BARLEY

Post-harvest Operations

INPhO - Post-harvest Compendium

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of the United Nations

BARLEY: Post-Harvest Operations

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Preface

Barley is grown in about 70 million hectares in the world. Global production is 160 million tons. Developing countries accounts for about 18 % (26 million tons) of total barley production and 25 % (18.5 million hectares) of the total harvested area in the world. Barley grain is mostly used as feed for animals, malt, and food for human consumption. Malt is the second largest use of barley. Farmers also use barley straw as animal feed in West Asia, North Africa, Ethiopia, Eritrea, Yemen, the Andes region and East Asia.

Barley dominates other grains in some developing countries having arid and semi arid climates where it is the only cereal and only staple food resource. It is the fourth most important cereal crop in the world after wheat, maize, and rice. Barley is cultivated in Tibet, Nepal, Ethiopia, and the Andes on mountain slopes, only possible rain fed crop in North Africa, the Middle East, Afghanistan, Pakistan, Eritrea, and the Yemen. Even in more developed countries, it is also very important species not only for animal feed but also for malting and exportation.

Crop quality and post harvest operations are very important for human nutrition in dry areas, on the other hand economic development and farmer revenue for more humid areas.

In the developing countries, farmers are mostly too poor to afford any loss of production.

In general, barley is more productive and its yield is more stable against seasonal variation than wheat and most of other small grains. Therefore, resource poor farmers tend to prefer barley production. Successive poor production seasons leads farmers particularly those of poor to replace wheat with barley for the aforementioned reasons. In dry years, barley flour is mainly used for bread making or it is added to wheat flour to make bread (Oluç, 1946).

The barley crop is considered as a kind of guarantee against very low yield or crop failure risks.

Due to the fact that barley crop is utilized for animal feed as well as human nutrition, poor production and any kind of loss after harvest adversely affect farmers' livestock production and consequently socio-economic conditions.

Growing crops and protecting them until consumption have been the major preoccupation of mankind since the inception of agriculture. Storage is an essential interim operation in the food pipeline that moves crops from producer to processor and foodstuffs from processor to consumer. It equilibrates the quantitative fluctuations derived from the imbalance of supply and demand. Hunger today may be threatening the lives of about 800 million people in the developing world, with approximately 60% of them living in Asia. People may suffer from food shortage or malnutrition heavily, especially in the poorest countries where agricultural production is never in surplus, where facilities for storage are lacking, and in regions subject to extreme climatic fluctuations from one year to the next (Navvaro, 1997).

While post harvest production systems and post harvest losses are largely controlled by market imposed political and economical conditions in developed countries, ecological factors play more decisive role in those systems and losses in the developing world. In developed countries qualitative aspects of food loss are of greater importance than the quantitative ones. In these countries cereal grains are stored in large centralized storage facilities or on-farm in bulk. Under these conditions quantitative losses are generally at low levels and therefore further loss reductions are not cost effective. Losses of biological origin such as grain or insect respiration, or limited drying due to aeration of grain in storage are common. These losses on an annual basis are usually less than 1%. Developing countries are characterized by small scale farming where deficiencies in handling and storage methods, and very often warm and humid climatic conditions promote rapid deterioration of the stored foodstuffs. In developing countries the major portion of grain and pulses (sometimes up to 80% of the national production) is kept on the farms for home consumption. Post harvest losses in food grains in developing countries have been estimated conservatively during the 1980s as 10-15% by the FAO's Special Action Program for the Prevention of Food Losses. However, actual losses may be higher in certain areas depending on storage types and conditions. For example, losses of corn due only to insects in farmers' stores in Nigeria, Swaziland and Kenya, were estimated to be in the order of 6-10% (Navarro, 1997).

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops in the world. It is widely grown fourth cereal and among top ten crop plants in the world. Barley was mainly cultivated and used for human food supply in the last century but nowadays it is significantly grown as animal feed, malt products and human food respectively. In addition, barley is very well known as a model crop for plant breeding methodology, genetics, cytogenetics, pathology, virology and biotechnology studies (Hockett and Nilan 1985; Hogberg, 1987). Barley is mainly produced in unfavorable climate and soil conditions of the world. Wide adaptation to these conditions mentioned above, versatile utility mainly for animal feed and food and superiority for malt and beer industry as a raw material are the main reasons that enable barley to be commonly cultivated crop plant over centuries. Barley is cultivated in highly diverse regions of the world from 330 m below sea level near the Dead Sea in the Middle East up to 4200 m on Atipano and the Andes in Bolivia.

Fertile Crescent of the Middle East consisting of Turkey, Iran, Iraq and Lebanon has been reported as original area of cultivation and most likely origin of barley, the most ancient crop of cereals (Harlan, 1979). According to the excavations, barley was domesticated in the Nile River Valley of Egypt at least 17.000 year ago (Wendorf et al., 1979).

1.1 Socio economic impact of the crop

Barley is very important cereal in terms of 132 million tons production, 55 million ha acreage and 2.4 t/ha yield in the world (Table 1.1.1). Barley production is generally and drastically affected by environmental and seasonal conditions. Considering the reasons, production, acreage and yield data are reported below as a-three year average. It is clearly seen from Table 1.1.1. that nearly 74% of world barley production is met by ten leading countries during the last three year period (1998-00).

Table 1.1.1: Status of Barley Production in Ten Leading Countries (Three year average, 1998-2000)				
Countries	Area harvested (000 ha)	Production (000 t)	Yield (kg/ha)	% of world production
World	55.778	132.393	2374	----
Canada	4.297	13.124	3059	9.9
Germany	2.155	12.671	5879	9.5
Russian Fed.	8.165	11.222	1380	8.5
France	1.575	10.036	6366	7.5
Spain	3.316	9.871	2962	7.4
Turkey	3.623	7.533	2072	5.6
USA	2.131	6908	3235	5.2
UK	1.187	6566	5541	5.0
Ukraine	3.574	6389	1787	4.8
Australia	3.185	5372	1726	4.1

The largest producer country was Canada with 4.2 million hectare acreage and 13.1 million ton production in the world. 10 % of world barley production is met by only Canada. France together with Germany has the highest yield level (6.4 t/ha and 5.9 t/ha) while Russian Federation together with Ukraine has the lowest one (1.4 t/ha and 1.8 t/ha).
Seven out of ten leading barley countries are in Europe and Eurasia (Russian, Federation, Germany, France, UK, Spain, Turkey and Ukraine), two of them (USA and Canada) are in Northern America and the last one is in Oceania (Australia). World barley production trend from 1961 to 2000 with an average of a-ten-year period is summarized in Table 1.1.2. If it is compared in terms of area harvested, production and yield level criteria, in spite of the fact that there are some decline in terms of area harvested (18%), both production and yield level have increased by 33% and 61%, respectively.

Table 1.1.2: Barley Production Trends in the World						
Years	Area harvested (000 ha)	Production % of first period	(000 tons)	% of first period	Yield (kg/ha)	% of the first period
1961-65	68.071	100	99.716	100	1465	160
1978-80	84.818	124	167.627	167	1978	135
1998-00	55.778	82	132.393	133	2374	161

1.2 World Trade

World barley grain export is totally 20 million tons and its value is 25 billion $ as average of three years between 1998 and 2000 (Table 1.2.1). Europe is the main exporter with 12.3 million tons barley grain export and 1.5 billion $ value. It is followed by Oceania, North and Central America and Asia. Leading barley grain exporting countries are France, Australia and Germany and Canada with 4.8, 3.6, 1.8 and 1.7 million tons, respectively in the world. These leading countries mainly export malting barley and naturally get more money due to 20-30 % of price superiority of malting barley grain over feeding barley.

Table 1.2.1: Amount and Value of Exported Barley in Main Exporter Continents and Countries (Three year average, 1998-2000)

Countries	**Export (10 Mt)**	**Value (1000 $)**
World	2.042.194	2.517.078
NC America	371.923	275.137
Canada	178.816	247.549
USA	96.333	124.374
Asia	145.106	131.382
Kazakhstan	57.161	43.495
Turkey	76.319	68.646
Europe	1.233.695	1.513.937
France	482.080	615.161
Germany	179.955	207.591
UK	136.802	180.110
Denmark	75.341	120.237
Ukraine	70.269	72.197
Oceania	362.180	461.696
Australia	360.549	459.405

World barley import is almost equal to the export in terms of amount and value with 19.5 million tons and 2.6 billion $, respectively (Table 1.2.2). On the contrary to export, Asia continent is the main importer with 10.7 million tons and 14 billion $ value and it is followed by Europe and Africa (Table 1.2.2). Saudi Arabia, China, Japan and Bel-Lux are the four leading importer with 4.3, 2.1, 1.5 and 1.4 million tons, respectively in the world. Generally Asian and African countries import feeding barley both for animal and human consumptions.

Table 1.2.2: Amount and Value of Imported Barley in Main Importing Continents and Countries (Three year average, 1998-2000)		
Countries	**Imports (10 Mt)**	**Value (1000$)**
World	1.951.172	2.637.466
Africa	170.272	172.169
Algeria	43.505	41.380
Libya	37.233	33.100
Tunisia	21.825	24.233
Morocco	52.732	49.476
North and South America	99.057	152.538
USA	74.310	106.107
South America	45.043	82.088
Colombia	17.233	30.355
Brazil	8.737	15.729
Asia	1.071.632	14.025.140
China	211.056	338.783
Japan	156.739	234.479
Jordan	58.565	75.786
Iran	41.205	62.576
Saudi Arabia	431.532	485.440
Europe	558.469	824.766
Bel-Lux	141.268	224.255
Germany	42.340	75.388
Italy	60.358	93.747
Netherlands	81.410	118.664
Russian Federation	42.626	37.909

1.3 Primary Product

Barley is mainly used as feed for animals. Barley grain is also very important source for malt and food for human. According to Bhatty (1993), barley is predominantly consumed for feeding animals even in some European countries such as Germany, France, UK, Denmark and Italy (Table 1.3.1). Ratio of the feed consumption changes from 70% (in UK) to 89 % (in Canada). The trend shows some variations, but globally 70% of barley production used directly or indirectly for feeding animals. Highly diverse regions of the world where maize can not be cultivated due to short growing period, cool temperature in spring and rainfall deficiency and higher evaporation, barley is predominantly grown as principal feed grain (Poehlman, 1985). Turkish highlands characterized with 1500 m altitude and severe cold and long winter period are a good example for this issue. A survey conducted on two provinces (Sivas and Kayseri) located in Turkish highlands indicated that barley is mainly grown (87 %) for animal feeding and according to the economical analysis result it is the most profitable crop for this purpose (Bayaner et al., 1993).

Barley with maize, oat and wheat is one of the most common feed grain of the world. If used as feed, its grain should be ground or cracked to improve efficiency in a given ration. It is overwhelmingly considered as carbohydrates and protein sources in livestock feed. Protein content, which is strongly affected by environmental conditions where barley is grown, changes from 10 % to 15%.

In addition to this, annually 5% of world production is generally retained for seed. Barley straw is used for animal bedding in developed countries but also for animal feeding especially in rural areas of developing countries. Mix cropping with vetches is another practice for quality forage production for grazing or cutting for making of hay or silage.

1.4 Secondary and Derived Products

The second largest use of barley grain is for malt. Globally, 30 % of the world barley production is used for malting purpose and 70 % for feed use. In addition to barley, wheat and rye are also malted but barley grain has been preferred to other grains. The reasons why barley is commonly used for malt are its husk protecting the coleoptiles during germination process and filtering, firm texture of barley grains and tradition. 90 % of malted barley is utilized for malting beer and the remainder for food substitutes. Table 1.4.1 clearly shows that barley malt can be substituted in to a lot of food stuffs such as biscuits, bread, cakes, desserts, etc.

Traditionally, barley is very important food crop plant in the semi-arid regions of Africa (Morocco, Algeria, Libya and Tunisia), Middle East (Saudi Arabia, Iran, Iraq and Syria), highlands of Nepal, Ethiopia and Tibet, Andean countries of South America (Peru and Chile) and in some Asian counties (China, North Korea and Himalaya).

Morocco is leading country in terms of food consumption in the world with 88.3 kg per capita (Table 1.3.1). Barley has also some by-products that can be used for various purposes. The most valuable by product is the straw which is used mainly for bedding in developed countries but also for animal feeding in developing and under-developed countries. Brewer's and distiller grains and sprouts from malting barley also have desirable protein level for animal diets.

Table 1.3.1: Feed and Food use of Barley in Some Countries (1)			
Countries	Feed use (% of Total)	Countries	Food use (kg-person /year) (1986-88)
Canada	89	Morocco	88.3
Turkey	88	Ethiopia	19.0
Denmark	87	Algeria	18.1
Spain	87	Afghanistan	15.4
Finland	86	Iraq	11.5
Italy	86	Tunisia	10.6
France	85	Libya	8.9
Sweden	85	Korea Rep.	7.5
Norway	81	Iran	7.1
Austria	79	Poland	6.1
Switzerland	79	Peru	4.8
Ireland	78	Japan	1.1
Germany, FDR	72	Netherlands	0.9
UK	70	New Zealand	0.9
(1) Bhatty, R.S. (1986). Non-malting uses of barley. In 'Barley: Chemistry and Technology'. Chapter: 8, P:355-418.			

Table 1.4.1: Food Uses of Malt as By-product (1)					
Food Stuff	Colour	Enzyme	Flavour	Sweetness	Nutrition
Biscuits and crackers	X	X	X	X	X
Bread	X	X	X	X	X
Breakfast cereal			X	X	X
Cakes	X		X	X	X
Dessert	X		X		
Ice cream	X		X		
Malted food drinks		X	X	X	X
Meat products	X				
Sauces	X		X	X	
Soft drinks	X		X	X	X
Type of malt products used	Soluble Extract (SE)	SE or flour	SE or flour, flake	SE	SE flour, flake
(1) From : Bamforth, CW, and Barclay, A.H.P., (1993). Malting Technology: the uses of Malt. Page: 298. Barley: Chemistry and Technology. A.A.C.C .Inc. St. Paul, Minnesota, USA.					

Due to the fact that barley grains have higher soluble dietary fiber and lower low density lipoprotein (LDL) content than that of wheat, some food manufacturers now favor barley as an excellent food stuff (Oakenfull, 1996). Soluble fiber has a cholesterol lowering property and LDL cholesterol is the fraction associated with increased risk of heart diseases. Considering these two important factors, a lot of hull-less barley have been registered specially for human consumption and its acreage has been increased even in the western countries such as Canada (Bhatty,1986).
In fact, although barley is used mostly as mixtures in flours for bread making either due to lower price of barley compared to wheat or due to its nutrition value. Similarly, barley malt and its extract are used in various types of commercial breads in Turkey and many developing countries. Such breads can include various ingredients. For example 'Diva' light form bread contains wheat flour, Wheat bran, Malt extract, Roasted whole malt flour, Warm water, Ascorbic acid (Vitamin C), Regular yeast, Salt (Diva unlu mamuller sanayii, Demirlibahçe, Ankara, Turkey). Various recipes containing barley products for human consumption in developing countries are described by Saari & Hawtin (1977). Some of these are given in the Annex. Intensive efforts are also made for promotion of barley as major human food in developed countries because of its valuable nutrition properties. Various Canadian recipes for use of barley as human food in the form of whole bread making and main dishes are described at www.albertabarley.com/recipes. Barley is also used for production of soft drinks in the form of barley juice in some developing countries such as in India (Kochar, 1981).

1.5 Quality Assurance

Grain quality is the most complicated trait and affected by many factors. Some of the criteria that are required by feed and malt industry are as follows:

1.5.1 Cultivar:

Uniform germination is a key point during malting process. Therefore, all grains used should originate from a single variety. This also applies to grains used for feed purposes, but in this case cultivars with same color can be stored and then easily used for feed making in the industry.

