sclerospora philippinensis*) in Madhya Pradesh. Post-flowering stalk rot (PFSR) is a common disease in Andhra Pradesh and Karnataka. Though not insects, nematodes reduce maize production in Andhra Pradesh, Karnataka, and Rajasthan.

Farmers reported that drought in the rainfed regions and waterlogging in times of excess rainfall are the most important abiotic constraints to maize production in India (Table 19). In central Uttar Pradesh, surface waterlogging was reported to occur twice in every five years during normal planting times, causing 60-80%

Table 18. Important biotic constraints affecting maize production in selected states of India, 2001.

State	District	Insects and nematodes	Diseases	Weeds
Traditional maize growing states				
Bihar	Munger	Caterpillar, stem borer, termites, weevil, rats	Rust, leaf blight	*Cynodon dactylon, Echinocloa*
	Siwan	Caterpillar, stem borer, termites, cutworm, weevil, rats	Rust, leaf blight	*C. dactylon, Echinocloa*, Cucurbitaceae family
	Begusarai	Caterpillar, stem borer, termites, weevil, rats	Rust, leaf blight, stalk rot	*C. dactylon, Echinocloa*, Cucurbitaceae family
Madhya Pradesh	Chindwara	Caterpillar, stem borer, termites, aphids, jassids, rats	Rust, downy mildew	*C. dactylon, Echinocloa, Amaranthus*
	Mandsaur	Caterpillar, stem borer, termites, aphids, jassids, maydis, grubs, moths, rats	Rust, downy mildew	*C. dactylon, Echinocloa, Amaranthus, Cynodon bengalensis*
	Jhabua	Caterpillar, stem borer, termites, jassids, maydis, rats	Rust, downy mildew	*Echinocloa, Amaranthus, C. bengalensis, Achyranthes aspera*
Uttar Pradesh	Bahraich	Termites, stem borer, caterpillar, cutworm, leaf roller	Rusts, brown spot, seed and seedling blight	*C. dactylon, Echinocloa, Trianthema monogyna*, wild rice
	Hardoi	Termites, stem borer, caterpillar, cutworm, leaf roller	Rusts, brown spot, seed and seedling blight	*C. dactylon*, Motha, *T. monogyna*
	Bulandsahar	Termites, stem borer, caterpillar, cutworm	Brown spot, seed and seedling blight	*C. dactylon*, Motha, *T. monogyna*
Rajasthan	Banswara	Grasshopper, stem borer, termites, nematodes, white grub	Downy mildew, leaf spot	*Echinocloa, Amaranthus*
	Bhilwara	Grasshopper, stem borer, termites, nematodes, white grub	Downy mildew, leaf spot	*Echinocloa, Amaranthus*
	Udaipur	Grasshopper, stem borer, termites, nematodes, white grub	Downy mildew, leaf spot	*Echinocloa, Amaranthus*
Non-traditional maize growing states				
Andhra Pradesh	Mahboobnagar	Stem borer, pink borer, termite	Post-flowering sheath rot, leaf blight	*Cyprus rotendrus, C. dactylon, Echinocloa*
	Karimnagar	Stem borer, termites, nematodes	Post-flowering sheath rot, leaf blight	*C. rotendrus, C. dactylon, Echinocloa*
	Nizamabad	Stem borer, termites, nematodes	Post-flowering sheath rot, leaf blight	*C. rotendrus, C. dactylon, Echinocloa*
Karnataka	Chitradurga	Stem borer, shoot fly, termites	Post-flowering sheath rot, leaf blight	*C. rotendrus, C. dactylon, Echinocloa*
	Dharwad	Stem borer, termites, nematodes, grubs	Post-flowering sheath rot, rust, leaf blight	*C. rotendrus, C. dactylon, Echinocloa, Amaranthus*
	Belgaum	Stem borer, termites, nematodes, grubs	Post-flowering sheath rot, leaf blight, rust	*C. rotendrus, C. dactylon, Echinocloa, Amaranthus*

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

crop damage. Excessive soil moisture when rainy season maize is being sown makes farmers delay planting, which in turn impedes plant growth and adversely affects production. Surface waterlogging and excessive soil moisture are causing maize to be gradually replaced by rice. Zinc deficiency is common, but very few farmers apply zinc to their maize crop because they cannot afford it, and because they are not aware of its uses.

3.2 Institutional and Economic Constraints

3.2.1 Output prices

During 2000/01, the Government of India fixed the minimum support price for maize grain at Rs. 4.40/kg (US$ 0.10/kg), which was about 7.2% higher than in the previous year. The RRA surveys found that farmers tend to sell their produce for less than this minimum support price. Farmers in Bihar were affected more severely than farmers in Madhya Pradesh and Uttar Pradesh (Table 20). In 1999/2000, the minimum support price was Rs. 4.15/kg (US$ 0.09/kg), and most farmers in all locations received 8-15% higher prices for their produce on the open market (Table 21).

In 2000/01, farm gate prices of most food grains in India declined and that of maize grain declined by 25-30% compared to the previous year's price. These low prices were due mainly to huge buffer stocks of food grains maintained by the government and a very lukewarm response of the government machinery for procurement. The 4% increase in maize production, as compared to that in 1999/2000, as well as the import of 235,000 metric tons of maize in 1999 (after continuous exports from 1992 to 1998) also pulled maize prices down during 2000/01. At the global level, maize prices also show a declining trend. Production efficiency will have to improve to step-up yield levels and compensate for the decline in prices if maize producers are to be protected from imports.

Table 19. Important abiotic constraints affecting maize production in selected states of India, 2001.

State	Agro-ecological region	District	Abiotic stresses
Traditional maize growing states			
Bihar	South Bihar Alluvial Plain	Munger	Water stress, zinc deficiency, late planting, flooding, wilting
	North West Alluvial Plain	Siwan	Water stress, zinc deficiency, late planting
	North West Alluvial Plain	Begusarai	Water stress, zinc deficiency, late planting, flooding, wilting
Madhya Pradesh	Satpura Plateau	Chindwara	Water stress, zinc deficiency, late planting
	Malwa Plateau	Mandsaur	Water stress, zinc deficiency, late planting
	Jhabua	Jhabua	Water stress, zinc deficiency, late planting
Uttar Pradesh	North Eastern Plain	Behraich	Water stress, waterlogging, late planting
	Central Plain	Hardoi	Water stress, waterlogging, late planting
	Western Plain	Bulandshar	Water stress, late planting
Rajasthan	Humid South Plain	Banswara	Late planting
	Sub-humid Southern Plain	Bhilwara	Acute water stress, late planting
	Sub-humid Southern Plain	Udaipur	Acute water stress, late planting
Non-traditional maize growing states			
Andhra Pradesh	Northern Telangana	Mahboobnagar	Water stress, late planting, zinc deficiency
	Northern Telangana	Karimnagar	Water stress, late planting, zinc deficiency
	Scarce rainfall zone	Nizamabad	Water stress, late planting
Karnataka	Central dry zone	Chitradurga	Water stress, late planting, wilting
	Northern dry zone	Dharwad	Water stress, late planting, zinc deficiency
	Northern dry zone	Belgaum	Water stress, late planting, zinc deficiency

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

Table 20. Prices of winter season harvested maize (Rs/kg[†]) in selected states of India, 2001.

		Farm gate prices			Nearest market prices		
State	District	Local	Composite	Hybrids	Local	Composite	Hybrids
Traditional maize growing states							
Bihar	Munger	3.00	3.25	3.00	3.25	3.50	3.25
	Siwan	3.50	3.50	3.50	3.65	3.65	3.65
	Begusarai	3.25	3.40	3.25	3.40	3.55	3.40
Madhya Pradesh	Chindwara	3.90	4.00	4.00	4.00	4.10	4.10
	Mandsaur	4.00	4.20	4.00	4.10	4.30	4.30
	Jhabua	3.75	4.00	3.90	3.90	4.10	4.10
Uttar Pradesh	Behraich	4.50	4.50	4.50	4.65	4.65	4.65
	Hardoi	4.50	4.50	4.50	4.60	4.60	4.60
	Bulandsahar	—-	—-	—-	—-	—-	—-
Rajasthan	Banswara	4.00	4.00	4.00	4.15	4.15	4.15
	Bhilwara	3.60	3.60	3.60	3.75	3.75	3.75
	Udaipur	3.75	3.75	3.75	3.90	3.90	3.90
Non-traditional maize growing states							
Andhra Pradesh	Mahboobnagar	—-	—-	—-	—-	—-	—-
	Karimnagar	—-	—-	—-	—-	—-	—-
	Nizamabad	—-	—-	—-	—-	—-	—-
Karnataka	Chitradurga	—-	—-	—-	—-	—-	—-
	Dharwad	—-	—-	—-	—-	—-	—-
	Belgaum	—-	—-	—-	—-	—-	—-

Source: IFAD-CIMMYT-India RRA Surveys, 2001. [†] US$ 1.00 = Indian Rs. 44.00 (May 2004). [‡] —- = not cultivated.

3.2.2 Markets

As in other developing countries, markets and road networks in the maize growing regions of India are not well developed. Roads in most maize growing regions are much poorer than the national average, and even feeder roads are not well laid out.

Markets for food grains in general, and maize in particular, are very thinly spread throughout the maize growing regions. Most maize production is sold in local village markets, where grain prices are 2-8% lower than those in the nearest regulated market (see earlier discussion). Grain prices in the latter markets are still lower than the government-established minimum support price. Farmers continue to sell their produce in the local village market because: (1) when grains are sold outside the village, transportation costs tend to be higher than marginal returns due to price difference, and (2) farmers tend to sell to local traders, especially if they need to pay back any loan they may have taken out to purchase inputs and for consumption purposes. Farmers were of the opinion that there is no other reliable way to sell their produce, as the volume is often very low. A collective effort for transportation and marketing would minimize transportation costs, allow quick product disposal, and fetch higher output prices.

3.2.3 Technological know-how

The technology transfer process (through the public extension system) in the study area was observed to be very weak. The private sector has a visible presence, particularly in areas where hybrids have been adopted. Important private seed companies in the region include Pioneer, Cargill, Ganga-Kaveri, and Bioseed. These companies were present mainly in Andhra Pradesh, Karnataka, and Bihar, where maize is cultivated as a commercial crop in relatively more favorable areas. Private seed companies promote their hybrids through local seed merchants.

The study found that farmers were not familiar with other improved maize technologies (e.g., herbicides, pesticides, and post-harvest management). Most reported they had no contact with village extension workers and obtained agricultural information from local seed and agro-input merchants and/or the radio. Access to television is very limited. There is a need to increase contacts between farmers and scientists to disseminate new information and allow higher returns to investment from agricultural research. Innovative attempts have been initiated in this direction by the Chandra Sekhar Azad University of Agriculture and Technology, Kanpur, through a help-line service. Farmers can call the help-line during a given time period and get the solution to their problems directly from experts at the university. There is a need to popularize such initiatives among farmers, to disseminate first-hand information, and to replicate the approach in other locations.

Table 21. Prices of rainy season harvested maize (Rs/kg[†]) in selected states of India, 2001.

State	District	Farm gate prices			Nearest market prices		
		Local	Composite	Hybrid	Local	Composite	Hybrid
Traditional maize growing states							
Bihar	Munger	4.50	4.60	4.50	4.65	4.75	4.65
	Siwan	4.70	4.70	4.60	4.85	4.85	4.75
	Begusarai	4.50	4.50	4.40	4.65	4.65	4.55
Madhya Pradesh	Chindwara	4.80	4.80	4.70	4.85	4.85	4.80
	Mandsaur	4.75	4.75	4.65	4.85	4.80	4.85
	Jhabua	4.75	4.75	4.65	4.85	4.80	4.75
Uttar Pradesh	Behraich	5.50	5.50	5.40	5.60	5.60	5.60
	Hardoi	4.80	4.80	4.80	4.90	4.90	4.90
	Bulandsahar	5.25	5.25	5.25	5.35	5.35	5.35
Rajasthan	Banswara	4.50	4.25	4.25	4.60	4.35	4.35
	Bhilwara	4.25	4.15	4.15	4.35	4.25	4.25
	Udaipur	4.25	4.15	4.15	4.35	4.25	4.25
Non-traditional maize growing states							
Andhra Pradesh	Mahboobnagar	—-‡	—-	3.50	—-	—-	4.45
	Karimnagar	—-	—-	3.60	—-	—-	4.50
	Nizamabad	—-	—-	4.00	—-	—-	4.75
Karnataka	Chitradurga	—-	—-	4.25	—-	—-	4.50
	Dharwad	—-	—-	4.00	—-	—-	4.50
	Belgaum	—-	—-	4.00	—-	—-	4.50

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

† US$ 1.00 = Indian Rs. 44.00 (May 2004).

