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CHAPTER II INSECT DAMAGE: Damage on Post-harvest

6. References

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CHAPTER III Vertebrate Pests: Damage on stored foods

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1. Introduction

General information on stored food losses at the farm and village level in developing countries is sparse and poorly documented. While it is known that millions of people throughout developing countries share their meagre households and foods with rats, mice, and pest birds, these problems mainly have escaped documentation by scientists and agriculturists. Farm families, living in or near poverty and nutritional catastrophe, suffer a double loss - a portion of their crop both before as well as after harvest.

While field crops are usually vulnerable to vertebrate pest damage during a short portion of the growing season, stored foods are vulnerable for as long as they are held in storage, sometimes for 6-12 months. Most storage of harvested crops occurs in farm household structures; these structures in the tropics and subtropics invariably are infested by one or more species of commensal and/or indigenous rodents and possibly depredatious birds. Stored foods are regularly lost due to the consumption, contamination, wastage, and spoilage by vertebrate pests. Most serious of all is the loss of seed for the next crop.

This chapter will attempt to show the extent of the problem, describe the vertebrate pest species responsible for stored food damage, and suggest some methods of managing and preventing damage by rodent and bird pests.

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1.1. Magnitude of the Problem

The first attempt to document the world-wide problems of stored food losses due to rodents was the mail survey by Hopf et al. (1976). The responses from a questionnaire about stored food losses included estimates made by stored food managers and agriculturists (Table 1). Almost all responses were guesses as to the actual amounts of stored foods lost due to rodents. The authors state: "The one single fact which emerges from the survey is the widespread ignorance of the magnitude of the rodent problem, and of means to control it."

The following year, Jackson (1977) reviewed stored food losses due to rodents on a world-wide scale, using published sources; however, he was faced with the same lack of precise data. Subsequently, the US National Academy of Sciences (1978) published its review of post-harvest food losses throughout the food pipeline in developing countries. It concluded "Although the methods of loss estimation are frequently suspect and the supporting data rough, there are, as we have noted, sufficient data to show that substantial amounts of food are being lost annually in the post-harvest system."

During the ensuing two decades since these reports were issued, very little new information on stored food losses at the farm and village level was added. Several conferences and books on rodents since 1980 have only touched on the subject of stored food losses (Dubock,ed., 1982; Meehan, 1984; and Richards and Ku, 1986). Rodent Pest Management (1988), Prakash's book, didn't include a separate chapter on post-harvest problems; however, stored food losses are mentioned briefly in three chapters summarising rodent problems in South America, Asia, and Africa. Similarly, Buckle and Smith (1994) included a chapter on rodent control in food stores, but new information was absent.

Table 1. Stored food losses at farm and village level as reported on the mail survey of Hopf et al. (1976).

Area	Type of storage	Commodities	Percent damage or loss
Asia:			
Bangladesh	Bamboo bins	Rice, wheat	5
India	Village stores	Rice, wheat	1.7
India	Village, bags	Rice, wheat, millet, sorghum	3.5-5
India	bins, bags	Mud and bamboo Rice, wheat, pulses, sorghum	2-5
Korea	Sacks	Rice, barley	20
Laos	Cribs, mud and bamboo bins	Rice	3
Malaysia	Cribs in roof	Rice	2-5

Nepal	Sacks	Maize	3-5
Philippines	Cribs, sacks	Rice, maize	2-3
Thailand	Sacks in roof, maize in cribs	Maize, rice	5
Turkey	Farm houses, underground pits	Wheat, rice, maize	5
Africa:			
Egypt	Houses and stores	Maize, wheat, rice, cottonseed	50
Ethiopia	Huts on stilts, underground, bags	Grains	5-15
Ghana		Grains, maize, rice	2-3
Malawi	Woven cane bins, grass baskets	Maize, groundnuts, sorghum, millet	0.5-1.5
Malawi	Cribs	Cob maize	15
Sierra Leone	Cane baskets	Rice	1-10
Sierra Leone	Sacks	Rice	10-100
Sierra Leone	Roof and cribs	Rice, maize	2-3

Sierra Leone	Roof and cribs	Rice, maize	2-3
Zaire	Bags in roof	Rice, maize	3
Zambia	Farm cribs	Cob maize, sorghum, millet	10
Latin America:			
Mexico	Cribs, sacks in roofs	Rice, maize	5-10
Brazil	Stacks, sacks, cribs	Rice, maize, beans	4-8

1.2. Losses by Crop Type due to Rodents

Losses occur due to various causes along the entire post-harvest pipeline. In this review, however, we are concerned mainly with losses caused by rodents and birds occurring in farm and village storage. Further, we will focus on cereal grains and legumes, since these two food groups together account for more than half of the world's food production.

1.2.1. Rice:

The data for rice losses from several causes in Asia probably approach the level of accuracy with which it is possible to assess losses on a large, nonexperimental scale. These are summarised for the Philippines by De Padua (1974), for Bangladesh by Greeley (1982), and forIndonesia by Winaro (1984). The losses in storage are primarily due to insects, rodents, and fungi. These range from 2-6 percentage in the three studies.

Table 2. Rice losses from harvest to milling in Asain countries (% weight loss)

	Philippines	Bangladesh	Indonesia (season)	
			Wet	Dry
Harvesting	1-3	1.45	0.89	0.63
Handling	2-7	1.03	--	--
Threshing	2-6	1.79	0.99	0.99
Drying	1-5	--	3.16	2.65
Storing	2-6	2.60	2.25	2.45
Milling	2-10	--	4.50	2.46

Post-harvest rice losses in developing countries are summarised in Table 3. The loss criteria were not given in the NAS (1978) report. In general, reported storage losses in rice are least in Asia, more in Africa, and most severe in Latin America. This may be because where research and documentation are done thoroughly, the loss estimates tend to be lower.

1.2.2. Maize:

Maize losses appear to be moderately serious in African countries and severe in the Latin American region (Table 4). There are few reports from Asia; consequently no

Table 3. Reported post-harvest losses of rice world-wide (US NAS, 1978, based upon FAO data, 1977 unless otherwise indicated).

Region/Country	Total Percent Weight Loss	Remarks	
Africa:			
Sierra Leone	10		
Uganda	11		
Rwanda	9		
Egypt	2.5	(Quoted in NAS, 1978)	
Asia:			
Bangladesh	7		
India	3-5.5	Improved traditional storage Boxall	

		and Greeley,1978)	
Indonesia	2-5		
Malaysia	5	On-farm storage (Quoted in NAS, 1978)	
Nepal	3-4	On farm storage	
Sri Lanka	2-6	On-farm storage (Quoted in NAS, 1978)	
Thailand	1.5-3.5	On-farm storage	
		On-farm storage (Quoted in NAS, 1978)	
Latin America:			
Belize	20-30	On-farm	

		storage (Quoted in NAS, 1978)	
Bolivia	16	On-farm storage	
Dominican Republic	6.5	On-farm storage	

conclusions can be drawn on losses from this region. FAO (1977) reported the losses in maize as averaging from 9.6 to 20.2 percent, mainly in storage and due primarily to insect damage, followed by fungus and rodent damage. However, the data are markedly inadequate. Maize presents considerable problems of loss estimation because it can be stored either on the cob or shelled. In South America the ears are bent down on the stalk and are left in the field to dry. This may lead to some rodent and bird damage before harvest.

Table 4. Reported post-harvest losses of maize world-wide (US NAS, 1978, based upon FAO, 1977 data unless otherwise indicated).

Region/Country	Total Percent Weight Loss	Remarks	
Africa:			

Africa:			
Benin	8-9	Traditional on-farm storage (Harris and Lindblad, 1978)	
Malawi	8	On-farm storage (TPI, 1977; Schulten, 1975)	
Nigeria	1-5	On-farm storage	
Rwanda	10-20	On-farm storage	
Zambia	9-21	On-farm storage (Adams and Harman, 1977)	

Asia:			
Pakistan	2-7		
Latin America:			
Belize	10-20	On-farm storage (Quoted in NAS, 1978)	
Brazil	15-40		
Dominican Republic	19	Farm storage	
Honduras	20-50	Traditional storage, poor facilities (Quoted in NAS, 1978)	
Mexico	10-25		
Nicaragua	15-30		
Paraguay	25	(Quoted in	

		NAS, 1978)	
Venezuela	10-25		

1.2.3. Wheat:

Farm losses of wheat reported from several countries indicate that this crop is lost in about the same percentage as rice (Table 5). The loss reports for wheat average 10 percentage, with the combined major causes being insects, rodents, and mould during storage. Rodents are a major problem of stored wheat in India, but are only partly responsible for the estimated 10 percentage losses there.

1.2.4. Millets and Sorghums:

Millets and sorghums are the main staple in drier regions of Africa, the Middle East, India, Pakistan, and China. Post-harvest technology is relatively unimproved for millets and sorghums as compared to that for the major cereal grains. Sorghum commonly stands in the field, or in piles, in Africa. This results in serious losses due to field rodents. The few reports on post-harvest losses in farm storage available are given in Table 5; these are relatively severe.

Table 5. Reported world-wide post-harvest losses from all causes of wheat, millets, and sorghum (US NAS, 1978, based on FAO, 1977 data unless otherwise indicated).

Region/Country	Total Percent Weight Loss	Remarks
Wheat:		
Pakistan	5-10	On-farm storage (Quoted in NAS,
India	8-25	(Quoted in NAS, 1978)
Rhodesia	10	On-farm storage (Quoted in NAS, 1978)
Sudan	10	
Bolivia	7	Stores
Brazil	1-4	Storage
Millets:		
India	5	Farm storage (Quoted in NAS, 1978)

Mali	2-4	On-farm storage (Guggenheim, 977)
Nigeria	0.1-0,2	On-farm storage
Zambia	10	On-farm storage
Zimbabwe	10-15	On-farm storage (Quoted in NAS, 1978)
Sorghum:		
Nigeria	0-37	On-farm over 26 months (Hall, 1970
Senegal	1-5	On-farm storage (Spencer et al. 1975)

Zimbabwe	25	On-farm storage (Quoted in NAS, 1978)

1.2.5. Grain Legumes:

Rodent damage to grain legumes (beans, peas, lentils, cowpeas, groundnuts) is minimal. Legumes are not preferred foods of rats and mice except for groundnuts. Damage in farm-level storage is given in Table 6. Most damage is due to insects and fungi, not rodents. Experienced observers agree that legume post-harvest losses most often exceed those of cereal grains.

Table 6. Post-harvest losses at farm-level of grain legumes due to all causes (NAS 1978).

Country	Total Percent Weight Loss	Remarks	
Kenya	30	On-farm	

		storage (De Lima, 1973)	
Zimbabwe	5	On-farm storage (NAS, 1978) (Groundnuts)	
Thailand	12-15	Farm stores (NAS, 1978)	
Honduras	20-50	On-farm storage (NAS, 1978) (Dry beans)	

1.3. Stored Food Losses at Farm Level

There are several studies of stored food losses at farm level carried out since 1980. The losses of stored paddy (rice) from open woven bamboo storage baskets at Bangladesh farm households was indirectly measured by trapping small mammals in farm structures and estimating their populations before and after removal trapping by inked tracking tiles (Mian et al. 1987; Ahmad et al. 1994). These two studies estimated stored food losses based upon the numbers of small mammals found in farm structures and the amounts of stored paddy they potentially could consume, contaminate, or hoard. It was found that this approximated 50 kg of paddy/farm family/year. This amount of paddy represents about 5 percentage of the average 1,000 kg stored by the farm families over a crop season.

1.3.1. Other Losses.

Much grain on smallholder farms is stored in various containers, including woven baskets, earthen jars, metal cans, and in jute bags. Jute bags are frequently damaged by rodents. Often the monetary loss of bag or basket damage is greater than the loss of stored grains.

Rodents also contaminate stored foods with their faeces, urine, and hairs. This contamination often is more serious than the actual food losses because of the public health aspects and the possibility of disease transmission. The foods must be cleaned before being prepared for human consumption.

1.4. Disease Implications

The rodents that frequent food stores and live in close association with humans (commensal) in many parts of the tropics and subtropics in developing countries are also known to be the reservoirs and vectors of several human diseases. Among these are plague, murine typhus, Lassa fever, leptospirosis, several types of haemorrhage fevers , including hantavirus, and salmonella infections. Roof rats, Norway rats, Polynesian rats, multimammate rats, and lesser bandicoot rats spread plague and murine typhus through their fleas. Lassa fever is known to be spread by the urine and faeces of the multimammate rat in parts of west Africa. Leptospires are bacteria present in the urine of roof rats and Norway rats. Hantavirus is spread in the droppings and urine of Norway rats and other rodents (Peromyscus, Sigmodon, Microtus, Oligorzyomys species). Argentine/Bolivian haemorrhage fevers are spread by the Calomys species in parts of

Bolivia and Argentina. Salmonella organisms are spread through the droppings of all the commensal rodents, house mice and rats alike. Prevention, reduction, or elimination of rodents from farm and village structures where these diseases are prevalent can reduce food losses as well as increase human health.

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CHAPTER III Vertebrate Pests: Damage on stored foods

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2. Major vertebrate pests of stored foods

2.1. Rodents

The rodent species that infest stored foods in farm and village structures differ in the several regions of the world. The primary rodent pests are the cosmopolitan, commensal rodents, of which the roof rat (Rattus rattus), also known as the black or ship rat, is the major rat species found in food storage facilities world-wide, followed closely by the abundant and ubiquitous house mouse (Mus musculus). Since the mouse consumes far less food daily, it may be of lesser importance than the rat species in terms of overall amounts of food lost. The Norway rat (Rattus norvegicus), also known as the sewer, barn, or brown rat, is not as common and widely distributed as the roof rat, but is a formidable pest of food stores in many temperate areas of the world.

Table 7. Regional commensal and peri-domestic rodents of stored foods.

Area	Scientific name	Common name	Remarks
Latin America:	Calomys laucha	Vesper mouse	Commensal
	C. musculinus	" "	"
	C. callosus	" "	"
	Akodon azarae	Grass mouse	
	Sigmodon hispidus	Cotton rat	Peri-domestic
	Oryzomys longicaudus	Rice rat	"
Africa:	Mastomys natalensis	Multimammate rat	Commensal
	Acomys caharinus	Spiny mouse	"
	Arvicanthis niloticus	Unstriped grass rat	Peri-domestic
	Tatera species	Gerbils	"

Asia:	Bandicota bengalensis	Lesser bandicoot rat	Commensal
	Rattus exulans	Little house rat	"

There are several rodent species that are important regionally (Table 7). Some are true commensals and live in human structures and others are occasional invaders, living mainly in field situations but entering structures in certain seasons (peri-domestic).

It is important to know about how much stored foods the several rodent species may consume daily, and, sometimes, the amounts eaten in a year, so this can be related to the amounts of stored foods at risk. In large central food stores, the amounts of grain in storage may be 500 to 5,000 metric tons (500,000-5,000,000 kg). Obviously, the estimated 5 to 9 kg of grain eaten yearly by one adult Norway rat represents an immensely small percentage of this stored mass. But when 5 roof rats (3-4 kg/year/rat), 3 bandicoots (6-9 kg/year/rat), and 10 house mice (1 kg/year/mouse) eat into a farmer's stored 1,000 kg of rice, the aggregate amount consumed equals 43 to 57 kg/year, a 4-6 percentage loss. These daily and yearly values are given for each rodent species in Table 8.

Table 8. Amount of food consumed daily and yearly by rodents infesting stored foods.

Rodent Species	Amount of food	Amount of food eaten

	consumed daily (g)	yearly (kg)
Norway rat, Rattus norvegicus	15-25	6-9
Roof rat, R. rattus	8-12	3-4
Polynesian rat, R. exulans	5-8	2-3
Bandicoot rat, Bandicota bengalensis	15-25	6-9
Unstriped grass rat, Arvicanthis niloticus	5-8	2-3
Multimammate rat, Mastomys natalensis	5-8	2-3
Spiny mouse, Acomys cahirinus	3-6	1-2
House mouse, Mus musculus	2-3	0.7-1
Vesper mouse, Calomys laucha	3-5	1-2
Grass mouse, Akodon azarae	3-5	1-2

2.1.1. Biology and Behaviour

Mus musculus (House mouse)

Description: Head and body 75-100 mm, tail 65-90 mm. Body weight about 15-20 g. The dorsum is dark brownish-grey, the venter light grey to creamy white. The tail is uncoloured, dark, sparsely-haired. The body is small and slender, the eyes and ears are prominent (Figure 1).

Range and Habitats: House mice have now spread around the world, occurring from the sub-Antarctic to the near Arctic, from temperate, tropical, steppe, and semi-desert regions. They habitually infest food stores and other premises in both urban and rural surroundings. They are found occupying such diverse habitats as cold stores; rice, sugarcane, and cereal grain fields; garbage dumps, salt marshes, and coal mines. In Alaska they have been captured in open tundra, far distant from human dwellings.

Natural history: House mice are terrestrial/arboreal. They are nocturnal. They make burrows in field situations, but also frequent the upper parts of rural farm structures in the tropics, nesting in the roofs and attic lofts. They make and use runways in fields and structures. Their range of movement is limited; usually an area of no more than 1-3 m2 suffices. Their food requirements are 2-3 g of food daily. In feeding, they nibble on foods, sampling the several types in the living area. They quite often consume only the kernel of the grain, discarding the rest, thus ruining the grain far in extent of what they actually consume. They are capable of breeding year-round. The gestation period is 19-20 days;

litter size averages 5.8 young, the young are weaned at 21 days, and sexual maturity is reached at 42 days.

Rattus rattus (Roof rat)

Description:

Head and body 140-220 mm, tail 160-250 mm uncoloured. The body is slender, the muzzle sharp, the ears prominent and mostly bare of hair (Figure 2). The body weight is 120-260 g. The dorsum is brownish-grey, the venter varies from light grey to creamy white to lemon yellow.