1.5.2 Moisture:

Low moisture content below %12 is the optimum moisture level and facilitates long term storage of barley grains in many developing countries, including Turkey. However, in the northern part of the world known as humid weather conditions, 16% of moisture is permitted.

1.5.3 Grain size:

Thousand kernels weight is a good indicator of mean kernel size. In addition to this, there is another specification for two and six rowed malting barley cultivars. For this 85% of grains should be retained on a 2.5 mm sieve and be free from extraneous matters. Test weight is also used for an indicator of grain and samples having 70% and higher test weight should be preferred especially for effective storage.

1.5.4 Protein content:

Low protein content is preferred from 9% to 12% for brewing and distilling purposes. Farmers can get more premiums if they apply suitable rate of nitrogen. So, contracted farming system between private malting companies and farmers is a common procedure in many countries to guarantee desirable protein level and grain size. In contrast, higher protein ratio with lysine amino acid is required by feed industry.

1.5.5 Modification capacity:

The grain lots finally should have ready and even modification potential with sufficient enzymes to mobilize the endosperm. This means that the grain has 95% and higher germination capacity and a starchy endosperm.

1.5.6 Microbial infections

Mould, yeast and bacterial infections are main sources of microbial infection. However, the most important one is fungi that their infections generally occur under field conditions. The main fungal species that infect grains in the field are Alternaria spp., Helminthosporium spp., Fusarium spp. and Cladosporium spp. During storage, these tend to decline and are replaced by species of Aspergillus and Penicillium that are able to grow under lower temperature. These fungi cause toxic effects when consumed both human beings and animals. Thus, malt and feed factories prefer to purchase barley grains free from microbial infections. Pest issues are discussed in section 4.

2. Post-Production Operations

2.1 Pre-harvest Operations

After physiological maturity, 10 or 15 days are required to harvest barley with combine in temperate dry lands. If this duration is exceeded, crop will get too dry and then cause shattering at harvest.

Harvesting time should be decided when barley stem becomes dry enough to be broken by hand easily in semi arid and arid areas. In humid regions seed moisture and hardness should be checked before deciding harvest by using teeth or using moisture meter.

In some areas rainfalls may force to postpone the harvest, but harvest before rainfall should be preferred, as seed after drying following rainfall may be discolored. In addition, delayed harvest can lead to yield losses. Klinner and Bigger (1972) found that yield loss of barley increased from 3.5% to 9.5 % as a result of delay in harvest date in the same location but loss increase was very low with wheat crop.

In humid or irrigated areas generally six-row and logging resistant varieties should be chosen. Akar *et al.* (1999) documented that lodging resistant barley cultivars gave 20 to 25% more yield than that of susceptible ones especially in excessive rainy seasons even in dray lands of Turkey (Figure 2.1). Yield and quality reducing economical diseases, pests and weeds should also be controlled either thorough use of resistant cultivars, agronomical procedures or pesticide use. In countries where malting industry is developed as in case of Turkey or malting barley export is common, the varieties should meet the quality requirements for malting.


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Figure 2.1. Barley cultivars resistant and susceptible to lodging

In years or in areas where winter season is mild, barley grows and produces excessive canopy. If spring is rainy, the crop lodges, pests and diseases develop, grains can not mature and consequently the yield drops. The farmers whose crops are in the threat of lodging, cut the crop with machine or scythe for animal feeding. In the Marmara region of Turkey, farmers are hesitant to graze the crop by sheep due to damage caused by animals in rainy seasons. (Gökgöl, 1969).

Barley physiologically matures upon kernel moisture content drops to about 40 %. Harlan (1920) found that translocation to the kernels ceased at a moisture content of 42%. It can be harvested without loss of yield or quality after reaching about 35% kernel moisture but the grain can not be safely stored until the moisture content decreased to 14%, (Baldridge *et al.*, 1985).

In Southeast part of Turkey, some of the agricultural enterprises (13.5 % of total surveyed) graze the barley crop when the vegetation is very low in the pasture areas. Some farmers (23 %) indicate that they graze barley crop early in spring to increase grain yield and 24.5 % of agricultural enterprises graze some portion of their barley acreages.

In North African countries (Algeria, Morocco and Tunisia), tall barley landraces and/or old varieties with long cycle phenology, have been grown. Broadcasting seed and offset disking the seed under in October/ November with 100 to 120 kg/ha seed rates are the practice of the farmers. Farmyard manure is used in livestock oriented farms. Generally, weed and disease control are not performed. Barley is grown as main crop in barley/weedy fallow or barley/cereal rotations. In Egypt, fallow/ barley/ pasture/ pasture cropping sequence was practiced in some areas. In those countries, barley is grown for double purpose: grazing during winter and after winter left for seed production if rainfall is sufficient (Anonymous, MEDRATE (EC-CIHEAM Co-operation project, 1998-2002) Regional Action Program ”Rain fed Agriculture” RAP-RAG Report of the Second Coordination Meeting, unpublished).

Excessive seed use can be considered as a kind of pre harvest loss. In some areas of developing countries, farmers tend to use higher seed rate as tradition or as compensation for winter kill of seedlings in harsh winter conditions. For instance in Turkey, particularly in dry land areas, the amount of seed planted is 30 to 60 % higher than recommended seed rate for barley. Farmers use higher rates to compensate the seedling kill by winter and losses resulting from improper seedbed and seeding method. A survey carried out in 3 main barley producing provinces in Turkey indicated that the seed rates changed from 160 to 362 kg/ha and averaged at 270 kg/ha (Balkan, 1981). Drought is a prevalent and constant threat on barley production in most of the developing countries. It seems that drought stress will be a more important stress in the future as a result of climate changes. The areas that can not be harvested due to drought are 5% of total barley acreage in southeast of Turkey and 34.6 % in Northern Syria (Somel *et al.*, 1984). Crop rotation and soil productivity were reported as the main factors in the variability of barley acreage in the Southeast of Turkey. 39.7 % and 32.2 % of farmers declared rotation and productivity as the main reasons for the change in barley acreage, respectively. Only 5% of farmers declared barley price as he main factor in variability (Somel *et al.*, 1987).

2.2 Harvesting

Depending on social economic situations such as plot size (acreage), altitude and slope, there are a lot of harvest methods in developing countries. Barley crops are harvested by hand tools such as sickle, scythe or just hand pulling, tractor mounted mower (Figure 2.2a) and combine. These methods are prevalent in mountainous areas where land is small and located on the sloping hills and harvesting machine can not access. Farmers on those areas are small scale, resource poor and mainly practicing animal husbandry. Hand pulling is generally employed in very dry years or areas with poor seed and straw yield and high price expectations. Hand harvest can also be adopted even in more humid seasons or flat fields when straw yield is very low, sometimes the hired combine machines cut the straw higher from the ground leaving majority of straw standing in the field. To obtain more straw, farmers, who produce whether livestock or not, harvest the crop near the ground by hand harvest tools as the barley straw is popular for animal feed and compost for mushroom production. The cost of the hand harvest changes from 35 to 60 EUROs per ha depending on demand and supply of labor of locations.

Most of the farmers (90 %) in Southeast of Turkey harvested the barley with combine, 10 % of farmers did harvest by hand. The percentage of hand harvest was 20.3 % in northern Syria. The harvest was made largely with the use of rented combines (94.4 %) and only 4.9 % of farmers used their own machines (Somel *et al.*, 1984).

Combine is available in areas where the main agricultural activity is cereal production (Yurdakul *et al.*, 1987). Combine harvest of barley crop is common in areas where topography is suitable, land size is large and farmers are relatively rich. Poor farmers in other areas generally raise livestock to sustain their lives. In developing countries combine harvesters are hired because most of the farmers can not afford to own combines. The loss in harvest with combines may be more prevalent in dry land areas where the harvest depends on the availability of combine harvester. In Turkey, barley is cropped in less acreage as compared to wheat. Therefore the combine harvesters come to the areas when wheat crops matured enough for harvest. Because the barley matures earlier than wheat, particularly in warm seasons, crops dry up extensively and become vulnerable to shattering loss and also bird damage at harvest. Following such years, barley harvested fields become as if planted due to emergence of shattered seed (Figure 2.2b).

Figure 2.2a. Harvest with a tractor mounted mower

Figure 2.2b. Emergence of seeds shattered during harvest

Speed of combine at harvest is very important in terms of grain loss. Although the speed should be 4 to 6 km/h during harvest it was measured to be 7 - 8 or even 9 km/h in farmer condition (Demirci, 1982). This is because of high demand of combine owners to earn more by harvesting more fields in a given time.

The price of harvesting is set by open market conditions of different part of countries. 20 - 30 USDs is the cost of harvesting one ha of barley or wheat. According to extensive 4 year investigations on the amount of grain losses of barley and wheat crops associated with combine harvest in most of the provinces of Turkey indicated that the loss was reduced to 5.7 % and 4.5 % from 7.5 % during the study years by training of combine drivers. There were no differences between locally made and imported combine machines and combines with different ages. However, reduced loss was observed with drivers who were the owners of the combines as compared to hired drivers (Table 2.2.1)

2.3 Transport

The means of transportation of barley grains to market or to the granaries depend upon farm size, physical and geographical conditions, availability of transportation facilities.
Small size farmers prefer to sell their crop in village. In the southeast of Turkey 9 % of farmers sell the barley crop in village, 26.4 % sell to state agency (TMO) and 13.2 % sells to merchants in local markets. Generally the crops are transported to markets by tractors or trucks. The cost of transportation is about 1.900 TL/ton (1985-1986), (Yurdakul *et al*., 1987).

2.4 Threshing

Threshing with "doven: Wooden threshing sled with flint blades, (Figure 2.4a)" which is driven by animals is not a common practice and particularly employed by small farmers in mountainous areas or in undeveloped areas of developing countries.

Table 2.2.1: Cereal Seed Losses at Harvest in Relation to Driver Training and Age of Combines in Turkey During 1978-1982

Observations	**Investigation years**			
	1978	**1979**	**1981**	**1982**
Number of combines	51	929	2530	2267
No. of trained combine drivers	-	191	796	1024
No. of untrained combine drivers	51	738	1734	1263
Number of provinces involved	4	25	48	37
Grain loss (%)				
Average	7,5	5,7	5,4	4,5
Trained drivers	-	4,7	4,8	3,9
Untrained drivers	7,5	6,0	5,7	4,8
Local made combines	-	5,5	5,4	4,4
Imported combines	-	6,2	5,3	4,6
Combines with 1-5 years old	-	6,4	5,1	4,6
Combines with 6-10 years old	-	5,2	5,3	4,4
Combines with 11-15 years old	-	5,1	5,3	4,8
Combines with >16 years old	-	6,1	5,4	4,1
Drivers (hired)	-	6,5	5,6	4,7
Drivers (owner)	-	5,0	5,2	4,3

Figure 2.4a. Wooden threshing sled with flint blades

For this, a special location is prepared by hardening the soil surface, usually circle of 10-20 m. diameter for every year use. For threshing, the bunches of harvested barley is scattered around this hardened soil and the ‘doven' is pulled by an animal, mostly bulls or horse, over the scattered bunches around the circle. Usually pieces of a large stone of 20-40 kg is placed or even the thresher or his/her children gets on the ‘doven' to increase its weight so that the it creates sufficient pressure on the bunches. As the ‘doven' is pulled over the bunches, the flint blades cut the straw separating the grains from the heads. Then, the mixture of straw and grains is separated through winnowing using wooden pitchfork like shovels.
In more developed parts, engine powered or tractor driven threshing machines (Figure 2.4b) have replaced the old animal driven wooden threshing sleds, before modern combine harvesters came into use. These machines are still in use particularly in mountainous areas in Turkey and other developing countries.

Figure 2.4b. Threshing with a tractor driven threshing machine (Vezirkopru, Samsun, Turkey)

In spite of lacking extensive survey data on the harvest losses during threshing with various equipments, a research in Turkey provided an estimation of such losses. It showed that the rate of broken grains of barley was between 1 - 5 % which is much more than that of wheat. Prior to harvesting with machines, batter and contra-batter of combine should be adjusted so that grains are not injured. Grain injury is worse than broken grains, since the broken grains can be separated during screening unlike the injured grains can not. The economic loss due to broken grains of barley amounted to 10 % of selling price of normal product (Tetik, 1982).

2.5 Drying

As the other grains, barley must be dried before putting in granaries. For this purpose harvested crop is left in open and sunny place for drying near the granary in village conditions. It is aerated by inverting the heap with shovel and covered with a material during the night. Following this process the grains are transported in the granary. On the other hand, the crop harvested with other means (sickle etc.) than combine harvester are made bunches (Figure 2.5a) with their straw and left in he field as groups (called ‘yıgın' or “tokurcun”) (

Figure 2.5b) until the moisture content is reduced to low levels (12-14 %) to be taken for threshing.

Figure 2.5a. Bunches of barley left for drying after harvest

Figure 2.5b. Stacks of barley (yıgın) in field
Vezirkopru, Samsun, Turkey

2.6 Cleaning

Cleaning barley grains is an important process for malt and feeding industries. During the cleaning process of malting barley product in Turkey, separated materials such as stones, earth, weed seeds and broken grains, and amounted to 10 % of total grains (A. Başgül, pers. comm.).

2.7 Storage

Generally barley is stored for a short period under shelter or in depots in order not to be affected by rainfall or other adverse climatic events. In Southeast Anatolia of Turkey 90 - 97.6 % of farmers store barley under shelter (roof shelter), 1.9 - 2.4 % leave the crop outside the closed areas (Yurdakul *et al.*, 1987). Barley is stored either in bags (0- 3.8 % of farmers) or in gross (96.2 -100 %). In northern Syria 90.1 % of farmers keep the crops in closed areas in bags (71.5 % of farmers) or in gross outside (27.8) (Somel *et al.*, 1987). Grains are stored in depots made by brick, cement, and wood or earth wells specially drilled. Storage types are described below.

2.7.1 Adobe depots:

Horizontal type adobe depots are used by rural people as their economic status permits only this type of depots. Some of these depots have ceiling made by tree or plant residue mixed with compacted soil. Outside and sometimes inside walls are filed with adobe. Floors are earth or cement covered by mud with cereal straw mix and white washed. In adobe depots, small amount of barley (5-10 tons) can be stored. Before the crop is put inside the depots, the floor is covered with straw, reed mat or in some cases with plastic cover. Adobe depots are known as unsuitable for storing barley grains.

2.7.2 Cement or pile depots:

The horizontal cement/pile depots are partly suitable for storing barley. These are used by some governmental institutions and farmers who produce relatively more amount of barley than small producers and merchants (Figure 2.7.2a,b). Cement and pile depots have cement floors and brick or stone walls covered with straw mixed with mud. Lime is applied on wall surfaces and roofs are covered with stainless undulated pane or tile. They do not have any aeration mechanism. Windows on opposite walls are situated near the roofs to provide aeration. Barley grain is handled generally by labor.

2.7.3 Wooden depots:

Wooden depots store barley in a good condition for long time and are usable for many years. Wooden depots constructed during Çorum- Çankırı Rural Development Project (FAO) are still functional in Turkey (Figure 2.7.3). They get moisture inside from the top at very low rate or with difficulty, but the walls provide good aeration resulting in cool product in the granary. The wooden granaries are constructed on elevated, easily aerated and southern parts of the farm buildings. One of the important drawbacks of the wooden depots is rodent damage to the crop and wood material. To protect the woods from damage caused by rodents, metal panes with slippery and dented corners are placed inside the wooden granaries. These stores are ideal for barley storage in developing countries if adequate measures are taken to prevent entry of rodents and rain. The second drawback of wooden granaries is the cost. Only rich farmers can afford to install wooden depots.