‡ —- = not cultivated.

Note: In the 1999/2000 crop season, the government announced a minimum support price of Rs. 4.15/kg, which is 7.2% higher than in the previous year.

4. Priority Constraints for Research

To develop a demand-driven maize R&D plan, it is important to systematically prioritize the abiotic, biotic, and socio-economic constraints discussed earlier. An objective and analytically driven R&D program is expected to improve research efficiency. This chapter is devoted to assessing and prioritizing constraints to maize production, particularly in the upland areas of India.

4.1 Methodology

Earlier, Widawsky and O'Toole (1996), Ramasamy et al. (1997), and Roy and Datta (2000) prioritized production constraints based on the yield gap concept. These studies assumed that the gap between yields produced in on-farm demonstrations and in farmers' fields was due to abiotic, biotic, and socio-economic constraints, and sub-divided the causes of the yield gap into several prevailing constraints. These authors argue that the technology is already available, and that the yield gap was essentially due to lack of information or non-availability of the necessary inputs. In the present study, we have not used the yield gap concept; instead, we estimated the damage due to prevailing constraints.

4.1.1 Abiotic and biotic constraints

To estimate the damage caused by prevailing abiotic and biotic constraints, the RRA survey asked farmers to estimate or assess three parameters. The first parameter was the maize yield losses caused by specific abiotic and biotic constraints that farmers were unable to control due to poor access to technology information or lack of resources to apply available technologies. The second parameter was the extent of maize area affected by a specific constraint; the third parameter was the probability of occurrence of the constraints, which gave the frequency of occurrence of the constraints and how much yields were adversely affected by them. These three parameters have significant impact on prioritizing production constraints.

Total expected damage due to a specific abiotic or biotic constraint was computed as follows:

$$D_i = \{(YL_i * A_i * p_i) * TMA\} * P_m$$

where D_i is total expected damage (in Indian rupees) due to the i^{th} constraint; YL_i is maize yield loss (kg/ha) due to the i^{th} constraint; A_i is the proportion of total maize area adversely affected by the i^{th} constraint; p_i is the probability of occurrence of the i^{th} constraint; TMA is the total maize area (hectares) in the target domain; and P_m is the price of maize (rupees/kg).

An attempt was also made to prioritize socio-economic constraints by computing the expected losses incurred as a consequence of the constraint. Farmers reported four major socio-economic constraints: (1) low prices, (2) lack of markets, (3) non-availability of improved seed, and (4) lack of technical know-how. The following steps were taken to assess the losses due to the first three constraints.

4.1.2 Low prices

Due to a glut of food grains, particularly rice and wheat, in most target locations, farmers complained about receiving prices for maize that were lower than the minimum support price announced by the government. The income loss due to these lower prices was computed as follows:

$$L_p = (MSP_m - PRM_m) * MP_t$$

where L_p is the income loss (in rupees) due to receiving lower prices of maize; MSP_m is the minimum support price (in rupees/kg) announced by the government; PRM_m is the price (rupees/kg) received by farmers in the nearest market; and MP_t is the quantity of maize (kg) marketed/sold in the t^{th} target domain.

4.1.3 Lack of markets

Due to inadequately developed markets for maize, farmers usually received lower prices in village markets than in organized markets located some distance away. The loss due to non-existence of maize markets in a village is computed as follows:

$$L_m = \{(PRM_m - PRM_v) - TC_{m,v}\} * MQV$$

where L_m is the income loss (in rupees) due to lack of markets in the village, PRM_m is the price received by farmers in the nearest market (rupees/kg); PRM_v is the price received by farmers in the village (rupees/kg); $TC_{m,v}$ is the transportation cost (in rupees/kg) between the organized market and the village; and MQV is the amount of maize (in kg) sold in the village.

4.1.4 Non-availability of improved cultivars

Due to a weak seed sector, farmers lacked access to higher-yielding maize varieties, especially hybrids. Losses due to non-availability of improved cultivars, particularly hybrids, is computed as follows:

$$L_s = \{(Y_h - Y_c) * A_c + (Y_h - Y_l) * (1\text{-}s)\, A_l\} * P_m{}^{1}$$

where L_s is the income loss (in rupees) due to non-availability of hybrid maize seed; Y_h is the yield of hybrid maize (in kg/ha); Y_c is the yield of composite maize (in kg/ha); Y_l is the yield of local maize (in kg/ha); A_c is the area under composite maize (hectares); A_l is the area under local maize (hectares); s is the share (%) of maize farmers' preference for local maize; (1-s) is the share (%) of maize farmers' preference for hybrid maize; and P_m is the price of maize (in rupees/kg).

The value of damage became the criterion for ranking farmer-identified maize productivity constraints in India. The higher the value of the damage, the higher the constraint ranked as a research priority. All production constraints were ranked according to their share in production losses.

[1] A_l, the area under local maize, has been multiplied by (1-s) on the assumption that farmers sow local maize due to non-availability of hybrids; thus if hybrids were made available, the current area under local varieties would switch over to hybrids. "Preferences" here refer to cultivating in a broad sense.

4.2 Prioritization of Maize Production Constraints

4.2.1 Abiotic and biotic constraints

Thirty-two abiotic and biotic production constraints were identified and prioritized based on the damage caused to maize production (Appendices 4, 5, and 6). The estimated total annual income lost as a result of these constraints was about Rs. 17,541 million (US$ 399 million) in BIMARU states and about Rs. 14,800 million (US$ 397 million) in KAP states.

In the traditional maize growing BIMARU states, more than 95% of the production damage was caused by 13 abiotic and biotic constraints (Table 22a). Fifty-two percent of the damage to maize production was attributed to four constraints: *Echinocloa*, *Cynodon dactylon*, rats, and termites. Caterpillars, water stress, stem borers, and weevils accounted for about 30% of the damage to total maize production in the selected states and were ranked as the next priority at the national level. Next in the priority ranking were zinc deficiency, rust, seed/seedling blight, cutworms, and leaf blight, which together are responsible for about 13% of total damage to maize production. The remaining 19 constraints contributed less than 5% to production losses and have low priority at the national level.

Table 22a. Prioritization of major constraints to maize production in traditional maize growing areas (BIMARU states), India, 2001.

Production constraint	Yield loss (%)	Area affected (%)	Probability of occurrence	Estimated damage: In millions of Rs.†	Estimated damage: % total production loss
Echinocloa	15-25	90-100	1.0	3,430	19.55
Cynodon dactylon	9-15	75-100	0.6-1.0	2,265	12.91
Rats	7.5-15	100	0.8-1.0	1,895	10.80
Termites	15-25	50-80	0.6-1.0	1,478	8.43
Caterpillars	8-10	80-100	1.0	1,525	8.69
Water stress	10-17.5	50-100	0.2-1.0	1,155	6.58
Stem borers	7.5	80-100	1.0	1,350	7.69
Weevils	6-10	100	1.0	1,256	7.16
Zinc deficiency	7.5-12.5	75-100	0.8-1.0	761	4.34
Rusts	3.5-12.5	50-75	0.5-0.7	323	1.84
Seed & seedling blight	15	75-80	0.5-0.8	669	3.82
Cutworms	3.5-12.5	25-60	0.4-0.6	298	1.70
Leaf blight	3.5-12.5	50-75	0.25-0.7	176	1.03
Miscellaneous	-	-	-	1,050	5.03
Total production losses				17,541	100.00

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
† US$ 1.00 = Indian Rs. 44.00 (May 2004).
Note: Estimated damage computed using: $D_i = \{(YL_i * A_i * p_i) * TMA\} * P_m$

In the non-traditional maize growing KAP states, more than 97% of production losses was reportedly due to the top 10 abiotic and biotic constraints (Table 22b). The top four constraints (*Echinocloa, C. dactylon,* termites, and caterpillars) already accounted for about 56% of production losses. Water stress and stem borers accounted for about 27% of the losses, while three constraints, namely weevils, zinc deficiency, and rust, caused 14% of production losses.

4.2.2 Socio-economic constraints

Farmers reported four key socio-economic constraints, and an attempt was made to prioritize them. In all the states included in this study, the highest income loss was due to non-availability of quality seed and lack of knowledge of suitable technologies (Table 23 and Appendix 7). These two constraints accounted for about 97% of the total estimated losses due to all four socio-economic constraints. Low prices and lack of markets appeared not to be of much significance. These results suggest that more emphasis should be given to strengthening the seed sector and implementing innovative technology dissemination methods in maize growing areas.

Rats and termites accounted for about 20% of total production losses. Since technological options for controlling these biotic constraints are already available, non-adoption appears to be the main constraint. Lack of appropriate input markets, inadequate information about improved technologies, and failure of collective action constrains the adoption of available rat- and termite-control technologies.

Table 22b. Prioritization of major constraints to maize production in non-traditional maize growing areas (KAP states), India, 2001.

Production constraint	Yield loss (%)	Area affected (%)	Probability of occurrence	Estimated damage: In millions of Rs.[†]	Estimated damage: % total production loss
Cyprus rotendrus	12.5-20	90-100	0.75-1.00	3,691.75	24.94
Leaf blight	10-15	75-100	0.50-1.00	2,299.71	15.54
Water stress	10-15	75-100	0.25-1.00	2,278.23	15.39
Stem borers	10-20	50-90	0.50-0.80	1,701.19	11.49
Cynodon dactylon	10-15	50-75	0.50-0.75	1,272.95	8.62
Echinocloa	7.5-10	75	0.50-0.75	1,032.72	6.98
Post-flowering stalk rot	10-15	50-75	0.25-0.75	719.36	4.86
Zinc deficiency	10	10-75	0.10-0.80	498.96	3.37
Termites	10-15	25-60	0.25-0.80	432.30	2.92
Late planting	10-15	25-50	0.25-0.50	418.75	2.82
Cylesia	10-15	0.25	0.50	189.77	1.28
Rusts	10	0.50	0.25	126.51	0.85
Shoot fly	10	50	0.50	64.74	0.43
Nematodes	5-10	10-25	0.25	32.66	0.22
Grubs	10	0.25	0.10	25.30	0.17
Wilting	25	10	0.20	12.95	0.08
Total production losses				14,797.85	100.00

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
† US$ 1.00 = Indian Rs. 44.00 (May 2004).
Note: Estimated damage computed using: $D_i = \{(YL_i * A_i * p_i) * TMA\} * P_m$

Table 23. Prioritization of socio-economic constraints to maize production in selected traditional and non-traditional maize growing states of India, 2001.

Constraints	State	Losses (Rs. 000[†])	Rank
Lack of remunerative prices	Bihar	484.76	2
	Madhya Pradesh	139.87	3
	Rajasthan	622.17	1
	Andhra Pradesh	119.68	4
	Karnataka	56.14	5
	Total	1,422.62	
Lack of quality seed	Bihar	10,082.72	3
	Madhya Pradesh	7,124.00	4
	Uttar Pradesh	17,272.29	1
	Rajasthan	17,134.82	2
	Total	51,613.85	
Lack of market	Bihar	406.41	2
	Madhya Pradesh	90.11	5
	Rajasthan	485.78	1
	Andhra Pradesh	358.74	3
	Karnataka	224.55	4
	Total	1,665.59	
Lack of knowledge	Bihar	6,326.02	5
	Madhya Pradesh	5,521.73	6
	Uttar Pradesh	11,959.97	4
	Rajasthan	12,673.54	3
	Andhra Pradesh	18,933.50	2
	Karnataka	20,602.32	1
	Total	76,017.08	
Total loss due to socio-economic constraints: Rs. 130,719,100			

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
† US$ 1.00 = Indian Rs. 44.00 (May 2004).
Note: Lack of knowledge is a qualitative parameter whose influence is implicit in previous estimations.