Range and Habitats:

Roof rats are found throughout the world due to use of manmade transport and colonising efforts. They inhabit a wide range of buildings in temperate areas, including houses, flats, shops, large food stores, warehouses, poultry houses, barns, markets, restaurants, and grain elevators. They also live in close association with humans in many cities, farms and villages in the tropics. They are still the most common rat found on sea vessels, from which they derive their name, "ship rat". They are found in sugarcane fields, and are orchard pests in many areas, causing damage to citrus fruits, macadamia nuts, cocoa, coconut, date palms, carob, and avocado fruits. In the Pacific Coast of North America, they occupy riparian habitat covered with the dense growths of the introduced blackberry, Rubus species.

Natural History:

Roof rats are arboreal and nocturnal. When living in structures, because of their agile climbing abilities, they prefer the upper parts; the attics, lofts, and open beams. They are the common rat in food stores, markets, grain elevators, poultry houses, and rural farm houses in the tropics and subtropics. They quite often nest outdoors in trees and tall shrubs. They feed on cereal grains, seeds, fruits, and nuts. They freely change their dietary needs, however, taking insects and herbivorous foods if necessary. They eat about 8-12 g of cereal grains daily. They live in close association with humans in many parts of Asia and even in interior parts of Africa, where they have invaded during the last half century. They are the common rat in food storage facilities throughout the tropic and subtropic world, from Latin America,. Africa, and Asia. Only in the temperate pats of their range are they replaced by Norway rats.

They have a definite social structure. A single dominant male was always present in a colony in Ghana. There were usually two or more females which were subordinate to the most dominant male but were themselves dominant over all other members of the group. A group territory around the feeding area was defended by the resident rats against strangers.

Roof rats have a gestation period of 20-22 days, average 6.2 young per litter, young are weaned at 28 days, and the young reach sexual maturity in 68-70 days. Breeding is usually bimodal, with peak production in the spring and fall months, but may be essentially continuous when climate, food, and shelter are optimum.

Rattus norvegicus (Norway rat)

Description: Head and body length 180-260 mm; tail 150-210 mm. The tail is bare, lighter coloured below than above. Body weight varies from 250-600 g depending on age. The ears are sparsely haired and set closer to the head than in the roof rat. The dorsum is brownish-grey, the venter is light to dark grey (Figure 3).

Range and Habitats: Norway rats are now found throughout the world. In the tropics they are essentially restricted to the seaports and along rivers. They infest food storage centres in coastal areas, but rarely are found inland. They occur indoors and outdoors. Inside buildings they prefer living in spaces between walls and floors, beneath piles of rubbish and waste foods. Outdoors they frequently are found near water, by drains, along ditches, streams, rivers, marshes, and distributed from northern South America southward to Argentina.

C. laucha occurs from southern Bolivia and southern Brazil to central Argentina and Uruguay, C. musculinus occurs in Argentina; and C. callosus ranges from Bolivia and southern Brazil to northern Argentina. Vesper mice occur in a variety of habitats, including montain grasslands, brushy areas, and forest fringes. They may find shelter in bunch grass, in holes in the ground, in rotting tree stumps, or among rocks. They are active mainly at night and possibly in the evening and early morning. They are found in open grasslands, on rocky hillsides, and in edges situations but occasionally are captured in the vicinity of marshes and swamps. They also frequent human dwellings and outbuildings.

Natural History: Vesper mice are terrestrial/arboreal and nocturnal. They do not make runways and rarely use those of other species. Nests have been found under boards and rocks, in crevices in the ground, and even high above ground in trees. They climb well and on the ground they often hop on the hind legs in the manner of Dipodomys. The diet is predominately vegetative but insects also are taken. They may eat about 3-5 g of food daily. The breeding season apparently extends from October until the following April and two litters may be produced. The gestation period is about 25 days in C. laucha. The data from a captive colony of C. musculinus showed the following: gestation, 24.5 days; litter size, 5.4 young; female sexual maturity, 72.5 days; male sexual maturity, 82 days. Calomys is a vector of the viral disease, Argentine haemorrhage fever.

Akodon azarae (Grass mice)

Description:

Head and body 90-140 mm, tail 55-100 mm. Akodon azarae range from 10-45 g body weight. The short tail and neck suggest the body form of voles (Figure 5). The dorsum is dark brown; the venter is greyish. Mice of the genus Akodon have been described as heavy-bodied, short-limbed, short-tailed, vole-like mice. The pelage is soft and full.

Range and Habitat:

Members of the genus range over all of South America; A. azarae occurs from extreme southern Bolivia, Paraguay, northern Argentina, southern Brazil, and Uruguay. South American grass mice occur in a variety of habitats, including relatively open country, grasslands, humid forests, and mountain meadows. They tolerate second-growth forests and man-made clearings. They range from near sea level to about 5,000 m. Some species are found frequently in human houses.

Natural History:

Although terrestrial, burrowing is not very important, but nests have been found 12-15 cm below ground. Various species of Akodon have been reported to be diurnal, nocturnal, and crepuscular, or active any time of day. The diet of A. azarae has been found to be herbivorous with a substantial amount of insects and other invertebrates. Considering the body weight, they probably eat about 3-5 g of food daily. The data on breeding are: gestation period, 23 days; litter size, 4.6 young; the young are weaned at 14-15 days; sexual maturity at about 60 days. The breeding season extends from August to May and there are probably two litters per year. Peak densities of 200/ha have been recorded from north-eastern Argentine pampas, decreasing to about 50/ha by late winter. At a semi-arid site in north-central Chile, the density of A. olivaceus was 30/ha in August and increased to 97/ha by November.

Rattus exulans (Polynesian rat)

Description:

This is a small, slender rat (Figure 6). The head and body measure about 120 mm, the tail is about the same length. Adults rarely weigh more than 110 g in the wild, usually much less (30-60 g) when living in houses. Their ears are relatively large and thin. The dorsum is brownish-grey, the venter a pale grey.

Range and Habitats:

Polynesian rats, sometimes also called little Burmese house rats, range from eastern Bangladesh, through Myanmar, Thailand, Malaysia, Cambodia, Laos, and into Vietnam. They also occur on islands in the South Pacific and the Hawaiian Islands. They were thought to have been carried to the islands by the Polynesians, hence their name. They are a common house rat in Indonesia and in south-eastern Asia, assuming the role of a house mouse in this environment. They live indoors in human dwellings, preferring the upper parts of the structures like roof rats. They also live outdoors in some island habitats, preferring jungle edge and tall grassy areas. They do not burrow or live in ground burrows or crevices.

Natural History:

Polynesian rats are arboreal and diurnal/nocturnal. They are herbivorous and, to a small extent, insectivorous. They feed on berries, seeds, coconuts, sugarcane, grass stalks, and insects. They consume 5-8 g of cereal grains daily. Home range is limited: 70-85 percent of recaptures were within 20-25 m of the original point of capture on Ponape, Guam, and Hawaii. The gestation period is 19-21 days, average litter size is 4.0-4.1 young, young are weaned by 20-28 days, and sexual maturity is attained at 90 days in both sexes. Polynesian rats coexist with other rat species; they were trapped from the same houses in Rangoon, Myanmar from which roof rats and lesser bandicoot rats were captured. In Indonesia they are reservoirs of plague and are a threat to humans when cohabiting in rural households.

<u>Bandicota bengalensis (Lesser bandicoot rat)</u>

Description: Lesser bandicoot rats are Asian versions of Norway rats. They measure 160-270 mm in head and body, the tail is 130-220 mm, dark in colour. Body weight is 250-600 g. The fur is coarse and rough-looking and the longer guard hairs are prominent (Figure 7). Animals range from brownish-grey to almost blackish-grey on the dorsum, the venter is light grey. Mammaries range from 12-20, averaging 16.

Range and Habitats:

Lesser bandicoot rats range from north-western Pakistan, India, and Nepal eastwards to the east coast of Vietnam, and southward through India, into Sri Lanka, Sumatra, and Java. They are primarily field rodents and pests of cultivated crops, but in many parts of India, Bangladesh, Myanmar, and Thailand, they have invaded cities, towns, and villages and become the main urban commensal rats in Bombay, Madras, Dhaka, Yangun (Rangoon), and Bangkok. In small towns and villages, they frequently occur inside and outside houses and food stores. In cultivated fields they occur in rice, wheat, and sorghum fields, and in waste areas between fields. They are peerless burrowing rodents, making extensive burrow mounds and easily-seen runways connecting burrows with feeding areas. Some burrow systems cover 10 m or more across and are up to 60 cm deep. They are good swimmers but weak climbers, since they are too heavy-bodied.

Natural History:

Lesser bandicoot rats breed throughout the year in Southeast Asia, but appear to have a bimodal cycle, with a peak in the dry winter months and a lesser peak during the monsoon months. The gestation period is 21-23 days, litter size averages 7-8 young, weaning takes 28 days, and the young become sexually mature in 60-75 days. They eat about 25 g of grain a day, but are notorious for hoarding 3-4 times more food a day than they eat. Their range of movement is limited to 30-50 m in diameter in fields and in urban environments they may move up to 150 m from shelter to food stores. They are gregarious, nesting in colonies under households in Myanmar towns and cities, yet are extremely aggressive when first approached by humans when in traps. They respond similar to Norway rats when exposed to baits and show almost the same tolerance to the several poisons so far tested for.

Mastomys natalensis (Multimammate rat)

Description:

Small rats, measuring 100-150 mm head and body length, with a tail about the same length (Figure 8). Body weight is 60-120 g. The dorsum is grey to brownish-grey, brown, or reddish-buff, the venter is lighter coloured. Females are distinguished by having 8-12 pairs of mammaries, continuously distributed from the pectoral to the inguinal regions.

Range and Habitats:

Multimammate rats occur as field and house rats over parts of Africa south of the Sahara Desert. They are regarded as peri-domestic rats in most parts of Africa where they occur, living in close association with humans. They occur in central food stores, in towns, markets, and in rural households. They are found in fields of maize, rice, groundnuts, millet, sorghum and also live in grasslands, and savannahs. They are typical unspecialised rats, showing a great ecological diversity in their extensive range.

Natural History: While omnivorous and having cannibalistic tendencies, they are mainly granivorous, living on seeds of wild grasses, millet, maize, and rice. They will also eat grass stems and rhizomes, and insects may comprise a large part of the diet. They are responsible for considerable damage to food stuffs in stores and houses, consuming 5-8 g of food daily. They are important from a public health standpoint because they are involved in the transmission of plague and Lassa fever. They can be prolific breeders: the gestation period is 23 days, litter size averages 10-12 but can be as much as 19 young, young are weaned at about 21 days, sexual maturity occurs after 90-100 days, and breeding appears to be strongly correlated with rainfall. Breeding increases most commonly a few weeks after the onset of the seasonal rains.

Acomys cahirinus (Spiny mouse)

Description:

Head and body measures 93-130 mm, tail measures 85-135 mm and is bicoloured. The dorsum ranges from brownish cinnamon to a uniform grey brown, the venter may be pure white to an overall slate grey. The hairs from behind the shoulder onto the rump are spiny;

the sides are not (Figure 9). The ears are naked, greyish-black in colour. The weight varies from 20 to 64 g.

Range and Habitats:

Spiny mice range all across the drier parts of north Africa and into the Nile Valley, south as far as central Uganda and Kenya, the Middle East including the Arabian Peninsula, eastward across southern Iran and into western Sind, Pakistan. They are common in houses, stores, gardens, date groves, and rocky hills and cliffs bordering the Nile Delta and Valley. They are numerous in tombs and temples in Egypt. Desert specimens usually inhabit rocky hillsides, cliffs, and boulder-strewn canyons but can be found in settlements and native huts.

Natural History: Spiny mice are nocturnal and crepuscular; they are terrestrial but some have been trapped in trees. They are opportunistic feeders. Food consists of a variety of plants, grass seeds, leaves, dropped grain, nuts, flowers, and various animal matter; dates are a staple in some areas. They could eat 3-6 g of food daily. They are relatively generalised mice resembling the genus Mus. The gestation period is prolonged, 35-42 days; litter size averages 3; the young are semiprecocial and are weaned at 14 days; sexual maturity is reached at 2-3 months. They may breed over the greater part of the year.

Arvicanthis niloticus (Unstriped grass rats)

Description:

Head and body are 106-204 mm, tail 100-152 mm. They are heavily-built, shaggy-coated rats, weighing 115 to 150 g (Figure 10). The dorsal pelage is greyish-brown to dark brown, the ventral pelage is light-brown to medium-brown with white tips. The head is rounded with a blunt nasal region. The tail is covered with small hairs, dark above and light below. The mammae number 3 pairs.

Range and Habitats:

Unstriped grass rats range in a broad belt across the Sahel region of Africa, from Senegal to Ethiopia and extending north into the Nile valley through Egypt and south into the Rift valley as far as mid-Tanzania. The genus-species-complex may consist of as many as five species: A. niloticus found in the Nile Valley of Egypt and the south-western tip of the Arabian Peninsula and from Senegal to Ethiopia, Kenya, Tanzania, and Zambia; A. abyssinicus, from Ethiopia, a high altitude form endemic to Ethiopia; A. blicki in central Ethiopia, a form found in Afro-Alpine moorlands only in Ethiopia; A. nairobae, from east of the Rift Valley in Kenya and Tanzania; and A. somalicus, from east-central Ethiopia, Somalia, and Kenya. They frequent grassy savannahs, riverine habitats, into irrigated agricultural fields, and occur around human habitations. They are localised in their distribution because of their water requirements, preferring irrigated croplands and other rather moist habitats.

Natural History:

Unstriped grass rats feed mainly on the seeds, leaves, and shoots of grasses; they are polyphagous, however, eating insects, the bark of certain woody plants, agricultural crops (millet, sorghum, vegetables), and stored foods. They consume from 5-8 g of food daily. They are basically diurnal (active during daylight hours) but, in response to intense heat, may also be nocturnal. They are capable of breeding year-round but usually breed during the dry season. The gestation period is 21-23 days, the litter size averages 5-6 per litter but can run as many as 12 young. They are gregarious, living in colonies and sharing groups of burrows. Densities vary greatly and may increase greatly under favourable conditions, ranging from 12/ha in normal years to 100/ha during an outbreak in Senegal in February 1976 and from 65-250/ha in the Semien Mountains National Park of Ethiopia.

Tatera species (Gerbils)

Description:

Head and body length is about 90-200 mm, depending on species; tail is 120-240 mm, some with short hairs and others with long hairs in the tail, and some with either a white or dark tail tip. Body weight varies from 50-220 g. The pelage is soft to medium. Colour ranges from pale sandy grey to dark brown mixed with grey above; the underparts are white. The body form is heavy and rat-like (Figure. 11). The head is rounded; the eyes rather large.

Range and Habitat:

The genus is mainly African except for T. indica, which ranges from Syria to India and Sri Lanka. Other members of the genus are found throughout the drier areas of Africa: T. robusta from Senegal to Somalia and central Tanzania; T. leucogaster from Angola and south-western Tanzania to South Africa; T. valida in savannah zones from Senegal to western Ethiopia and south to Angola and Zambia. They inhabit sandy plains, grasslands, savannahs, woodlands, and cultivated areas.

Natural History:

Gerbils are nocturnal and terrestrial. They usually walk on all four limbs but when alarmed they flee by means of running bounds of up to 1.5 meters in height and more than 3 meters in length. They are able to do this because of their powerful, well-developed hindlimbs. They are burrowing animals, with deeper burrows with many chambers and tunnels, used for resting during the day, rearing the young, and for food storage. They are mainly granivorous but will eat fruits, some leaves and roots, and insects (especially in the dry season). Gestation varies from 22 to 30 days; overall litter size for the genus is 1-13, with averages of 4.5 in T. leucogaster, 5 in T. indica, and 6 in T. robusta. Young are born in an undeveloped state and remain in the nest for a month before accompanying the adults out to forage. Some species breed during the rainy season (T. leucogaster), all-year in T. indica, and during the dry season following the rains in T. robusta.

2.2. Pest birds

Birds, not prone to living inside the farm or village structures as rodents are, rarely have the opportunity to damage or consume stored foods. It is only in those outdoor situations where grains or seeds are exposed during drying or threshing that birds have the chance to eat them, or they may get into stored grains where they are stored in open cribs. Consequently, the losses of stored foods due to bird activities are small as compared to those caused by rodents. The several species of pest birds that are found in post-harvest situations in South and Southeast Asia are house and tree sparrows, Passer domesticus , P. montanus (Figure 12), common pigeons (Columba livia) (Figure 13), doves (Streptopelia species) (Figure 14), Asiatic house crows (Corvus splendens), and common mynas (Acridotheres tristis) (Figure 15). These are mainly pests in threshing and grain drying yards in farm household situations. The amounts of grain they consume are small as compared to that taken by rodents in farm stores. Birds rarely infest structures as rodents do; instead they rely on their mobility to quickly seek out places to feed.

Post-harvest losses of cereal grains due to birds are seen at threshing and drying stages. When grains are threshed in the field, or in clearings at the farm households, birds are attracted by the abundant grain. When grains are spread on the ground for drying in the tropic sun, birds are similarly attracted. Unless birds feed in large flocks, the amounts of grain they consume are negligible as compared to rodents. Garg et al. (1966) found that sparrows, mynas, crows, and pigeons visited and fed on wheat at threshing yards and estimated the losses caused mainly by the birds (a few yards had small numbers of rats) at 244 g/day/yard or about 7.3 kg/yard for the 30-day threshing season at Harpur, India. In Pakistan, mynas, crows, and pigeons were seen frequently at grain storage centres and at farm yards but they mainly fed on waste or spilled grain at these sites.

Libay et al. (1983) reported on losses of feed for ducks on farms in the Philippines due to European tree sparrows, Passer montanus. Losses at 4 farms where bird counts averaged 149-177 over the 14-month study were estimated at 4.5-5.0 kg/day of rice. This was equivalent to US $0.40-0.45/day for the 4 farms or $146-164/year. At the largest farm the loss represented 4 percentage of the total amount of duck feed used.

The common pest birds in food storage situations in Africa are sparrows (genus Passer) and weavers (genus Ploceus). Maize and sorghum are sometimes stored in open crib-type structures and in these situations these birds may cause damage.