2.7.4 Vertical wooden depots:

In addition to horizontal ones, these types of storages can also be seen in rural areas. They are constructed under large spaces in houses such as balcony or veranda of double floor village houses. They have top and bottom openings where barley grain circulation can be made (Figure 2.7.4).

b

Figure 2.7.2 a, b. Horizontal cement/pile depot

Figure 2.7.3. Horizontal wooden depot

Figure 2.7.4. Vertical wooden depot

2.7.5 The vertical earth well depots:

They are built in farm buildings and disinfected by lime or heat in areas where the wood materials are expensive and inaccessible. They are in various types. Although the farmers in rural areas generally sell the product immediately after harvest some part of grains are stored for the next season's seed and animal feed. Acting as the rules of free market, the farmers having very large land and no debt either sell the product
or keep it in earth horizontal depots until sell off. On the other hand, farmers who have insufficient acreage of land and insufficient economic power to construct granaries, dig earth wells to store the grains in areas where the direction is northern and water table is below 5-6 m. If well granaries are constructed so that water entrance from the bottom and sides is prevented, they are suitable for safely storing of dry and clean product after harvest for a long period. Some farmers place the cereal straw in the bottom of the well before placement of grains. After removal of the grains the straw is burnt prior to storage of next load of grains.To some extend, this practice removes the moisture of the well and helps to disinfect the pests and fungi in the well. Before the grain is put inside, new cereal straw is spread on the bottom of the well at 20-30 cm thickness. Then, some amount of grain is put and side walls of the well is covered with cereal straw at the same height as the grain load. Then the grain is put again and side walls are covered with straw. The well is filled up this way and the top of the well is covered tightly with a mixture of various materials (cereal straw+ fine soil+ mud +stone etc.). In order to check the stored grains in the well, an iron rod is pushed into the grains along the well and in the next day it is checked by hand whether it is warmed or not. If

the rod is warmed, it is understood that the product in the well has a storage problem. There are different kinds of applications of the storage method in various countries.
According to Donahaye *et al.* (1995) fifty tons of locally grown barley were stored in an underground pit hermetically sealed inside a polyethylene liner at Kibbutz Lahav. Gas measurements and observations showed that a satisfactory hermetic seal was obtained within the liner after seven weeks of storage (1.0-32 per cent O_2). However, the efficiency of the seal was reduced by the gnawing activity of rodents which damaged the liner, and this appears to be a limiting factor for this type of storage. Changes in moisture content and in germination power were minimal during the storage period. Marked seasonal temperature changes were only recorded at the periphery of the grain bulk, while at the center the temperature remained stable. Barley grains which was removed after 15 months of storage, during nine of which the liner was sealed, was clean, of natural brightness and color, of low moisture content, and uninfected.

2.7.6 Modern Silos:

A lot of feed and malt companies store their raw material to be processed during the year in big silos made of concrete (Figure 2.7.6a) or steel (2.7.6b) immediately after barley harvest in Turkey. In addition to these, Soil Product Office (TMO), a governmental organization and monopoly on cereal long term storage in Turkey, stores the barley in big silos by modern methods across the country. Its storage capacity is almost 5 million tons and 10 to 50 % of this capacity has been allocated for long term barley storage during the last thirty years (B. Baran, 2003, per. com.)
In Turkey, barley grain is also stored as heap in open areas and in closed vertical and horizontal depots and the tops of the heaps are leveled (Esin, 1990). They are as follows:

2.7.6.1 Modern open heap depot units:

There are two types of this storage systems; oval and circular, respectively. The former is loaded with transposable machines while the latter is loaded with constant ones. In Turkey, capacity of oval units changes from 2.5 tones to 5 tones whereas that of circular units starts from 10 tones (Figure 2.7.6.1).

Figure 2.7.6a. Concrete depot

Figure 2.7.6b. Steel depot

Figure 2.7.6.1.Circular heap depot

2.7.6.2 Polyethylene and earth covered heaps:

The system invented by old Anatolian civilizations was developed by TMO and commonly used by the governmental organization throughout Turkey when especially its modern storage capacity is not enough to store enormous amount of barley and wheat and some food legumes grains. It is the first model of hermetic storage system in the world and has been used by TMO during the last sixteen years. Selecting of sandy soils and 5 to 10 % of sloppy zones are two important prerequisites to safely store barley and wheat grains for short and long term storage. Two layers PVC are set on the soil and barley grains are filled in the PVC then grains are covered by PVC over liners and the heaps created with 2 m height are re-covered with 5 to 10 cm soil layer (Figure 2.7.6.2 a,b,c). Long term yield losses in this hermetic storage system in TMO conditions are 0.5 to 1% throughout Turkey (B. Baran, 2003, pers. com.).

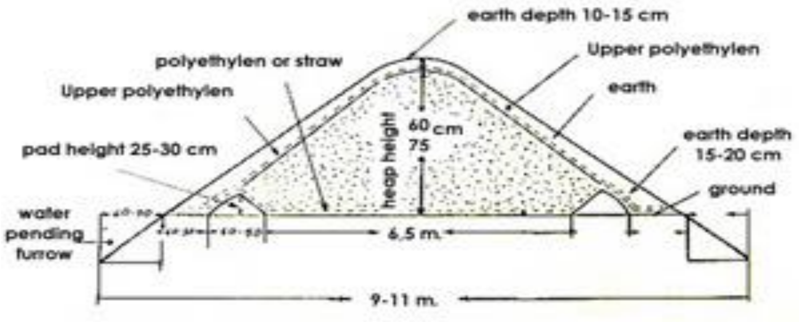

Figure 2.7.6.2a. Diagram of an earth covered heap


b


c

Figure 2.7.6.2b,c. Earth and polythene covered heaps

2.7.6.3 Oilcloth covered heaps:

This storage system is completely the same polyethylene and earth covered heaps excluding coverage material. In this type of storage, oil clothed material is used instead of PVC (Figure, 2.7.6.3).

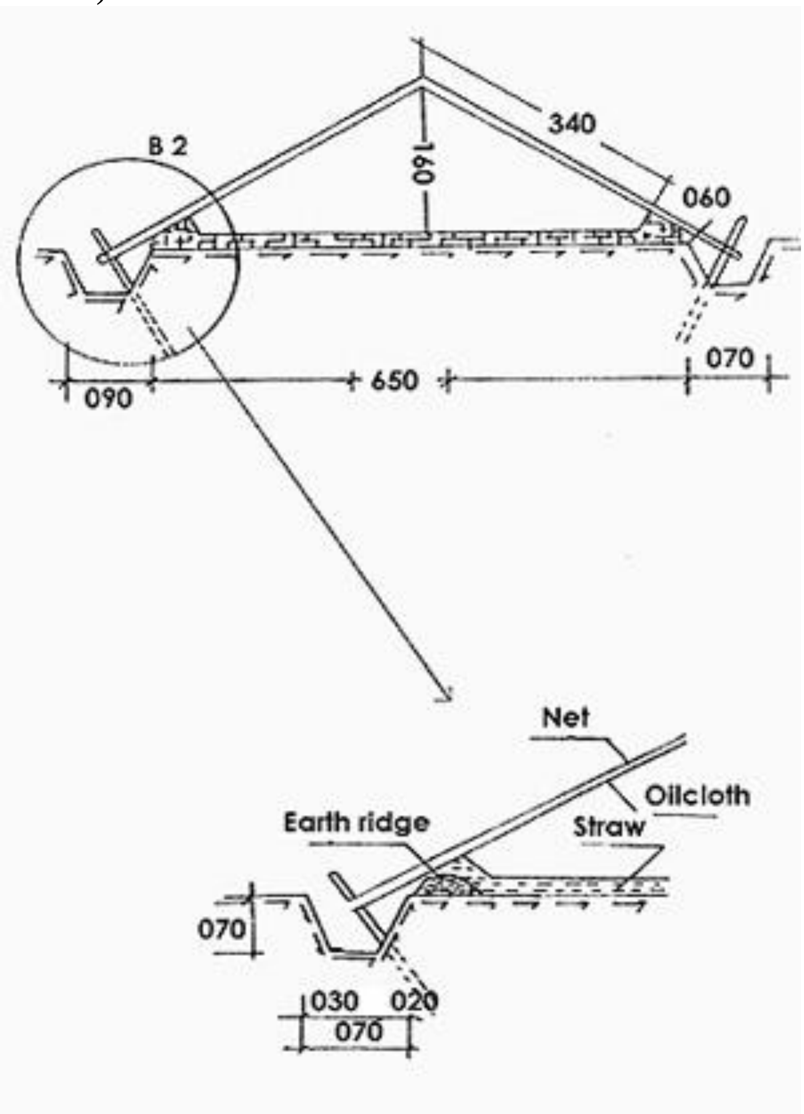

Figure 2.7.6.3. Vertical cross section of heap with oilcloth surrounded by earth pad

2.7.6.4 Low stone walls covered PVC:

This is another sound example for hermetic storage method. In this system; floor is cemented with low walls made of stone or brick. Then polyethylene is laid on the floor and barley grains are filled and then covered with PVC. Varnava *et al*. (1995) examined the method under Mediterranean conditions with small modifications. A large (75 x 25m) concrete platform with low walls was filled with barley and covered with a PVC over liner and a polyethylene under liner. The barley formed a pile of 4,018 tones with a peak of 7 m high and was stored for 34 months under hermetic seal. Periodic monitoring was carried out to determine temperature fluctuations, inter granular gas composition, insect infestation, and grain quality parameters. Ambient temperatures were shown to create temperature gradients in the upper layers, and moisture migration occurred towards the peak of the grain bulk. However, the resulting spoilage by moulds was limited to 0.22% weight loss on an annual basis. An additional 0.12% loss due to insect damage, and spillage resulted in an annual storage loss of 0.34%. Possible solutions to this problem were discussed. The platform successfully protected the grain against insect, bird, and rodent attack and provided safe storage during the rainy season. At the end of storage, the PVC over liner which had been used continuously since 1988 remained with low gas-permeability, retained its mechanical characteristics and was suitable for reuse.

2.8 Gender participation and post harvest operations

The operations during and after harvest requires more labor than the pre harvest procedures. The gender participation operations seem to depend on the level of overall development and mechanization. In very rural areas the harvest and post harvest operations are based on the working of all family members, man and women, in most cases including the children as well. This is because the harvest is done by hand using physical instruments such as sickle, scythe, hand pulling or tractor mounted mower and requires a lot of labor. The families can not afford hiring labor and therefore all members participate in harvest. Similarly, threshing is also based on participation of both females and males. In such areas females participate by actively doing the harvest job or threshing as well as preparing the food for the members in the field. However, in more developed areas where operations are more mechanized the involvement of women is decreased. The operators of the harvest machines, threshers or combiners are mostly males and in most cases women may participate in supply of food in the field.

3. Overall Losses

Durable foodstuffs with low moisture content form the basis of most human diets precisely because these commodities can be stored for extended periods and are continuously available, provided that there is no insect infestation or spoilage. However, losses occur at every stage of grain handling, storage and processing. These losses may be either quantitative or qualitative. The magnitude of losses is highly variable and in certain cases they may even reach 100%. Qualitative losses are more difficult to evaluate then quantitative ones. Qualitative losses for example, may consist of changes in the physical appearance, nutritional degradation, loss of germination, presence of fragments and insect infestation, contamination by mould or development of mycotoxins. Some of them are difficult to detect visually (Navarro, 1997).

Overall losses of cereals including barley, wheat, maize and rice can be investigated under two important stages, pre and post harvest losses. The first stage consists of pre harvest losses resulting from weeds, insect pests and diseases and is estimated to be approximately 35% of total cereal harvest production (Schildbach, 1989). If appropriate techniques can be developed and applied to avoid such losses, world cereal production can be increased by 1/3 or higher.

The post harvest losses may result from inappropriate procedures during and after harvest and unsuitable storage conditions such as unbalanced humidity, temperature and O2 /CO2 levels which allow infestation of the stored grains by microorganisms, insect pests and rodents. Post harvest losses of cereals in the developing countries conservatively estimated by FAO's Special Action Program as %10-15 during 1980s (Navarro, 1997). In rural areas of developing countries, traditional storage systems are very common and due to very low socio-economic situation, new technologies cannot be easily introduced to these conditions. Navarro *et al*. (1998) clearly reported that, annual losses of 5-10% at village level mainly caused by rodents and insect pests are usually considered as inevitable. In Turkey, as in other developing countries, the cereals are stored in farmer granaries generally in unsuitable conditions and the storage loss varies from 5 to 10 % (TMO report, 1981).

4. Pests Control

Barley is a host for numerous pathogens and insect pests attacking the plant at different stages of growth. The attacks at different stages would have various consequences on productivity but the degree of their impact on quantity and quality of the post harvest products may vary according to production, environment, crop husbandry and post harvest procedures. The biological factors affecting the stored grains are illustrated in the Fig. 4.1.

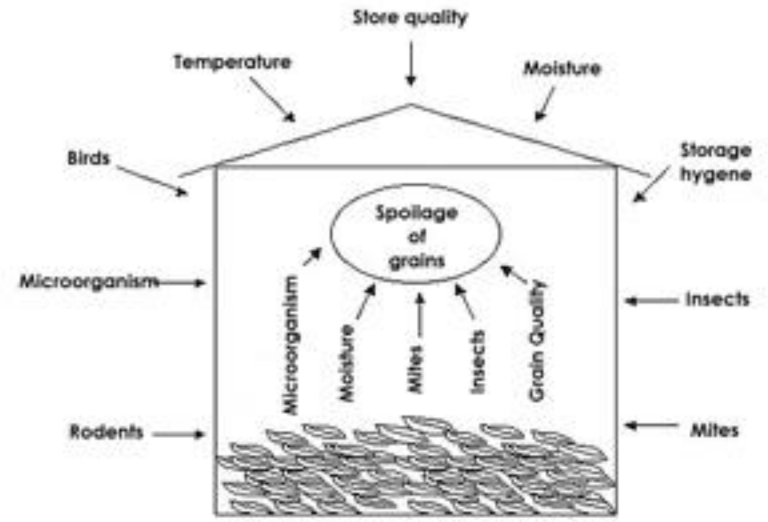

Figure 4.1. External and internal factors affecting storage quality of barley grains

The storage microorganisms and pests cause economical losses in stored grains in many parts of the world. The loss is higher especially in developing countries because the grain storage structures do not have adequate conservation properties. The post harvest loss of 5-10% for grains is usually considered inevitable at the village level in developing countries (Navarro *et al.*, 1997) but this is likely to be higher for barley in rural areas of many developing countries.

4.1 Post harvest microorganisms

4.1.1 Field diseases with effect on post harvest procedures

Undoubtedly, the infection / infestation of harvested or stored grains by pathogens, saprophytes and insect pests directly reduce the quantity and quality of the grains. Occurrence of pests and diseases at vegetative stage and near the harvest time is, also important factors reducing the quantity and quality of the products. Although agents that attack the crop at earlier stages appear as less significant for the post harvest operations, they can reduce the quantity and quality of the products significantly under suitable conditions. For example, species of fungi producing mycotoxins and sunny bug injecting various enzymes could play very substantial role in quality of the stored grain. Thus, these agents and their relation with post harvest procedures are also described briefly.

The importance of field diseases is various parts of the world are depicted in Table 4.1.1. As seen in the table, diseases caused by *Helminthosporium* species seem to be the most widely occurring diseases. The common root rots, spot blotch and the seed borne leaf stripe are treated in this group. The smuts seem to be ranking 4th in general following scald and yellow rust.

4.1.1.1 Root and foot rots:

The root and foot rots reduce the yield and quality of the barley crop through reducing tillering and amount and weight of the grains. These are caused by mainly soil borne pathogens, but some may also be transmitted through the seeds. Among the root infecting pathogens, *Helminthosporium sativum* is the most widely occurring species. The *Fusarium* species *F. culmorum*, *F. graminearum* and *F. nivale* can also infect the crowns and some even infect the leaves and heads later.