5. Agenda for Maize Research and Development in India

Maize R&D is considered important in India. An independent All India Coordinated Research Improvement Project on maize was established in 1957, which has made significant contributions and was elevated to the Directorate of Maize Research in 1994. The private seed sector also participates in maize breeding research and seed production, carrying out more than 50% of maize R&D in India. There have been several research outputs during the last two decades. Between 1988 and 1999, the public and private sectors released 41 improved cultivars, which included 24 full-season hybrids, 5 medium-duration hybrids, 7 early-duration hybrids, and 5 composites (Directorate of Maize Research 1999). Public sector research was more focused on developing composites, while the private sector devoted more research efforts to developing hybrids. Since hybrids have higher yield potential, the private sector was successful in disseminating their products in more favorable regions. The public sector should also attach higher priority to developing hybrids with high yield potential and early maturity. Improved management practices were also developed to manage weeds, water stress, and insect pests. Yet the benefits for maize improvement were not realized to the same extent as they were for rice and wheat. Why the benefits of R&D efforts did not reach maize producers is an issue of concern. A fragile maize seed sector and ineffectual extension mechanisms in the study domain were commonly cited as factors hindering the adoption of improved cultivars and management practices. Hence there is a need to document analytically-based reasons for low farmer adoption of improved maize technologies.

In this study, maize research priorities were developed in consultation with both public- and private-sector maize scientists. The list of constraints elicited during the RRA surveys in different regions was presented to the scientists for developing alternative research strategies. Three criteria were used to prioritize farmer-identified production constraints and develop the R&D plan for maize in India: (1) research efficiency, (2) poverty in the target domain, and (3) marginality of the environment. The prevailing opinion was that highly efficient research on production constraints in acute poverty-ridden and marginal environments should receive the highest research priority.

Research efficiency was computed using the following parameters:

- estimated yield loss due to a specific constraint,
- expected benefit (yield gain) as a result of developing and adopting improved technologies for alleviating the constraint,
- probability of success in developing the desired technologies, and
- expected farmer adoption in the target domain.

The latter two parameters were estimated based on historical trends in different target domains. Information on people living below the poverty line, drawn from the National Sample Survey Organization, Government of India, was used as a criterion for prioritizing the R&D agenda. An indicator of marginality of the production environment was used to give due priority to fragile and harsh environments. The inverse of maize yield was used as a proxy for this variable, such that lower maize yields would indicate more marginal production environments.

5.1 Regional Priorities

Each region has specific climate, production environment, and resource endowment; therefore, problems vary across regions. This section describes how research agendas for different regions and production environments were prioritized. Based on the indicators used for prioritization, production constraints for winter season irrigated maize in the eastern region ranked as the most important, followed by constraints in the southern region with high and medium rainfall, and then by those in the central and western regions. Alleviating production constraints for spring and rainy season maize in the eastern region had the lowest priority. Research and development agendas by region are described below and presented in Table 24.

5.1.1 Central and western region

The central and western region is characterized as a low yielding maize environment, where mostly local/ traditional varieties are cultivated mainly for household food security. Based on average annual rainfall, the region was divided into two sub-regions: (1) the low rainfall (less than 500 mm per year) sub-region covering most of Rajasthan; and (2) the medium- to-high-rainfall (500-900 mm per year) sub-region covering the whole of Madhya Pradesh and parts of central and western Uttar Pradesh. In the low-rainfall sub-region, moisture stress was the key constraint to maize production, and aggressive breeding efforts to overcome the drought problem are needed, as they are thought to be more relevant than water-saving or water management technologies. The use of biotechnology to develop transgenic maize for drought management would benefit poor and resource-scarce farming communities in the low rainfall sub-region. Other key research priorities in this sub-region are inadequate availability of quality seed, lack of early maturing varieties (needed for drought management), and broadleaf and grassy weeds.

In the medium-to-high rainfall sub-region, key research priorities are similar to those in the low rainfall region: inadequate availability of quality seed, moisture stress, unbalanced fertilizer use, lack of early maturing varieties, and broadleaf and grassy weeds.

Public and private seed sectors are weak in both sub-regions. Most farmers in these sub-regions are resource poor and cannot afford to buy improved seed, even if available. Under such a scenario, the agricultural research institutions and state agricultural universities based in the sub-regions may initiate seed multiplication programs and sell at reasonable prices, and hence pass on the benefits of research to farmers confronted with poverty and water scarcity.

Given the poverty level and low yields, the region needs to prioritize maize research. The research environment is difficult, however, and may require higher research outlays than are needed in favorable environments. The research lag may be high with a low probability of success because the production environment is risky, fragile, and under stress. A focused and completely revamped research strategy to address the key research priorities could generate technologies suited to farmers' resources and production environments.

5.1.2 Eastern Uttar Pradesh and Bihar

In this region, maize production is gradually shifting from the rainy to the winter season, when the crop is grown mainly under irrigation, so that yield levels are higher and unit costs are lower. Lack of quality seed, inappropriate crop establishment, and a lack of balanced use of nutrients during the winter season were the top three researchable issues in this region. A strong policy research analysis, assessing the reasons for non-availability of improved seed and developing appropriate strategies to overcome this constraint, would allow further expansion of the area under winter maize. Similarly, diagnostic surveys to understand the reasons for inappropriate crop establishment and lack of balanced use of nutrients would provide deeper insights for undertaking in-depth research programs. Other problems in the eastern region for winter and irrigated maize (minimization of post-harvest losses, management of Turcicum leaf blight, and post-flowering stalk rot) would also benefit from research efforts. Inter-cropping with maize and transplanting maize under late sown conditions are other high-priority research issues for which public and private sector research is in progress.

In the high and medium rainfall regions of Eastern Uttar Pradesh and Bihar, the priority constraints are related to appropriate variety development. The development of medium- and full-season cultivars for high rainfall regions and of extra-early or early cultivars for medium rainfall regions are the highest priority. Researchable issues are more or less the same within the eastern region but their ranking varies depending on the location's rainfall regime. For example, weeds have a higher priority in high rainfall regions than in the medium rainfall areas. Development of drought-escape varieties along with appropriate management practices may be the best research strategy.

5.1.3 Southern region

This non-traditional maize growing region encompasses Andhra Pradesh and Karnataka, and is characterized as high yielding. Maize is grown for commercial purposes, mainly to meet the growing demand for poultry feed. It is grown in varying rainfall regimes (or sub-regions) in this region: low (<500 mm), medium (500-750 mm), and high (>750 mm). Among the three rainfall regimes, the high rainfall area is the most important, and the low rainfall sub-region is the least important for maize production.

Table 24. Top 10 priority constraints for maize research by region and rainfall regime, India, 2001.

Rainfall regime	Traditional maize growing areas (Northern India)		Non-traditional maize growing areas (Southern India)
	Central and Western Uttar Pradesh, Madhya Pradesh, Rajasthan	**Eastern Uttar Pradesh and Bihar**	**Karnataka and Andhra Pradesh**
Low	Moisture stress (drought) Inadequate availability of quality seed Lack of early maturing varieties Unbalanced/improper use of fertilizers Broadleaf and grassy weeds Post-flowering stalk rot *Chilo partellus* (stem borers) Brown stripe downy mildew (BSDM) Termites Improper maize-based intercropping system		Drought Lack of quality seed Post-flowering stalk rot Stem borers Turcicum leaf blight Improper nutrient management Zinc deficiency Storage pests
Medium		Lack of extra early & early varieties with quality seed Occasional drought Inadequate crop establishment method Post-harvest losses Inadequate use of fertilizers (low N) Weed problems Stem borers Maydis leaf blight Bacterial stalk rot Mixed cropping	Turcicum leaf blight Post-flowering stalk rot Lack of quality seed Stem borers Water management (irrigated environment) Waterlogging (irrigated environment) Micronutrient deficiency Weed management Storage pests Early maturing hybrids (irrigated environment)
Medium to high	Inadequate availability of quality seed Moisture stress (drought) Unbalanced/improper use of fertilizers Lack of early maturing varieties Broadleaf and grassy weeds *Chilo partellus* (stem borers) Post-flowering stalk rot Lack of location-specific transfer of technology for rainfed conditions, especially for farm women Maydis leaf blight Banded leaf and sheath blight (BLSB)		
High		Lack of appropriate medium, full-season seed Inadequate crop establishment method Inadequate use of fertilizers Weed problems Stem borers Excess water (waterlogging) Postharvest losses Maydis leaf blight Bacterial stalk rot Mixed cropping	Drought (AP) Lack of quality seed Post-flowering stalk rot Brown stripe downy mildew (KAR-Kharif) Turcicum leaf blight Stem borers Banded leaf and sheath blight Weed management Storage pests
Spring		Lack of quality seed of early maturing varieties for spring season Stem borers Inappropriate crop establishment Unbalanced fertilizer use Post-harvest losses Maydis leaf blight Promotion of intercropping	
Winter (irrigated)		Lack of quality seed Inappropriate crop establishment Unbalanced fertilizer use Post-harvest losses Turcicum leaf blight Post-flowering stalk rot Promotion of intercropping Transplanting maize under late sown conditions	

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

Drought, non-availability of good quality seed, and post-flowering stalk rot are the top research priorities in both the low and high rainfall sub-regions. Research strategies for drought would differ depending on the rainfall regime. In the low rainfall sub-region, persistent drought during crop growth is a serious problem. In contrast, it is terminal drought that affects production in the high rainfall sub-region. Breeding efforts along with *in-situ* moisture conservation could alleviate the drought problem. Non-availability of good quality seed is another problem limiting maize production. Though there are many private and public seed companies in the region, it appears that availability of unadulterated seed is still a problem. Policy research to critically diagnose the problem and assess impediments for acquiring good quality seed is a prerequisite to prescribing the solutions. Simultaneously, strict enforcement of quality control standards should be aggressively initiated in the region to overcome the problem of farmer exploitation by seed companies.

In the medium rainfall region, Turcicum leaf blight (TLB), post-flowering stalk rot, and non-availability of good quality seed are the key priority constraints and research issues. Strong breeding efforts are required to address the problem of TLB. A combination of breeding efforts with plant protection and crop management research is required to manage post-flowering stalk rot. The seed sector needs to be strengthened through policy research and institutional support to solve these problems.

5.1.4 Anticipatory research

Maize is gradually spreading to non-traditional maize growing areas (to meet increasing household and feed industry demands), and its uses are also changing. Though the majority of the rural population is still using maize as a staple food, the higher-income stratum prefers it for soup and vegetable purposes and increasingly uses maize oil. The broiler industry requires better protein convertibility and low-cost feed materials to improve competitiveness. Therefore, it is important to incorporate end-users' needs into the on-going research program, and the research focus may need to be shifted to address new challenges. In this context, the priority research topics identified included quality protein maize, baby corn, popcorn, sweet corn, high oil content, wax starch, and dual-purpose maize (food and fodder). In addition, a research focus aimed at developing innovative institutional arrangements to strengthen production-marketing-processing linkages would benefit producers, consumers, and the emerging poultry industry, because market access also poses a major obstacle in traditional maize growing areas.

5.2 National Research Priorities

At the national level, the Directorate of Maize Research develops the research agenda for frontier areas and coordinates research of common interest in different locations.

Results of the research prioritization exercise in this study show that research priorities across the selected maize growing regions in India may vary depending on research targets/objectives: efficiency, poverty, and marginality of environment (see Table 25). When efficiency is the main focus of research, the top priorities may be confined to new niches, such as the non-traditional areas of Andhra Pradesh and Karnataka or in eastern Uttar Pradesh and Bihar, where maize has emerged as a new winter season crop. The private sector is also active in these new niche areas. If poverty alleviation is the main objective for maize research, alleviating constraints in poverty-ridden Eastern Uttar Pradesh and Bihar, followed by Karnataka and Andhra Pradesh, and the Central and Western Regions of Uttar Pradesh, Rajasthan, and Madhya Pradesh, has high priority. If marginality of the production environment is the focus of research, alleviating maize production constraints in Eastern Uttar Pradesh and Bihar, and the Central and Western regions is important.

There is, however, a trade-off when one moves from one objective to another, i.e, between research efficiency, poverty alleviation, and marginality. The trade-off means that, using a given efficiency criterion, research efforts would address the yield-maximizing and cost-reducing objective with an overall increase in employment opportunities and farmers' income. When poverty alleviation comes to the forefront, however, efficiency is sacrificed to some extent. Similarly, when marginality of the environment, which can cover a larger area, is emphasized, research efficiency would have to be sacrificed. For example, if poverty alleviation becomes the primary research objective, the loss in terms of research efficiency is about 5%, but it covers 17% more poor people. Similarly, if marginality is considered an objective, there would be a reduction of approximately 33% in research efficiency, but a larger maize area (roughly 25%) in marginal environments would be included for research.