The easiest method of control is to keep birds from access to stored foods. This is done by using wire mesh as screening, or using local-made netting, where foods are to be stored in open crib-type structures. The inside of the structure is lined with the wire mesh or netting before the grains are placed inside. Where birds are pests at threshing and drying yards, the use of bird-scaring devices or human bird scarers will help to keep birds from feeding.

The nests of house sparrows in the eaves or crevices around farm structures may be destroyed by pulling the nest contents out with a hooked stick or a wire bent to form a hook.

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CHAPTER III Vertebrate Pests: Damage on stored foods

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3 Indicators of pest infestation

3.1 Rodents

As rats and mice move around in their living environment, moving from food sources to their nests and shelter, they leave behind characteristic traces that betray their presence; these are called rodent signs and are useful in determining the presence and degree of rodent infestation inside structures. Since rats and mice are secretive and come out after darkness, we rarely see them directly. However, family members of farm households should be aware of rodents in the farm structures, since in their daily activities they should see signs of rodents. Especially at night, they should be aware of the foraging activities of rodents in the household, sighting them in the structures or hearing their squeaks, gnawings, and rustlings. Some of the evidence observers should look for are detailed below.

3.1.1 Droppings.

Faecal droppings are found wherever rodents are active - along their pathways, near walls, and near food and shelter. If the droppings are of several sizes it may indicate animals of different ages or it could indicate an infestation of several species of rodents. Rat droppings are usually 10-15 mm in length, while those of mice are only 3-6 mm long. Numbers of droppings are not very useful in estimating the size of the infestation, since they may have accumulated over a considerable period of time. However, if the area is swept clean and examined the next day, some idea of numbers may be estimated. In general, roof rats make 37-60 droppings daily, house mice drop about 50 or so. Rodent droppings are one of the main contaminants of food stuffs, especially grains.

3.1.2 Runways

Runways are frequently travelled routes. Rodents leave greasy fur marks where they repeatedly use the same paths to and from food. These greasy smears persist as marks on beams, pipes, vertical boards where they climb into the lofts of houses, and around gnawed holes they use to go through walls.

3.1.3 Tracks

Rat and mouse tracks indicate past or present rodent infestation. In dust or mud, the trail of the tail and the 4-toed front feet and the 5-toed rear feet can be seen. Sometimes a fine dust of talc or wheat flour can be laid where rodent presence is suspected.

3.1.4 Burrows

Burrows are readily seen when terrestrial or fossorial rodents infest a premises. These are usually, but not necessarily, on the outside of the structure.

Burrows are made by Norway rats, bandicoot rats, and sometimes, house mice. In general roof rats, Polynesian rats, multimammate rats, and vesper mice will not make burrows. Burrows are indicated by the soil mounds at their entrances, by the burrow opening itself, and by runways connecting burrows.

3.1.5 Gnawings

All rodents gnaw and gnawed materials in certain instances reveal their presence. The gnaw marks may be seen as actual tooth-marks, as small particles resulting from gnawing, or as round holes around pipes, under doors, through walls, into jute bags, clothing, books, and cardboard boxes.

3.1.6 Nests

Nests are found indoors and outdoors in areas offering concealment and access to food sources. They may be found in attics, lofts, between walls, under wooden floors, and in burrows in or near the farm structures. Nests are usually globular or cup-shaped, constructed of soft grasses, leaves, and stems, and sometimes, of cloth or jute fibres from the farm household.

3.1.7 Damage

Damage to jute bags, woven bamboo baskets, and other food storage containers is evidence of rodent presence. The damage to bags consists of frayed-looking holes in the sides, bottom, or top of the bagged grain. Grains are usually spilled out and trail away from the bag towards the rodents' burrows or nests. Gnawed holes in the side of the grain basket indicates the presence of rodents in the farm household. Likewise, clothing items, paper materials (books, newspapers, etc.), and bars of soap may be gnawed upon by rodents in the household.

3.1.8 Sightings

The members of the farm household may sight rodents during the day or night in the farm structures. Sometimes, rodents are disturbed during the daytime. The finding of dead rodents in the farm structures is not conclusive evidence of a current infestation since domestic predators like cats or dogs may have brought them in from outside. Trapping is another means of determining if rodents are present.

3.1.9 Sounds

The sounds that rodents make will confirm their presence. These sounds are generally made at night when the rodents are foraging for food.

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4 Management of rodent populations

The prevention of losses of stored foods due to rodents by subsistence and small-holding farmers comes down to relatively inexpensive methods that the farm family can afford. These consist mainly of three things: 1) sanitation and good housekeeping, 2) denying rodents access to stored foods, and 3) elimination or reduction of rodents in the farm structures.

4.1 Sanitation and good housekeeping

Sanitation and good housekeeping in small-holding farmers housing structures means keeping all spilled grains swept up daily, not allowing food scraps to accumulate, and keeping the cooking area and cooking utensils and pots clean every day. It means sweeping the floors of the living quarters and the cooking area daily; keeping grains, vegetables, fruits, spices, and herbs used in daily food preparation in tins, jars, or earthenware containers when not in use, to prevent rodents from eating them.

All vegetation near the farm structures should be keep cut away from the buildings, especially any fruit trees or vines. Vegetable gardens should be planted away from the living quarters. Nearby grassy and weedy areas should be kept cleared.

Whenever grains are put outside for drying or winnowing to remove seeds, stems, stones and dirt, the area should be thoroughly swept after these tasks are finished. f grains are threshed in the farm compound, the area should be swept to recover all grains.

If livestock are kept in the farm structures, such as goats, sheep, or cattle, the family members should keep the animals' area clean and especially to keep any uneaten food swept up and disposed of by burying or burning.

4.2 Denying rodents access to foods

Keeping rodents out of stored grains may be difficult, especially if the amounts to be stored for even a month or two approximates 1,000 kg, the harvest from a half to one hectare of land. Much of the grain is stored in jute bags, woven baskets, or open cribs. None of these will keep rodents from the foods. Wire mesh, metal and ceramic containers, or brick and concrete bins are needed to keep rodents out. These items, unfortunately, are expensive and usually beyond the reach and pockets of subsistence and small-holding farmers. A collective or co-operative venture, whereby several farmers pool their resources and store their grains collectively in a structure especially made for that purpose, may be tried. This venture would require an unusual degree of Cupertino among neighbours, however, and could easily be subject to dispute as to amounts placed and withdrawn from storage. Some co-operatively agreed authority would have to record carefully the amounts of grain stored and to control and account for withdrawals.

Metal-covered wooden bins may be made to hold grains, using the metal from old kerosene tins to cover the exterior. Or discarded metal food tins may be flattened and used to rodent-proof a wooden bin. If wire mesh is available, this may be used instead of metal tins.

Care must be taken to cover all surfaces and not leave any gaps between overlapping pieces of mesh or metal. Rust is an ever-present possibility and so galvanised or tinned metal should be used if available. Otherwise, several coats of paint may retard rusting in the tropics.

The average farm family needs to protect the seed grain for the next planting very carefully. This can be done by storing it in small ceramic or metal containers with tight- fitting lids.

If the farm family keeps chickens, ducks, or pigeons, these should be maintained where rodents would not have access to their foods or food scraps, nor to their chicks or eggs. The birds should be penned at night in cages made with wire mesh too small for rodents to climb through. All excess uneaten foods or food scraps should be cleaned daily after the birds have been fed and buried or burned.

4.3 Eliminating or reducing rodent numbers

Rodents living in farm structures may be killed or their numbers reduced by destroying their nesting places in the roof or upper beams of the buildings. These areas, where accessible, should be sought out and the nests actually physically removed. This will not drive the animals out of the structure, however; the rodents may be killed with sticks when disturbed or dislodged from their harbouring places. If burrowing rodents are present in or around the farm structures, their burrows should be dug up and destroyed and the rodents killed when disturbed. If the farm family can afford even one trap, this can be set nightly for a number of weeks and should eliminate most rodents from the structures. Another form of trapping is the use of glue boards. These are squares of heavy cardboard that is covered on the upper surface with a vert sticky adhesive that entangles the feet and fur of any rodent venturing onto its surface. The rodent then is killed with a stick and disposed of and the glue board set again. Rain, dust, and dirt on the glue board will make it ineffective.

Medium-income farm families may be able to afford the use of poison baits around the farm structures, in addition to all of the steps given above. The use of poisons around the

household will have to done very carefully, however, to prevent the poisoning of children and household pets and domestic livestock. Baits should only be used in covered containers into which a child, chicken, pigeon, cat, or dog cannot gain access to the poison. All baits should be placed out of sight, and on the ground or floor level. All poison baits should be used only in a manner consistent with the label directions.

The few rodenticides that can be used by farm householders are the anticoagulants and zinc phosphide. The several anticoagulants that may be available in developed countries consist of baits incorporating warfarin, coumatetralyl, diphacinone, chlorophacinone, brodifacoum, difenacoum, bromadiolone, flocoumafen, or difethialone at several concentrations.

Anticoagulants: Anticoagulants are mixed with baits in very small amounts, varying from 0.0375 percentage to 0.005 percentage concentrations. These baits do not kill quickly; instead they must be eaten by the rodents for several days and then the clotting ability of the blood is reduced, causing death by haemorrhage. In general, the spiny mice are very little affected by anticoagulants, so these are not recommended for their control. Also, the earlier anticoagulants (warfarin, coumatetralyl, diphacinone, and chlorophacinone) are relatively slow to kill roof rats and house mice; up to 21 days may be required to kill off most mice. To eliminate these species, the "second-generation" anticoagulants (brodifacoum, difenacoum, bromadiolone, flocoumafen, difethialone) should be used. Baits for household rodents should preferably be placed in bait containers or under cover where children and domestic animals will not have access to them. A surplus of bait should be maintained at the baiting sites for up to 10 days. Then all uneaten baits should collected and disposed of by deep burial. Zinc phosphide: Zinc phosphide is mixed with bait materials at usually a 2 percentage concentration. This material is hazardous to humans and all domestic animals, including chickens, so should be used with extreme care by the householder. Baits should preferably be used in bait containers or at least placed under cover where children and domestic animals do not have access to them. Zinc phosphide kills rodents quickly; most animals that eat enough of the bait will die within 8 to 24 hours; some may die on or after the second day of baiting. After placing baits out for a few days, all uneaten baits should be retrieved and buried several feet in the ground. Generally after two or three days, all baits that weren't eaten in the first few days will be rejected by any surviving rodents. Zinc phosphide should be effective against all pest rodent species previously mentioned in this chapter.

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7. Annex

Table 1. Stored food losses at farm and village level as reported on the mail survey of Hopfet (1976)

Area	Type of storage	Commodities	Percent damage or loss

Asia:
Bangladesh Bamboo bins Rice, wheat 5
India Village stores Rice, wheat 1.7
" Village, bags Rice, wheat, millet,
sorghum 3.5-5
" Mud and bamboo Rice, wheat, pulses,
bins, bags sorghum 2-5
Korea Sacks Rice, barley 20
Laos Cribs, mud and bamboo bins Rice 3
Malaysia Cribs in roof Rice 2-5
Nepal Sacks Maize 3-5
Philippines Cribs, sacks Rice, maize 2-3
Thailand Sacks in roof, Maize, rice 5
maize in cribs
Turkey Farm houses,
underground pits Wheat, rice, maize 5
Africa:
Egypt Houses and stores Maize, wheat, rice,
cottonseed 50
Ethiopia Huts on stilts,

underground, bags Grains 5-15
Ghana ---------
Grains, maize, rice 2-3
Malawi Woven cane bins, Maize, groundnuts,
grass baskets sorghum, millet 0.5-1.5
" Cribs Cob maize 15
Sierra Leone Cane baskets Rice 1-10
" " Sacks Rice 10-100
" " Roof and cribs Rice, maize 2-3
Zaire Bags in roof Rice, maize 3
Zambia Farm cribs Cob maize, sorghum,
millet 10
Latin America:
Mexico Cribs, sacks in
roofs Rice, maize 5-10
Brazil Stacks, sacks,
cribs Rice, maize, beans 4-8

Table 3. Reported post-harvest losses of rice world-wide (US NAS, 1978, based upon FAO data, 1977 unless otherwise indicated).

Region/Country Total Percent Remarks
Weight Loss

Africa:
Sierra Leone 10
Uganda 11
Rwanda 9
Egypt 2.5 (Quoted in NAS, 1978)

Asia;
Bangladesh 7
India 3-5.5 Improved traditional storage (Boxall and Greeley, 1978)
Indonesia 2-5
Malaysia 5 On-farm storage (Quoted in NAS, 1978)
Nepal 3-4 On farm storage
Sri Lanka 2-6 On-farm storage (Quoted in NAS, 1978)
Thailand 1.5-3.5 On-farm storage
2-15 On-farm storage (Quoted in NAS, 1978)
Latin America;

Belize 20-30 On-farm storage (Quoted in NAS, 1978)
Bolivia 16 On-farm storage
Dominican Republic 6.5 On-farm storage

Table 4. Reported post-harvest losses of maize world-wide (US NAS, 1978, based upon FAO, 1977 data unless otherwise indicated).

Region/Country Total Percent Remarks
Weight Loss

Africa:
Benin 8-9 Traditional on-farm storage (Harris and Lindblad, 1978)
Malawi 8 On-farm storage (TPI, 1977; Schulten, 1975)
Nigeria 1-5 On-farm storage
Rwanda 10-20 On-farm storage
Zambia 9-21 On-farm storage (Adams and Harman, 1977)

Asia:
Pakistan 2-7

Latin America:
Belize 10-20 On-farm storage (Quoted in NAS, 1978)
Brazil 15-40 Farm storage
Dominican Republic 19 Farm storage
Honduras 20-50 Traditional storage, poor facilities (Quoted in NAS, 1978)
Mexico 10-25
Nicaragua 15-30
Paraguay 25 (Quoted in NAS, 1978)
Venezuela 10-25

Table 5. Reported world-wide post-harvest losses from all causes of wheat, millets, and sorghum(US NAS, 1978, based on FAO, 1977 data unless otherwise indicated).

Region/Country Total Percent Remarks
Weight Loss

Wheat:
Pakistan 5-10 On-farm storage (Quoted in NAS, 1978)
India 8-25 (Quoted in NAS, 1978)

Rhodesia 10 On-farm storage (Quoted in NAS, 1978)
Sudan 10
Bolivia 7 Stores
Brazil 1-4 Storage

Millets:

India 5 Farm storage (Quoted in NAS, 1978)
Mali 2-4 On-farm storage (Guggenheim, 1977)
Nigeria 0.1-0,2 On-farm storage
Zambia 10 On-farm storage
Zimbabwe 10-15 On-farm storage (Quoted in NAS, 1978)

Sorghum:

Nigeria 0-37 On-farm over 26 months (Hall, 1970)
Pakistan 5
Zimbabwe 25 On-farm storage (Quoted in NAS, 1978)

Table 6. Post-harvest losses at farm-level of grain legumes due to all causes (NAS 1978).
Country Total Percent Remarks

Weight Loss

Kenya 30 On-farm storage (De Lima, 1973)
Zimbabwe 5 On-farm storage (NAS, 1978)
(Groundnuts)
Thailand 12-15 Farm stores (NAS, 1978)
Honduras 20-50 On-farm storage (NAS, 1978)
(Dry beans)

Table 8. Amount of food consumed daily and yearly by rodents infesting stored foods.
Rodent Species Amount of food Amount of food
consumed daily (g) eaten yearly (kg)

Norway rat, Rattus norvegicus 15-25 5.5-9.1
Roof rat, R. rattus 8-12 2.9-4.1
Polynesian rat, R. exulans 5-8 1.8-2.9
Bandicoot rat, Bandicota bengalensis 15-25 5.5-9.1
Unstriped grass rat, Arvicanthis niloticus 5-8 1.8-2.9
Multimammate rat, Mastomys natalensis 5-8 1.8-2.9
Spiny mouse, Acomys cahirinus 3-6 1.1-2.2
House mouse, Mus musculus 2-3 0.7-1.1
Vesper mouse, Calomys laucha 3-5 1.1-1.8

Grass mouse, Akodon azarae 3-5 1.1-1.8

Table 20. Descriptions of commensal and indigeneous rodents of stored foods.

Common name Head & Tail Weight Food consumed
Scientific name body (cm) (cm) (gm) Daily (gm)
Norway rat 16-25 12-20 250-550 15-25
Rattus norvegicus stocky bicolored

Roof rat 14-22 16-25 120-260 10-15
R. rattus slender unicolored

Polynesian rat 8-12 8-12 50-110 4-7
R. exulans slender unicolored

House mouse 7-10 8-11 15-21 2-3
Mus musculus slender unicolored

Bandicoot rat 17-27 12-20 300-600 15-25 (hoards 3X)
Bandicota bengalensis stocky bicolored

Multimammate rat 10-15 10-15 80-140 5-8

Mastomys natalensis slender unicolored

Unstriped grass rat 11-20 10-15 115-150 5-8
Arvicanthis niloticus stocky bicolored

Spiny mouse 9-13 8-13 20-64 3-6
Acomys cahirinus slender bicolored

Vesper mouse 6-8 3-5.5 10-18 3-5
Calomys laucha slender bicolored

Grass mouse 9-14 5.5-10 10-45 3-4
Akodon azarae stocky bicolored

Zygodontomys (Cane mice)
Description: Head and body length is 130-145 mm and tail length is 93-100 mm. The tail is usually shorter than the head and body. The body weight is 45-70 g. The dorsal pelage is grayish to agouti brown and the the venter is grayish white to buffy gray. The tail is bicolored; whitish below and gray brown above; the ears are brown. Zygodontomys resembles Oryzomys but may be distinguished by their relatively shorter tail and shorter hind feet.
Range and Habitat: Z. brevicauda occurs from southern Costa Rica to western Ecuador and

across most of northern South America, usually below 500 m elevation. They are broadly tolerant of a variety of habitat types; living in open country and in areas of low bushes and thick ground cover, including croplands, pasture, and clearings in evergreen forest. They are attracted to cultivated fields and may become agricultural pests.