4.1.1.2 Foliar diseases:

There are a number of microbial agents causing different kinds of blotches and lesions on leaves of barley. Symptoms may be in the forms of spots, lesions, stripes or blotches. The most widely occurring fungal foliar diseases are scald (*R. secalis*), spot blotch (*Helminthosporium sativum*), Powdery mildew (*Erysiphe graminis*), Rusts (*Puccinia* spp.) and the barley leaf stripe (*Pyrenophora graminea*). The common characteristics of these symptoms are that they reduce the photosynthesis area. Often diseased plants have less ears and smaller and lighter grains.

Among the foliar diseases, the most important one is *P. graminea* (Fig. 4.1.1.2) which is wide spread disease in Mediterranean region including Morocco (Boulif, M., 1990; Lyamani, 1990; Arifi, 1990), Turkey (Cetin *et al.*, 1995) and is also recorded in Korea (Lee, 1981). The disease is seed borne and infects the plant during germination process and develops systemically within the plant. The first symptoms appear at the seedling stage as pale, white stripes along the main leaf axil. This stripe develops and becomes easily visible and extended as the plant grows and finally leaves may be thorn apart as a result. Infected plants are stunted and produce no or few heads and the heads would have shriveled grains. Under moist conditions, sporulation takes place on the leaves and spores are spread by the wind to the ears of heads where the spores infect the floral parts which produce infected seeds. Infection of the floral parts is favored by cool and humid conditions. The infected seeds have to be treated with seed treatments if it is to be used as seeds.

Table 4.1.1: The Ranking of Importance of Main Pre-harvest Diseases of Barley in Different Parts of the World [1]

Region	Stem rust	Yellow rust	Leaf rust	Powdery mildew	Helm. spp.*2	Scald	Smuts
Middle east	6	3	5	1	2	5	4
South and Far East	5	1	6	3	2	7	4
North Africa	7	5	4	3	1	6	2
East Africa	7	4	3	5	2	1	5
Mediterranean Europe	7	3	6	2	1	5	4
South & Far east Asia	6	1	5	3	2	7	4

(1) Adapted from Srivastava (1977) and Kamel (1981); *2: *Helminthosporium* spp.

Figure 4.1.1.2. Severe infection of barley leaf stripe (*Pyrenophora graminea*)

4.1.2 Ear diseases

The smuts (*Ustilago* spp.) directly affect the yield and quality of the grains. This is because they replace the grains with their dark spore masses (Fig. 4.1.2 a, b). Three types of smuts may occur in barleys; loose smut, semi covered smut and covered smut. Their symptoms are similar and all produce dark spore masses in the place of grains in the ears and no grain is harvested from such plants. Their symptomatic differences are related to appearance of the spore balls. In loose smut (*U. nuda*), the seed coat is totally destroyed and spores can be freely flown away by the wind and only the axil of the heads may remain on the plant. In *U. nigra*,

Figure 4.1.2a. Covered smut of barley (*Ustilago hordei*)

Figure 4.1.2b. Loose smut of barley (*Ustilago nuda)*

the seed coat remains relatively intact and spore balls remain on the heads until late. However, towards the maturity the seed coat may be thorn apart and spores can be spread by the wind. In contrast, the seed coat of *U. hordei* is the strongest among the three smut species and remains intact until the harvest time. These structures are broken apart during harvest and spores are attached onto the clean seeds. The transmission of these three smut species is through infected or contaminated seeds. Loose smut spores infect the floral structures and as a result the fungus settles in the embryo of the floret. In contrast, the spores of *U. nigra* and *U. hordei* are carried on the seed coats to the next season. These spores infect the seedlings during germination and the fungus develops systemically up to the heads where they produce the spore balls in the place of grains. Apart from the smuts, *Claviceps purpurea* can also occur on barley heads as hard black horn like structures in the place of grains, if care is not taken.

The use of clean seeds or seed treatment is the most feasible means of control of the smuts. However despite this possibility, the smuts cause still significant yield losses in many developing countries, since seed treatment is not practiced properly. There are various reports indicating different levels of losses in various countries, resulting from the smuts. These are for *U. nuda* in Iraq (Hamdany *et al.*, 1990), for *U. hordei* and *U. nuda* in Morocco (Lyamani, 1990), in India (Atyheya *et al*., 1981) and in Tunisia (El Ahmed *et al*., 1981) and for the three species of *U.hordei*, *U.nigra* and *U. nuda* in Turkey (Öğüt & Onan, 1995) and in Jordan (Mamluk, 1981).

4.1.3 Grain infecting field microorganisms

Many fungal species may be found in barley grains, but usually many of them would be unimportant. For example, Aktas (1999) have reported 23 fungal species in the barley grain flora in Eskisehir, Turkey and found the *Alternaria alternata* most frequently occurring species, but reported that the rest was at very low level of contamination levels, apart from *U. nuda* which was found in 44% of the 199 samples.

The main fungi infecting the heads and seeds of barley in the field belong to the genus *Fusarium.* The species infecting the barley heads include *F. graminearum, F. poae, F. avenaceum, F. sporotrichoides* (Salas *et al*., 1997), *F. culmorum, F. moniliforme and F.nivale* (Richardson, 1979).

The *Fusarium* species infect the grains and heads of barley in warm and humid areas especially if the wet and rainy periods coincide with the crop maturity. The occurrence of head blights have been stated in North West of Russia (Schipilova & Gagkaeva, 2000), in India (Paramjit *et al.*, 2000), in Mexico (Gilchrist *et al.*, 2000) and in Poland (Wisniewska *et al.*, 1997). Those that have been reported to occur on barley seeds by Richardson (1979) include *Fusarium culmorum, F. graminearum, F. moniliforme, F. nivale* and *F. poae.* These species can also be involved in formation of leaf blotches and root/foot rots (Figure 4.1.3). Apart from *Fusarium* spp., the species of *Alternaria*, *Cladosporium* and *Dreschlera* can infect the grains especially on the embryo side before harvest causing black points. These are common fungi that can be found world wide, but their frequency and severity may differ according to conditions. All grain infecting fungi reduce the quality of grains and could be the main cause of spoilage. They not only reduce the quality of grains, but also the toxins produced by some of the species may cause health concerns for livestock and men. The grains infected by such species are also more vulnerable to storage fungi such as *Penicillium* spp. and *Aspergillus* spp. Classification of the genera *Fusarium, Alternaria, Helminthosporium, Penicillium,* and *Aspergillus* which are the main post harvest micro organisms is illustrated in the Table 4.1.3.

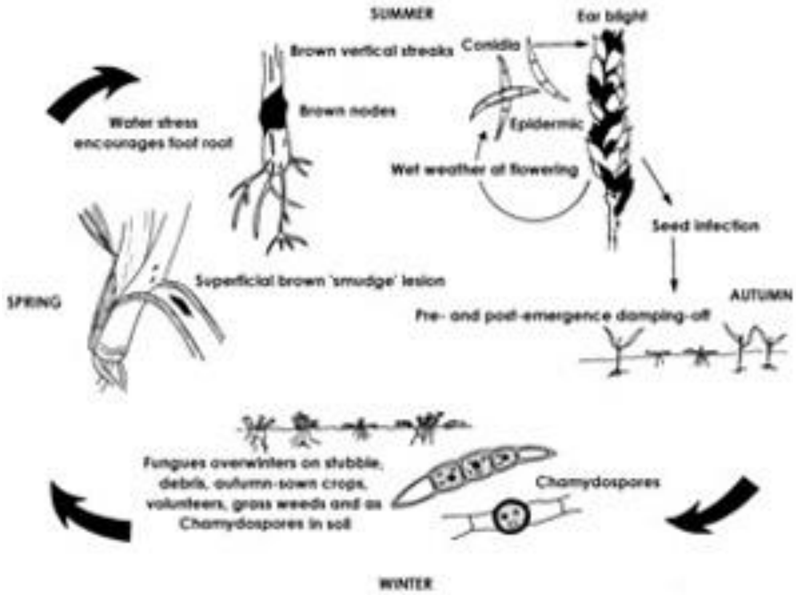

Figure 4.1.3. Life cycle of Fusarium species (Parry, 1990)

Table 4.1.3: Classification of the Most Important Genera of Fungi Associated with Infection and Spoilage on Barley Grains (Kingdom:Mycota, Division:Eumycota)

Division	**Sub-division**	**Class**	**Family**	**Genus**
Eumycota				
	Ascomycotina	Plectomycetes	Euroticeae	*Aspergillus*
				Penicillium
	Basidiomycotina	Teliomycetes	Ustilaginales	*Ustilago*
	Deuteromycotina	Hyphomycetes	Helminthosporiaceae	*Helminthosporium*
				Alternaria
	Deuteromycotina	Hyphomycetes	Tuberculariaceae	*Fusarium*

4.1.4 Storage microorganisms

Stored barley grains are subjected to infection by many species of micro organisms. Although there are a few species of bacteria and yeasts that can infect the stored barley grains, the main storage microorganisms are species of fungi.

The most important fungal species causing spoilage of barley in storage belong to the genus of *Aspergillus* and *Penicillium*. In general *Aspergillus* species can be adapted to conditions without free water and can grow at lower humidity R.H.70% (Dube, 1990) whereas *Penicillium* species are abundant mainly in grains with high moisture content stored at lower temperatures. Similar to *Penicillium* spp., species of *Rhizopus*, *Mucor* and *Nigrospora* can also invade the high moisture grains before or during the storage (Sauer *et al.*, 1992). There are many other less important species of fungi that can be isolated from barley grains stored under unfavorable conditions. For example Lacey (1988) isolated 65 different species of fungi from wheat and barley grains stored in underground pits or in buildings in Iran. However, only the species of *Aspergillus*, *Penicillium* and *Alternaria* were indicated to be significant.

The means and time of invasion of the grains by storage fungi are significant for the establishment of management strategies. In general, it is considered that the wet weather conditions near the harvest time would favor invasion of grains by storage fungi. However, Tuite & Christensen (1955) found no storage fungi growing from the surface sterilized barley seeds collected from barley fields of Minnesota in a wet and showery season. Sauer (1992) reviewed the studies on time of invasion of grains by storage fungi and indicated that the fungi causing damage to grains in storage do not invade the grains to any significant degree or extent before harvest. Therefore it may be concluded that the storage fungi contaminate the grains during or after harvest, as the conidia of *Aspergillus* and *Penicillium* species are present in the air. Here, the procedures and conditions during harvest, transportation and storage determine the extent of the invasion of grains by storage fungi.

Aspergillus and *Penicillium* species may be seen world wide, but *Aspergillus* spp. (Figure 4.1.4 a) is more of a problem in tropical countries while *Penicillium* spp. (Figure 4.1.4 b) species are more abundant in tropical countries (Dube, 1980). However, their occurrence on barley grains is not limited to geographical regions and they occur in all parts of the world providing the favorable storage conditions. The limiting factors for their occurrence and severity are mainly crop husbandry practices, quality and moisture of grains and characteristics of storage facilities.

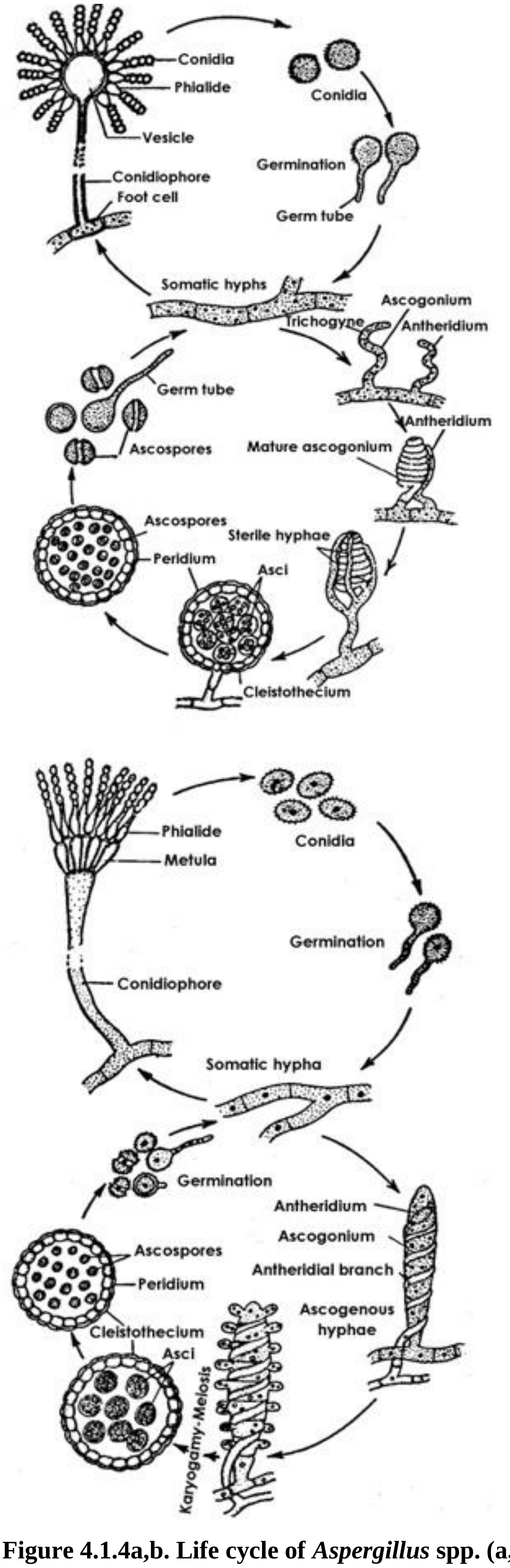

Figure 4.1.4a,b. Life cycle of *Aspergillus* spp. (a,top) and *Penicillium* spp. (b, bottom) (Dube, 1990).

In developing countries, majority of the farmers lack the essential knowledge of good crop husbandry practices and much improvement is needed for availability and use of improved cultivars, field levelling and control of weeds, diseases and pests. Improper and inadequate crop husbandry practices result in production of low quality grains such as shriveled, smaller and broken grains. Although most farmers tend to wait until the crop is dry enough for harvest, they can not avoid adverse weather conditions such as rain during harvest time and threshing. Such grains are more vulnerable to invasion by storage fungi. All these factors help multiplication of storage fungi and increase the risk of spoilage.

In addition to crop husbandry practices and crop quality, the type, quality and conditions of the storage facilities are the major factor determining the occurrence and severity of the storage microorganisms on barley grains. Apart from the large scale professional barley producers and traders, majority of farmers in developing countries do not even have storage facilities. The small scale farmers store the grains mostly in sacks or as bulks in buildings made up of wood or bricks but with no control facilities. The larger farmers can store the bulk grains in underground or above ground pits, usually with a polyethylene liner and covered with polyethylene sheets and other coverings. Here, lack of atmosphere control facilities is the key factor which promotes development of storage fungi on the grain. In such storage facilities, it is impossible to keep the grain at a suitable temperature and dry enough to prevent the growth of storage fungi. As a result, the storage fungi develops steadily on grains using the available moisture deteriorating the grains. During growth, fungi increase the respiration and heating of the grains (Sauer *et al.*, 1992). The grains invaded by the storage fungi loose their germination capacity and its normal color and may be decayed totally depending on the extent of the growth of fungi.

The genera of *Aspergillus* and *Penicillium* are taxonomically placed in the Euroticeae family of the class Plectomycetes in Ascomycotina subdivision of Eumycota division in the fungal kingdom. Since sexual stages of some of the species are identified, the genera of *Aspergillus* and *Penicillium* are studied in the sub division of ascomycotina. However they extensively reproduce asexually through conidia and in fact, in many species sexual stage is absent or unidentified. They over winter as mycelia or conidia, but the species with asexual stages can also use the cleistothocia which contain the asci carrying the sexual ascospores as over wintering organ. The conidia are produced on conidiophores which are produced on the foot cells of the somatic hyphae which is hyaline, septate. The hypha is branched and multinucleate in *Aspergillus* (Fig. 4.1.4a) while it is highly branched and uninucleate in *Pencillium* (Fig. 4.1.4b). The color of the conidia such as blue, green, black or yellow gives the colony color and is a useful tool for the identification of species. The conidia resemble the glass beads and are produced as chains on phialide which is produced by metula on vesicle at the end of the conidiophores. The number and shapes of these reproduction structures are the major differences between the species of *Aspergillus* and *Penicillium*.