If all research objectives (efficiency, poverty alleviation, and marginality of the production environment) are combined, the key national priorities are as listed in Table 25. Based on these priorities, seven problems common across all regions were identified, and the following key research areas are suggested:

- Policy research
  - Lack of quality seed
  - Unbalanced nutrient use
- Drought, moisture stress, and water management
- Poor crop establishment
- Turcicum leaf blight
- Post-flowering stalk rot
- Stem borers
- Post-harvest losses

At the national level, these research issues need to be addressed through efficient networks. Under the All India Coordinated Research Project on Maize (AICRIP), research projects focusing on improvement of promising cultivars, advanced agronomic practices, nutrient management, and diseases and pests are being carried out for the overall development of the country's maize sector. Recently, efforts are also being geared up for minimizing post-harvest losses and exploring alternative uses of maize, especially for mal- and under-nourished segments of society.

Table 25. Overall research prioritization for maize in India, 2001.

			Ranking by priority index used			
State group	Rainfall regime	Production constraint	Efficiency	Poverty	Marginality	Weighted rank
EUP & Bihar	Winter (irrigated)	Lack of quality seed	2	1	1	1
KAP	High	Drought (AP)	1	9	9	2
KAP	High	Quality seed	3	10	10	3
EUP & Bihar	Winter (irrigated)	Inappropriate crop establishment	4	2	2	4
EUP & Bihar	Winter (irrigated)	Unbalanced fertilizer use	5	3	3	5
EUP & Bihar	Winter (irrigated)	Post-harvest losses	7	4	4	6
KAP	High	Post-flowering stalk rot	6	11	11	7
EUP & Bihar	Winter (irrigated)	Turcicum leaf blight	10	5	5	8
KAP	High	Brown stripe downy mildew (BSDM) (KAR-Kharif))	8	12	12	9
EUP & Bihar	Winter (irrigated)	Post-flowering stalk rot	11	6	6	10
KAP	High	Turcicum leaf blight	9	13	13	11
EUP & Bihar	Winter (irrigated)	Promotion of intercropping	14	7	7	12
KAP	High	Stem borers	12	14	14	13
KAP	High	Banded leaf and sheath blight	13	15	15	14
EUP & Bihar	Winter (irrigated)	Transplanting maize under late sown conditions	15	8	8	15
KAP	High	Weed management	16	16	16	16
KAP	High	Storage pests	17	17	19	17
KAP	Medium	Turcicum leaf blight	18	33	28	18
KAP	Medium	Post-flowering stalk rot	19	34	29	19
KAP	Medium	Quality seed	20	38	30	20
KAP	Medium	Stem borers	21	41	32	21
KAP	Medium	Water management (irrigated environment)	22	44	34	22
KAP	Medium	Waterlogging (irrigated environment)	23	47	37	23
KAP	Medium	Micronutrient deficiency	24	54	45	24
C&W UP, MP, Raj	Medium to high	Inadequate availability of quality seed	26	18	17	25
KAP	Medium	Weed management	25	56	49	26
C&W UP, MP, Raj	Medium to high	Moisture stress (drought)	27	19	18	27
KAP	Medium	Storage pests	28	60	54	28
C&W UP, MP, Raj	Medium to high	Unbalanced/improper fertilizer use	30	20	20	29
KAP	Medium	Early maturing hybrids (irrigated environment)	29	64	58	30
C&W UP, MP, Raj	Medium to high	Lack of early maturing varieties	31	21	21	31
EUP & Bihar	Spring	Lack of quality seed of early maturity for spring season	32	22	31	32
C&W UP, MP, Raj	Medium to high	Broadleaf and grassy weeds	33	25	22	33
EUP & Bihar	High (kharif)	Lack of appropriate medium, full-season seed	36	23	35	34
EUP & Bihar	Medium (kharif)	Lack of extra early & early varieties with quality seed	35	24	35	34
C&W UP, MP, Raj	Medium to high	Stem borers	34	26	23	36
EUP & Bihar	High (kharif)	Inadequate crop establishment method	39	27	39	37
EUP & Bihar	Medium (kharif)	Occasional drought	38	28	39	37

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

† TOT = Transfer of technology.

Note: C&W: Central and Western region; UP: Uttar Pradesh; MP: Madhya Pradesh; KAP: Karnataka and Andhra Pradesh; KAR: Karnataka; Raj: Rajasthan; EUP: Eastern Uttar Pradesh; AP: Andhra Pradesh.

Table 25. Overall research ...cont'd.

State group	Rainfall regime	Production constraint	Ranking by priority index used: Efficiency	Poverty	Marginality	Weighted rank
C&W UP, MP, Raj	Medium to high	Post-flowering stalk rot	37	32	24	39
EUP & Bihar	Spring	Stem borers	40	29	41	40
EUP & Bihar	High (kharif)	Inadequate fertilzer use	42	30	42	41
EUP & Bihar	Medium (kharif)	Inadequate crop establishment method	41	31	42	41
EUP & Bihar	Spring	Inappropriate crop establishment	43	35	46	43
EUP & Bihar	High (kharif)	Weed problems	45	36	47	44
EUP & Bihar	Medium (kharif)	Post-harvest losses	44	37	47	44
C&W UP, MP, Raj	Medium to high	Lack of location-specific TOT[†] for rainfed conditions, especially for farm women	46	42	25	46
C&W UP, MP, Raj	Medium to high	Maydis leaf blight	47	43	26	47
EUP & Bihar	Spring	Unbalanced fertilizer use	48	39	50	48
EUP & Bihar	High (kharif)	Stem borers	49	40	51	49
EUP & Bihar	Medium (kharif)	Inadequate fertilizer use (low N)	51	45	52	50
EUP & Bihar	Spring	Post-harvest losses	50	46	52	50
C&W UP, MP, Raj	Medium to high	Banded leaf and sheath blight (BLSB)	52	50	27	52
EUP & Bihar	High (kharif)	Excess water (waterlogging)	54	48	56	53
EUP & Bihar	Medium (kharif)	Weed problems	53	49	56	53
EUP & Bihar	Spring	Maydis leaf blight	55	51	59	55
EUP & Bihar	High (kharif)	Post-harvest losses	57	52	60	56
EUP & Bihar	Medium (kharif)	Stem borers	56	53	60	56
EUP & Bihar	Spring	Promotion of intercropping	59	55	62	58
C&W UP, MP, Raj	Medium to high	Termites	58	57	33	59
EUP & Bihar	High (kharif)	Maydis leaf blight	61	58	64	60
EUP & Bihar	Medium (kharif)	Maydis leaf blight	60	59	64	60
C&W UP, MP, Raj	Medium to high	Brown stripe downy mildew (BSDM)	62	63	38	62
EUP & Bihar	High (kharif)	Bacterial stalk rot	64	61	66	63
EUP & Bihar	Medium (kharif)	Bacterial stalk rot	63	62	66	63
C&W UP, MP, Raj	Medium to high	Improper maize-based intercropping system	65	67	44	65
EUP & Bihar	High (kharif)	Mixed cropping	67	65	69	66
EUP & Bihar	Medium (kharif)	Mixed cropping	66	66	69	66
C&W UP, MP, Raj	Medium to high	Rats	68	68	55	68
C&W UP, MP, Raj	Medium to high	Weevils during storage	69	69	63	69
C&W UP, MP, Raj	Medium to high	Cob borer (*Helicoverpa armigera*)	70	70	68	70
C&W UP, MP, Raj	Medium to high	Nematodes	71	71	71	71
KAP	Low	Drought	72	76	86	72
KAP	Low	Quality seed	73	78	87	73
KAP	Low	Post-flowering stalk rot	74	81	89	74
KAP	Low	Stem borers	75	83	90	75
KAP	Low	Turcicum leaf blight	76	84	92	76
KAP	Low	Improper nutrient management	77	87	93	77
C&W UP, MP, Raj	Low	Moisture stress (drought)	79	72	72	78
KAP	Low	Zinc deficiency	78	89	94	79
C&W UP, MP, Raj	Low	Inadequate availability of quality seed	81	73	73	80
KAP	Low	Storage pests	80	90	96	81
C&W UP, MP, Raj	Low	Lack of early maturing varieties	82	74	74	82
C&W UP, MP, Raj	Low	Unbalanced/improper fertilizer use	83	75	75	83
C&W UP, MP, Raj	Low	Broadleaf and grassy weeds	84	77	76	84
C&W UP, MP, Raj	Low	Post-flowering stalk rot	85	79	77	85
C&W UP, MP, Raj	Low	Stem borers	86	80	78	86
C&W UP, MP, Raj	Low	Brown stripe downy mildew (BSDM)	87	82	79	87
C&W UP, MP, Raj	Low	Termites	88	85	80	88
C&W UP, MP, Raj	Low	Improper maize-based intercropping system	89	86	81	89
C&W UP, MP, Raj	Low	Lack of location-specific TOT[†] for rainfed conditions, especially for farm women	90	88	82	90
C&W UP, MP, Raj	Low	Maydis leaf blight	91	91	83	91
C&W UP, MP, Raj	Low	Lack of package for sloping & eroded lands	92	92	84	92
C&W UP, MP, Raj	Low	Nematodes	93	93	85	93
C&W UP, MP, Raj	Low	Weevils during storage	94	94	88	94
C&W UP, MP, Raj	Low	Cob borer (*Helicoverpa armigera*)	95	95	91	95
C&W UP, MP, Raj	Low	Rats	96	96	95	96

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

[†] TOT = Transfer of technology.

Note: C&W: Central and Western region; UP: Uttar Pradesh; MP: Madhya Pradesh; KAP: Karnataka and Andhra Pradesh; KAR: Karnataka; Raj: Rajasthan; EUP: Eastern Uttar Pradesh; AP: Andhra Pradesh.

6. Summary and Conclusions

During the last three decades, maize production in India has markedly increased, largely driven by the growing demand from the feed industry. This study diagnosed the performance of maize in two distinct production environments, identified production constraints, and developed R&D priorities at the national and regional levels.

Maize is grown in two distinct production environments: (1) traditional areas, which are mostly marginal and rainfed, and (2) non-traditional maize-growing areas, which are mostly commercial and more favorable production environments. In traditional areas, a large share of maize output is retained to meet household food grain requirements, while in non-traditional areas, most maize production is supplied and sold to the feed industry. Yields in non-traditional areas are much higher than the national average. Production in these areas has rapidly increased as a result of area expansion, crop substitution, and yield improvements due to adoption of modern maize varieties.

Rainy season maize yield levels in the traditional areas (particularly Rajasthan, Madhya Pradesh, Uttar Pradesh, and Bihar) are lower than both the national and global averages. Winter maize is emerging as a new crop in Eastern Uttar Pradesh and Bihar. Maize has also gained importance in the non-traditional maize growing areas of Andhra Pradesh and Karnataka. Across India, less area is planted to winter maize than rainy-season maize, but yield levels during the winter season are considerably higher and comparable to global averages and yields in many developed countries. Similarly, general maize yields in Andhra Pradesh and Karnataka are much higher than the national average. Maize production in these non-traditional environments, however, suffers from lack of irrigation facilities, which are essential, especially for winter maize.

Adoption of improved cultivars was common in non-traditional areas and seasons but low in traditional areas. Hybrids outperform local and composite cultivars both in terms of yield and profitability. Hybrids are popular mostly in Andhra Pradesh and Karnataka, where the seed sector is strong. In other production environments, there is only a limited area under hybrids. Lack of short-duration hybrids, unsuitable environment, and absence of a strong seed sector impose major obstacles to adoption of hybrids in traditional maize growing areas.

Farmers' maize production problems were documented in this study. Weeds, mainly *Echinocloa* and *Cynodon dactylon,* are the major constraints to maize production, followed by rats and termites. These four constraints appear to be common across production environments and across all crops being grown in the region. Caterpillars, water stress, stem borers, and weevils also reduce maize production and must receive priority. Other constraints were related to zinc deficiency, rust, seed/seedling blight, cutworm, and leaf blight.

Non-availability of hybrids and poor information dissemination were found to be the principal socio-economic constraints. A strong seed sector and an effective extension network would go a long way towards augmenting income from maize.

Based on the existing constraints and research opportunities, an R&D agenda was developed for different regions. Three criteria were used for prioritizing the research agendas: efficiency, poverty alleviation, and marginality of the environment. Among regions, the eastern region (the winter season under irrigated conditions) should receive the highest research priority, followed by the southern region, the central and western regions, and the eastern region (the high rainfall season). One of the most important constraints common to all regions was non-availability of good quality seed. Other researchable issues were drought (terminal or occasional), moisture stress, and water management. Among biotic constraints, Turcicum leaf blight, post-flowering stalk rot, and stem borers were most important at the national level.