Natural History: Cane mice are terrestrial and have habits much like meadow voles (Microtus). They make runways through dense grass and are active at night. Nests are made of grass and are built at the ends of short burrows in banks or under tree roots. The diet includes seeds, grasses, corn, rice, and fruit. They probably eat about 4-7 g of food daily. The gestation period is 25 days, litter size averaged 4.6 young, and birth weight 3.5 g. The young opened their eyes after about 7 days and were weaned at 9-11 days. Females reached sexual maturity at about 26 days and males at 42 days. Reproduction can occur throughout the year but the timing is frequently controlled by rainfall.

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CHAPTER IV PHASEOLUS BEAN: Post-harvest Operations

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1. Introduction

The common dry bean or *Phaseolus vulgaris L.,* is the most important food legume for direct consumption in the world. Among major food crops, it has one of the highest levels of variation in growth habit, seed characteristics (size, shape, colour), maturity, and adaptation. It also has a tremendous variability (> 40,000 varieties). Germplasm collection in beans compares well with other important commodities on a worldwide basis.

Phaseolus vulgaris is produced in a range of crop systems and environments in regions as diverse as Latin America, Africa, the Middle East, China, Europe, the United States, and Canada. The leading bean producer and consumer is Latin America, where beans are a traditional, significant food, especially in Brazil, Mexico, the Andean Zone, Central America, and the Caribbean. In Africa, beans are grown mainly for subsistence, where the Great

Lakes region has the highest per capita consumption in the world. Beans are a major source of dietary protein in Kenya, Tanzania, Malawi, Uganda, and Zambia. In Asia, dry beans are generally less important than other legumes, but exports are increasing from China (25 and 37).

In Latin America, Africa, and Asia, the bean is primarily a small-scale crop grown with few purchased inputs, subjected to biological, edaphic, and climatic problems. Beans from these regions are notoriously low in yield, when compared to the average yields in the temperate regions of North America and Europe (26). Yet yields can be improved in all zones.

Beans are a nearly "perfect" food. Nutritionally rich, they are also a good source of protein, folic acid, dietary fibre and complex carbohydrates. Further, when beans are part of the normal diet, the use of maize and rice proteins increases since the amino acids are complementary. Beans are also one of the best non-meat sources of iron, providing 23 percentage-30 percentage of daily recommended levels (23) from a single serving.

Consumption of beans is high mostly because they are a relatively inexpensive food (23). For the poor of the world, they are a means of keeping malnutrition at bay (36). Any advances in scientific research that benefit bean yields, particularly in developing countries, help to feed the hungry and give hope for the future.

1.1 Economic and social impact

1.2 World Trade

Statistics for dry bean production are vague. Figures for the biggest producers and consumers in developing countries are underestimated because beans are often intercropped and/ or grown in remote areas. As a result data are often imprecise. Political disturbances or war sometimes makes statistical analysis difficult or impossible to perform as in the case of Kenya, Rwanda, and Eastern Europe. Illegal trading also occurs across various borders. FAO figures for Asian countries include Vigna, of which there are 150 species in the tropics. A climbing or prostrate plant, Vigna is rarely erect and has various, small seeds that are not broad and flat. The most economic species is the cowpea Vigna unguiculata (L.) Walp. aggreg. whose dried seeds are an important pulse crop in the tropics and subtropics. Including Vigna in the statistics means that P. vulgaris has to be estimated. In short, for developing countries, it is best to take field experience into account when interpreting the statistics.

The centre of origin of the crop is attributed to the central Andes, Central America, and Mexico. Pre-Colombian times documented minor trade between regions. In the seventeenth century, returning colonists took beans to Spain. Thence the Portuguese introduced beans to Brazil and East Africa. Beans became useful for travellers both at sea and on land. European bean consumption began and increased to become one of the few foci of stable trade in the world. Other country to country trade is opportunistic and dependent on the vagaries of climate, causing a continually shifting pattern in world marketing. For example, Chile is now exporting only half the dry beans it did in 1990-92. Morocco has shifted from an exporter in the early 1990s to a big importer in the mid 1990s. Previously substantial exports from Tanzania to Europe have evaporated as Rwandan refugees obtain any surplus product (24).

Over 12 million tons of dry beans are produced annually world-wide, with a total production value of US million $5717. Of this production, 81 percentage occurs in tropical countries. Today, Brazil remains the most important country for production and consumption of beans in the world (13), followed by Mexico. These two countries are nearly self-sufficient in the crop, but bean imports can be essential to supplement periodic production shortfalls. The United States has lost its position as top world exporter to China. Unlike rice and wheat, fundamental to the Chinese diet, dried beans are not government controlled in China. Farmers have a valuable cash crop with production almost wholly for export. This has made China the fastest growing supply source in the world although quality control is lacking (25). In 1994, South Africa imported 58,000 tons of beans to supplement its own production, which has been falling since 1990. China provided 89 percentage of these imports (18).

In East Africa and Central America, the bean is an important staple. Throughout sub-Saharan Africa mostly women farmers grow it traditionally as a subsistence crop. Yet the East Africa Bean Research Network's (EABRN) recent economic surveys show that approximately 50 percentage of producers sell part of their harvest, primarily to urban populations. The income-generating aspect of bean production is becoming more significant principally near urban markets, where populations increasingly rely on bean as an inexpensive source of protein (7).

Table 1. Major dry bean production and consumption by areas (Yearly average in 1000 tons) 1993-95.

Region[a]	Production 1993-95	Value (US million $)[b]	Consumption 1993-95	Import(-)/Export(+) 1993-95	Comments
Brazil	2931	1260	3096	- 165	World's biggest producer & consumer
East Africa[c]	1696	644	1678	- 18	Uganda and Kenya biggest consumers/producers of area
East Asia[d]	1524	594	1918	+ 394	China world's leading exporter (+633), Japan imports increasing
N. America	1400	812	983	+ 417	Mainly USA, world's 2nd

					Mainly USA, world's 2 biggest exporter (+353)
South Asia[d]	1336	494	1296	- 40	Per capita consumption low
Mexico	1308	510	1275	+ 33	Exports recently increasing
Europe	581	407	825	- 244	W. Europe biggest importers, UK especially
C. America & Caribbean	420	214	459	- 39	Guatemala biggest consumer/ producer of area
South Africa	393	193	481	- 88	Imports increasing, mainly low-cost from China
W. Asia & N. Africa	364	204	373	- 9	Iran & Turkey chiefly for export, Egypt & Algeria importing
Southern Cone	311	196	97	+ 214	Chile & Argentina mostly for export
Andean	278	178	341	- 63	Venezuela biggest consumer/ producer of

					area
Australia	26	11	18	+ 8	Recent increase for export

Regions are in order of production and defined as:

East Africa	Burundi, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Tanzania, Uganda, Zaire
East Asia	Cambodia, China, Indonesia, Japan, Korea Rep., Myanmar, Philippines, Thailand, Vietnam
South Asia	Bangladesh, India, Nepal, Pakistan, Sri Lanka
Europe	Albania, Austria, Benelux, Bulgaria, Czechoslovakia, France, Germany, Greece, Hungary, Ireland, Italy, Poland, Portugal, Romania, Spain, Sweden, United Kingdom, former USSR, Yugoslavia
C. America & Caribbean	Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Nicaragua , Panama
South Africa	Angola, Lesotho, Madagascar, Malawi, Republic of South Africa, Swaziland, Zimbabwe
W. Asia & N. Africa	Algeria, Egypt, Iran, Israel, Jordan, Lebanon, Morocco, Saudi Arabia, Tunisia, Turkey, Yemen

Southern Cone	Argentina, Chile, Paraguay, Uruguay
Andean	Bolivia, Colombia, Ecuador, Peru, Venezuela

Calculations based on implicit border prices.
Kenya figures calculated from area planted and expected yields, and probably underestimated.
Asian figures adjusted using scientists' information (FAO Asian data includes *Vigna* in dry beans).

SOURCE: Compiled by author from FAO databases http://www.fao.org/WAICENT/Agricul.htm (9).

Some high quality dry beans are exported to European markets and elsewhere, constituting a significant proportion of export crops in many countries, notably Ethiopia, Zimbabwe, and Tanzania. These crops have considerable foreign exchange value (23).

The Southern Cone countries of Latin America produce beans mainly for export. Argentina prefers meat protein and began producing beans only for export. Grain that is below export quality remains within a country to sell off cheaply. Thus a producer becomes a consumer as well. This is also the case for Bolivia, where local consumption has risen as a result of information campaigns on the nutritional value of beans.

Europe remains the world's biggest importer of high quality beans. In Asia, beans are less important than other pulses and the statistics are unreliable.

Clearly dry bean production and consumption continue to expand at greater and greater rates as populations increase. As a food crop for the poor, beans have big potential, particularly in developing countries.

1.3 Primary Product

Common bean is grown for its green leaves, green pods, and immature and/or dry seeds. The dry seeds of P. vulgaris are the ultimate economic part of the bean plant. They are appreciated throughout the developing world because they have a long storage life, good nutritional properties and can be easily stored and prepared for eating.

Traditional markets have accentuated local preferences in seed colour and size of seed coat, but dry beans have similar composition. The different bean classes give identical total calories per gram. So it is easy to interchange or substitute different bean types within a major seed-coat class in recipes that require milling mashing or mixing. The consumer may not readily discern the bean type.

There are some limits on the use of dry beans and research is finding ways to overcome them. The long preparation time can be inconvenient and expend much fuel. Changes in the product during post-harvest storage can damage the grain including seed hardening, hard shell, hard-to-cook effect, moisture absorption, mould growth, seed discoloration, flavour and odour. Anti-nutrients such as protease inhibitors and lectins can block the digestion process. Factors promoting flatulence are another undesirable effect (30). There is genetic variability for most of these factors.

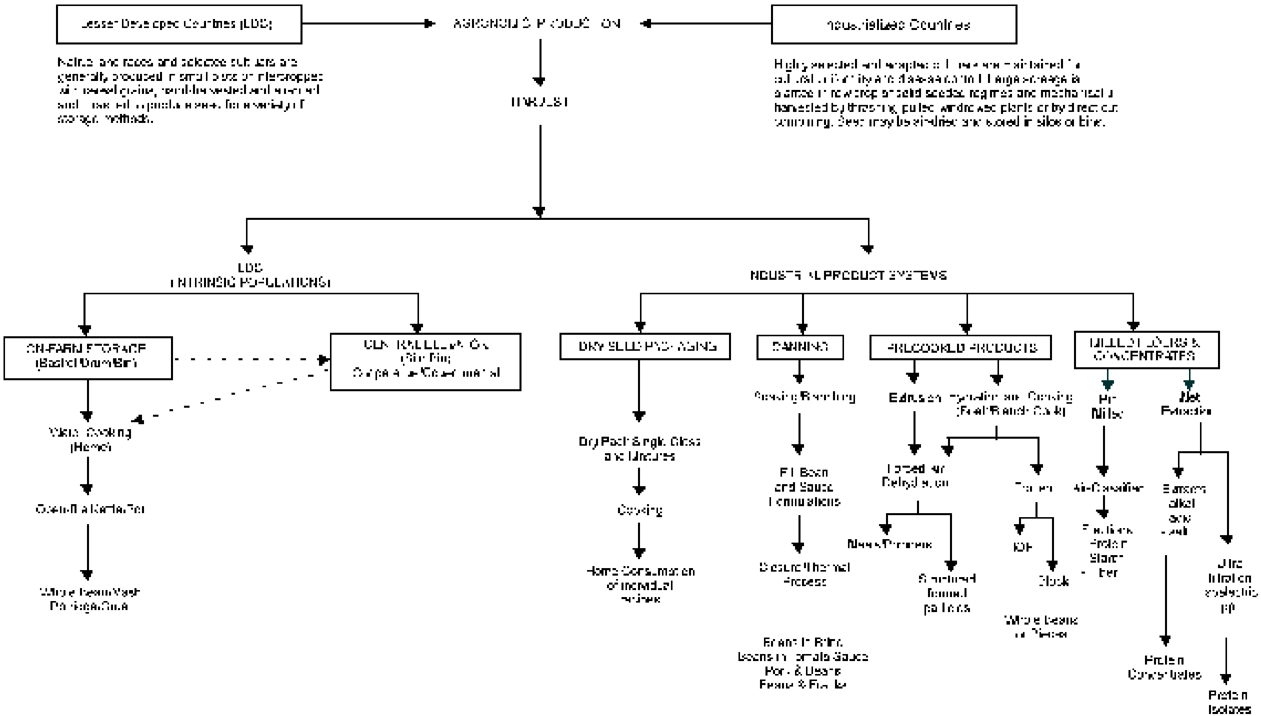
The major commercial processors of beans are developed countries. Some of their products are found on the supermarket shelves in the cities of developing countries. They are sold as "luxury" items for the middle and upper classes. This may eventually lead to commercial products being produced within developing countries. All have canning factories. South Africa produces a Bantu bean gravy and relish, Brazil a bean puree cake, Chile makes extruded products for infant foods using black beans and Guatemala pre-cooked flour. Mexico uses black beans for products similar to tempeh and pinto beans to manufacture tortillas and tacos (30). Manufacturing of bean products will increase as demands for convenience foods increase. This is a rapidly expanding market for dry beans.

1.4 Secondary and Derived Product

Dry leaves, threshed pods, and stalks are fed to animals and used as fuel for cooking, especially in Africa and Asia (30). In Peru and Bolivia, where high altitudes prolong cooking times and fuel costs, the ancient tradition of toasting grains comparable to corn and peanuts may be the reason why popping or "toasted" beans have been developed. They are cooked similarly to popcorn.

Dry beans are mostly eaten whole in cooked recipes. Some manufactured products use bean flour (see Figure 1). Roasted beans can be pin-milled to produce whole flour or cracked by corrugated rollers for easy removal of hulls by air aspiration. Hulls may be ground as high fibre (40 percentage) flour to desired particle size (30).

FIGURE 1. OUTLINE ILLUSTRATING PROCESSING STRATEGIES AND EDIBLE BY-PRODUCTS OF COMMON DRY BEANS IN LDC AND INDUSTRIALIZED COUNTRIES.



SOURCE: (30)

1.5 Requirements for export and quality assurance

Dry beans have numerous seed types, a wide spectrum of colours and colour patterns, varying degrees of brilliance and several seed shapes and classes (34). Of about 600 varieties grown in the world, 62 are commercial market classes and 15 of these are internationally recognised.

The United States classifies dry beans as follows: Red Mexican, Pinto, Navy, Small White, Yellow Eye, Great Northern, White Marrow, White Kidney, Cranberry, Dark and Light Red Kidney, Pink and Black. These classes have become international.

Seed size is classified as small (>900 seed kg-1), medium (600 to 900kg-1) and large (>600 seed kg-1). Seed shape also varies among market classes and has become standardised (3).

Photo 1: Some of the great diversity of bean seed types 

1.6 Consumer preferences

There is always a premium price for traditional, high quality bean varieties. Worldwide more sophisticated consumers are willing to pay for a quality product. In Latin America, colour preferences are still paramount. Local producers grow beans of the area's preferred colour, which they can sell at high prices. Imported beans of other colours will sell for low prices. At the cheaper end of the market, consumers have no strict criteria. In Africa where mixed varieties are preferred, bean colour is not as important as uniformity of cooking.

Cooking time varies regionally and can be a criterion for consumer acceptance. It is less of a factor where pressure cookers are used, as in many Latin American regions but may be more prominent where firewood is the main fuel source in Central Africa and Guatemala (30).

Producers are concerned about risk avoidance and yield of good quality beans. They recognise the importance of good adaptation of cultivars and resistance or tolerance to major negative characteristics. They are also concerned about culinary quality, taste and selected traits such as seed size, colour and plant growth habit (8).

Photo 2: Mixed varieties are preferred in Africa 

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CHAPTER IV PHASEOLUS BEAN: Post-harvest Operations

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2. Post Production Operations

Traditional high-yielding (> 1000 kg ha^{-1}) bean environments are in subtropical regions like those in Chile, Argentina, the Pacific coast of Mexico, the United States, and in some Asian and European countries. In these areas the crop is often irrigated and sole cropped, so diseases and insect problems are few. Bean farmers in these regions are more affluent than those in the tropics and grow crops to sell to large cities within the country or to export to other nations. However, an estimated 90 percentage of world dry bean production occurs under stress conditions where average yields are low (< 600 kg ha^{-1}). Such regions are found in tropical and subtropical Latin America and Africa, where small-scale farmers often intercrop beans for subsistence and apply few or no inputs because they have limited resources. Diseases, insects, adverse climatic and edaphic factors, and other problems cause severe yield loss (28).

Wherever beans are grown on a small-scale, the whole family becomes involved in the harvesting and cleaning of the crop in most of Africa. Women are primarily responsible for bean production in Kenya, Rwanda, Burundi and Uganda. The bean is one of the few crops a woman can grow and be allowed to market for cash. Thus Ugandan women groups are targeting beans as one of the crops to be produced on a large scale (17 and 21). In fact, women make substantial contributions to the agricultural labour, household income generation, choice of crops planted and choice of seeds. Women also assume a large role in Peru, Ecuador, and Bolivia (Andean zone).

Latin America is the part of the world where women help the most by picking, threshing, and cleaning crops. In Africa, women help during all stages, or may be the only ones who do the work. This profile changes when machinery is used. Women are not usually involved in mechanical harvesting.

2.1 Pre-harvest operations

Pre-harvest operations are diverse. Developed countries use highly mechanised techniques. In Latin America, except Argentina where beans are produced on large holdings with high technical input, small holders usually produce beans. Mexico, Brazil, Chile, and Cuba have three types of bean producers, large-, medium-, and small-scale. Colombia, Venezuela, Dominican Republic, Peru, Guatemala, and Costa Rica have limited areas of large-scale, highly mechanised production (33). For mechanised harvesting, the plant needs to be uniform and upright with pods off the ground. Breeding for an improvement in plant architecture would help mechanised harvesting become more efficient and cut down on losses.

At harvest, the variety needs to be ready all at the same time. If plants are too mature pods open. Breeding for uniform ripening is being pursued. Some disease and insect resistant varieties are available but dissemination of new varieties is slow. Networks such as PROFRIZA (Proyecto Regional de Frijol para la Zona Andina) and PROFRIJOL (Proyecto Regional de Frijol para Centro América, México y el Caribe) in Latin America, and ECABREN (Eastern and Central Africa Bean Research Network) and SADC (Southern Africa Development Community) in Africa are helping in this aspect. They encourage small holders to produce seed and develop improved varieties (10).