4.1.5 Mycotoxins in barley grains

The most important biological risk factor in the barley grains is the mycotoxins produced by various fungi that invade barley grains before or during storage. These fungi can be grouped in two groups. Some fungal species infecting the grains before harvest may produce mycotoxins in barley grains. These include the species of *Claviceps* spp. and *Fusarium* spp. The second group includes the storage fungi *Aspergillus* spp. and *Penicillium* spp.

The most known field infecting toxigenic fungus is the ergot *Claviceps purpuea* (Fr.) Tul. It may infect 38 gramineaceous species including barley Jones & Clifford, 1978). The fungus infects the florets during anthesis and sclerotia (known as ergot) is formed in place of the grains and these contain various alkaloids which may be hazardous to animals and humans. The fungus is more common in grass species and less frequent in barley (Gair *et al.,* 1987)

but it has been reported from India (Richardson, 1979). During harvest and threshing, the ergots formed in heads of barley or grasses in the field are mixed with the harvested grain trough breakage. The ergotism in livestock results from grazing eating diseased grains in pastures but it may also result from eating stored barley grains containing ergots.
There are a number of *Fusarium* species that can produce mycotoxins. Those that have been reported to occur on barley seeds by Richardson (1979) include *Fusarium culmorum, F. graminearum, F. moniliforme, F. nivale and F. poae.* These species can also be involved in formation of leaf blotches and root/foot rots. The *Fusarium* species have been shown to produce various mycotoxins such as Trichothecenes, zearalenone (ZEN), moniliformin, fumonosins and fusarins (Wilson & Abramson, 1992). So far, more than 70 individual trichothecenes have been identified but only the deoxynivalenol (Vomitoxin-DON) and nivalenol have been found to have significance on naturally infected commodities (Shepherd & Gilbert, 1986). Salas *et al.* (1997) reported that some toxins are specific for some *Fusarium* species. In his study barley infecting *Fusarium* species produced 10 different mycotoxins and DON and 15-DON was specific for *F. graminearum*, T-2, HT-2 and T-2 TET for *Fusarium sporotrichioides* and presence of NIV somewhat specific for *F. poae*.
In general, infection of the seeds by *Fusarium* species is favored by humid and rainy periods at generative periods.
Further fungal growth is promoted by moist storage conditions. However, if the grain is dried, the growth of the grain micro flora would be retarded.
Apart from the *Fusarium* species the storage fungi *Aspergillus* and *Penicillium* species are also responsible for production of a number of mycotoxins in storage. Wilson & Abramson (1992) reported production of 17 different mycotoxins or potential mycotoxins by *Aspergillus* species and 14 by *Penicillium* species, some being produced by both. The most well known mycotoxins produced by *Aspergillus* species are aflatoxins and those produced by *Penicillium* species are naphthoquinones. The general mycotoxin problems in stored grains are reviewed by Wilson & Abramson (1992), *Fusarium* mycotoxins by Shepherd & Gilbert (1986) and mycotoxins of mould species in cereal grains and animal feedstuffs by Buckle, A.E. (1986), Scudamore *et al.* (1986) and Paterson & Kozakiewicz (1997).
Although the mycotoxins are identified academically, there are few documents, most being in developed countries, indicating the extent of the toxicological problems in practice. Gilbert *et al.*(1983) found deoxynivalenol (Vomitoxin-DON) at insignificant concentration levels (<0.02 mg/kg) in feeding and malting barleys in England and Scotland. Similarly, the ADAS microbiologists found Ochratoxin A, Sterigmatocystin and citrinin in only 6, 3, and 1 barley samples respectively in 108 barley stores in England and Wales (Buckle, 1986).
However, the severity of occurrence of mycotoxin on livestocks was considered to be insignificant. In contrast, Ehling *et al.* (1997) indicated that WHO (1993) reported a relatively high mean DON concentration in food/feeds in South America, Africa and Southern China, the individual results varied considerably between 0.01 - 92 ppm. Scudamore *et al.* (1986) summarized the reports of outbreaks of mycotoxic porcine nephropathy linked with the ochratoxin A in feedstuff in livestock in a number of European countries including Denmark, Sweden, Netherlands, Hungary and Yugoslavia. The extent of Mycotoxin problem has been investigated in a number of developing countries by various workers. Lacey (1988) surveyed the wheat and barley stores in high oesophageal cancer area of Iran for toxigenic fungi and mycotoxins to study the linkage between the grain microflora and cancer incidence. The study concluded that despite the poor storage facilities, serious deterioration of the grains and detection of aflatoxins and ochratoxins, the cancer incidence and severity could not be linked with the mycoflora and mycotoxins of the wheat and barley grains in the area. However, it is clear that the storage facilities in the area need to be improved significantly to ensure better preservation of the quality of the grains. Similarly, Karacan *et al.* (2000) surveyed the grains

from the regions of Marmara, Aegea, Black Sea, Mediterranean, Central Anatolia and Southeast Anatolia for microbial flora and mycotoxins such as aflatoxin, Ochratoxin A, DON, ZEN, T-2, HT-2 and tenuazonic acid. They found that the predominant fungi in black point formations were *Alternaria sp., Penicillium* spp. *and Aspergillus* spp. and the toxin concentrations were at ignorable levels. However, Gagkaeva and Levitin (1997) detected high level of toxigenic potential in *F. graminearum* Schwabe populations from wheat and high level mycotoxin contamination risk in the grains in South European part of Russia, although there was no such record for the far east parts. Bacha *et al.* (1988) indicated that mycotoxins are involved in the death of many cattle, horses and poultry died in Tunisia in 1970s and studied the mycotoxins of Tunisian cereals in 1988. The conclusion was that the Aflatoxins B1, B2, G1 and G2 all produced by *Aspergillus flavus* Link were detected especially in humid areas. Citrinin was encountered only in stores with hygene problems and ochratoxin A was absent in locally produced cereals.

4.2 Post harvest pests

Barley is a host for more than 100 species of insect pests. Various groups of insect pests attack the barley crop at different stages, reducing the yield and quality. The feeding of insects on barley crops results in loss of yields or grain quality. Yield loss usually occur through killing of plants or reduction in number of tillers, heads or grains as a result of feeding, injection of various toxins or acting as vectors for various microbial disease agents like barley Yellow Dwarf Virus (BYDV). The loss of grain quality occurs through shriveling, reduced weight and biochemical changes in the grains. Especially the effects of insects on grain quality have much relation with the post harvest operations. The shriveled and low quality grains are more vulnerable the spoilage by the storage microorganisms and storage insects. The low quality grains are broken apart more easily during harvest and threshing and provide better nutrition for the storage microorganisms and insect pests. Therefore, the insects infesting the crop in the field would also have a significant effect on deterioration of the grains in storage.

Many of the insect pests of barley are polyphagous feeding also on other cereals and grass weeds. No barley crop would be free from the insect pests, but just a few of the insects become key pests causing significant losses in various parts of the world. Majority of the pests have secondary importance and they cause economical losses occasionally only if the agro ecological conditions become suitable.

The insect pests of barley may be studied in 6 different groups considering their feeding habits and the type of damage they cause: 1) Soil borne insects; 2) Sap feeding insects; 3) Chewing insects; 4) Borers; 5) Storage pests; 6) Nematodes 7) Moluscae, Rodents and Birds. The insect pests of barley, infesting the crop in field are reviewed by Starks & Webster (1985) and Gair *et al.* (1987) and those in stored cereals are reviewed by Wilkin & Hurlock (1986).

4.2.1 Preharvest insects

4.2.1.1 Soil insects:

This group of insects mostly cause damage to the underground parts of the plants. The most important insects in this group include wire worms and false wire worms, the common species being *Agriotes lineatus, A. mancus, A. obscura, A. sputator, Athous haemorhoidalis* and *Ctenicera* spp. The adults of these insects feed on maturing cereals and grasses including barley, but the major damage are caused by the larvae which passes through the summers and winters deeper in the soil. As a consequence of larval feeding, the plants are totally killed or the established tillers produce shriveled grains. In addition to wire worms, there are a number of other species feeding on underground parts of barley. Among these, the white grubs in the genus *Phyllophaga*, many ants (formicididae), webworms (*Crambus* spp.) and Billbugs (*Sphenophorus* spp.) were reported to feed on underground parts of barleys in North America (Starks & Webster, 1985). Briggs (1978) reported that the larvae of Crane flies caused about 0.2% loss in barleys of Great Britain.

4.2.1.2 Sap feeding insects:

This group of insects includes mostly the arthropods which feed on leaves and stems. During feeding they may inject various toxins and transmit various diseases. They multiply rapidly giving 10 generations in a season. The aphids are in this category. Although the predominant species may vary from country to country, the aphids occur in all continents (Vickerman and Wratten, 1979). The English grain aphid (*Sitobion avenae* (Fabricius)) infects other cereals, transmits BYDV and is a pest of barley in Europe, Asia as well as North and South America. Among the aphids, the Russian wheat aphid (*Diuraphis noxia*) is the most known cereal aphid and reported to occur in wide range of geography including North America, Latin America, South Africa, North Africa, Central and West Asia (Elmalı, 1999). They are small and have soft bodies with various colors such as whitish gray, green and black and sucking mouthparts. They over winter on weeds and infest almost all species of graminea. They suck the nutrients from the green parts of the plants, inject various toxins and also transmit important cereal diseases such as Barley Yellow Dwarf Virus (BYDV) and as a result reduce tillering and grain quality. The extent of damage varies depending on the species, population density and time of infestation. Total devastation of cereal crops in Konya province, Turkey due to Russian wheat aphid is reported (Elmalı, 1999). The control measures include development and use of resistant cultivars Starks and Webster (1985), early sowing, removal of alternative hosts and insecticide sprays. Other sap feeding insects include Chinch bug (*Blissus leucupterus* (Say)), leafhoppers (Family Cicadellidae), planthoppers (Fulgoridae) and mites such as *Aceria* spp., *Petrobia* spp., *Penthaleus* spp. *and Oligonychus* spp. Some mite species can also be found in cereal stores. For example, flour mite (*Acarus siro*) can feed on broken pieces of grains in cereal stores.

Among the sap feeding insects in developing countries include the sunny pest and cereal bugs. The most known species are *Eurygaster integriceps* and *Aelia rostrata* respectively. Various species can also be present in different countries. These include *E. Maura, E. Austrica, A. acuminata, A. syriaca, A. furcula, A. melanota, A. turanica, A. virgata, A. albovittata and A. sibirica.* The sunny pest and cereal bug species over winter in high forestry areas and move to cereal fields including barleys in the spring. The nimphs and adults suck the vegetative parts starting from seedling stage causing drying out of plants, reduced tillering and white heads. Later in the season the nymphs and adults feed on the maturing grains causing production of empty or shriveled grains. The infested grains loose their quality as a result of shriveling and also due to the enzymes injected. Such grains would also act as a host for the spoilage microorganisms and storage insects. The grains that have 2% or more sucked grains are considered to be of low quality. The sunny pests and cereal bugs are among the most serious insect pests of cereals in many countries in Asia, Africa and Eastern Europe and cause significant economical losses. In Turkey alone approximately 12 million USD is spent for the control of these insects and despite this, significant damage still occurs. They are predominant pests in West Asia and North Africa. Individual reports of importance have been made for Iran (Anonymous, 1967) and Turkey (Ozkan *et al.*, 1999). Control of these insects is very difficult and requires integrated approach such as development and protection of biological control agents, establishment of green belts, use of efficient fungicide applications and improvement of tolerant/resistant cultivars.

4.2.1.3 Chewing insects:

The most important species of insects with chewing mouth parts is the Cereal leaf beetle (*Oulema melanopus* L.) which feeds on the epidermis opening narrow channels, consequently reducing the photosynthesis area and reduced grain weight. Other species include the widely occurring armyworms (*Pseudaletia unipuncta*), cutworms (*Euxoa auxiliaris, Agrotis orthogonia*), grasshoppers and other minor insects such as Mormon cricket (*Anabrus simplex*), blister beetles (*Epicauta* spp.), (Starks and Webster, 1985). These species generally feed on leaves and stems of barley as well as other cereals. The symptoms that the species cause include defoliation of the plants, blotching and streaks on the leaves, breakage of the stalks and damage on florets and grains.

4.2.1.4 Borers:

The insects in this group usually grow through the stems of barley. The species include barley joint worm (*Harmolita hordei*), wheat stem maggot (*Meromyxa* spp.), fritfly (*Oscinella frit*) and lesser cornstalk borer (*Elasmopalpus lignosellus*). The species of sawflies are the major hymenopterous pests of small grains in North America, Europe, North America and East Asia. The saw fly species include *Trachelus tabidus, T. libanensis, Cephus pygmaeus* and *C. cinctus* (Starks & Webster, 1985). The symptoms include stunting or death of plants, formation of shrunken or prematurely whitened heads, shriveling of grains and cutting of stems as in saw flies.

4.2.1.5 Nematodes:

There are a few nematodes that may be recorded on barley. The seed gal nematode (*Anguina tritici*) is mainly a pest of wheat but it may sometimes be observed on barley. This causes stunting of plants, deformation of leaves and produces galls on heads in place of grains. The contaminated grains are not suitable for use as seeds, food or feed.
Apart from the seed gal nematode, Cereal cyst nematodes infect the roots and produce pin head like cysts on roots. The most widely occurring cereal cyst nematode agent is *Heterodera avena* but species of *H. filipjevi, H. mani, H.bifenestra, H.iri, H. hordecalis* and *H. latipons* are among the causal agents. Other nematodes infecting the barley roots include *meloidogyne* spp. producing knots and *Pratylenchus* spp. producing brown lesions on the roots. Other nematodes of minor importance include stunt nematode (*Tylenchorhynchus* spp.), sheath nematodes (*Hemicycliophora* spp.) and pin nematodes (*Paratylenchus* spp.).
The nematodes in barleys reduce the water and nutrient uptake resulting in retarded plant growth, reduced tillering and grain weight, producing symptoms like similar to nutrient deficiencies. The effect of majority of nematodes on barley is not well known, but yield losses of up to 50 % has been reported due to cereal root knot nematode and yield gain of 21% as a result of control of Root lesion nematode of *P. pallax* in Wales (Gair *et al.*, 1987).

4.2.2 Storage pests

The main cereal storage pests are from the various families of the orders of Coleoptera (Beetles) and Lepidoptera (Butterflies and moths) and also include mites (Table 4.2.2). The species of Coleoptera have hardened front wings and chewing mouth parts, while the adults of Lepidoptera have loose wings and siphoning mouth parts, larvae having chewing mouth parts. Both order have complete metamorphosis, egg - larva - pupa - adult (beetle) for Coleoptera (Fig. 4.2.2) and egg - Larva (or caterpillar) - Pupa - Adult (Butterfly or moth) for Lepidoptera (Morril, W.L., 1995).
The storage insects feed on many food sources that can be found in stores, although some have preferences. Therefore, it is impossible to separate them on the bases of commodities.

However, here, the insects causing economically important damage to cereals, barley in particular, are explained. The storage pests of cereals can be studied in four different groups: 1) Primary storage insects, 2) Secondary storage insects, 3) Storage mites, 4) Birds and rodents.

4.2.2.1 The primary storage insects:

This group of insects constitutes the most damaging storage insects. This is so because they feed internally within the grains and without careful examination it is difficult to observe them until the damage is very obvious at which time the degree of damage becomes irrecoverable. The adults chew a hole in the grain and the females lay their eggs in these holes after mating. The larva passes through the larval instars within the grain transforming to pupa and then into an adult weevil. The larva, with its chewing mouth parts feeds on the endosperm but some portions of embryo can also be consumed. These insects prefer drier grains for feeding and can feed on grains with moisture content of 2%.