The study observed that maize has potential for product diversification under a new economic regime. Demand for maize is shifting from food to feed for livestock and poultry. For foods, new types of maize-based products (soups, vegetables, edible oils) are in demand among people in the higher-income strata. New opportunities need to be tapped by providing appropriate technologies to farming communities.

Future maize production will largely depend on how markets are developed. Except in the southern non-traditional maize growing region, the production-marketing linkages are extremely weak and need to be strengthened. Linkages are stronger in southern regions because innovative institutions for poultry production, in the form of contract farming, have emerged. The new arrangements are win-win propositions for maize and poultry producers, the hatchery and feed industry, and the consumers. The new arrangements are responsible, to a great extent, for the large-scale area expansion of maize into the southern region. There is a need to develop mechanisms for strengthening the production-marketing-processing maize system in the northern traditional maize growing areas, so that the poverty-ridden maize producers can also benefit.

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Appendix 1. Important maize cultivars in selected traditional maize growing states of India, 2001.

		Kharif (Wet)			Rabi (Dry)		
State	District	Local	OPVs	Hybrids	Local	OPVs	Hybrids
Biha	Munger	Tulbuliya	Shweta, Kanchan, Vijay, laxmi	Cargill, Bioseed	—	Vijay, Devki	Pioneer, Cargill
	Siwan	Tulbuliya, Tinpakhiya	Shweta, Mashina Pant Makka	Cargill	—	Vijay	Pioneer
	Begusarai	Tulbuliya, Tinpakhiya	Pant Makka	Cargill	—	Vijay, Pant Makka	Pioneer, Cargill
Madhya Pradesh	Chindwara	Sathi, Mogar	Chandan, Jawahar-8, NLD	Cargill	Sathi	Chandan, Jawahar, NLD	Ganga-2
	Mandsaur	Sathi, Mogar	Chandan, Jawahar-8, NLD	Ganga-2	Sathi	Chandan, NLD	Ganga-5
	Jhabua	Sathi	Chandan, Jawahar-8, Jawahar-12, NLD	Ganga-5	Sathi	Chandan, Jawahar-8	—
Uttar Pradesh	Behraich	Jaunpuri	Shweta, Kanchan	Deccan-103	Jaunpuri	Shweta, Kisan	Proagro-4212,
	Hardoi	Jaunpuri	Shweta, Kanchan, Azad Uttam	Pioneer, Ganga-5	Jaunpuri	Shweta, Kanchan, Azad Uttam	Ganga Kaveri
	Bulandshar	Meerut	Shweta, Kanchan, Azad Uttam	Ganga-5	—	—	Ganga-5
Rajasthan	Banswara	Sathi	Navjot, Mahi Kanchan, Mahi Dhawal	Pioneer, Ganga-5	Sathi	Navjot, Mahi Kanchan	—
	Bhilwara	Negadi, Sathi	Navjot, Mahi Kanchan, Mahi Dhawal	Ganga-2, Ganga-11, Deccan-103	Negadi, Sathi	Mahi Kanchan	Deccan103,
	Udaipur	Negadi, Sathi	Navjot, Mahi Kanchan, Mahi Dhawal	Ganga-2,Ganga-11, Deccan-103	Sathi	Navjot, Mahi Kanchan	Ganga-11, Cargill Ganga-11 Ganga-11, Deccan-103

Appendix 2. Important cropping systems in maize growing states of India, 2001.

				Area under maize (%)	
State	Agro-eco regions	District	Common crop rotations	Rainy season	Winter season
Bihar	South Bihar alluvial plain	Munger	maize/millets/kulthi (pulse)-fallow, maize-linseed, maize+cowpea/early arhar-cowpea/ oilseeds, maize/millets-barley/arhar/lentil/urd/gram/oilseeds, paddy-wheat, maize+ bottlegourd/bittergourd/melons	30	40
	Northwest alluvial plain	Siwan	paddy-wheat, maize-wheat, maize+sunflower-pulse (gram, arhar, pea, beans)- sugarcane/tobacco/chilis/oilseeds/potato	15	25
	Northeast alluvial plain	Begusarai	paddy-wheat/maize, maize-jute/tobacco/ginger/gourd/turmeric/vegetables (brinjal, tomato, pea)	10	40
Madhya Pradesh	Satpura plateau	Chindwara	maize/soybean/pulses/urd/paddy-wheat/maize/gram/vegetables, maize-wheat	20	30
	Malwa plateau	Mandsaur	maize/soybean/pulses/urd-groundnut/oilseeds/sorghum-maize-fallow, maize/ soybean/urd-groundnut/oilseeds/sorghum	15	25
	Jhabua hills	Jhabua	paddy/maize/cotton/soybean/pulses(arhar+ (mustard/potato)/oilseeds, groundnut/kodo-wheat	20	40
Uttar Pradesh	Northeast plain zone	Behraich	paddy/maize-wheat, maize-rapeseed-sugarcane, maize+gourd-wheat, maize+urd/ moong-wheat, paddy-wheat-maize	30	15
	Central plain	Hardoi	maize-wheat/sugarcane, paddy/maize-wheat, maize, potato-wheat, maize-potato+ coriander-vegetables, maize-mustard-onion, maize-potato-cucumber, maize-chilis	25	10
	Western plain	Bulandshar	paddy/maize-wheat, maize-wheat-sugarcane, maize-potato-sugarcane, maize-mustard- urd/moong, maize-potato-cucurbits, maize+urd/moong-wheat, maize/sorghum-wheat	35	—[†]
Rajasthan	Humid south plain	Banswara	maize/paddy/cotton/sorghum/groundnut/sesame-fallow, maize-wheat/gram/barley, maize-wheat-sugarcane, maize-wheat-greengram	35	40
	Sub-humid south plain	Bhilwara	maize/sorghum/pearl millet-fallow/maize-wheat/oilseeds	30	—-
	Sub-humid south plain	Udaipur	maize/sorghum/barley/pearl millet-wheat/fallow	25	—-
Andhra Pradesh	North Telangana	Nizamabad	maize-wheat/sugarcane, paddy/maize-wheat, maize, potato-wheat, maize-potato+ coriander-vegetables, maize-mustard-onion, maize-potato-cucumber, maize-chillies	25	—-
	North Telangana	Karimnagar	paddy/maize-wheat, maize-rapeseed-sugarcane, maize+ gourd- wheat, maize+urd/ moong-wheat, paddy-wheat-maize	30	—-
	Scarce Rainfall Zone	Mehboobnagar	paddy/maize-wheat, maize-wheat-sugarcane, maize-potato-sugarcane, maize-mustard- urd/moong, maize-potato-cucurbits, maize+urd/moong-wheat, maize/sorghum-wheat	35	—-
Karnataka	Central Dry Zone	Chitradurga	maize/paddy/cotton/sorghum/groundnut/sesamum-fallow, maize-wheat/gram/ barley, maize-wheat-sugarcane, maize-wheat-greengram	35	—-
	North Dry Zone	Dharwad	maize/sorghum/pearl millet-fallow, maize-wheat/oilseeds	30	—-
	North Dry Zone	Belgaum	maize/sorghum/barley/pearl millet-wheat/fallow	25	—-

Source: IFAD-CIMMYT-India RRA Surveys, 2001.

[†] —- = not cultivated.

Appendix 3. Maize cultivation calendar by season, in selected maize growing states of India, 2001.

State	Operation	Fortnight and month: Rainy season	Fortnight and month: Winter season	Labor performing task
Bihar	Land preparation	II, May	I, II, Oct; I, Nov	Male
	Planting	I, June	I, II, Nov	Male, Female
	Fertilizer application	I, II, June	I, II, Nov	Male, Female
	Weeding	II, July	II, Nov; I, II Dec	Female, Male
	Harvesting	I,II, Sep; I, Oct	I, II, Mar	Male, Female
Madhya Pradesh	Land preparation	I,II, May	I, II, Oct; I, II, Nov	Male
	Planting	II, May; I, June	I, II, Nov	Male, Female
	Fertilizer application	I, June	I, II, Nov, Dec	Male, Female
	Weeding	I, II, July	II, Dec; I Jan	Female, Male
	Harvesting	II, Aug; I, II, Sep	II, Feb; I, II, Mar	Male, Female
Uttar Pradesh	Land preparation	I, II June	II Oct, I, II Nov	Male
	Planting	II June, I July	II Nov, I Dec	Male, Female
	Fertilizer application	II July, I Aug	II Nov, I Dec	Male, Female
	Weeding	II July, I Aug	II Dec, I Jan	Female, Male
	Harvesting	II Sept, I Oct	I, II Mar	Male, Female
Rajasthan	Land preparation	I, II May	II, Oct; I, II, Nov	Male
	Planting	I, II June	I, II, Nov	Male, Female
	Fertilizer application	I, II June	I, II, Nov, Dec	Male, Female
	Weeding	II June, I, II July,	II, Dec; I Jan	Female, Male
	Harvesting	II, Aug; I, II, Sep	I, II, Mar	Male, Female
Andhra Pradesh	Land preparation	I, II June	-	Male
	Planting	I June, II June	-	Male, Female
	Fertilizer application	I July, II July	-	Male, Female
	Weeding	II July, I Aug	-	Female, Male
	Harvesting	I Sept., II Sept	-	Male, Female
Karnataka	Land preparation	I, II May	-	Male
	Planting	I, II June	-	Male, Female
	Fertilizer application	I, II June, I July	-	Male, Female
	Weeding	II June, I, II July	-	Female, Male
	Harvesting	II Aug, I, II Sep	-	Male, Female

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
I – first fortnight.
II – second fortnight.

Appendix 4. Production constraints and their impact on maize production, BIMARU states, India, 2001.

Constraint and state	Agroecological zone	Yield loss to due to constraint (%)	Area affected by constraint (%)	Probability of occurrence of constraint	Estimated damage (Rs. million†)
Echinocloa					
Uttar Pradesh	Western plain	25.0	90	1.0	955.83
Bihar	North western alluvial plain	15.0	100	1.0	663.93
Uttar Pradesh	Central plain	25.0	100	1.0	561.11
Bihar	North east alluvial plain	12.5	100	1.0	403.98
Uttar Pradesh	North eastern plain	20.0	100	1.0	325.00
Madhya Pradesh	Malwa	15.0	100	1.0	187.00
Bihar	South Bihar alluvial plain	15.0	100	1.0	181.00
Madhya Pradesh	Jhabua	15.0	100	1.0	76.00
Madhya Pradesh	Satpura	15.0	100	1.0	74.00
				Total	**3,430.00**
Cynodon dactylon					
Bihar	North western alluvial plain	15.0	100	1.0	663.00
Bihar	North east alluvial plain	12.5	100	1.0	404.00
Uttar Pradesh	Western	9.0	100	1.0	382.00
Uttar Pradesh	Central plain	9.0	100	1.0	202.00
Madhya Pradesh	Malwa	15.0	100	1.0	187.00
Bihar	South Bihar alluvial plain	15.0	100	1.0	182.00
Uttar Pradesh	North eastern plain	9.0	100	1.0	146.00
Madhya Pradesh	Satpura	15.0	100	1.0	74.00
Madhya Pradesh	Jhabua	10.0	75	0.6	23.00
				Total	**2,265.00**
Rats					
Bihar	North western alluvial plain	12.5	100	1.0	553.00
Bihar	North east alluvial plain	12.5	100	1.0	403.00
Uttar Pradesh	Western	7.5	100	0.8	255.00
Madhya Pradesh	Malwa	15.0	100	1.0	187.00
Uttar Pradesh	Central plain	7.5	100	0.9	151.00
Bihar	South Bihar alluvial plain	10.0	100	1.0	121.00
Uttar Pradesh	North eastern plain	7.5	100	0.9	109.00
Madhya Pradesh	Jhabua	15.0	100	1.0	76.00
Madhya Pradesh	Satpura	7.5	100	1.0	37.00
				Total	**1,895.00**
Termites					
Bihar	North western alluvial plain	15.0	80	0.8	424.00
Uttar Pradesh	Central plain	25.0	75	0.8	336.00
Uttar Pradesh	North eastern plain	25.0	75	0.6	183.00
Bihar	North east alluvial plain	15.0	50	0.7	169.00
Uttar Pradesh	Western plain	20.0	75	1.0	57.00
Madhya Pradesh	Malwa	17.5	75	0.8	131.00
Bihar	South Bihar alluvial plain	15.0	80	0.8	116.00
Madhya Pradesh	Jhabua	17.5	50	0.8	36.00
Madhya Pradesh	Satpura	17.5	50	0.6	26.00
				Total	**1,478.00**
Caterpillars					
Uttar Pradesh	Western plain	8.0	100	1.0	339.00
Bihar	North western alluvial plain	7.5	90	1.0	298.00
Uttar Pradesh	Central plain	10.0	100	1.0	224.00
Bihar	North east alluvial plain	7.5	80	1.0	194.00
Uttar Pradesh	North eastern plain	10.0	100	1.0	162.00
Madhya Pradesh	Malwa	10.0	100	1.0	125.00
Bihar	South Bihar alluvial plain	7.5	90	1.0	82.00
Madhya Pradesh	Jhabua	10.0	100	1.0	51.00
Madhya Pradesh	Satpura	10.0	100	1.0	50.00
				Total	**1,525.00**
Water stress					
Bihar	North western alluvial plain	10.0	100	1.0	442.00
Madhya Pradesh	Malwa	17.5	90	0.8	157.00
Uttar Pradesh	Central plain	15.0	75	0.6	151.00
Madhya Pradesh	Jhabua	17.5	100	1.0	89.00
Uttar Pradesh	Western	15.0	60	0.2	76.00
Uttar Pradesh	North eastern plain	15.0	50	0.6	73.00
Madhya Pradesh	Satpura	17.5	90	0.9	70.00
Bihar	North east alluvial plain	10.0	50	0.3	48.00
Bihar	South Bihar alluvial plain	10.0	75	0.5	45.00
				Total	**1,155.00**

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † US$ 1.00 = Indian Rs. 44.00 (May 2004).