2.2 Harvesting

Once harvested and separated from the plant, the bean seed continues to ripen, thus biochemical reactions occur, which deteriorate the quality. Therefore at harvest, humidity content, temperature, and climate affect or modify the deterioration agents (12).

There are two types of mechanised dry bean harvesting: conventional undercutting, rodding, or winnowing then combining; and the direct harvest system requiring only one pass of the combine. The latter system has some problems associated with it, such as high header losses and the difficulty of threshing immature plants and weeds. The reduced harvest cost, and lower risk from high winds and water staining, more than compensate. Moisture levels should be about 13 percentage-15 percentage (26). Depending on the size and type of machinery used, 1 hectare of beans may be harvested in 1-2 hours.

In developing countries, harvesting is mostly manual. Plants are pulled up and placed in rows (if a threshing machine is used), or more commonly in piles, very early in the morning to avoid pods opening. When harvesting is done totally by hand, 1 hectare requires 50-80 men hours. Climbing species have to be harvested pod by pod as they mature upwards. Humidity should be about 12 percentage-13 percentage (12). Unthreshed beans are not left long, usually removed for shelter by nightfall for fear of rain. Careful harvesting is important to the bean yield. Mistakes at this point could undo all the benefits of earlier proper practices.

Small-scale farmers need equipment they can use in their fields, thus small-scale technology needs to be developed.

2.3 Transport

Problems of transport do not usually affect small-scale farmers. On the farm, distances are short and covered often on foot. Most of the crop does not leave the farm; some is kept for seed and the rest eaten. Although farms are usually distant from markets, and roads may be in poor condition, the time taken to transport dry beans is not as consequential as it is for green foods. Intermediaries usually take the cost of transport and make the profit on it. There is price duplication on beans between the original seller and the buyer to cover the cost of storage and transport. In theory, small holders could accomplish this themselves in a co-operative. This has not worked in some Latin American countries because the intermediary is also usually the supplier of other goods to the farmer (e.g., chicken feed). The farmer, who does not sell the crop to the intermediary, loses the complementary services. Intermediaries often use the price differential for different grain types to quote farm-gate prices for new varieties.

Large volumes of beans are transported by truck or semi-trailer for domestic markets and by intermediary bulk containers for export. In both cases, handling is kept to a minimum and the more advanced procedures have moisture gradients and temperature controls. Sanitation of containers must be carefully inspected and controlled (31).

2.4 Threshing

Once harvested, the bean plants are either left in the field or taken elsewhere to dry. Bigger producers use drying silos or dryers designed for sacks. Plants must not be piled too high, as air must pass through them to avoid the risk of heating. Smaller amounts may be dried on patios, wooden platforms, under house pilings, in ceiling spaces, hung from wires under a roof and in fine weather, directly on fences or bars around the house.

Threshing methods vary widely. Big-scale producers use moving machinery, which require calibration to avoid losses. Standing machinery can be used for smaller production, carried to the field and run on diesel oil or gasoline. Usually the dried plants are piled on plastic sheets or jute bags then beaten with sticks or run over by animals, tractors, or even light trucks. Beans used for seed are best threshed by hand as this causes least damage but is only suitable for small amounts. In Guatemala and El Salvador, a thin walled box is used on a table made of strips of bamboo, wood, or 12-mesh wire. Separations are wide enough for beans to pass through; the chaff remains on the table. This method has the advantage of less beating of the seed and is useful in areas of small production (12).

Photo 3: Hanging beans to dry under patio roof 

Photo 4: Threshing by beating with sticks 

2.5 Drying

Drying can be done artificially or naturally (see Table 2). The artificial methods are used for larger production. Natural methods prevail in developing countries and women help in the operation.

The object in drying the seed is to achieve a final humidity of 11 percentage-12 percentage for better storage. Three practical rules should be observed: for each 1 percentage humidity reduced, double the storage potential; for every 5 _C lower temperature of seed, double the storage potential; if the sum of the temperature (in _C) and humidity (in wb) is less than 45, storing conditions are adequate (12).

Table 2. Some different systems for drying beans

Drying systems	Examples	Conditions required	Recommendations
Artificial:			
Stationary	False-bottomed drier - air flow forced through perforated floor from open chamber below	Continuous air flow	Temperature not to exceed 40_ C, RH 40% at start, 70% at end
	Tunnel system - forcing air over seeds packed in hemp sacks		Do not use more than 4-9 _C temp. differential above air supply temperature Do not dry below 13%
Intermittent	Silo modifications of brick	Fast - air temp. < 70 _	

	or wood (700-800 kg capacity)	C Slow - < 60 _C (0.25% per hour)	
	Drying wagons or trailers		
Natural:			
Sun and wind	On patios and roads in wave form < 10 cm thick	Immediately after cleaning. Early hours before sun heats concrete/asphalt	Use plastic sheeting under and cover with jute or cloth to absorb humidity
	Suspended trays with wire netting base	Seeds piled < 10 cm high, periodically stirred	Trays suspended 50 cm from ground and parallel to it, or slightly angled (23_) in direction of wind and sun
	Coffee dryers	< 60 _C, well ventilated	

SOURCE: Compiled by author from (12) and (14).

2.6 Cleaning

Big-scale producers use air and sieving machinery with padded equipment to clean the crop. The distance and number of drops is kept minimal to avoid damaging the seed. The finished product is then bagged (14).

Most small-scale methods of cleaning use sieves and air, then a manual pick through for damaged or discoloured seed. Sieves usually have a metal mesh, with mesh size according to seed size, smaller particles falling through. In windy areas, natural air currents are used, the seed being allowed to fall onto the ground or onto sackcloth from the height of a person with arms raised. The wind takes away the lighter material. Alternatively, electric fans may be used or a motor pump.

The small-scale farmer might use the portable cleaner type Clipper 3W (bicycle), which works with an electric motor, petrol, or with foot pedals, like riding a bicycle. Manual sorting is traditionally done on a table. It is more efficient if the surface is painted pale blue for better contrast and the seed placed in a box with a slanted bottom and an exit at the end (12).

Women play a major role in cleaning seed. Their hands are smaller and defter for this kind of work.

Photo 5: Sieve method of cleaning 

Photo 6: The wind blows away lighter material 

Photo 7: Manual sorting of beans 

2.7 Packaging

Commercially, beans are often transported direct in container trucks. Various types of bags are used by the bean industry-laminated paper, burlap, and polypropylene are most used in shipments (2).

Beans are usually sold loose in open sacks or in clear plastic bags so that the colour and quality can be easily seen.

Photo 7: Beans for sale in open sacks 

2.8 Storage

Farmers have three main reasons for storing bean seed: to keep it safe for consumption; to keep it safe for the next harvest; and to speculate the selling price. When everyone harvests at the same time prices go down, so some farmers reserve seed for later sale at a higher price.

The condition of dry beans going into storage and the storage conditions they experience affect their final quality (26). Conventional storage types for quantities over 1 ton have temperature and humidity controls. The traditional storage methods follow the same principal to keep seed with fewer than 12 percentage humidity and in dry ventilated conditions. Small-scale farmers lower the moisture content of stored bean seed to less than 12 percentage without necessarily understanding the reasons behind it. They just know from experience that humidity will rot the seed.

Bean moisture control, storage temperature, and relative humidity strongly influence dry bean quality and the final product. High moisture and high temperature during storage results in "bin burn", a defect that gives the beans a brown discoloration and an off-flavour. Beans given bad storage conditions may result in defective cooked grain texture. Bean grains that do not soften enough because they fail to absorb water during soaking are called "hard shell". Those that absorb enough water but do not soften enough during a reasonable cooking time are called "hard-to-cook".

Hard grain is both genetically and environmentally controlled. The incidence of hard shell increases as seed moisture content decreases experienced under conditions of high temperature and low relative humidity. Hard shell has been found by most researchers to be highly heritable, with relatively few genes involved. Natural reversibility under high relative humidity occurs.

In contrast, hard-to-cook defect is irreversible and develops during storage under high temperatures (> 21 ºC) and high relative humidity. The mechanism by which the hard-to-cook defect develops is still not clearly understood. The inheritance and genetic variability of hard-to-cook has not been determined (27).

Small-scale farmers usually store bean seed for less than 6 months. They sell their surplus as soon as possible because they need cash and are afraid of losing seed to weevils. They leave the risks of storage for intermediaries. Beans being kept for seed can be treated with insecticides and stored safely for longer periods.

Types of storage range from sophisticated silos to pits in the ground, with all kinds of containers being used on a small scale. Ensuring that containers are clean before use is important.

Table 3. Examples of storage facilities for dry beans

Type	Examples	Storage period	Storage purpose	Storage conditions	Comments
Bulk	Silos - wood,	3-6 m	Marketing	14%-15%	Heated air temp not to

	steel, or concrete	> 6 m	Later sale	humidity 12%-14% humidity	exceed 45 °C, RH < 40% Protect from contamination of other crops, chemicals, etc.
200-1000 kg	Containers - plastic, metal, wood, aluminium	3-6 m	Consumption, some marketing, some seed	11%-12% humidity	Hermetically sealed containers best
< 200 kg	Earthenware pots, straw baskets, sacks, gallon tins	< 3 m	Consumption, some seed	< 12% humidity	Containers mostly stored in farmer's house.

Source: Compiled by author from many of sources cited.

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CHAPTER IV PHASEOLUS BEAN: Post-harvest Operations

3. Overall Losses

This is a troublesome concept when dealing with beans. In the United States, with conventional harvest systems, losses average 4 percentage of yield, ranging from 1 percentage to 12 percentage. It mostly happens during the combining operation, with about half of this loss attributed to header and half to threshing loss (26).

Where beans are grown on a small scale or for subsistence, losses are much higher. Only rough estimates can be made and they are unreliable. Losses may be zero when beans are harvested by pulling plants from small plots and transporting bundles immediately to the threshing place, as performed by women in Uganda as no pod shattering occurs. When pulled and heaped for field drying before threshing, pod shattering depends strongly on weather conditions, and if these are adverse, losses can be heavy (20 percentage-30 percentage).

See under 4.1 for storage losses to bruchids.

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CHAPTER IV PHASEOLUS BEAN: Post-harvest Operations

4. Pest Control

4.1 Relative status of major pest species

Many species of insect pests attack beans both before and after harvest. The living bean plant can often recover after insect attack has been controlled, but stored dry beans cannot. There are two major post-harvest pests of dry beans world wide-the Mexican Dry Bean Weevil, *Zabrotes subfasciatus* (Boheman), and the Bean Weevil, *Acanthoscelides obtectus* (Say).

Both belong to the order Coleoptera and the family Bruchidae, commonly known as bruchids. Indirectly, these insects force the rapid sale of post-harvest grain and short storage periods in granaries, thus causing post-harvest price collapse and marked seasonal price fluctuation (32).

Most of the many other insect species that attack stored beans migrate from other products (e.g., maize, sorghum, or rice) stored in the same warehouse. They only cause minor damage to their secondary host, beans (4).

In general, when beans are stored at 14 percentage-15 percentage moisture content or less, mould is not a problem. Since farmers are aware of this, losses caused by mould are negligible. Damage caused by rodents has not been reported. This is probably because dry beans in their raw state are highly toxic to warm-blooded animals.

4.1.1. Details of each major pest

Z. subfasciatus predominates more in warmer areas and *A. obtectus* at higher altitudes in the tropics and throughout temperate climates in general (4). In Africa, however, this differentiation is less marked (1). *Z. subfasciatus* does not attack beans in the field. Fresh eggs are attached to the testa of bean seed. The adults exhibit strong sexual dimorphism. Females are large and have four characteristic cream-coloured spots on the elytra. The male is entirely brown. *A. obtectus* scatters its eggs among stored seed and oviposits in maturing bean pods in the field. It is difficult to distinguish between male and female as size and colouring are the same (32).

4.1.2 Life history

In storage, the life histories of *Z. subfasciatus* and *A. obtectus* are similar. Larvae of both species moult four times before pupating. During the last larval instar, the feeding and pupation cell becomes externally visible as a circular window in the seed where the larvae feed on the lower testa surface. After pupation, the adult may remain in the cell for several days before pushing or biting out the window with its mandibles. Adults are short-lived, and mate and oviposit soon after emergence (4).

For the Mexican bean weevil, the egg stage lasts 5-6 days, different larval instars 14 days, pupal stage 6-7 days; adults live 10-13 days; and females lay an average of 36 eggs. For the bean weevil, the egg stage lasts 6-7 days, combined larval and pupal stage 23 days; adults live 14 days; female lay about 45 eggs. Sex ratios tend to be 1:1 in both species (4).

Photo 9: Bean Weevil and characteristic "window" left in seed 

4.1.3 Damage symptoms and levels of loss

Losses correlate directly with length of storage, the longer the beans are stored, the greater the loss. There are two types of losses: quantitative, or the number of seeds or parts of seeds eaten by insects; and qualitative, or the grains contaminated by excrement or insect bodies. These losses may be augmented by subsequent attacks from fungi or bacteria because larval stage completion elevates temperature and relative humidity, inviting secondary rotting by micro-organism attack.

Damage shows in the circular holes or "windows" left in the bean when bruchids emerge. Losses caused by bruchids are known to be substantial on all continents. In Ethiopia, stored bean damage by bruchids reached up to 38 percentage with a corresponding weight loss of about 3.2 percentage (20). Burundi and Rwanda losses to bruchids are commonly about 30 percentage (19). Estimates in Mexico and Central America have been as high as 35 percentage (32).

Unclean storage conditions are the main cause of bruchid infestation. Storing beans with other grains, or newly harvested beans with the infested residue from other harvests, encourages bruchids to flourish (33).

4.2 Pest Control

Plant resistance as a principal method of insect control is effective, practical, and of low cost to farmers. Cultivars with genetic resistance to the Mexican bean weevil have been identified (15). High levels of resistance to these weevils have recently become available in commercial bean types (5). The resistance is a simply inherited dominant gene that can be rapidly backcrossed into local varieties.

Strict cleanliness in storage sites should be maintained. Control may be effected at two levels: domestic and small-scale farmer level, and large commercial level.

Domestic and small farm level

Reducing storage temperature to < 10 º C significantly affects bruchid growth and reproduction because most are adapted to higher temperatures of 20-32 º C. So storing beans in the freezer compartment of a refrigerator completely eliminates the insect in any of its stages.

A mechanical control is to store the beans mixed with ashes, which fill the spaces between seeds making it hard for bruchids to infest. The optimal mix of ash is 20 percentage of the weight of bean seed being treated. This method only works before infestation. Sand, lime, or other fillers can be substituted for ash.

Coating with edible vegetable oils (e.g., peanut, maize, or soybean) is a relatively effective control permitting storage for at least 6 months without fear of insect damage. It also makes the seed look more attractive. The oil penetrates bruchid eggs and destroys them. It reduces oviposition and increases adult mortality. In general it should be applied at a rate of 5 mL per kg of seed. Control by oil is inexpensive and simple.

Some control of *Z. subfasciatus* is achieved by storing beans in their pods as *Zabrotes* prefer laying their eggs on shelled beans. For control of *A. obtectus* early harvest reduces exposure time to the insect in the field. Beans should then be shelled and cleaned immediately to eliminate eggs and insects coming from the field on pods.

Commercial level

Curative control in warehouses is possible by disinfestation and/or protection. Several chemical products are available for both.

Disinfestation eliminates at the time of treatment and leaves no residue so beans can be eaten immediately after. For the same reason, beans are liable to reinfestation. Phosphine (aluminum phosphide) and methyl bromide are the most used disinfestants. Phosphine eliminates all stages of the insect, including those within the seed. Methyl bromide leads to ozone depletion and its use will be phased out (35). It can affect germination when temperatures are high so is not recommended for use on seed to be planted. Both phosphine

and methyl bromide are very toxic to humans and should be applied only by experts. Bean sacks should be completely covered with a plastic sheet and the edges sealed against the ground to prevent gas escape. Beans should be kept covered thus for 1-2 days after fumigation for gas to penetrate seed.

Protection is done by mixing seed with an insecticide that has residual effects. This is suitable for seeds for planting only. They cannot be reinfested once treated. Malathion kills 85 percentage-99 percentage of *Zabrotes* adults in the first 24 hours after application. Lindane gives longer protection but is toxic to humans and must only be used for seeds for planting. Pyrethrins are a more promising product as they are not toxic.

Application of insecticides must always be carried out with adequate knowledge of the product and potential dangers. It is not the best means of control in many situations. Oil treatments are just as effective at the smaller scale level (32).

Photo 10: Disinfestation in warehouse 

4.2.1 Residue problems

Residues are not a major problem in dry beans because the pods absorb insecticides. In the tropics, the sun's radiation is perpendicular therefore loss of residues is high. Bush-type beans have a growth period of about 90-95 days in the tropics and 100-120 days in cooler regions. Ideally, farmers fumigate 3 to 5 times beginning at 15 days and finishing at about 60 days. This would leave at least a 2-month margin between last application and consumption. Climbing beans have a longer growing period of 150-180 days, and in the Andes (2700 m) of 180-270 days. Again preferably farmers should fumigate about 8 times over this longer period still leaving a 2-month margin at the end. However, in some areas of

Latin America, farmers may spray as late as one week before harvesting. Residue problems will still not be as serious for dry beans as for fruit and vegetables that are eaten raw. In storage, insecticides are not used on beans for consumption. Given the above factors, it is highly unlikely that residues remain in dry beans (César Cardona, 1997, personal communication). There is a need to research this aspect.

4.2.2 Discussion on pest control

In Latin America, small holders hardly used insecticides before 1985 but have since taken quickly to their use, despite the implied cost. All use pesticides, fungicides, and insecticides to some extent and cannot be prevented from using these products. Intercropping reduces the need for pesticides. Some research would be useful, not only for residue problems, but to determine the effect that using insecticides has on the farmer.

In Africa, pest control is left to Nature, as small-scale farmers cannot afford pesticides. Ideally, integrated pest management (IPM) principles can be applied and information is reaching the farmers. Research should focus on low-input IPM approaches that include current farming practices, host-plant resistance, and natural biological control (1).