Table 4.2.2: Important insect pests of barley stores				
Order	**Family**	**Species**	**Common name**	**Type*1**
Coleoptera	Dermestidae	*Trogoderma granarium*	Khapra Beetle	***
	Ostomatidae	*Tenebrioides mauritanicus*	Cadelle	*
	Bostrychidae	*Rhyzopherta dominica*	Lesser grain borer	***
	Silvanidae	*Oryzaephilus surinamensis*	Sawtoothed grain beetle	*
	Silvanidae	*Oryzaephilus mecator*	Merchant grain beetle	*
	Tenebrioidae	*Tribolium castaneum*	Red flour beetle	*
	Tenebrioidae	*Tribolium confusum*	Red flour beetle	*
	Tenebrioidae	*Tribolium molitor*	Red flour beetle	*
	Tenebrioidae	*Gnathocerus cornutus*	Broad horned flour beetle	*
	Curculionidae	*Sitophilus granaries*	Granary weevil	***
	Curculionidae	*Sitophilus oryzae*	Rice weevil	***
	Curculionidae	*Sitophilus zeamais*	Maize weevil	***
	Cucujidae	*Leomophloeus(Cryptolestes)ferrugineus*	Red grain beetle	*
	Cucujidae	*Ahasverus advena*	Foreign grain beetle	*
Lepidoptera	Gelechiidae	*Sitotroga cerealella*	Angoumois grain	***
	Pyralidae	*Anagasta (Ephestia) kuehniella*	Mediterranean flour moth	*
	Galleriidae	*Ephestia cautella*	Tropical warehouse moth	*
	Galleriidae	*Ephestia eutella*	Tobacco moth	*
	Galleriidae	*Ephestia figuliella*	Raisin moth	*
	Galleriidae	*Pyralis farinalis*	Meal moth	*
	Galleriidae	*Plodia interpunctella*	Indian meal moth	*
Acarina	Acaridae	*Acarus siro*	Grain mite	*
*1: ***: Primary grain pest; *: Secondary grain pest				

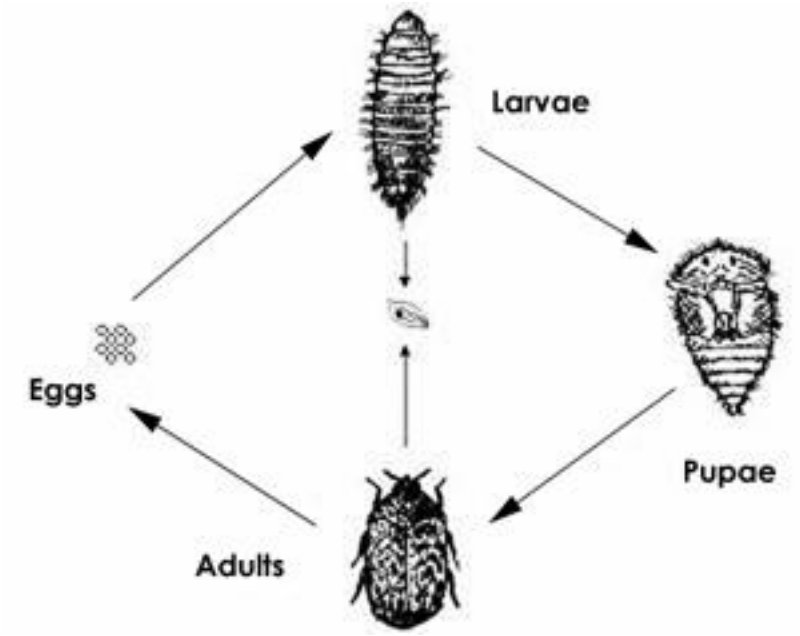

Figure 4.2.2. Life cycle of *Trogoderma granarium*, a member of Coleoptera (Adapted from Yasar, 1996 and Akan, 2003).

Economically, the most important species in this group are the grain weevil species (*Sitophilus* spp.), namely rice weevil (*S. oryzae*), maize weevil (*S. zeamais*) and granary weevil (*S. granarius*). The adults are dark brown, the egg, larva and adult stages all take place in the grain and adults can fly to fields to re-infest the crops. They occur worldwide and can cause significant losses in cereals in Turkey (Dörtbudak *et al.*, 1988).
Other economically important species in this group include Lesser borer (*Rhyzopertha dominica* (Fabricus)). This species is cylindrical, 3 mm long, strong flier and favor dust particles and broken grain particles. The less damaging primary storage insect is the Lepidopter Angoumois grain moth (*Sitotroga cerealella*). The adult moth of this species is 5-8 mm long and can not feed on whole grains with its sucking type of mouth parts. The females lay their eggs among the grains and the larva feeds into the grains, feeds there, pupates and then transforms into adults. This species favors feeding on broken grain pieces and grain dust.

4.2.2.2 The secondary storage insects:

The insects that feed on parts of the grain such as broken grains or particles of grains, dusts or flours are considered in this group. The species in this group feed on the outside of the grains and prefer embryos. The adults are 3-4 mm long, brown or reddish - brown in color. The best known species in this group are flour beetles (*Tribolium* spp.). There are slight differences between the *T. confusum* and *T. castaneum* especially in the structure of antennas and eyes. The females lay their eggs among the grains and the compaction of dusts and grain particles are very favorable for the flour beetles to survive. The adults can live up to 5 years and when the environment becomes unfavorable they secrete quinons which turns the flour into pink color.
The saw-toothed grain beetle (*Oryzaephilus* spp.) and merchant beetle (*O. mercator*) are among the common storage grain infesting species. Development from egg to adult takes place in 25 days. The eggs are laid singly or as groups on the feed sources. The larva is pale yellow with dark segments on thorax and the adults are black, 2.5-3 mm long. Larvae can not damage the whole grains but can feed on broken grain pieces, dusts and flour. The grain beetles (*Cryptolestes* spp.) group also has three species namely flat grain beetle (*C.pusillus*),

rusty grain beetle (*C. ferrugineus*) and flour beetle (*C. turcicus*). These can feed externally on the grains consuming embryo as well as broken grain pieces, dust and flours.
In addition, a number of dermestids such as *Trogoderma variable*, *T. glabrum* and most importantly the Khapra beetle (*T. granarium*) cause significant damages in cereal stores. The adults of khapra beetle have a very short life span of about 1-3 weeks, the larvae can remain alive for several months without food and can tolerate to adverse conditions such as 2% moisture and 44 °C o temperature (Pedersen, 1992). All this makes the Khapra beetle one of the most significant storage pests of cereal grains and difficult to eradicate. The Khapra beetle is the most damaging dermestid in countries of India, Pakistan and arid regions of Africa (Pedersen, 1992). Ring (1965) reported the records of total loss of 300 tones of barley in USA, 30 tones of grains in southeastern Turkey and average grain loss of around 20-30% in Turkey due to Khapra beetle. The occurrence and importance of Khapra beetle in grain stores are reported for Afghanistan, Iran, Iraq, Jordan, Kuwait, Libya, Pakistan, Saudi Arabia, Sudan and U.A.R. (Anonymous, 1967) and in Saudi Arabia (Rostom, 1993).
Additional insects that may cause damage to stored cereals include Catedelle (*Tenebroides mauritanicus* L.), Cigarette beetle (*Lasioderma serricorne*) and drugstore beetle (*Stegobium paniceum* L.), Indian moth (*Plodia interpunctella*), the almond moth (*Cadra cautella*), tobacco moth (*Ephestia elutella*) and Mediterranean flour moth (*Anagasta kuehniella*) (Pedersen, 1992).
In addition to the insects that favor drier grains and those feeding on broken grain pieces, dusts and flour, there are a number of insect species feeding on moist grains under damp and moldy conditions. These are more of a problem especially in humid areas and with storages without sufficient drying and aeration facilities. These include foreign grain beetle (*Ahasverus advena*), hairy fungus beetle (*Typhaea stercorea* L.), Mealworms (*Tenebrio molitor, T.obscurus, Alphitobius diaperinus*), psocids - booklice (*Liposcelis* spp.) and mites (*Acarus* spp.).

4.2.2.4 Storage mites:
Apart from the members of the coleoptera and diptera, the mites (Acaridae family in Arthropoda) are studied together with the insect pests due to the nature of their behaviour and damage. Although many mite species are predators of many insect pests and also feed on moulds, some species are also pests of stored grains especially in temperate climates (Wilkin, 1975). The mites can also feed on the embryos of the grains. The most important mite species causing damage to barleys in storage is the *Acarus siro* L. which favors damp grains and conditions. Favorable conditions are 23 -25 °C and 75 - 85 % R.H. (Pedersen, 1992). It is reported to be a significant problem in barley stores in tropical and subtropical countries but it may be present in where ever the conditions are suitable. *A. siro* has been significant problem in cereal stores in UK (Wilkin & Hurlock, 1986) and in souteastern part of Turkey (Yildirim, *et al.*,1997). Together with *A. siro*, *Lepidoglyphus destructor* and *Cheyletus eruditus* have been reported to be important pests of cereal grains in Turkey (Emekçi and Toros, 1999). Some other species have also been reported in various countries. For example, *Acaropsis sollers* is reported in Saudi Arabia (Rostom, 1993), and together with this *Tyrophagus sp., Calogyphus berlesi, Rhizoglyphus sp.* and *Oribatula sp.* in Iraq (Mahmood, 1992).

4.2.2.5 Birds and rodents:
Barleys, as well as many other crops are subject to damage by birds and rodents. They can cause damage both in the field and in storage. Birds can pick up the seeds following sowing if especially shallow seeding practiced. The birds can pick the grains from the heads near the harvest time causing significant losses for example in south east Anatolia of Turkey (Akın,

1973) as well as in many other locations. In addition, the birds can also enter the unprotected grain stores and eat the grains. Among the most important bird species causing such damage are crows (*Corvus* spp.) and sparrows (*Passer domesticus, Sturnus vulgaris*).
Rodents can also cause important losses in field and stores. The *Microtus* spp. and *Microtus arvalis* are common problems especially in fields. These can eat the seeds and seedlings in the field after sowing. Their control in field is difficult but application of LPG gas into the tunnels or placement of seeds treated with Zinc phosphide near the open end of the tunnels are practiced by some farmers for this purpose. The rodents are also among the major problems in storage. The rodents are capable of passing through very small holes and can be real problems in barley stores in developing countries. The major species that infest barley stores as well as many other commodities include *Mus musculus* and *Rattus rattus*. These are present almost in all developing countries. They are reported to cause damage in stores in all parts of Turkey (Yildirim *et al.*, 1997) and in Pakistan, Sudan and other parts of the Near East region (Anonymous, 1967).

4.3 Control of post harvest microorganisms and pests

In order to minimize the losses due to post harvest losses caused by microorganisms, insects or other pests, application of appropriate control measures is necessary. These procedures include better crop production practices, control of diseases and pests in field, better harvest technology, controlling the storage atmosphere and use of pesticides at various stages such as in field, on seeds or in storage effectively. The control measures for post harvest diseases and pests and their status in developing countries are as follows.

4.3.1 Better crop husbandry practices

Since the post harvest diseases and pests favor low quality, shriveled and broken grains, the production of better quality grains is the first stage for management of post harvest pests. The procedures to achieve this include selection of right cultivars, use of quality seeds, practicing good soil tillage, appropriate fertilization and other crop production practices.

4.3.2 Preharvest control of diseases and pests in field

Control of field diseases and pests is necessary for production of good quality grains. Moreover, many post harvest diseases and pests originate from field infection/infestation. Grain infecting fungi such as *Fusarium* spp., *Alternaria* spp. and *Helminthosporium* spp. infect the grains in the field before harvest and continue their spoilage in storage under appropriate conditions. Similarly grain veewils (*Sitophilus* spp.) can infest the grains in the field and then be transported to the storage together with the grains. Therefore their control in the field would help in preventing, or at least minimize, initial infestation of the grains before storage. The pre harvest control measures include use of resistant cultivars, seed treatments for seed borne diseases such as smuts (*Ustilago* spp.), barley leaf stripe (*P. graminea*) and wire worms, fungicidal sprays for foliar diseases which lower the grain quality such as Scald (*R. secalis*) and powdery mildew (*Erysyphe graminis*) and insecticidal sprays for sunny pest (*Eurygaster integriceps*) and cereal bugs (*Aelia* spp.). However despite the recommendations, control measures are not taken adequately in most of the developing countries. This is because most of the farmers are not aware of the importance of the diseases and pests and control technology or their financial status does not allow them to focus on this. As a result, the barley grains produced are of lower quality than the potential, which are vulnerable to storage diseases and pests. However in some countries, state agricultural organizations may execute the protection programs for pests causing economical losses in wide areas. For example, the survey and insecticide spray for the control of sunny pest and cereal bug in Turkey have been carried out by the institutions of Ministry of Agriculture until recently.

However, there is a growing debate as to the efficiency and feasibility of this approach. In order to achieve the control of diseases and pests, practical integrated strategies need to be developed and the technologies should be transferred to the farmers.

4.3.3 Appropriate harvest procedures

Harvest procedures not only affect the direct grain losses but also affect the grain quality and as a result the losses due to post harvest diseases and pests. To minimize this effect, the harvest should be done at right time as the moist grains are more vulnerable not only to storage micro organisms such as *Penicillium* spp. and *Aspergillus* spp. but also to a number of storage pests such as *A. advena*, *T. stercorea L.*, *T. molitor* and *Liposcelis* spp. The efficiency of threshing procedures can also affect the grain quality.

The portion of broken grains may increase if harvest delayed and thresher adjustments and procedures are not done properly (Demirci, 1982). In such situation there would be higher risk of microbial spoilage and insect damage in stores as such grains would provide more nutrient sources for many post harvest insects, especially secondary storage insects such as flour beetles (*Tribolium* spp.) and saw-toothed grain beetle (*Oryzaephilus* spp.) which feed on broken grain pieces, dusts and flour.

In very rural areas of most developing countries the small farmers harvest the crop by hand and leave the crop outside until threshing time. The threshing may also be done with rather primitive methods which would result in higher portion of broken grains. Similarly, even with the medium size farmers who harvest the crop with combines, the harvest procedures are not appropriate to minimize the grain loss and breakage, due to inadequate training of the operators. To improve this, efficient extension activities are needed for the training of farmers and combine operators.

4.3.4 Drying the grains

Many post harvest diseases and pests favor moist grains in storage. These include microorganisms such as *Penicillium* spp. and *Aspergillus* spp. and insect pests such as foreign grain beetle (*A. advena*), hairy fungus beetle (*T. stercorea* L.), mealworms (*T.enebrio* spp.), booklice (*Liposcelis* spp.) and mites (*Acarus* spp.). In order to avoid the spoilage by these agents, the grains may have to be dried if the moisture content is too high at harvest time. The efficiency of grain drying has been reported for the control of *Acarus* spp. (Wilkin, 1975). The moisture content of the grains must not be over 13-14% in order to avoid infestation by these microorganisms and insect pests. The large producers and traders may have drying facilities but the small and medium size farms do not. However some farmers dry the grains in the open air before placing them in storage

4.3.5 Building of better storage facilities and control of storage atmosphere

The characteristics of the storage facilities and atmosphere in them are the major factors determining the extent of development of storage microorganisms, pests on barley grains and resulting damage. Therefore, ideally the storage facilities should have sufficient isolations and controllable atmosphere to create the most adverse conditions for the development and multiplication of microorganisms and pests. There are many storage types with different degrees of sophistication and facilities, described in previous sections of this title. The better quality storage facilities are present only for large companies and organizations in the developing countries. The majority of small and medium size barley producers in developing countries do not even have storage facilities and they store their grains either as bags in buildings, or as bulk in wood or concrete stores. The medium and large size farmers may also store the grains in underground or above ground pits. In most cases these would be covered polyethylene sheets and have almost no atmosphere control facilities.