Appendix 4. Production constraints and their...cont'd.

Constraint and state	Agroecological zone	Yield loss to due to constraint (%)	Area affected by constraint (%)	Probability of occurrence of constraint	Estimated damage (Rs. million[†])
Stem borer					
Uttar Pradesh	Western plain	7.5	100	1.0	318.00
Bihar	North western alluvial plain	7.5	90	1.0	298.00
Bihar	North east alluvial plain	7.5	80	1.0	194.00
Uttar Pradesh	Central plain	7.5	100	1.0	168.00
Uttar Pradesh	North eastern plain	7.5	100	1.0	122.00
Madhya Pradesh	Malwa	7.5	100	1.0	93.00
Bihar	South Bihar alluvial plain	7.5	90	1.0	82.00
Madhya Pradesh	Jhabua	7.5	100	1.0	38.00
Madhya Pradesh	Satpura	7.5	100	1.0	37.00
				Total	**1,350.00**
Weevils					
Uttar Pradesh	Western plain	8.0	100	1.0	339.00
Bihar	North Western alluvial plain	6.0	100	1.0	265.00
Uttar Pradesh	Central plain	10.0	100	1.0	224.00
Bihar	North East alluvial plain	6.0	100	1.0	194.00
Uttar Pradesh	North eastern plain	10.0	100	1.0	162.00
Bihar	South Bihar alluvial plain	6.0	100	1.0	72.00
				Total	**1,256.00**
Zinc deficiency					
Bihar	North western alluvial plain	7.5	100	1.0	331.00
Bihar	North east alluvial plain	7.5	75	0.8	145.00
Madhya Pradesh	Malwa	12.5	100	0.8	124.00
Bihar	South Bihar alluvial plain	7.5	100	0.8	73.00
Madhya Pradesh	Jhabua	12.5	90	0.8	46.00
Madhya Pradesh	Satpura	12.5	75	0.9	42.00
				Total	**761.00**
Rusts					
Bihar	North east alluvial plain	12.5	75	0.7	212.00
Bihar	North western alluvial plain	3.5	50	0.5	38.00
Madhya Pradesh	Malwa	5.5	75	0.6	31.00
Bihar	South Bihar alluvial plain	3.5	75	0.6	19.00
Madhya Pradesh	Satpura	7.5	75	0.6	16.00
Madhya Pradesh	Jhabua	6.0	50	0.5	7.00
				Total	**323.00**
Seed and seedling blight					
Uttar Pradesh	Western plain	15.0	80	0.8	407.00
Uttar Pradesh	Central plain	15.0	75	0.6	151.00
Uttar Pradesh	North eastern plain	15.0	75	0.6	109.00
				Total	**669.00**
Cutworm					
Bihar	North western alluvial plain	12.5	50	0.5	138.00
Bihar	North east alluvial plain	12.5	25	0.5	50.00
Uttar Pradesh	North eastern plain	3.5	50	0.6	17.00
Uttar Pradesh	Central plain	3.5	50	0.4	15.00
Uttar Pradesh	Western plain	5.0	60	0.6	76.00
				Total	**298.00**
Leaf blight					
Bihar	North western alluvial plain	7.5	50	0.5	83.00
Bihar	North east alluvial plain	3.5	75	0.7	59.00
Bihar	South Bihar alluvial plain	7.5	75	0.5	34.00
				Total	**176.00**
Late planting					
Bihar	North western alluvial plain	7.5	50	0.3	42.00
Madhya Pradesh	Jhabua	17.5	50	0.6	26.00
Bihar	South Bihar alluvial plain	7.5	50	0.5	22.00
Uttar Pradesh	North eastern plain	7.5	25	0.5	15.00
Bihar	North east alluvial plain	7.5	25	0.3	15.00
Madhya Pradesh	Malwa	12.5	25	0.3	11.00
Madhya Pradesh	Satpura	12.5	25	0.5	8.00
				Total	**140.00**
Brown spot					
Uttar Pradesh	Western plain	6.0	75	0.8	152.00
Uttar Pradesh	Central plain	6.0	75	0.6	60.00
Uttar Pradesh	North eastern plain	6.0	75	0.6	44.00
				Total	**256.00**

Source: IFAD-CIMMYT-India RRA Surveys, 2001. [†] US$ 1.00 = Indian Rs. 44.00 (May 2004).

Appendix 4. Production constraints and their...cont'd.

Constraint and state	Agroecological zone	Yield loss to due to constraint (%)	Area affected by constraint (%)	Probability of occurrence of constraint	Estimated damage (Rs. million[†])
Flooding					
Bihar	North east alluvial plain	25.0	25	0.3	50.00
Bihar	South Bihar alluvial plain	25.0	25	0.3	22.00
				Total	**73.00**
Wilting					
Bihar	North east alluvial plain	25.0	25	0.3	50.00
Bihar	South Bihar alluvial plain	25.0	25	0.3	22.00
				Total	**73.00**
Waterlogging					
Uttar Pradesh	North eastern plain	35.0	25	0.3	42.00
Uttar Pradesh	Central plain	25.0	25	0.2	28.00
Uttar Pradesh	Western plain	10.0	10	0.2	8.00
				Total	**79.00**
Downy mildew					
Madhya Pradesh	Malwa	7.5	75	0.6	42.00
Madhya Pradesh	Satpura	7.5	50	0.6	11.00
Madhya Pradesh	Jhabua	7.5	50	0.5	9.00
				Total	**62.00**
Madhya Pradesh	Jhabua	15.0	100	0.8	61.00
				Total	**61.00**
Uttar Pradesh	North eastern plain	7.5	50	0.4	24.00
Uttar Pradesh	Central plain	7.5	25	0.4	17.00
Uttar Pradesh	Western plain	7.5	25	0.2	16.00
				Total	**57.00**
Cucurbitaceae family					
Bihar	North east alluvial plain	7.5	50	0.3	36.00
				Total	**36.00**
Stalk rot					
Bihar	North east alluvial plain	7.5	25	0.6	36.00
				Total	**36.00**
Trianthema monogyna					
Uttar Pradesh	Western plain	7.5	15	0.5	24.00
Uttar Pradesh	North eastern plain	7.5	50	0.3	18.00
Uttar Pradesh	Central plain	7.5	25	0.4	17.00
				Total	**59.00**
C. bengalensis					
Madhya Pradesh	Malwa	10.0	25	0.4	13.00
Madhya Pradesh	Jhabua	3.5	100	0.6	10.00
				Total	**23.00**
Maydis					
Madhya Pradesh	Malwa	7.5	50	0.4	18.00
Madhya Pradesh	Jhabua	7.5	50	0.2	4.00
				Total	**22.00**
Leaf roller					
Uttar Pradesh	Western plain	3.5	50	0.5	38.00
Uttar Pradesh	North eastern plain	3.5	50	0.3	8.00
Uttar Pradesh	Central plain	3.5	25	0.4	7.00
				Total	**53.00**
Amaranthus					
Madhya Pradesh	Jhabua	3.5	75	0.5	6.00
Madhya Pradesh	Malwa	3.5	25	0.2	2.00
Madhya Pradesh	Satpura	3.5	25	0.2	1.00
				Total	**9.00**
Jassids					
Madhya Pradesh	Malwa	3.5	25	0.3	3.00
Madhya Pradesh	Satpura	3.5	25	0.2	1.00
Madhya Pradesh	Jhabua	3.5	10	0.2	1.00
				Total	**5.00**
Aphids					
Madhya Pradesh	Malwa	3.5	25	0.3	3.00
Madhya Pradesh	Satpura	3.5	25	0.2	1.00
				Total	**4.00**
Grubs					
Madhya Pradesh	Malwa	7.5	10	0.2	2.00
				Total	**2.00**
Moths					
Madhya Pradesh	Malwa	3.5	10	0.2	1.00
				Total	**1.00**

Source: IFAD-CIMMYT-India RRA Surveys, 2001. [†] US$ 1.00 = Indian Rs. 44.00 (May 2004).

Appendix 5. Production constraints and their impact on maize production, Karnataka and Andhra Pradesh states, India, 2001.

Constraint and state	Agroecological zone	Yield loss to due to constraint (%)	Area affected by constraint (%)	Probability of occurrence of constraint	Estimated damage (Rs. million†)
Cyprus rotendrus					
Karnataka	North Dry Zone (Dharwad)	20	100	1	1,050.0
Andhra Pradesh	North Telangana (Nizamabad)	18	100	1	885.5
Andhra Pradesh	North Telangana (Karimnagar)	15	90	1	637.6
Karnataka	North Dry Zone (Belgaum)	15	100	0.8	548.2
Andhra Pradesh	Scarce Rainfall Zone (Mehboobnagar)	13	100	1	182.3
					3,303.0
Leaf blight					
Andhra Pradesh	North Telangana (Nizamabad)	15	100	0.8	569.3
Karnataka	North Dry Zone (Dharwad)	15	80	0.8	472.3
Andhra Pradesh	North Telangana (Karimnagar)	15	80	0.8	453.4
Karnataka	North Dry Zone (Belgaum)	15	75	0.8	411.1
Karnataka	Central Dry Zone (Chitradurga)	15	75	0.8	218.4
Andhra Pradesh	Scarce Rainfall Zone (Mehboobnagar)	15	80	1	175.0
					2,300.0
Stem borer					
Karnataka	North Dry Zone (Dharwad)	18	60	0.8	413.2
Andhra Pradesh	North Telangana (Nizamabad)	13	80	0.8	404.8
Andhra Pradesh	North Telangana (Karimnagar)	10	90	0.8	318.8
Karnataka	North Dry Zone (Belgaum)	20	50	0.5	243.6
Karnataka	Central Dry Zone (Chitradurga)	15	75	0.8	233.0
Andhra Pradesh	Scarce Rainfall Zone (Mehboobnagar)	10	80	0.8	87.5
					1,701.0
Water stress					
Andhra Pradesh	North Telangana (Nizamabad)	15	90	1	683.1
Andhra Pradesh	North Telangana (Karimnagar)	13	90	1	531.3
Karnataka	North Dry Zone (Dharwad)	10	80	1	419.8
Andhra Pradesh	Central Dry Zone (Chitradurga)	13	90	1	164.0
Karnataka	North Dry Zone (Belgaum)	10	75	0.3	91.3
					1,205.4
Cynodon dactylon					
Karnataka	North Dry Zone (Dharwad)	15	50	0.8	295.2
Karnataka	North Dry Zone (Belgaum)	15	50	0.8	274.1
Andhra Pradesh	North Telangana (Nizamabad)	15	60	0.6	273.2
Andhra Pradesh	North Telangana (Karimnagar)	15	50	0.6	212.5
Andhra Pradesh	Scarce Rainfall Zone (Mehboobnagar)	10	75	0.5	54.6
					1,110.0
Echinocloa					
Andhra Pradesh	North Telangana (Karimnagar)	9	75	0.8	239.1
Andhra Pradesh	North Telangana (Nizamabad)	10	75	0.6	227.7
Karnataka	North Dry Zone (Dharwad)	7.5	75	0.8	221.4
Karnataka	North Dry Zone (Belgaum)	10	75	0.5	182.7
Andhra Pradesh	Scarce Rainfall Zone (Mehboobnagar)	8	75	0.6	52.5
					923.4
Post-flowering stalk rot					
Andhra Pradesh	North Telangana (Nizamabad)	15	75	0.5	284.6
Andhra Pradesh	North Telangana (Karimnagar)	10	60	0.5	141.7
Karnataka	North Dry Zone (Dharwad)	10	75	0.3	98.4
Karnataka	North Dry Zone (Belgaum)	10	75	0.3	91.3
Andhra Pradesh	Scarce Rainfall Zone (Mehboobnagar)	10	50	0.8	54.6
Karnataka	Central Dry Zone (Chitradurga)	10	75	0.3	48.5
					719.1
Zinc deficiency					
Andhra Pradesh	North Telangana (Nizamabad)	10	75	0.8	303.6
Andhra Pradesh	North Telangana (Karimnagar)	10	60	0.6	170.0
Karnataka	North Dry Zone (Dharwad)	10	10	0.3	13.12
Karnataka	North Dry Zone (Belgaum)	10	25	0.1	12.1
					498.8

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † US$ 1.00 = Indian Rs. 44.00 (May 2004).