Many pest control technologies have been developed over the years but few have reached the end-users. In collaboration with farmers, these techniques should be refined. Collaboration with social scientists is urged for this effort. Dissemination of resistant and/or high yielding varieties to small-scale farmers would increase yields.

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CHAPTER IV PHASEOLUS BEAN: Post-harvest Operations

5. Economic and Social Considerations

All important constraints are not biological in origin. Socio-economic factors related to farmer adoption of new technologies, seed distribution, and market requirements may also restrict bean production. New technology development is limited by the degree of organisation, resources, and the number of trained personnel within national programs (36). Networks such as PROFRIZA and SADC have proved to be a most efficient way of introducing new technologies to the small-scale farmer. Network participants include international organisations, national research institutions, state and private universities, ministries of agriculture, and nongovernmental organisations. But the most important partners are the small holders. They share their knowledge with scientists and play an active role in research aimed at developing and evaluating new technologies (10).

The small-scale farmer's main cost and biggest problem is often the purchase of high-quality seed. Network members have supported small holders by supplying high-quality seed at low cost, by developing strategies for its production and distribution, and by providing training for technicians and farmers. Seed systems need to be tailored for specific agroecological and socio-economic environments. The small seed packet technique of distribution through a diversity of channels is simple and has impressive potential for impact. In Rwanda, calculations show that 100,000 or just fewer than 10 percentage of all farmers can be reached (29).

Photo 11: Small seed packet distribution 

Breeding for resistance to diseases and pests, and for better yields, is important. The bruchid-resistant commercial bean type will make a great difference to the small-scale farmer once he has access to it. Farmers can get better prices for their beans if they can store them until the lean months when prices are highest; and this storage would also stabilise bean prices in general by providing a more continuous supply (32). The small-scale farmer would also benefit from small technology, portable, and suitable for use in his fields. Breeding of upright plants for machine harvesting would increase efficiency of commercial production. A main constraint to expanding crops in Brazil is the lack of a bean cultivar with a suitable plant type for mechanical harvest. Uniformity of maturity is also needed (6).

The introduction of improved technology has increased small-scale farming production in many areas, thus improving family nutrition and income. For example, in the Great Lakes region of Africa, the population is increasing rapidly and farms are tiny (0.5-1.0 ha) with no land for expansion. Climbing beans were introduced here 8 years ago. Now about half a million Rwandan farmers grow climbing beans on 20 percentage of the country's bean land, increasing yields (8). Another example is that of the area around Santa Cruz, Bolivia, where small-scale farmers used to leave their farms and go out to find work during the winter months. They now plant beans, a new crop for them, thanks to newly introduced varieties. This has given them access to the Brazilian market in urban areas. They have improved income and have fewer weeds, as the land is not left fallow. Women in Bolivia choose the bean seed and they have also promoted increased consumption.

Storage problems (bruchids, and discoloration, hard-shell, and hard-to-cook defects) cause the greatest post-harvest losses in beans. These problems have management solutions such as control of relative humidity and temperature for the defects, and various disinfestation and protection controls for bruchids. Genetic solutions are also available. They are cheaper in the long run but have not been exploited.

Other means of adding value to the produce are to increase different kinds of consumption, and to commercialise the end product. Beans: can be eaten as cooked dry grain, immature beans, green pods, or popped. In Africa, the young tender leaves are also eaten (22). Not all bean-consuming areas take advantage of these different uses of beans. In Peru, large quantities of seed of a single variety of popping bean are now being multiplied, which will open potential markets for snack foods in urban areas (11). Dietary habits are changing in high-income countries, as illustrated by estimates of 12,000,000 vegetarians in the USA. Because of these changes in preference, major food companies are now developing a new array of bean-based processed foods, including microwave products (23).

All evidence points to a continuing increase in total demand for beans in Latin America and Africa, and an increasing market opening in Asia. Agricultural research can make a vital contribution to improving bean production, thus helping to narrow the growing food gap. In this effort, improvements to stress tolerances, both biotic and abiotic, are likely to be far more important than increases in yield potential (23).

Beans, often a subsistence or small-farmer crop, do not receive the research attention that cash crops, such as coffee or cotton, enjoy (33). The crop offers a low-cost alternative to beef and milk. One hectare planted to traditional bean varieties in Latin America produces 123 kg of protein compared to 3-4 kg for beef cattle on the same amount of land. Donor funds for bean research are decreasing at a time when world demand is increasing for this cheap source of protein and calories. Research by international institutions is reaching the small farmer through established networks. Funding such research helps feed the poor of the world, especially women, who are often the first to suffer when food supplies are scarce.

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CHAPTER V OILSEEDS: Post-harvest Operations

Preface

The IDRC experience with post-harvest research support for oilseeds can be grouped into categories concerning household level soybean utilisation; small to medium scale expelling of oilseeds; linking post-harvest concerns to the work of the Oil Crops Research Network (ORN); improving the performance of national vegetable oil/protein production-to-consumption systems; networking the COMESA Region to improve the performance of the regional production-to-consumption system (pcs); and modelling of production-to-consumption systems.

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CHAPTER V OILSEEDS: Post-harvest Operations

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1 Introduction

Sub-Saharan Africa is a net importer of edible vegetable oil, protein cake and meal required for the dairy, poultry and pork industries. The entry of private-sector interests into post-liberalisation economies in African countries has highlighted the importance of production of annual oilseeds. When recent surpluses of palm oil pushed the commodity near discount prices, it became the interest of those holding the oil-surplus to sell their edible oil wherever they could.

There is a growing understanding that the national requirements for edible oil and protein cake can be met by engaging smallholder farmers in the production of annual oilseeds. Such production would make full use of the capacity of the domestic processing industry. In turn this activity would create or sustain jobs to produce both oil and the feed cake.

A cursory examination will show that many countries have weak or non-existent dairy and animal products industries, an effect of the overriding policy to make sufficient cooking oil available to the urban consumer. This policy ignored the potential of involving the domestic farmer in oilseed production, thus providing the domestic protein cake for the dairy and meat production industries.

At the same time, it is known that the region has a great agro-climatic potential for increased production of annual oil-bearing seeds like sunflower seeds and soybeans, which have substantial market demand especially in South Africa.

On average in the Eastern and Southern Africa region, only Zimbabwe has demonstrated long-term self-sufficiency in oilseeds, with a mix of sunflower seeds and soybeans. Only in years of drought does the country have to import both edible oil and protein cake. Preferably, Zimbabwe would buy the right quantities of the oilseed to ensure that the local processing industry is fully utilised.

1.1 Economic and Social Impact

Oil-bearing plants offer a range of opportunities for small holder farmers, particularly in Sub-Saharan Africa:

Manual processing near the farm gate as a small scale enterprise, and home utilization of the co-products-the edible oil is consumed in food for body energy to counter protein-energy malnutrition or under-nutrition; the protein-rich cake (sunflower, Niger seed, sesame) is fed to cattle for increased milk production, to poultry and to pigs.

Consuming the whole oil-bearing seed as a snack (e.g. groundnuts), or baking the oilseed (sesame) into a snack food such as biscuits.

The sale of farm surplus to the domestic crushing and refining industries (sunflower, sesame, Niger seed, mustard, rape).

The sale of high-grade farm surplus for export to the confectionery industries in the industrialized nations (groundnuts and sesame) (Makoko, M.S. and H.R. Balaka. 1991).

1.2 World trade

The annual oil-bearing crops of most importance to Sub-Saharan Africa, each with its own agro-climatic zone, include:

Groundnut (or peanut) (*Arachis hypogae*)

Sesame (called simsim in East Africa) (*Sesamum indicum*)

Sunflower (*Helianthus annuus*)

Rapeseed (Turnip rape, or Polish canola) (*Brassica rapa,* formerly *campestris)*

Rapeseed (Argentine rape, or Argentine canola) (*Brassica napus*)

Safflower (*Carthamus tinctorium*)

Niger seed (*Guizotia abyssinica*) has particular importance in Ethiopia, where it is called noug. Mustard seed (*Brassica carinata*) and linseed (*Linum usitatissimum*) also have special importance in Ethiopia particularly.

Two additional annual crops must be mentioned, though neither is technically considered an oilseed. Cotton (*Gossypium spp*) is not planted for its edible oil, but rather for the fibre, for use in the textiles industry. However, substantial tonnage of cotton seed are a by-product; and the oil, after crushing and refining makes a substantial contribution to the supply of national vegetable oils in most countries of Eastern and Southern Africa. As well, the press-cake is an important raw material for animal feeds.

Similarly, countries which have solvent extraction capability make use of the germ from maize (*Zea mais*) removed in roller milling in order to improve the shelf life of the maize meal (flour) by reducing its tendency to become rancid. The oil recovered from the germ can also make a substantial contribution to domestic supplies of vegetable oil.

Soybean (*Glycine max*) represents a special opportunity in many countries. The world-wide demand for soybeans is driven by the demand for protein meals for the dairy and meat production industries. Containing only 18 percentage by weight of oil, it cannot be crushed easily by manual or mechanical means to extract the oil. It requires expensive and sophisticated solvent extraction methods (or extrusion followed by motorised expelling). In the industrialised world, the oil is viewed nearly as a by-product, important to make the high-protein feed cake. In Eastern and Southern Africa, only South Africa, Zambia, Zimbabwe and Kenya have real solvent extraction capacity, which sends specific price signals to small holder farmers. There is substantial demand for soybeans from South Africa alone, whose representatives have travelled as far north as Uganda to seek contracts for the production of surplus for export.

In the rest of the region, and in Sub-Saharan Africa, soybeans are an exotic crop to most small holder farmers. It has been found that farmer adoption of the crop is strongly enhanced when home level utilisation is taught along with production practices. In this way, soybeans have a strong potential role as nutritional intervention, with resultant changes in household level food patterns.

The coconut palm (*Cocos nucifera*) and the oilpalm (*Elaeis guineensis*) (perennials) are concentrated along the eastern coast (coconut), and certain high-rainfall areas on or near inland lakes (oil palm). Oil palm is also found in some islands within Uganda's portion of Lake Victoria, along the northern shore of Lake Malawi and on the shore of Lake Tanganyika. (Research documentation on coconut palm production and postproduction can be obtained from National Coconut Development Programme, PO Box 6226, Dar es Salaam, Tanzania).

The annuals, with the exception of soybeans, have high levels of edible oil content and protein in the press-cake.

Table 1. Oil and protein content of selected oilseeds (% content on a per weight basis) (from Zulberti, C. 1988)

Oilseeds	Oil	Cake	Protein	
			In cake -----------	In seed
Groundnut	40	52	50	26
Rapeseed	40	56	52	29
Sesame	44	40	40	22
Sunflower	44	37	43	16
Soybean	18	79	46	36

1.3 Primary product

After crushing or expelling annual oilseeds yield edible vegetable oils, fats, soapstock and the protein-rich presscake. Edible oil in liquid form is preferred by consumers and known as cooking oil in Southern Africa. The same oil after hydrogenation becomes solid white cooking fat the preference of consumers in Kenya and a portion of the population in Tanzania and Uganda.

Household level soybean utilisation

Home-processed soybean has the potential of making a significant impact on the chronic undernutrition of children in Sub-Saharan Africa:

Soybeans are an excellent and affordable source of protein and of dietary fat (still the lowest cost per kg of protein in comparison to cowpeas, milk powder, poultry, pork and beef) (Osho, S.M. 1995a);

Home processing is easy and is feasible with inexpensive, common household utensils;

Soy protein has a good combination of the major essential amino acids required by the body; and daily consumption of a cereal/soybean based food will provide the amino acid complement of legumes and cereals.

Home level processing can be scaled up to small-scale manufacture, which can later grow into medium-size food processing plants.

Case study

IDRC supported two phases (phase I, 1987-1990; Phase II, 1991-1994) of collaborative work among the International Institute of Tropical Agriculture (IITA, PMB 5320, Ibadan, Nigeria) in Ibadan, the Nigerian Institute of Agricultural Research and Training (IAR&T) in Ibadan, the National Cereals Research Institute (NCRI) in Badeggi, and the National Agricultural Extension Research and Liaison Services (NAERLS) in Zaria. (see Osho, S.M. 1995a; Osho, S.M. 1995b: detailed project reports can be requested from IITA).

The project aimed to achieve the following:

Document the status of soybean utilisation in Nigeria;

Develop household level processing technologies for soybeans;

Develop small scale processing technologies for soybeans using the extruder and oil press; and

Disseminate results of the technologies to extension workers.

The key ingredients in the strategy for achieving project results included: the baseline survey, product development research, training and extension programs, and continually assessing the project impact.

Major results achieved include:

The home level processing and small scale processing technologies developed can remove the anti-nutritional factors which are contained in the raw bean, improving taste and nutritional absorption;

1993 had trained over 67,000 people trained on uses of soybeans;

The United Nations Children Fund (UNICEF) funded a wider implementation of the IDRC-supported results with a project The Dissemination of Soybean Processing and Utilisation Technologies in Nigeria.

The establishment of a soybean utilisation centre at one of the country's busiest markets for buying and selling agricultural produce, in which upwards of 3000 people conduct business activities daily;

By 1994, the number of small and medium size food processing plants had grown to 50, from 3 in the late 1980's;

IITA has been developing plans for sharing its experiences and expertise with national research and extension programs in other countries in West Africa, and in Eastern and Southern Africa.

Case Study in Zambia

"Results of surveys carried out by the National Food and Nutrition Commission (NFNC, PO Box 32669, Lusaka, Zambia) with FAO/UNDP assistance indicate a high prevalence of malnutrition in Zambia, particularly in the children aged 0-4 years. High prices and the present economic situation of the country make the animal protein a scarce commodity for the average man. Soybeans can help the situation a great deal because..." (Jahaveri, F. and D. Wynne, 1985).

Two years after the publication of that initial set of home level recipes, efforts at influencing the production of soybeans in the small holder sector were augmented by a training program for agricultural extension personnel with explicit emphasis on household level utilisation of soybeans. A manual finally reached publication in 1990 (Javaheri, F. 1990). By then, there were upwards of 40 non-governmental agencies active in the promotion of the growing and home-level utilisation of soybeans. (More information can be obtained through the Integrated Crop Management/Food Legumes Project, PO Box 30563, Lusaka, Zambia)

Prior to the early 80s, soybean production was limited to commercial farmers. The development of naturally nodulating varieties made it possible for smallholders to participate. By 1990, almost 40,000 smallholder farmers were producing soybean, mostly for sale to the one solvent-extraction parastatal company, but with some retention as food for the household.

APROMA (Association des Produits a Marche CEE/ACP, 52, Avenue Louis Lepoutre B-1060 Bruxelles, Belgique), a promotional arm of the European Union, began to show interest in soybeans in the early 90's, especially in relation to Southern Africa, and sponsored two regional meetings of agricultural scientists, economists, nutritionists, and marketers (APROMA. 1993, APROMA 1995).

APROMA funded a process to establish a data base on soyabean production, to be hosted by the Zimbabwe Commercial Farmers Union (Commercial Oilseed Producers Association (COPA), 7th Floor Agriculture House, 113 Leopold Takawira Street, PO Box 592, Harare, Zimbabwe). The intention was to begin with South Africa, Zimbabwe and Kenya, to add data from other countries as their soybean production rose, and to serve as a common source for the prediction of surplus and deficit countries, and thus serve as a tool for increasing inter-country trade in soybeans.

Case study on Kenya

Kenya has depended on locally hydrogenated fats from imported palm oil, at a cost of USD 60 million annually for 80 percentage of its vegetable oils and fats. Recognising that substantial imports of the oilseed meals required for dairy, poultry and pig feeds for its meat industries added to the size of the import bill, and kept local farmers from economic participation in this sub-sector, a GTZ/Government of Kenya project was initiated in the early 90s to promote soybean growing. Farmer-adoption of the new crop was inhibited by the lack of knowledge of home preparation of this potential food source yielding surplus quantities which could be sold to the three large scale industries which had solvent extraction capability. The project encouraged national extension agencies to train householders in home preparation, is championing the formation of the Kenya Soybean Association (KESA), and the use of the crop in child-feeding interventions (GTZ Soybean Project, PO Box 41607, Nairobi, Kenya).

The International Soybean Centre (INTSOY, University of Illinois, 169 Environmental and Agricultural Sciences Building, 1101 West Peabody Drive, Urbana, IL 61801, USA) is promoting the development of soybean products, and providing an invaluable repository of knowledge and teaching about soybean utilisation. INTSOY has had frequent and helpful technical linkages to the work in Nigeria, Zambia and Kenya.

1.6 Consumer preferences

Farmers of oilseeds want maximum income from the sale of their surplus crop. Their main customers, oilseed crushers, want maximum oil extraction per kg of oilseed bought. In few countries, at this time, are there well established standards of farmgate payment to the farmer by oil content, in part because a quick tool for establishing oil content does not yet exist.

Users of cooking oil face a different problem. Pure oils from sesame, sunflower, Niger seed have different "boiling point" temperatures, at which the oil begins to smoke or vaporise. Cooking time varies for each type of oil Thus, these pure oils are not easily substituted one for the other without adaptations to cooking times.

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CHAPTER V OILSEEDS: Post-harvest Operations

2.8 Storage

2 Post-Production Operations

Small to Medium Scale Processing of Oilseeds

In Tanzania, starting in the mid-80's, a manual press for sunflower oil extraction was developed, which in the next twelve years reached very high levels of dissemination in many countries. This was the technology, which spawned many rural enterprises and began to affect planting patterns. The US Appropriate Technology International (ATI, 1828 L Street NW, Suite 1000, Washington, D.C. 20036 USA) was the prime mover, attracting the interest and financial participation of other agencies, including IDRC.

In South Asia including India and Pakistan, IDRC funded work aimed at improving the efficiency and cost-effectiveness of the ubiquitous motorised screw expellers. This work contributed to a collaborative research and dissemination network.