The grains in these primitive storage facilities would have almost no protection against the storage microorganisms and insect pests other then the covering. In fact if the covering is of good quality and properly placed, the grain could be protected at least for a season. However in many cases the grains in such pits are exposed to moisture, internal and external heating problems and s a result become vulnerable to storage microorganisms and pests. 65 different species of microorganisms have been reported from such storages in Iran (Lacey, 1988) and 16 species of mites in Iraq (Mahmood, 1992). Of course the storage environment in better storage facilities would be more suitable for the grains for protection against the storage grains and pests, but their costs would be too high for the ordinary farmers in developing countries. Therefore, in most cases these farmers keep the grains for domestic use only and sell the rest as soon as they harvest. However, the farmers with primitive storage facilities can improve the quality of their storage by not leaving any opening or cracks in the walls of the stores or covering properly to minimize the entry of outside moisture or organisms into the stored grains.
In order to promote safer and more effective storage of cereal grains, alternative storage methods suitable for the small farmers in developing countries are needed. For this purpose hermetic storage method which is based on storing the grains in totally sealed small PVC containers and keeping the grain quality through allowing consumption of the all O_2 by the present organisms to produce CO^2. With this method, Populations of *R. dominica* and *T. castaneum*, *Cryptolestes sp.* were reduced significantly (Ferizli and Emekçi, 1999). The method is also recommended for the tropical and sub tropical countries (Navarro *et al.*, 1994).

4.3.6 Use of Pesticides

4.3.6.1 Rodenticides:

Despite the care taken not to leave any holes or cracks on the walls of storage, the rodents can find their way to the stored grains. The rodents are important problems especially in developing countries because the store structures are not properly constructed. In the very rural areas and small farms the rats are caught with mechanical traps on which attractive foods, such as cheese, are placed. However, medium size farmers tend to use rodenticides in various formulations. For example in Turkey, the rodents are chemically controlled through placement of pellets (such as Difenacum 0.05%), grains treated with the poisonous rodenticides (Coumatetraly 0.75, Brodifacoum 0.05%, Zinc phosphide, 80-95%) or tablets (aluminium phosphide 56-57%, 1 tablet for $1m^3$) in the grain stores. The use of zinc phosphide treated grains as baits is reported for Sudan (Anonymous, 1967) as well.

4.3.6.2 Sanitation of stores before storage:

In order to protect the grains in store from the storage microorganisms and insect pests, the stores should be cleaned and sanitized before the grain is placed. Otherwise small amount of microorganism or insects can grow and develop in time after storage and cause extensive damage, if the environmental conditions are suitable for them.
Some farmers do apply lime to the walls of ordinary building stores to eliminate the microorganisms before storage. The insect pests existing in the store can be destroyed before the grain is stored with the use of Malathion, Bromophos, Chlorpyrifos-Methyl and Primiphos methyl. For the application, WP or EC formulation of the insecticides must be used and all surface area must be sprayed.
However, majority of small scale farmers ignore to do this and the losses are encountered frequently resulting from the existing micro organisms and pests in stores.

4.3.6.3 Use of grain protectants:

The protection of grains from spoilage fungi such as *Penicillium* spp. and *Aspergillus* spp. is more difficult in developing countries. Although application of propionic acid as sprays is widely used in many developed countries for this purpose (Sauer *et al.*, 1992) especially the smaller farmers in developing countries do not practice this. Use of protectants is an efficient way of protecting grains especially from contamination of the storage insects. The major objectives for application of grain protectants are to kill the most important insects in the grain and prevent them from establishing an infestation after the storage. One protectant application may be sufficient during only one storage season (Harein & Davis, 1992).

The earlier protectant insecticide studies in the USA, India and Kenya are reviewed by Harein and Davis (1992) and included diatomaceous earths, silica aero gels, magnesium oxide, aluminium oxide and activated clays in the form of inert dust acting as toxic and repellent insecticide. Although the inert dusts have residue problems they still seem to interest the producers in developing countries (Mittal & Wrightman, 1989). The insecticides that have been developed as effective grain protectants include Malathion, Pyrethrins, Dichlorvos, Chlorpyrifos-Methyl and Pirimoiphos - Methyl against many important storage insects such as *A. advena, Sitophilus* spp., *Oryzaephilus* spp., *Cryptolestes* spp., *Trogoderma* spp. and *Tribolium* spp. at various degrees. Although the small size farms in developing countries ignore use of protectant fungicides, the medium size farms use these protectant fungicides as this is more suitable for their loosely built stores which are unsuitable for fumigation. Recommendations for application of insecticides in cereal storage in Turkey are summarized in Table 4.3.6 as an example. Care should be taken to minimize and monitor the development of insect resistance against these insecticides.

The grain protectants are applied either as dust to the grains such as (Malathion, Pyrethrins, Chlorpyrifos-Methyl and Pirimoiphos - Methyl or some may be more effective if applied as sprays as in the case of dichlorvos which acts as semi fumigant dissolving in the store atmosphere but not being able to penetrate into the depth of bulk grain.

4.3.6.4 Fumigation:

Despite every effort that is made, it may not be possible to achieve complete isolation of the grain stores from their environment, control the atmosphere and destroy the storage microorganisms and pests in the grain that is placed in the store. In such cases the microorganisms and pests can grow and multiply in time at various speed depending on the atmosphere conditions and their requirements. Then it may be necessary to fumigate the stores to destroy them or decrease their population.

Various fumigation agents have been developed but only two are widely used currently, methyl bromide and phosphin. These are available in most developing countries, but only the medium and large scale farmers, traders and industry apply fumigation in their barley grain in stores in the developing countries. Methyl bromide is currently considered hazardous and its use is limited in developed countries, but it is still used widely in grain stores in developing countries as it is cheaper and more widely available. The more advanced phosphin group of fumigants (Aluminium phosphide, Magnesium phosphide) are costly and not widely used by the small farmers, but medium and large scale farmers use the phosphins in different forms. However, some developing countries are also considering removal of methyl bromide from use. For example Turkey is planning to ban the use of methyl bromide from use in stores in 2005 and in other areas in 2008. Therefore alternative fumigants are gaining importance in similar countries.

Various fumigation technology is available for all kinds of storage facilities including the sophisticated atmosphere controlled silos, underground or above ground pits under polythene covering, wood or concrete stores. The principle of phosphin fumigation is based on release of the gas into the stored grain atmosphere and keeping it as long as possible. Here, the most critical factor is the efficiency of covering of the stored grain. Therefore special care needs to be taken to cover the grains especially in the pits which are common practices of grain storage (Fig. 4.3.6.4.). The farmers need to have sufficient experience and knowledge of the technology for effective application of fumigation.

In order to achieve maximum benefit from fumigation and reduce fumigant use the following steps must be taken:

- selection of the most appropriate fumigation method,
- insuring that the store is isolated from the outside environment by filling in any wholes, cracks and openings,
- application of the fumigants according to the recommendations,
- revision of dosage rates to avoid overdosing;
- reducing the frequency of treatments by preventing or reducing reinvasion of pests subsequent to fumigation.

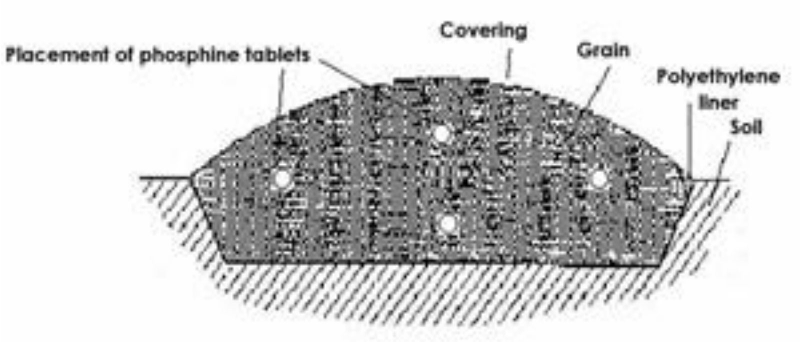

Figure 4.3.6.4. Storage of a covered pit and application of phosphine tablet for developing countries (Akan, 2003).

Table 4.3.6: Recommendations for Use of Insecticides and Fumigants in Grain Stores in Turkey [(1)]				
Insecticide	**Formulation**	**Recommended dose (Preparation) for**		
		100 m^2	**1 ton grain**	**1 m^3 (Vol.)**
Malathion %25 W/W	WP	500 g		
Malathion 190 g/l	EC	650 ml		
Malathion 650 g/l	EC	200 ml		
Bromophos 360 g/l	EC	250 ml		
Primiphos-methyl 500 g/l	EC	300 ml		
Methacrifos 500 g/l	EC	200 ml	20 ml	In 1 lt water
Chlorpyiphos-Methyl	EC	425 ml		
Malathion %2 W/W	Dust		500 g	
Fenitrothion %3 W/W	Dust		133,2 g	
Fenitrothion %1 W/W	Dust		400 g	
Aluminium phosphide %57	Tablet		9-30 g	3-12 g
Aluminium phosphide %57	Granule sack			8,5 g
Methyl bromide %98	Liquid gas			25 g
Dichorvos 550 g/l (DDVP)	EC			0,150 ml (in 10 ml water)
Dichorvos 1000 g/l (DDVP	EC			In 1 lt. water at 25 °C or over
[(1)] Adapted from Yasar (1996); Yildirim *et al.*, (1997)				

Ideal fumigation techniques are known only by professional grain producers, traders or industrialists in the developing countries. Majority of the small scale farmers are unaware of these techniques. Even in the medium - large size farms, the efficiency of fumigation is generally low and still significant losses occur due to storage diseases and pests. The main reason for inefficient grain preservation in smaller farms in developing countries is the inadequacy of technical knowledge and unsuitability of present storage systems for their conditions as well as financial resources for establishment of better storage facilities.

5. Economic and social considerations

The main costs of the modern storage investment are construction, maintenance and energy. Although majority of barley grains are stored in modern structures in developed countries, construction and maintenance of these infrastructures can not be affordable in developing 7countries. However, introduction of such facilities was realized in some developing countries by using international funds. Result of these attempts has summarized by Navarro (1997): ‘a major effort over recent decades has been devoted to improving storage conditions of cereal and pulse crops, reducing losses in tropical countries. Past attempts at introducing "state-of-the-art" storage structures into several developing countries for this purpose have

met with failure and are witnessed by many such "white-elephants" standing empty and abandoned'.
In order to reduce cost of storage construction and increase adoption of new storage systems, socio-economic conditions of developing countries should be considered more. New technology has to meet the following very important requirements:
1)Design must be similar to those of traditional storage structures (cylindrical container, raised above ground on a platform, with an upper loading port and a lower spout to remove the grain;
2) Reduction in cost of manufacture by incorporation of certain elements of the structure that are usually freely obtainable locally (raised platform, straw roof);
3) Achievement of a minimal and affordable price with an anticipated life-time of several years.
4) Application of a method of grain preservation that is environmentally sound, user friendly, and does not require application of chemical pesticides;
5)Acceptability of the structure by farming societies.
(Navarro, 1998).
If these conditions are taken in to considerations, new storage systems can be accepted by small scale farmers living trough the developing world. Navarro *et al.*(1997) have proved that more appropriate storage systems have also been widely introduced, and have enabled the successful transfer and updating of modern conservation and control technologies with consequent reduction in storage losses. Reduction of storage losses at the small-scale and subsistence farmer levels has proved to be far more difficult than in the commercial or public sectors. This is because the available storage conservation technologies are costly and not applicable to most of the traditional storage methods unless radical changes are made. Therefore new solutions must be found, appropriate to the local conditions, and acceptable to the societies into which they are to be introduced.
A good example illustrates the benefits of introduction of this approach in to developing countries. Navarro *et al*. (1994) reported that net benefits from PVC hermetic units for rice and maize per tons was 100$ and 80$, respectively.
Losses of small grains after harvest are at least 5-10% especially for small scale farmers under rural areas in developing countries, but the magnitude of the losses sometimes may reach up to 100 % depending on climate and storage conditions (Navarro *et al.*, 1998). However, introduction of hermetic storage systems, which are easily applicable, cost effective and eco-friendly technology especially for small scale farmers, into rural areas dramatically decreases grain losses down to 0.15% (Navarro *et al.*, 1998).
Developing countries urgently need international collaboration in order to finance and execute research and development projects and transfer/introduce the existing and prospective technologies to their societies especially in rural areas. Considering their problems and priorities, the following procedures are recommended to be put into practice by Navarro (1997) a) development of appropriate storage technologies for developing countries; b) development of non-chemical control methods; c) development of novel pesticides based on biotechnological approaches; d) further development of IPM strategies and e) evaluation and development of new fumigants and other alternatives. In order to achieve all this, international collaboration must be established and sufficient resources should be allocated for research and technology transfer work in this area.

6. References

Akar, T., M. Avcı, M., Dusunceli, F., Tosun, H., Ozan, A.N., Albustan, S., Yalvac, K., Sayım, İ., Ozen, D., Sipahi, H., 1999. The problems and solutions of cereals cultivation in Central and transitional zones of Central Anatolia. *In* Proceeding of symposium on ‘the problems and solutions of cereals cultivation in Central Anatolia, ed. H. Ekiz, 8-11 June 1999, Konya, Turkey, Gurcan Ofset Printhouse ISBN: 975-487-071-3, pp: 77-86 (in Turkish).

Akan, K., Dusunceli, F. 2003. The insects of stored small grain cereals. Unpublished report, Central Research Institute for Field Crops, CRIFC, Ankara.

Akın, T., 1973. Guneydogu Anadoluda mahsullere zarar veren dag sercesine (*Passer montanus* L.) karsı öldürücü etkisi olan queletx ilacının tesir derecesinin tesbiti. Plant protection research annual, Ankara, Turkey, pp. 66 (in Turkish).

Aktas, H., 1999. Determination of the fungal flora of barley seeds and their sensitivities against *Drechslera sorokiniana* 'Sacc.' Subram. and Jain. *In* Proceeding of symposium on ‘the problems and solutions of cereals cultivation in Central Anatolia, ed. H. Ekiz, 8-11 June 1999, Konya, Turkey, Gurcan Ofset Printhouse ISBN: 975-487-071-3, pp 705 - 710 (in Turkish).

Anonymous, 1967. Report of the second session of the near east plant protection commission held at Tripoli, Libya, 6-13 May 1967, Meeting report No:PL:1967/M/3, FAO, Rome, 36 pp.

Anonymous, 2002. MEDRATE (EC-CIHEAM Co-operation project, 1998-2002) Regional Action Program ”Rain fed Agriculture” RAP-RAG Report of the Second Coordination Meeting, unpublished.

Arifi, A.,1990. Distribution and importance of the main barley fungal foliar diseases in Morocco. *In* proceedings of the 8th congress of the Mediterranean phytopathological union, October 28 - November 3rd, Agadir Morocco, 1990, pp.309-312.

Atheya, S.C., Dikshit, N.N. and Ram, L., 1981. Barley diseases in India. *In*< Proceedings of barley diseases and associated breeding methodoly workshop., Rabat, Morocco, pp. 219-234.

Bacha, H., Hadidane, R., Creppy, E.E., Regnaul, C., Ellouze, F. and Dirhemier, G., 1988. 1988. Monitoring and identification of fungal toxins in food products, animal feed and cereals in Tunisia. *J. Stored prod. Res.* Vol. 24, No:4, pp.199-206.

Baldridge D. E., D. E. Brann, A.H. Ferguson, J.L. Jerry, R.K. Thompson, 1985. Cultural practices. *In* Barley, D. C. Rasmusson ed., American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Publishers Madison, Wisconsin, 1985.

Balkan, C., 1981. Research on agricultural economics and training national project, İzmir,Turkey (in Turkish).

Bamforth, CW, and Barclay, A.H.P., 1993. Malting technology the uses of Malt. Barley: Chemistry and Technology. A.A.C.C .Inc. St. Paul, Minnesota, USA, pp. 298.