Appendix 5. Production constraints ...cont'd.

Constraint and state	Agroecological zone	Yield loss to due to constraint (%)	Area affected by constraint (%)	Probability of occurrence of constraint	Estimated damage (Rs. million†)
Termites					
Andhra Pradesh	North Telangana (Nizamabad)	10	60	0.5	121.4
Andhra Pradesh	North Telangana (Karimnagar)	10	50	0.4	94.4
Andhra Pradesh	Scarce Rainfall Zone (Mehboobnagar)	10	25	0.5	18.2
Karnataka	Central Dry Zone (Chitradurga)	15	40	0.3	38.8
Karnataka	North Dry Zone (Dharwad)	15	50	0.3	98.4
Karnataka	North Dry Zone (Belgaum)	10	50	0.3	60.9
					432.1
Late planting					
Andhra Pradesh	North Telangana (Nizamabad)	15	40	0.5	151.8
Andhra Pradesh	North Telangana (Karimnagar)	15	40	0.3	70.8
Andhra Pradesh	Scarce Rainfall Zone (Mehboobnagar)	10	50	0.5	36.4
Karnataka	Central Dry Zone (Chitradurga)	20	25	0.5	64.7
Karnataka	North Dry Zone (Dharwad)	15	25	0.3	49.2
Karnataka	North Dry Zone (Belgaum)	15	25	0.3	45.6
					418.5
Rusts					
Karnataka	North Dry Zone (Dharwad)	10	50	0.3	65.6
Karnataka	North Dry Zone (Belgaum)	10	50	0.3	60.9
					126.5
Cylesia					
Karnataka	North Dry Zone (Dharwad)	15	25	0.5	98.4
Karnataka	North Dry Zone (Belgaum)	15	25	0.5	0.9
					99.3
Shoot fly					
Karnataka	Central Dry Zone (Chitradurga)	10	50	0.5	64.7
					64.7
Nematodes					
Karnataka	North Dry Zone (Dharwad)	10	25	0.1	13.12
Karnataka	North Dry Zone (Belgaum)	10	25	0.1	12.10
Andhra Pradesh	North Telangana (Karimnagar)	5	10	0.3	5.90
Andhra Pradesh	Scarce Rainfall Zone (Mehboobnagar)	5	10	0.2	1.46
					32.58
Grubs					
Karnataka	North Dry Zone (Dharwad)	10	25	0.1	13.12
Karnataka	North Dry Zone (Belgaum)	10	25	0.1	12.10
					25.22
Wilting					
Karnataka	Central Dry Zone (Chitradurga)	25	10	0.2	12.90
					12.90

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † US$ 1.00 = Indian Rs. 44.00 (May 2004).

Appendix 6. Prioritization of biotic and abiotic constraints to maize production in selected states and agro-ecological regions of India, 2001.

Constraint by state and agro-ecological region	Yield loss due to constraint (%)	Area affected by constraint (%)	Proba-bility of occurrence	Value of damage (Rs. million[†])	Priority rank
BIHAR – South Bihar alluvial plain					
Echinocloa	15.0	100	1.0	181.74	1
Cynodon dactylon	15.0	100	1.0	181.74	2
Rats	10.0	100	1.0	121.16	3
Termites	15.0	80	0.8	116.31	4
Stem borer	7.5	90	1.0	81.78	5
Caterpillar	7.5	90	1.0	81.78	6
Weevil	6.0	100	1.0	72.70	7
Zinc deficiency	7.5	100	0.8	72.70	8
Water stress	10.0	75	0.5	45.44	9
Leaf blight	7.5	75	0.5	34.08	10
Late planting	7.5	50	0.5	22.72	11
Flooding	25.0	25	0.3	22.72	12
Wilting	25.0	25	0.3	22.72	13
Rusts	3.5	75	0.6	19.08	14
			Total	1,076.66	
BIHAR – Northwest alluvial plain					
Echinocloa	15.0	100	1.0	663.93	1
C. dactylon	15.0	100	1.0	663.93	2
Rats	12.5	100	1.0	553.28	3
Water stress	10.0	100	1.0	442.62	4
Termites	15.0	80	0.8	424.92	5
Zinc deficiency	7.5	100	1.0	331.97	6
Stem borer	7.5	90	1.0	298.77	7
Caterpillar	7.5	90	1.0	298.77	8
Weevil	6.0	100	1.0	265.57	9
Cutworm	12.5	50	0.5	138.32	10
Leaf blight	7.5	50	0.5	82.99	11
Late planting	7.5	50	0.3	41.50	12
Rusts	3.5	50	0.5	38.73	13
			Total	4,245.31	
BIHAR – Northeastern alluvial plain					
Rats	12.5	100	1.0	403.98	1
C. dactylon	12.5	100	1.0	403.98	2
Echinocloa	12.5	100	1.0	403.98	3
Rusts	12.5	75	0.7	212.09	4
Stem borer	7.5	80	1.0	193.91	5
Caterpillar	7.5	80	1.0	193.91	6
Weevil	6.0	100	1.0	193.91	7
Termites	15.0	50	0.7	169.67	8
Zinc deficiency	7.5	75	0.8	145.43	9
Leaf blight	3.5	75	0.7	59.39	10
Cutworm	12.5	25	0.5	50.50	11
Flooding	25.0	25	0.3	50.50	12
Wilting	25.0	25	0.3	50.50	13
Water stress	10.0	50	0.3	48.48	14
Post-flowering stalk rot (PFSR)	7.5	25	0.6	36.36	15
Cucurbitaceae family	7.5	50	0.3	36.36	16
Late planting	7.5	25	0.3	15.15	17
			Total	2,668.11	
MADHYA PRADESH – Satpura plateau					
Echinocloa	15.0	100	1.0	74.87	1
C. dactylon	15.0	100	1.0	74.87	2
Water stress	17.5	90	0.9	70.75	3
Caterpillar	10.0	100	1.0	49.91	4
Zinc deficiency	12.5	75	0.9	42.11	5
Stem borer	7.5	100	1.0	37.44	6
Rats	7.5	100	1.0	37.44	7
Termites	17.5	50	0.6	26.20	8
Rusts	7.5	75	0.6	16.85	9
Downy mildew	7.5	50	0.6	11.23	10
Late planting	12.5	25	0.5	7.80	11
Aphids	3.5	25	0.2	0.87	12
Jassids	3.5	25	0.2	0.87	13
Amaranthus	3.5	25	0.2	0.87	14
			Total	452.09	
MADHYA PRADESH – Malwa plateau					
Rats	15.0	100	1.0	187.26	1
Echinocloa	15.0	100	1.0	187.26	2
C. dactylon	15.0	100	1.0	187.26	3
Water stress	17.5	90	0.8	157.30	4
Termites	17.5	75	0.8	131.08	5
Caterpillar	10.0	100	1.0	124.84	6
Zinc deficiency	12.5	100	0.8	124.84	7
Stem borer	7.5	100	1.0	93.63	8
Downy mildew	7.5	75	0.6	42.13	9
Rusts	5.5	75	0.6	30.90	10
Maydis	7.5	50	0.4	18.73	11
Cynodon bengalensis	10.0	25	0.4	12.48	12
Late planting	12.5	25	0.3	11.70	13
Aphids	3.5	25	0.3	3.28	14
Jassids	3.5	25	0.3	3.28	15
Amaranthus	3.5	25	0.2	2.18	16
Grubs	7.5	10	0.2	1.87	17
Moths	3.5	10	0.2	0.87	18
			Total	1,320.91	
MADHYA PRADESH – Jhabua Hills					
Water stress	17.5	100	1.0	89.35	1
Rats	15.0	100	1.0	76.59	2
Echinocloa	15.0	100	1.0	76.59	3
Achyranthes aspera	15.0	100	0.8	61.27	4
Caterpillar	10.0	100	1.0	51.06	5
Zinc deficiency	12.5	90	0.8	45.95	6
Stem borer	7.5	100	1.0	38.29	7
Termites	17.5	50	0.8	35.74	8
Late planting	17.5	50	0.6	26.81	9
C. dactylon	10.0	75	0.6	22.98	10
C. bengalensis	3.5	100	0.6	10.72	11
Downy mildew	7.5	50	0.5	9.57	12
Rusts	6.0	50	0.5	7.66	13
Amaranthus	3.5	75	0.5	6.70	14
Maydis	7.5	50	0.2	3.83	15
Jassids	3.5	10	0.2	0.36	16
			Total	563.46	
UTTAR PRADESH – Northeastern plain					
Echinocloa	20.0	100	1.0	325.47	1
Termites	25.0	75	0.6	183.08	2
Caterpillar	10.0	100	1.0	162.73	3
Weevil	10.0	100	1.0	162.73	4
C. dactylon	9.0	100	1.0	146.46	5
Stem borer	7.5	100	1.0	122.05	6
Rats	7.5	100	0.9	109.85	7
Seed & seedling blight	15.0	75	0.6	109.85	8
Water stress	15.0	50	0.6	73.23	9
Brown spot	6.0	75	0.6	43.94	10
Waterlogging	35.0	25	0.3	42.72	11
Wild rice	7.5	50	0.4	24.41	12
Biskhapra (weed)	7.5	50	0.3	18.31	13
Cutworm	3.5	50	0.6	17.09	14
Late planting	7.5	25	0.5	15.26	15
Leaf roller	3.5	50	0.3	8.54	16
			Total	1,565.71	

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † US$ 1.00 = Indian Rs. 44.00 (May 2004).

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † US$ 1.00 = Indian Rs. 44.00 (May 2004).

Appendix 6. Prioritization of biotic and abiotic...cont'd.