Manual oilseed crushing-the Bielenberg ram press

In late 1984, ATI and Lutheran World Relief (LWR) initiated a program to help Tanzanian village groups to establish, own and manage small-scale sunflower seed oil extraction enterprises. A year later, ATI staff engineer Carl Bielenberg designed the ram press. In early 1989, a small workshop was convened to review the ATI progress to date, and to exchange experiences about the technology's manufacture, design and dissemination (ATI 1989).

A further workshop in September 1990, with a much larger number of participants, again took stock of progress with the technology (Kamau, John Mugeto 1990) and its dissemination (ATI 1990). By then, dissemination of the ram press was active in Zimbabwe (the ATI-led Zimbabwe Oil Press Project, 132 Harare Street, P.O. Box 1390, Harare, Zimbabwe; Africare, PO Box 508, Harare, Zimbabwe), in Zambia (Africare, PO Box 33921, Lusaka, Zambia), in Kenya (Action Aid and ApproTech, PO Box 10973, Nairobi, Kenya). (See also Zulberti, C. 1990.; Navarro, L., J. Muthaka. 1990; Zulberti,C., O. Schmidt and J.Mugeto. 1990)

Concurrently in Zimbabwe, the Intermediate Technology Development Group (ITDG, Gorland House, 7 Jason Moyo Ave., PO Box 1744, Harare) accrued valuable technical information and collected detailed business-performance on several pilot installations of the Tinytech mechanised systems applied to sunflower at the medium-scale enterprise level.

ATI then developed the concept of a regional OILS project, to which IDRC made a financial contribution between mid 1993 and mid-1995. The regional project was to facilitate the interaction among national groups which were disseminating ram presses in their own countries, to enable support visits from the technical resource people, particularly those in the Tan-Press project of ATI's located at the Centre for Agricultural Mechanisation and Rural Technology (CAMARTEC) in Arusha. (ATI June 1994; ATI 1995).

A further regional workshop on the theme of small scale oil expressing technologies and enterprises was organised by AGROTEC (UNDP/OPS Programme on Agricultural Operations Technology for Small Holders in East and Southern Africa) 4-10 September, 1994, in Arusha, Tanzania. The proceedings of the workshop are extensive, and can be obtained from AGROTEC (P.O. Box BW 540, Borrowdale, Harare, Zimbabwe). By the time of that workshop, the number of ram press enterprises in Tanzania exceeded 1000, the low hundreds in Zambia and Zimbabwe, were just beginning to reach 100 in Uganda and numbered over 100 in Kenya.

One of the important features of that workshop was the declaration by the dissemination agencies that they were positioning themselves as midwives, not manufacturers, of the ram press technology. They gave descriptions of the kind of efforts being undertaken to devolve manufacture, sales and service of the ram press to indigenous companies and commercial agencies, to ensure maximum prospects of sustainability after the end of the short-term intervention projects.

In Kenya, ApproTech is pioneering a new approach to franchising the manufacturers of the ram press. The manufacturer is permitted to place a sticker from the Kenya Bureau of

Standards (KBS) on each ram press built, as long as the workshop meets the qualifications and standards "policed" by ApproTech. At the same time, prospective buyers of the press are counselled to buy a ram press only if it carries the sticker of the KBS.

(Also, at the meeting the UK Natural Resources Institute (NRI, Central Avenue, Chatham Maritime, Chatham, Kent, UK ME4 4TB) provided an excellent keynote on technical issues of oilseeds processing. They proposed a protocol for systematic studies in Tanzania and Zimbabwe on protein cake-quality, and rural utilisation in feed for different farm animals. NRI was shortly going to publish a comprehensive manual on processing of oilseeds and utilisation of co-products in sub Saharan Africa. (See also Gordon, A. and A. Swetman, 1990))

Motorised expelling of oilseeds

The most common screw expeller being manufactured in South Asia is based on a design dating from 1906. Little change was made to the design by the many foundry and metal working shops building the machine. In the mid-80s, IDRC supported applied research work with the Pakistan Council for Scientific and Industrial Research (PCSIR) and with the Indian Council for Agricultural Research (ICAR), aimed at improving the performance of the technology. Other agencies began to show interest, and post-IDRC support led towards multi-country and interagency collaboration:

Improvement of the screw configuration in to increase the yield of oil while decreasing the energy consumption; reducing the machine's weight to make it more portable for the hills of Nepal, and other distant locales with few or no roads);

Improved heat treatment processes for the parts in order to reduce the operating costs;

Redesign of the cage lock and gear drive for weight reduction and facilitation of local manufacture;

Improvement of the cone adjustment mechanism in order to allow the processing of a greater range of oilseeds while avoiding jamming of the system.

The main collaborators were the Germany-based FAKT (Association for Appropriate Technologies in the Third World, Gaensheidestrasse 43, 1000 Stuttgart 1, Germany), the PCSIR of Pakistan, the Tinytech company in India (Tinytech Plants Private Limited, Rajkot--360 002, India). and the Nepalese Development and Consulting Services (DCS) in Butwal.

By 1990, substantial progress had been achieved (Dietz et al, 1990):

Machine weight reduced from 1000 kg to 230 kg while maintaining an hourly throughput of 20 kg of rapeseed;

Drive power requirement reduced from 6 kW to 5 kW;

Energy consumption reduced from 100 Whr/kg to 65;

Basic design of the machine had switched from foundry casting to welding.

Documentation can be obtained from FAKT, while the expelling machinery can be obtained from Tinytech (who have been marketing the equipment in Southern Africa, particularly in Zimbabwe).

2.8 Storage

A major rural problem is how to store the press cake produced by ram press operations on sunflower. If a buyer for the feed cake, containing the crushed hull is not easily found the product could become rancid. The buyer of the cake will also have to know which formulation to use to compensate for the high level of husk/hull fibre.

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CHAPTER V OILSEEDS: Post-harvest Operations

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5 Economic and Social Considerations

Between 1975 and 1992, IDRC had supported 47 separately funded activities, for a total cost of over CAD $14 million, aimed at improving oilcrop research and the vegetable oil and protein systems in Africa and South Asia. IDRC's support for this subsector has strong justification. Edible oils and fats are essential components of the human diet, but these countries were among the lowest in per capita dietary oil and fats intake; had low yields of oil crops; yet they have land and climate suitable for increasing oil crop production without displacing other crops. In addition, oilseed crop improvement was given low official priority in most of the countries in South Asia and Africa. The first 12 projects, funded from 1975 to 1980, largely focused on oilseeds production improvement.

In 1981, the Oil Crops Research Network (ORN), based in Ethiopia, was established. The initial intention was simply to provide better linkages among IDRC-supported oil crops projects and to provide technical support to make these projects more effective. This objective was subsequently expanded so that the Network could interact with all oil crop improvement programmes in the two regions. The original breeding focus in national programs and in the Network expanded to include agronomy, plant protection, and on-farm research. The network and its four sub-networks (Brassicas; Sunflower; Sesame; Other Oilcrops) provided an important on-going focus for production-oriented research, and served as an important and valuable vehicle of inter-country co-ordination and communication via an annual newsletter (Omran, Abbas. 1984-1993, vols 1-10 respectively).

By 1991, after 10 years of supporting the Oil Crops Network, it was clear that breeding, agronomic research, and even farming systems research (FSR) approaches alone would not achieve the repeatedly stated goals of enhancing the subsector's contributions to improved nutrition and stimulation of the economy which countries in the region wished to see and believed to be feasible.

In part, because the Network had existed for ten years now and in part because of the relevance of the VOPS (K) work (described in the following sections) for defining a future strategy for the Network, a review process was initiated within IDRC in early 1991 (Zulberti et al. 1990).

5.1 Overview of costs and losses

The mid-1980 saw large surplus quantities of inexpensive palm oil becoming available from the Far East. The international price of palm oil dropped from a high of USD 750 per ton to below USD 300 within months, if not weeks. One impact of this palm oil surplus, taking Kenya, as a typical example, was a drastic reduction in the farm gate price being offered to sunflower farmers. The main refiner of edible vegetable oil in Kenya, through its subsidiary company established to promote oilseed production by smallholder farmers, adjusted the farm gate price of sunflower seed to match the international price of palm oil less the domestic crushing cost. Not surprisingly, in a period of 2-3 years, the number of small scale farmers participating in sunflower production plummeted from a high of 80,000 to around a tenth that number (Oilcrops Development Limited, Nakuru, Kenya). At the same time, many small to medium scale crushers, suppliers of oil to the giant refiner, saw their throughput (and the jobs of their workers) curtailed in similar measure as the refiner switched sourcing of raw vegetable oil from the indigenous crushing plants to importing palm oil from abroad.

The fundamental question which IDRC felt it needed to address in the light of these circumstances was the following: since oilseed farmers had been rendered non-competitive by the volumes of cheap palm oil, should the focus of research support switch to helping these farmers to find and grow alternate crops? Was further investment in applied research on mainly annual oilcrops now inappropriate or ill advised? Would national economies, especially from the perspective of consumers of edible oil, be better off if they switched to importing the palm oil and found alternative competitive employment for the farmers and processors thus affected by international events?

A healthy, vigorous debate ensued within IDRC. One group argued that as the countries of Eastern and Southern Africa were perpetually short of foreign exchange, importation of palm oil was unaffordable at any low price because it would increase the foreign exchange debits. The rural economy would prosper in the long run if oilcrop production remained an integral part of national agricultural policy and strategy.

It was agreed within IDRC, therefore, to fund an initial study by one consultant of the vegetable oil/protein system (VOPS) of Kenya, as a representative example. The Social Sciences Division and several programmes within the Agriculture, Food and Nutrition Sciences Division (< biblio >) provided financial support for the study. This work was well publicised within Kenya and within the Oilcrops Research Network.

Inter-divisional support followed for three phases of the project Vegetable Oil/Protein

System (Kenya) followed--the VOPS(K) project from early 1988 onward (Anonymous. 1989). Seven teams of researchers, and subsector stakeholders and key players did quick surveys of key aspects of the national sub-sector. (Figure 1 gives a schematic presentation of the aspects of the subsector examined, and underlines the importance of looking at both present consumption and at future demand for the various end-products from the vegetable oil/protein system.)

The results from the work were published by Egerton University (PO Box 536, Njoro, Kenya) (Oggema et al. 1988; Odhiambo et al. 1988; Bartilol et al. 1988; Karau and Namwamba, 1988; Gichohi et al. 1988a; Gichohi et al. 1988b; Gitu et al. 1988; China et al. 1988; Zulberti and Lugogo 1989---the series of 10 working papers from Egerton University), and were presented as well to the substantial membership of the Oilcrops Research Network (Zulberti, C. 1990).

These results were discussed at a workshop of sub-sector participants in Kenya. Annual workshops followed, for discussion of sub-sector progress or of special themes such as the policy environment (Anonymous. May 1991).

VOPS(K) steadily developed and increased the (public) knowledge base of the subsector's structure, behaviour and performance. VOPS(K) produced a newsletter to serve the subsector through information exchange and research publication. Also, additional resources have been attracted to the subsector (from the World Bank for the Agricultural

Sector Management Project (ASMP, Ministry of Agriculture, Livestock Development, and Marketing (MALDM), PO Box 30028, Nairobi, Kenya) phase II, and from FAO for the Rural Oilseeds Production and Processing Project (ROPPP, same address)) for training and further applied research. These achievements have increased local ability and confidence to develop sound policies for subsector improvement.

5.2 Major problems

The most important signals to smallholders are producer price, and costs of inputs. A national enabling policy will encourage value-added processing near the farm gate and redistribution of the co-products to the farming communities. The liberalised economies are now presenting smallholder farmers with new problems and new opportunities. Smallholder farmers are having increased difficulty in affording the cost of high-yielding hybrid seeds, now being marketed by the new private enterprise companies. Thus, the small holders still require a relatively powerful yielding species, the seed of which they can retain for planting the next season. National agricultural research and extension systems have, in the last five to ten years, been less able to supply those needs because of funding cutbacks. As well, smallholder access to agricultural credit has been eroding in the newly liberalised economies.

5.3 Proposed improvements

The concept, inherent in the VOPS (K) project, of mobilising the sub-sector's key players and stakeholders, rather than hiring independent consultants, to delineate, characterise and "troubleshoot" the subsector, was promising. Thus, even as the VOPS (K) work was ongoing, the Oilcrops Research Capacity (Eastern and Southern Africa)-ORCESA--project was initiated in 1991. The burden of this complementary project was to seek to "replicate" the VOPS (K) approach in two additional countries of the region, Zambia and Tanzania (Mbwika et al. 1992; Mbwika and Theora 1992). The intention was to have ongoing interaction by this project's implementers, the Agricultural Research Foundation (AGREF, PO Box 39189, Nairobi, Kenya), with the VOPS (K) project, and the ORN.

Several years after initiation these projects achieved considerable progress and accomplishments.

From the VOPS (K) and ORCESA work, the potential was recognised that the ORN could explicitly incorporate into its future scope the PCSR (production to consumption system research) approach which would help to focus on a broader set of interventions in national programs, more likely to remove constraints to farmer uptake of the technical results from the ORN's work to date.

A series of co-ordinated technical evaluations of the work of the Oilcrops Research Network and its components (Thomas Development Associates, 1992, 1993), vigorous interaction between the Network and the VOPS (K) project (Omran, Abbas (ed) 1988; Omran, Abbas (ed)

1989a.: Omran, Abbas (ed) 1989b.), and a special consultancy (Riley, 1992) culminated in the suggestion that the focus of the network should shift to include a Production to Consumption Systems Approach (PCSA). The PCSA framework emphasises a comprehensive understanding of the whole subsector as the basis for optimising its performance

However, IDRC's shrinking resource base coupled with its programmatic and structural reorganisation made it impracticable to achieve the recommendations agreed to in the last meeting of the Network in August 1992 (Navarro, 1995). Strenuous efforts to interest other donors to augment (and supplant) IDRC's waning support for the Network did not prove fruitful in the short lead-time available to the Network's Steering Committee.

The national oilcrops research programme in Nepal presented its own look at its complex vegetable oil/protein system at the meeting (Paudyal et al. 1992), and demonstrated that the PCSA was a tool useful to national agricultural research systems.

Although IDRC was unable to offer further substantial financial support to the ORN, progress in the PCSA based projects provided the impetus to apply the PCSA within another recent project, the Vegetable Oil and Protein System Improvement Network (VOPSIN).

VOPSIN was an IDRC-funded PCSA-based project for an integrated research and action endeavour to contribute to the sustainable development of the vegetable oil protein sub-sector in the Eastern and Southern Africa region. The primary recipient institution was the

Preferential Trade Area (PTA) secretariat for Eastern and Southern Africa in collaboration with the Agricultural Research Foundation (AGREF). (In 1994, the PTA was renamed the Common Market for Eastern and Southern Africa (COMESA, PO Box 30051, Lusaka, Zambia). The project's purpose was improved performance and growth of the sub-sector. Its goals were improved human nutrition, rural employment and incomes, enhanced contribution to the economy and protection of the natural environment, with special attention to the numerous rural and poor populations who depend on the concerted collaboration of stakeholders and players in the sub-sector with the support of concerned governments and donors.

VOPSIN employed a PCS framework, which was developed from earlier project experiences in Kenya, Zambia and Tanzania. The PCS approach visualises the target Oil Crops Production to Consumption System as constituted by the groups of people, the resources and processes they command, and the interactions among themselves and with the environment, which affect the production, processing, movement, trade and final utilisation of the oil crops. This visualisation is the basis to understand the conditions and performance of the sector, and therefore to identify problems and opportunities to intervene in the sector and improve its performance.

The PCS approach calls for stakeholder participation and necessarily brings together multiple disciplines in an effort to impact the sector. It encourages the subsector participants to join in:

Building the necessary knowledge base about the subsector;

Continuous critical examination of the accruing knowledge and identification of the limiting constraints and action gaps;

Developing priority agendas for research, policy and organizational adjustments plus investments aimed at improving the performance of the subsector;

Fostering interest and resources from within the subsector.

The project ran from mid-94 to the end of 1996. IDRC resources were applied to install, operate, and to help raise additional funds for the continued operation of VOPSIN. Progress was achieved in furthering national and regional attention and action in the subsectors of a number of countries, and knowledge about the respective national subsectors was accrued and disseminated (Anonymous. March 1997).

The VOPSIN project also collaborated with the agencies involved in the APROMA-funded process f or the establishment of a regional soybean production database.

Work begun by the Junta del Acuerdo de Cartagena (JUNAC) in the early eighties (Dubois et el. 1984; JUNAC 1985; UNIDO/JUNAC 1985) led to UNIDO's collaboration and the formulation of an input/output model of production to consumption systems. UNIDO produced a computer-based simulation model, MEPS (method for the evaluation and assessment of production to consumption systems), using the Symphony spreadsheet software. This model was not fully achievable in many developing countries, because the required hard data were missing.

The IDRC-supported work in eastern Africa constitutes a mobilisation of sub-sector participants with the goal that they would ultimately be able to generate the data necessary for the more rigorous modelling. (such as MEPS and its successor, E-MEPS) Thus, the analyses of the systems research and the systems approach written by, primarily, IDRC staff at the time (Navarro et al. 1992; Navarro and Schmidt 1993) complemented the JUNAC/UNIDO work.

Further, IDRC also commissioned a useful and informative review of the methodologies useful to production-to-consumption studies (Sellen et al 1993).

In sub-Saharan Africa, the manual ram press appears to have the highest chance of success as a rural intervention to initiate small off-farm enterprises, a start for the evolution of more value added domestic activities. Edible oil, generated near the farm gate, and redistributed to households nearby, does not need to have long shelf life-it will be consumed quite quickly. Consequently, the oil needs to be only filtered, not refined, bleached and deodorised. The small-scale rural enterprises have a market niche, complementary to that of the large-scale crushers and refiners, which supply mainly the urban markets. Since on average, 80 percentage of the population is rurally located, the market niche is substantial in volume, and the number of potential rural enterprises is substantial in number.

While the total number of ram presses, in Tanzania as an example, are not sufficient yet to demonstrate a significant share of the national edible oil requirement, they do have substantial singular impact, on the rural economy of the smallholder.

Rurally located, off-farm processing adds value to the produce, and brings direct rural benefits, far more than the former "export" of the oilseed to distant (domestic) industrial installations and the costly redistribution of the co-products back to the rural areas.

Case studies on the profitability and viability of these enterprises

have been documented in Kenya, Uganda, Tanzania, Zambia, and Zimbabwe. The entrepreneur is limited by having insufficient cash supply to enable her/him to purchase enough oilseeds at harvest time so that the enterprise can run year-round. Commercial banks, and their interest and willingness to lend money for such off-farm processing businesses are vital to the process, especially since governments have ceased to administer rural credit.

From the view point of examining international competitiveness, a country has to first assess its niche for the domestic production of oilseeds and the total of their co-products, not of vegetable oil or protein cake separately. National planners will have to decide whether it is more cost-effective to fill national requirements and potential requirements from national production of oilseeds rather than from import of either edible oil or of protein cake.

Next comes the task of determining whether the country has a competitive edge for export of the oilseed, or its co-products to international markets, and the role which smallholder farmers can and will play in that export situation.

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CHAPTER VI WHEAT: Post-harvest Operations

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1. Introduction

Wheat, has been the staple food of the major civilisations in Europe, Western Asia, and North Africa for 8,000 years. During the past four decades the crop has undergone historic changes. Asia experienced benefits from the "Green Revolution", started in the mid 1960s. The region made great strides in food production, achieving sufficiency in basic grains. Crop production is dictated by Nature, but post-production operations play an important role in creating a stable food supply. It is estimated that about 25.0 million tons of wheat are lost during post-harvest stages (including storage and post-production). About 46 percentage of this loss is recorded in developing countries.

In Asia wheat, rice and maize are the major food grains contributing over 90 percentage of the total food grains. Regional production data show (see Table 1) an estimated 42 percentage of the world's wheat, rice and maize during 1997 were produced in Asia, followed by 31 percentage in Europe and 16 percentage in North Central America (NC America). Asia contributes about 92 percentage of world's rice production followed by South America and Africa at about 3 percentage each. NC America contributes half of the world's maize production, followed by Asia, Europe and South America who contribute 27 percentage, 11 percentage and 8 percentage, respectively.

Table: 1. World Cereal Production (million tons) - Estimates 1997

	Wheat	Rice (Paddy)	Course grains	Total
Asia	249	520.2	198.6	967.8
Africa	15.5	16.8	78.4	110.6
Central America	3.4	2.1	28.7	34.2
South America	18.8	18	61.2	98
North America	93	8.1	291	392.1
Europe	132.6	2.6	172.6	307.8
CIS	80.1	1.4	67.6	149
Oceania	18.2	1.4	9.6	29.3
World	**610.6**	**570.6**	**907.6**	**2088.8**

Developing Countries	283.6	544.1	357	1184.7
Developed Countries	327	26.5	550.6	904.1

Source: Food outlook, FAO Rome, No. 1, 1998

The major wheat producing and consuming countries in Asia are China, India, Iran, Pakistan and Turkey. The production of wheat in Asia for the years 1991 - 1997 is shown in Table 2.

Table: 2. Wheat Production in the Asian Developing Countries (000, tons)

Country/Year	1,991	1,993	1,995	1,997
Afghanistan	1,726	1,700	1,700	1,700
Bangladesh	1,004	1,176	1,245	1,400
China	95,954	106,395	101,964	120,000
India	55,135	57,210	65,767	68,700
Iran	8,793	10,732	11,228	11,200
Iraq	1,476	1,187	1,236	1,063

Iraq	[illegible]	[illegible]	[illegible]	[illegible]
Jordan	62	57	58	51
Korea DP RP	135	123	125	100
Lebanon	59	55	49	45
Mongolia	538	450	257	198
Myanmar	123	139	89	110
Nepal	836	765	942	1,072
Pakistan	1,457	16,157	17,002	16,667
Saudi Arabia	4,036	3,430	2,453	1,500
Syria	2,140	3,627	4,184	4,300
Turkey	20,419	21,016	18,015	18,700
Yemen	100	160	171	170
Others	28	48	60	63

Source: Food outlook, FAO, Rome, No.1, 1998

Wheat is grown under diverse climate conditions, from dry land with limited moisture for the duration of the growing season (e.g.located in much of the USA, Australia, CIS, West Asia and North Africa); and land with adequate water throughout the season such as the countries of Western Europe. Half of the developing world's wheat growing area comprises large irrigated tracts, mostly found in India, Pakistan and China.

Bread wheat (Triticum aestivum L.) is planted on 93 percentage of the global wheat growing area. The spring-habit and winter-habit crop is durum wheat (T. turgidum var. durum). Two-thirds of the cultivated land devoted to wheat is sown with spring types in the developing world. Winter wheat covers a significant expanse of Turkey, Iran, China, USA and Europe.

Since 1950 the world wheat production tripled to 611 million tons in 1997. The growth rate was much faster from 1960-1980 than in the last 18 years. Three quarters of the production is attributed to an increase in yield rather than an increase in area. The most impressive changes have taken place in the large mixed cereal sectors of the developing world such as China. The traditional importers of wheat among the developed countries have also experienced rapid gains in yield. In West Asia and North Africa the yields have been smaller with a slower pace of change. Yields are also low in the tropical belt, which produces less than one percentage of world's wheat. The average wheat yield in developing countries in 1950 was about 700 kg/ha. By 1996 average yield tripled to 2241 kg/ha. This progress stemmed from development of new wheat varieties, which were shorter in stature, high yielding, and earlier to mature. These were supplemented with technologies including methods of sowing, seed rate, irrigation, fertilising, moisture conservation and integrated pest management. Potential yield, particularly in the African and Asian developing countries was not fulfilled as a consequence of inadequate application of improved practices. lack of water, fertilisers, pesticides, improved seeds and socio-economic constraints where the majority of the people below the poverty line are living.

1.1 Economic and Social Impact

Improved wheat production enlarged the demand for agricultural labour. In one study in India, it was estimated that an average increase of 23 man-days per hectare per crop season was needed to accommodate extra fertiliser application, irrigation, weed control, and harvest volume. Assuming an increase of only 10-15 man-days of labour for a given wheat crop, 30 million hectares of modern varieties would require from 300-450 million man-days of additional labour per year, a benefit for employment. These operations promote secondary employment in harvest and post-harvest operations including transportation, storage, manufacturing and merchandising of fertilisers, herbicides and farm tools. Multiple cropping was stimulated by early maturing wheat varieties and the use of fertiliser, further expanding employment.

There has been rapid evolution in the management practices employed for improved high yielding varieties (HYV). In the Indian and Pakistani Punjab, farmers mostly use nitrogenous and phosphate fertilisers and take advantage of improved water management practices. They apply herbicides to control the grassy weeds that have proliferated. Mechanical land preparation and the use of tractors have also been widely adopted. Mechanisation has been increased partly because of the adoption of early-maturing semi-dwarf varieties.

Much of the world's wheat is grown in dry land areas. Even without the introduction of new varieties, substantial gains in productivity have been realised through improved tillage methods to conserve moisture before planting, to execute more timely planting and to maintain better weed control. In Turkey's dry Anatolian Plateau, earlier ploughing, clean fallow and broad-leaf weed control quickly became the norm in the 1970s. The adoption of improved management practices was a major factor in doubling wheat yields and making Turkey self-sufficient.

In the past decade, industrialised countries adopted reduced and zero tillage methods to conserve soil and reduce costs (i.e. energy costs). These techniques are now being tested in less developed countries. One notable example is the direct drilling of wheat in rice stubble. This method has generated tremendous productivity improvement for the eight million hectares of wheat planted in Asia. In industrialised countries yields are high, but these results are costly. This is true for Western Europe where numerous inputs are used. The level of inputs for wheat production is still very low in many developing countries. However fertiliser is widely used on much of the wheat grown on dry land in West Asia and some parts of North America. A combination of more effective research, extension in crop management and appropriate policies to provide inputs is needed to achieve better socio-economic status of the community.

The agricultural advances experienced in the late 1960s in Asia were repeated elsewhere during the 1970s, as semi-dwarf varieties spread to less favourable growing environments. Semi-dwarf wheat varieties were rapidly applied in Mexico during the early 1960s. By 1967 use had expanded to irrigated wheat areas of Northern India and Pakistan. Within a period of 5 years, HYV had been selected by more than half of the wheat growers. The planting of HYV also encouraged the use of fertilisers and provision of improved water supplies. Wheat yields in India, Pakistan and Mexico more than doubled between 1965 and 1985. By 1985, over 50 million-hectares of wheat in the developing countries were cultivated with semi-dwarf wheat. Excluding those from China, most of these varieties incorporated germ plasma from the CIMMYT in Mexico.

Gains in wheat crop productivity created overall benefits for employment, nutrition and income. The expanded wheat production saved hundreds of millions of dollars for India, Pakistan, Iran, Indonesia, Bangladesh, Republic of Korea and Turkey. Otherwise these countries would have been obligated to import food to sustain their large, growing populations.

The consumption of wheat world-wide can be divided into two main categories of countries. These are defined by production and consumption patterns, further dictated by the degree of economic development.

The first group comprises the industrialised counties where wheat is a traditional staple food for all except Japan. Western Europe is a developed market that has historically imported wheat, excluding France. (Japan is not an importer of this grain). The USA, Canada, Argentina, Australia and France have been major exporters of wheat. Centrally planned economies that have traded wheat include the CIS and Eastern Europe.

The second group incorporates the developing countries. Among them, North Africa, West Asia and the southern portion of South America represent traditional wheat consuming countries. Next are the large mixed cereal systems of India, China, Mexico and Brazil where wheat has been a major crop only in selected regions. Tropical countries between latitudes 23°N and 23°S are territories where wheat has not commonly been produced or consumed.

The nutritional impact of the new varieties was higher when measured in actual calories, protein and essential amino acids. The enhanced productivity of the HYV led to a rise in total protein and energy supply of at least 20 percentage. The earlier maturity of some new varieties made multiple cropping possible, which augmented the nutritional balance.

Throughout the developing world the use of wheat per capita has rapidly grown. In the large mixed-cereal economies of India, China and Mexico, higher levels of consumption have been met from greater domestic production and self-sufficiency. Other countries, such as the traditional wheat consumers of North Africa and West Asia have used imports to meet increased consumption. The substitution of wheat for maize, roots, tubers and other foods has accelerated in many countries in conjunction with rising income; urbanisation plus government subsidies to ensure low bread prices for consumers. Wheat consumption has risen more slowly in the developed nations partially due to stable population growth. The utilisation of wheat is highest in Eastern Europe and CIS, where 40 percentage is used as animal feed. In many richer countries, the per capita consumption of wheat is declining as high-energy animal products replace it.

1.2 World Trade

Actual production and consumption patterns have sharply altered the world trade in wheat. Western Europe is a net exporter and India and Pakistan (excluding border leakage) are self-sufficient (Exception: Pakistan during 1997 imported about 4.0 million tons to offset Afghan and Kashmir refugee food requirements and leakage. During 1998 the imports are expected to be less than one million tons). The largest importers are CIS, West Asia, North African countries and the tropical belt.

The developing world's share of all wheat imports is currently around 60 percentage. At the same time imports have risen and wheat has assumed greater importance in the local diet. There is a global surplus of wheat. Prices have declined by 46 percentage terms since 1950. Stocks have reached record levels over the past decade.

The forecast for world trade is significantly below levels reached in the early 1990s. In 1997-98 production was down more than 10 percentage exceeding 17 million tons from 1996-97 levels among the traditional exporting countries Argentina, Australia, Canada and the European Union. The loss is only partially offset by a 6.6 million-ton increase in the projected production in the United States. Nevertheless, supply available for export has become a lesser concern because of record production. Coupled with the absence of large purchases from China and CIS, the gradual upward trend of the past 25 years is expected to continue unabated.

1.3 Primary product

The wheat grain consists of four major parts. Their weight is expressed as a percentage of the total seed as follows:

-Seed Coat (Bran): 10 percentage

-Aleuron layer (Bran):2 percentage

-Endosperm:83 percentage

-Germ:5 percentage

Total100 percentage

The endosperm contains starch granule cells, fixed in the protein matrix, and is coated with cellulose wall. The endosperm is surrounded with aleuron cell layer. The grain has a protective covering called the seed coat. Scutulum separates the germ from the endosperm. The germ embodies the rudimentary root and shoot of the future plant (Figure 1).

In the industrialised world, wheat milling yields flour and mill feed. Before milling, the grain is cleaned and the moisture content of the grain is increased to easily separate the bran (the outer portion of the kernel called seed coat plus the aleuron layer) and the germ from the endosperm. The milling process yields generally 72 to 74 percentage flour. The rest is mill feed. The percentage of flour is multiplied in developing countries, particularly when a given country is trying to diminish wheat imports. If only excessively coarse bran is removed to produce whole-wheat flour, recovery runs as high as 90 percentage (called small milling process). In South Asia, the whole grain is milled and the flour recovery is 99 percentage or more.

The composition of proteins and carbohydrates are considerably different in various food grains. Protein content of durum wheat is low, while whole wheat measures as high as 14.6 percentage. The nutritional composition of commonly used food-grains is listed in Table 3.

Table: 3. Nutritional Composition (%) of Various Food Grains

Food-grain	Protein	Fat	Carbohydrate	Crude fibre	Ash
Wheat	10.6 - 14.6	1.6 - 2.1	66.9 - 75.9	1.7 - 2.3	1.3 - 2.2
Barley	8.3 - 11.8	1.8 - 2.1	68.0 - 72.0	4.3 - 5.7	2.3 - 2.7
Rice	8.4 - 12.0	0.9 - 1.3	70.5 - 76.3	0.9 - 1.3	9.6 - 13.4
Maize	9.5 - 11.5	4.0 - 5.0	68.0 - 75.0	1.7 - 2.0	1.2 - 1.6
Sorghum	8.0 - 9.5	1.9 - 2.0	70.0 - 74.2	2.0 - 2.5	1.7 - 2.0

Millet	9.4 - 10.5	3.2 - 3.8	68.5 - 71.5	1.5 - 1.8	1.8 - 2.2
Gram	16.3 - 17.9	0.17 - 0.19	60.2 - 62.3	1.9 - 2.7	2.1 - 2.6

Source:Derived from materials cited in 6. References

The major primary wheat products of Asia, particularly South Asia is flour, Suji and Maida, which are widely marketed. The Suji and Maida are commonly used for cookies and desserts. The nutritional composition of these products is given in Table 4.

Table 4: Average Composition (%) of Wheat and Wheat Products in South Asia

Commodity	Moisture	Protein	Total Ash	Crude Fibre	Fatty Acid (mg) *(mg)*	Gluten
Wheat	13.3	12.7	1.4	2.4	20.5	8
Flour	12.4	11.8	1.3	2	77	7
Suji	13.4	10	0.7	0.4	31.9	5.6
Maida	12.9	7.9	0.6	0.07	48.2	6.8

Source: Pingale, S. V. 1978. Handling and storage of food grains. *ICAR, New Delhi India.*

The roller milling process was developed to get the best possible separation of endosperm from the bran. The flour extraction rate depends upon the type and design of the mill. Milling losses are highest in the older mills. In South Asia small stone mills driven by a one horsepower motor have been developed as a cottage industry. The mill grinds wheat into coarse flour (called *atta*) and has eliminated the drudgery of hand pounding the grain in most villages.

Industrialised countries have systems for grading flours based upon texture, protein, ash content and other physical and chemical measurements. Automated commercial bakeries demand detailed grading systems, as they need precise and consistent flour characteristics to manufacture wheat products. Such exacting standards are not necessary in most developing countries, with the exception of large bakeries in big cities that seek standardised flour.

1.4 Secondary and Derived Products

The advanced milling process yields wheat bran, semolina, wheat germ and wheat germ oil as the main secondary and derived products. Wheat is a valuable ingredient of feed given to milk and beef livestock and poultry because it contains more nutrients than the traditional feed grains such as maize, sorghum and barley. In developing countries, whole-grain wheat is usually fed to animals only when the grain has sprouted, shrivelled, or become damaged.

Mill feed, the by-product of wheat milling (about 25-30 percentage), is an advantageous raw material for mixed feeds. The mill feed percentage is lower in some countries because millers seek to maximise the output of flour. Mill feeds contrast in nutritional value, but typically contain 13 to 14 percentage protein and 2.5 to 3.0 percentage fat (both higher than whole wheat), and 9 to 12 percentage fibre, having feeding value only for ruminants. Mill feeds are more vulnerable to severe storage losses than whole grain because of their high oil content. Mill feed must be safeguarded against birds, rodents and insects. It must be protected from moulds induced by excess moisture.

1.5 Requirements for export and quality assurance

Half to three fourths of the wheat produced in developing countries does not enter marketing channels. The families who grow it periodically bring a sack of wheat to town for grinding at a small mill and carry the flour back home for family use.

The farmers sell the rest of their wheat (25 to 50 percentage of production) to a local grain merchant or to a government agency. This wheat enters the marketing process of storage for a few months to a year, followed by milling into flour, then distribution to commercial bakeries or food shops where the urban consumer buys flour for home baking.

Wheat from most developing countries is unlikely to reach the export market as they export only 10-13 million tons (1997) per year; nearly all of which originates in just three countries-Argentina, Turkey, and occasionally India. On the other hand, over 70 million tons of wheat a year was imported by over 100 developing countries in recent years.

1.6 Consumer preference

To identify desirable qualities in wheat, farmers prefer the ability to resist diseases, mature at the proper time, not lodge or shatter before harvest and yield good plump grain. The miller prefers uniform grain free of foreign matter, with low moisture content, higher protein and yield of flour. The baker looks for flour that produces dough that can hold gas bubbles and make a large loaf of bread with good internal texture and colour. The consumer has a strong preference for appearance, texture, aroma and flavour of bread, biscuits, cakes and other products-characteristics that may be traced partly to the wheat kernel. Scientists who develop new wheat varieties and production standards must consider all these specifications of the farmer, miller, baker and consumer for wheat production.

Sixty-five to seventy percentage of the world's wheat flour is consumed as bread. In European countries the demand for semolina products is much higher than for wheat flour products. Over 90 percentage of wheat is consumed as flour in the developing nations of South and West Asia.

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