Constraint by state and agro-ecological region	Yield loss due to constraint (%)	Area affected by constraint (%)	Proba-bility of occurrence	Value of damage (Rs. million†)	Priority rank
UTTAR PRADESH – Central plain					
Echinocloa	25.0	100	1.0	561.11	1
Termites	25.0	75	0.8	336.66	2
Caterpillar	10.0	100	1.0	224.44	3
Weevil	10.0	100	1.0	224.44	4
C. dactylon	9.0	100	1.0	202.00	5
Stem borer	7.5	100	1.0	168.33	6
Rats	7.5	100	0.9	151.50	7
Seed & seedling blight	15.0	75	0.6	151.50	8
Water stress	15.0	75	0.6	151.50	9
Brown spot	6.0	75	0.6	60.60	10
Waterlogging	25.0	25	0.2	28.06	11
Biskhapra (weed)	7.5	25	0.4	16.83	12
Wild rice	7.5	25	0.4	16.83	13
Cutworm	3.5	50	0.4	15.71	14
Leaf roller	3.5	25	0.4	7.86	15
			Total	2,317.37	
UTTAR PRADESH – Western plain					
Echinocloa	25.0	90	1.0	1,012.36	1
Termites	20.0	75	1.0	674.91	2
Seed & seedling blight	15.0	80	0.8	431.94	3
C. dactylon	9.0	100	1.0	404.94	4
Caterpillar	8.0	100	1.0	359.95	5
Weevil	8.0	100	1.0	359.95	6
Stem borer	7.5	100	1.0	337.45	7
Rats	7.5	100	0.8	269.96	8
Brown spot	6.0	75	0.8	161.98	9
Water stress	15.0	60	0.2	80.99	10
Cutworm	5.0	60	0.6	80.99	11
Leaf roller	3.5	50	0.5	39.37	12
Biskhapra (weed)	7.5	15	0.5	25.31	13
Wild rice	7.5	25	0.2	16.87	14
Waterlogging	10.0	10	0.2	9.00	15
			Total	4,265.97	
ANDHRA PRADESH- North Telangana					
Cyprus rotendrus	17.5	100	1.00	885.50	1
Water stress	15.0	90	1.00	683.10	2
Leaf blight	15.0	100	0.75	569.30	3
Stem borer	12.5	80	0.80	404.80	4
Zinc deficiency	10.0	75	0.80	303.60	5
PFSR	15.0	75	0.50	284.60	6
C. dactylon	15.0	60	0.60	273.20	7
Echinocloa	10.0	75	0.60	227.70	8
Late planting	15.0	40	0.50	151.80	9
Termites	10.0	60	0.50	121.40	10
			Total	3,905.40	
ANDHRA PRADESH- North Telangana					
C. rotendrus	15.0	90	1.00	637.60	1
Water stress	12.5	90	1.00	531.30	2
Leaf blight	15.0	80	0.80	453.40	3
Stem borer	10.0	90	0.75	318.80	4
Echinocloa	9.0	75	0.75	239.10	5
C. dactylon	15.0	50	0.60	212.50	6
Zinc deficiency	10.0	60	0.60	170.00	7
PFSR	10.0	60	0.50	141.70	8
Termites	10.0	50	0.40	94.40	9
Late planting	15.0	40	0.25	70.80	10
Nematodes	5.0	10	0.25	5.90	11
			Total	2,875.80	

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † US$ 1.00 = Indian Rs. 44.00 (May 2004).

Constraint by state and agro-ecological region	Yield loss due to constraint (%)	Area affected by constraint (%)	Proba-bility of occurrence	Value of damage (Rs. million†)	Priority rank
ANDHRA PRADESH- Scarce Rainfall					
C. rotendrus	12.5	100	1.00	182.30	1
Leaf blight	15.0	80	1.00	175.00	2
Water stress	12.5	90	1.00	164.00	3
Stem borer	10.0	80	0.75	87.50	4
C. dactylon	10.0	75	0.50	54.60	5
PFSR	10.0	50	0.75	54.60	6
Echinocloa	8.0	75	0.60	52.50	7
Late planting	10.0	50	0.50	36.40	8
Termites	10.0	25	0.50	18.20	9
Nematodes	5.0	10	0.20	1.46	10
			Total	826.90	
KARNATAKA- Central Dry Zone					
Stem borer	15.0	75	0.80	233.00	1
Leaf blight	15.0	75	0.75	218.40	2
Late planting	20.0	25	0.50	64.70	3
Shoot fly	10.0	50	0.50	64.70	4
PFSR	10.0	75	0.25	48.50	5
Termites	15.0	40	0.25	38.80	6
Wilting	25.0	10	0.20	12.90	7
			Total	681.30	8
KARNATAKA-North Dry Zone					
C. rotendrus	20.0	100	1.00	1,049.50	1
Leaf blight	15.0	80	0.75	472.30	2
Water stress	10.0	80	1.00	419.80	3
Stem borer	17.5	60	0.75	413.20	4
C. dactylon	15.0	50	0.75	295.20	5
Echinocloa	7.5	75	0.75	221.40	6
Termite	15.0	50	0.25	98.40	7
PFSR	10.0	75	0.25	98.40	8
Cylesia	15.0	25	0.50	98.40	9
Rusts	10.0	50	0.25	65.60	10
Late planting	15.0	25	0.25	49.20	11
Nematodes	10.0	25	0.10	13.12	12
Grubs	10.0	25	0.10	13.12	13
Zinc deficiency	10.0	10	0.25	13.12	14
			Total	3,320.95	
KARNATAKA- North Dry Zone					
C. rotendrus	15.0	100	0.75	548.20	1
Leaf blight	15.0	75	0.75	411.10	2
C. dactylon	15.0	50	0.75	274.10	3
Stem borer	20.0	50	0.50	243.60	4
Echinocloa	10.0	75	0.50	182.70	5
Water stress	10.0	75	0.25	91.30	6
PFSR	10.0	75	0.25	91.30	7
Termites	10.0	50	0.25	60.90	8
Rusts	10.0	50	0.25	60.90	9
Late planting	15.0	25	0.25	45.60	10
Zinc deficiency	10.0	25	0.10	12.10	11
Nematodes	10.0	25	0.10	12.10	12
Grubs	10.0	25	0.10	12.10	13
Cylesia	15.0	25	0.50	0.90	14
			Total	2,047.60	

Source: IFAD-CIMMYT-India RRA Surveys, 2001. † US$ 1.00 = Indian Rs. 44.00 (May 2004).

Appendix 7. Value of damage due to socio-economic constraints to maize production in selected states and agro-ecological regions of India, 2001.

State and agro-ecological region	Socioeconomic constraints: Lack of remunerative price	Lack of market	Lack of quality seeds	Lack of technical knowledge	Total
BIHAR					
South Bihar alluvial plain					
Damage (Rs 000[†])	106.32	86.14	1,688.09	1,040.72	2,921.27
% total damage	3.64	2.94	57.78	35.63	
Northwest alluvial plain					
Damage (Rs 000)	216.85	180.71	5,225.16	3,293.52	8,916.24
% total damage	2.43	2.03	58.60	36.94	
Northeast alluvial plain					
Damage (Rs 000)	161.59	139.56	3,169.47	1,991.78	5,462.40
% total damage	2.96	2.55	58.02	36.46	
MADHYA PRADESH					
Satpura plateau					
Damage (Rs 000)	32.88	25.29	1,604.05	1,245.80	2,908.02
% total damage	1.13	0.87	55.16	42.82	
Malwa plateau					
Damage (Rs 000)	52.98	26.49	3,334.14	2,583.68	5,997.29
% total damage	0.88	0.44	55.60	43.08	
Jhabua Hills					
Damage (Rs 000)	54.01	38.33	2,185.81	1,692.25	3970.40
% total damage	1.36	0.96	55.06	42.63	
UTTAR PRADESH					
Northeastern plain					
Damage (Rs 000)	na	na	2,285.02	1,414.79	3,699.81
% total damage			61.77	38.24	
Central plain					
Damage (Rs 000)	na	na	6,717.22	4,833.25	1,1550.47
% total damage			58.11	41.84	
Western plain					
Damage (Rs 000)	na	na	8,270.07	5,711.93	13,982.00
% total damage			59.15	40.85	
RAJASTHAN					
Humid South plain (Banswara)					
Damage (Rs 000)	45.56	28.47	546.32	1,701.58	2,321.93
% total damage	1.96	1.22	23.54	73.32	
Sub-humid South plain (Bhilwara)					
Damage (Rs 000)	318.13	258.48	8,294.25	5,485.98	14,356.84
% total damage	2.22	1.80	57.77	38.22	
Sub-humid South plain (Udaipur)					
Damage (Rs 000)	258.48	198.83	8,294.25	5,485.98	14,237.54
% total damage	1.81	1.39	58.25	38.53	
ANDHRA PRADESH					
Northern Telangana (Mehboobnagar)					
Damage (Rs 000)	57.16	145.02	na	4,583.15	4,785.33
% total damage	0.65	3.03		95.77	
Northern Telangana (Karimnagar)					
Damage (Rs 000)	24.50	138.66	na	10,563.25	10,726.41
% total damage	0.22	1.29		98.47	
Scarce Rainfall Zone					
Damage (Rs 000)	37.50	75.10	na	3,787.10	3,899.70
% total damage	0.96	1.92		97.11	
KARNATAKA					
Central Dry zone					
Damage (Rs 000)	16.29	24.90	na	8,140.00	8,181.19
% total damage	0.19	0.30		99.49	
Northern Dry zone (Dharwad)					
Damage (Rs 000)	24.46	111.15	na	4,210.24	4,345.85
% total damage	0.56	2.55		96.87	
Northern Dry Zone (Belgaum)					
Damage (Rs 000)	15.39	88.50	na	8,252.08	8,355.97
% total damage	0.18	1.05		98.75	

Source: IFAD-CIMMYT-India RRA Surveys, 2001.
[†] US$ 1.00 = Indian Rs. 44.00 (May 2004).
na = not applicable.

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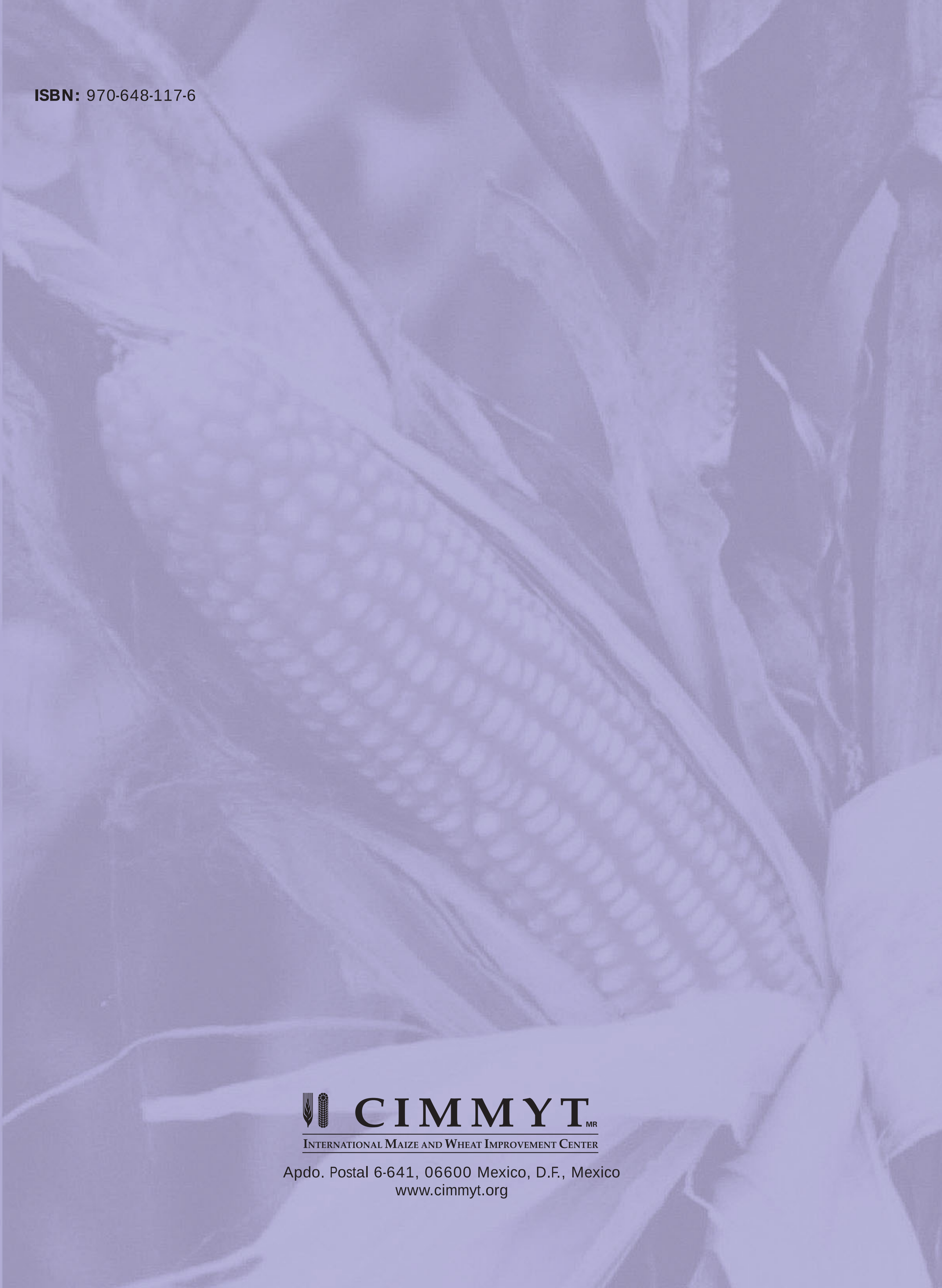

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