Bateman, G.L., Ehle, H and Wallace, H.A.H., 1986. Fungicidal treatment of cereal seeds. *In* Seed treatment, ed. K.A.Jeffs, BCPC, UK, pp. 83-111.

Bayaner, A., Uzunlu, V., Keating, J.D.H., and Tutwiler, R., 1993. Agricultural Structure and Constraints to Increased Production in the Eastern Margin of Central Anatolia. Highland Regional Program. ICARDA-TARM. Ankara, Turkey.

Bhatty, R.S, 1986. Hulless barley: Development and Civilisation. *In* VII. Int. Barley Genetics Symp. , Canada, pp:106-111.

Boulif, M., 1990. Breeding for resistance to barley leaf stripe (*Pyrenophora graminea*) in the Mediterranean region. *In* Proceedings of the 8th congress of the Mediterranean phytopathological union, October 28 - November 3rd, 1990, Agadir, Morocco, pp.117.

Briggs, D.E., 1978. Barley, Chapman and Hall, London.

Buckle, A.E., 1986. Moulds and mycotoxins in cereal and other components of compound animal feeds. *In* Spoilage and mycotoxins of cereals and other stored products, *International biodeterrioration*, Vol:22, Supplement, ed. B. Flannigan, pp 55-60.

Casanova, A., Dohler, R., Farrant, D.M., Rathmell, W.G., 1977. The activity of the fungicide nuarimol against diseases of barley and other cereals. *In*. Proceedings of the British Crop Protection Conference, pests and diseases 1, .pp 1-7.

Cetin, L., Albustan, S., Dusunceli, F., Tosun, H. and Akar, T., 1995. Determination of resistance barley breeding materials developed for Central Anatolia to barley leaf stripe (*Pyrenophora graminea*). *In* proceedings of the 7th Turkish phytopathological congress, 26-29 September, Adana, Turkey, pp. 126-129 (In Turkish).

Demirci, K., 1982. Crop losses with combine at harvest: examples of Turkey and State Farms *In* proceedings of the seminar on pre and post harvest, 13-17 Dec. 1982, Printing house of Ankara. Ministry of Agriculture and Forestry, Central Logistic Directory, Yenimahalle, Ankara, pp.127-132 (in Turkish)

Donahaye, E. J., Navarro, S. and Miriam Rindner, 1995. Storage of Barley in an underground Pit Sealed with a Polyethylene Liner. *J. stored Prod. Res.*< 31, 63-70.

Donahaye, E.J., 2000. Current status of non-residual control methods against stored product pests. *In* proceedings of the XIVth International Plant Protection Congress July 25-30, Jerusalem, Israel, Crop Protection, 19: 571-576.

Dörtbudak, N., Yılmaz, D. and Aydın, M., 1988. Investigation on the resistance to protective chemical used against granary weevil (*Sitophulus granaries* L.) destructive on the stored grain in Ankara and Eskisehir. *In* plant protection research annual, Ankara, Turkey, pp. 74.

Dube, D.C., 1990. An introduction to fungi. Vikas publishing house pvt ltd., 608 pp.

Ehling, G., Cockburn, A., Snowdon, P. and Buschhaus, H., 1997. The significance of the Fusarium toxin deoxynivalenol (DON) for human and animal health. *Cereal Research Communication*, Vol.25, No.3/1, 443-447.

Emekci, M. and Toros, S., 1999. Investigations on the stored grain mites. *In* Proceeding of symposium on ‘the problems and solutions of cereals cultivation in Central Anatolia, ed. H. Ekiz, 8-11 June 1999, Konya, Turkey, Gurcan Ofset Printhouse ISBN: 975-487-071-3, pp: 483-497 (in Turkish).

El Ahmed, A., Ghodbane, A., Laribi, F. and El Felah, 1981. Barley diseases in Tunisia and sources of resistance. Pages 262-272, *In* Proceedings of 'Barley diseases and associated breeding methodoly workshop'., Rabat, Morocco.

Elmalı, M., 1999. Rus bugday afidinin Konya ili tarımı acısından önemi ve cözum önerileri.
In Proceeding of symposium on ‘the problems and solutions of cereals cultivation in Central Anatolia, ed. H. Ekiz, 8-11 June 1999, Konya, Turkey, Gurcan Ofset Printhouse ISBN: 975-487-071-3, pp. 449-461 (in Turkish).

Eren, Y., 1982. Grain loss at combine harvest. *In* Seminar on pre and post harvest proceeding, 13-17 Dec. 1982, Printing house of Ministry of Agriculture and Forestry, Central Logistic Directory, Yenimahalle, Ankara (in Turkish)

Esin, T., 1990. Pest and Diseases of stored dry grains. TMO Alkasan Matbaası, 1990 (in Turkish).

Evcim, 1982. Grain loos with local made harvesters. *In* proceedings of the seminar on pre and post harvest procedures, 13-17 Dec. 1982, Printing house of Ankara. Ministry of Agriculture and Forestry, Central Logistic Directory, Yenimahalle, Ankara (in Turkish).

FAO : Production Yearbook Vol: 54-2000 Rome, Italy.

FAO : Trade Yearbook Vol:53-1999 Rome, Italy.

Ferizli, A.G. & Emekci, M. 1999. Alternatif ve çevre dostu bir depolama tipi: Hermetik depolama. *In* Proceeding of symposium on 'the problems and solutions of cereals cultivation in Central Anatolia, ed. H. Ekiz, 8-11 June 1999, Konya, Turkey, Gurcan Ofset Printhouse ISBN: 975-487-071-3, pp: 491-497 (in Turkish).

Gagkeva, T. and Levitin, M., 2000. Composition of *Fusarium graminearum* schwabe populations collected from different regions of Russia. *In* Proceedings of the 5th European Seminar, Szeged, Hungary, 26 August - 5 September, 1997; Cereal Research Communications Vol.25, No.3/2, pp. 591 - 594.

Gair, R., Jenkins, J.E.E. and E. Lester, 1987. Cereal pests and diseases. Farming press ltd. 268 pp.

Gilbert, J., Shepherd, M.J., Startin, J.R., 1983. A survey of the occurrence of the trichothecene mycotoxin deoxynivalenol (vomitoxin) in UK grown barley and imported maize by combined gas chromatography-mass spectrophotometry. *Journal of the science of food and agriculture.* Vol:34, 86-92.

Gilchrist L., Vivar, H., Franco, J. And Crossa, J., 2000. Comparing *Fusarium graminearum* infection period in wheat and barley. *In* Proceedings of the 5th European Seminar, Szeged, Hungary, 26 August - 5 September, 1997; Cereal Research Communications Vol.25, No.3/2: 739-740.

Gökgöl, M., 1969. Cultivation and Breeding of Cool season cereals (wheat, barley, rye and Oat), Özaydın matbaası, İstanbul,1969, (in Turkish).

Gumustekin, H., Akın, K., 1998. Marmara bölgesinde arpa acık rastık etmenine (*Ustilago nudo hordei* "Jest" Rostr. Saffn) karsı arpa cesit ve hatların reaksiyonlarının tespiti uzerinde arastırmalar. Unpublished report, The Thrace agricultural research institute, Edirne, Turkey

Hagberg, A. 1987. Barley as a model crop on plant genetic research. *In* proceedings of the 5th Int. Barley Genet. Symp. S.Yasuda and T.Konishi, eds., Sanyo Press, Okoyama, Japan, pp. 3-6.

Hamdany, M.A., Salih, M.M. and Al-Dulami, I.A., 1990. Selection of mildew and smut resistant lines from barley induced mutants. *In* proceedings of the 8th congress of the Mediterranean phytopathological union. October 28 - November 3rd, Agadir Morocco, 1990, pp. 279 - 280.

Harein, P.K. & Davis, R., 1992. Control of stored grain insects. *In* Storage of grains and their products, Sauer, D. B. ed., American Association of Cereal Chemists, pp. 491 - 534.

Harlan, H.V., 1920. The daily developments of kernels of barley from flowering to maturity. *J. Agric. Res.* 19:393-429.

Harlan, J.R.1979. On the origin of barley. *In* Origin, Botany, culture, winter hardness, Genetics, Utilization, Pests. Agric. Handb. 338.US.Dept.Agr.Washington, D.C., pp. 10-36.

Hockett, E.A., and Nilan R.A.1985.Genetics. *In* Barley. D.C. Rasmusson, ed. American Society of Agronomy, Madison, WI, pp 187-230.

Jones, D.G. & Clifford, B.C., 1978. Cereal Diseases, their pathology and control. 2nd ed. John Wiley & Sons, 309 pp.

Kamel, A.H., 1981. Barley diseases in the dry areas. *In* Proceedings of the workshop on barley diseases and associated breeding methodology. Rabat, Morocco, pp. 27-42.

Kansu, İ.A., 1994. Genel entomoloji, Kıvanc matbaası, Ankara, Turkey. 426 pp. (In Turkish).

Karacan, H., Yılmaz, A., Yalcın, D. and Pembeci, C., 2000. Determination of the incidence of black point occurrence in wheats in Turkey and examination of its effect on product quality. *In* Abstracts of Oral and Poster presentations of the 6th international wheat conference, 5-9 June, Budapest, Hungary, pp. 128.

Klinner, W.E. and G. Bigger, 1972. Some effects of harvest date and design features of cutting table on the front losses of combine harvesters. *Journ. Agr. Eng. Res.* 17(1):71-78.

Lacey, J. 1988. The microbiology of cereal grains from areas of Iran with a high incidence of oesophageal cancer. *J. Stored Prod.Res.* Vol.24, No.1, pp.39-50.

Lee, E.S., 1981. Helminthosporium stripe in korea. *In* Proceedings of 'Barley diseases and associated breeding methodology workshop', Rabat, Morocco, pp. 75-85.

Luz,W.C. and Vieria, J.C., 1982. Seed treatment with systemic fungicides to control *Cochliobolus sativus* on barley. *Plant Disease*, 66:135-136.

Lyamani, A., 1990. Fungal foliar diseses of wheat and barley in Morocco. *In* proceedings of the 8th congress of the Mediterranean phytopathological union. October 28 - November 3rd, Agadir Morocco, 1990, pp. 128.

Mahmood, S.H. 1992. Mite fauna of stored grain seeds in central Iraq. *J. Stored prod. Res*. Vol. 28, No:3:179-181.

Mamluk, O.F., 1981. Review of smut diseses in Jordan. *In* Proceedings of 'Barley diseases and associated breeding methodology workshop'., Rabat, Morocco, Pages 192-198.

Mittal, S. and Wightman, J.A. 1989. An inert dust protects stored groundnut from insect pests. *Int. Arachis Newsl.* Nov. 1989, Int. Crops.Res. Inst. Semi-Arid Tropics, pp.21-22.

Morril, W.L., 1995. Insect pests of small grains. APS press, Minnesota, USA,140 pp.

Navarro S., Donahaye, E.J., Ferizli, G.A., Miriam Rindner and Azrieli, A., 1998. A sealed granary for use by small-scale farmers. *In* Proc. 7th Int. Working Conf. Stored-Product Protection, Vol. I., Zuxun, J., Quan, L., Yongsheng, L., Xianchang, T., and Lianghua, G. Eds. 14-19 October, 1998, Beijing, China., pp. 434-443.

Navarro, S., 1997. Stored crops: the search for food security. *In* stored crops, foodstuffs - Introduction, E. Warrell Ed., The Crop Protection Directory, International Edition. 209-210.

Navarro, S., Donahaye, E. and Fishman, S., 1994. The future of hermetic storage of dry grains in tropical and subtropical climates. *In* Proc. 6th Intern. Working. Conf. Stored Prod. Protection E. Highley, E.J., Wright, H.J. Banks and B.R. Champ eds., CAB International, University Press, Cambridge, pp. 130-138.

Navarro, S., Donahaye, E., Ferizli, A.G., Rindner, M. and Azrieli, A., 1998. A sealed granary for use by small scale farmers. The 7th International Working Conference on Stored - Product Protection. 14-19 October, 2998. Beijing, China.

Navarro, S., Donaheye, E., and Fishman, S. 1994. The future of hermetic storage of dry grains in tropical and subtropical climates. *In* Proc. 6^{th} Intern. Working. Conf. Stored Prod. Protection, E. Highley, E.J., Wright, H.J. Banks and B.R. Champ eds., CAB International, University Press, Cambridge, pp. 130-138.

Oakerfull, D., 1986. Food applications for barley. *In* VII^{th} Int. Barley Genetics Symp. Canada, P:50-57..

Oluc, M.,1946. Agricultural economy of Trace region Ismail Akgun matbaası, (in Turkish).

Ogut, M. and Onan, E., 1995. Investigation on the determination of barley smuts (*Ustilago* spp.) occurring in the Agean region, *In* the Plant Protection Research Annual, Ankara, Turkey, 1995, Page 77.

Ozar, A.İ. and Yucel, A., 1981. Survey studies on the stored grain pests in the southeast Anatolia region. *In* Plant Protection Research Annual, Ankara, Turkey, pp. 93-94..

Ozkan, M., Kocak, E., Babaroglu, N.E., Gökdogan, A and Altun, V., 1999. Problems caused by sunn pest and cereal bug in cereal fields and their solutions in Central Anatolia region. *In* Proceeding of symposium on 'the problems and solutions of cereals cultivation in Central Anatolia, ed. H. Ekiz, 8-11 June 1999, Konya, Turkey, Gurcan Ofset Printhouse ISBN: 975-487-071-3, pp: 462-472 (in Turkish).

Ozkan, M., Kocak, E., Babaroglu, N.E., Gökdogan, A and Altun, V., 1999b. Problems caused by corn ground beetle in cereal fields and their solutions in Central Anatolia region *In* Proceeding of symposium on 'the problems and solutions of cereals cultivation in Central Anatolia, H. Ekiz, ed., 8-11 June 1999, Konya, Turkey, Gurcan Ofset Printhouse ISBN: 975-487-071-3, pp: 473-476 (in Turkish).

Paramjit, S.B., Kumar, V., Aujla, S.S., 2000. Current status of research on Fusarium head scab of wheat in India. *In* Proceedings of the 5th European Seminar, Szeged, Hungary, 26 August - 5 September, 1997; *Cereal Research Communications,* Vol.25, No.3/2: 795-796.

Parry, D., 1990. Plant pathology in agriculture. Cambridge University Press, 385 pp.

Paterson, R.R.M., Kozakiewicz, Z., 1997. Penicillium and Aspergillus mycotoxins - diagnostic characters and quantitative data from commodities and cultures. *Cereal Research Communications*, Vol.25, No.3/1: 271 - 275.

Pedersen, J.R., 1992. Insects: Identification, damage and detection. *In* Storage of grains and their products, Sauer, D. B. ed., American Association of Cereal Chemists, pp.435-489.

Richardson, M.J., 1979. An annoted list of seed-borne diseases, CAB., 320 pp.

Rostom, Z.M., 1993. Survey of some granivorous and non-granivorous insects and mites in Saudi Arabia. *J. Stored Prod. Res.* Vol.29, No.1: 27-31.

Saari. K. and Hawtin, L., 1977. Back to barley, recipes for the world's oldest food crop. Forth regional winter cereal workshop - Barley, Amman, Jordan, April 24-28, 1977.

Salas, B., Steffenson, B.J., Casper, H.H. and Prom, L.K. 1997. Fusarium species pathogenic to barley and their associated toxins. *Cereal Research* Communications, Vol:25, No:3/1: 483-487.

Sauer, D.B., Meronuck, R.A. and C.M. Christensen, 1992. Microflora. *In* Storage of grains and their products, Sauer, D. B. ed., American Association of Cereal Chemists, pp.313-340.

Schipilova, N.P. and Gagkaeva, T.Y., 2000. The forms of manifestation of Fusarium head blight on the seeds and heads of cereal crops. *In* Proceedings of the 5th European Seminar, Szeged, Hungary, 26 August - 5 September, 1997; Cereal Research Communications Vol.25, No.3/2: 815-816.

Scudamore, K.A., Clarke, J.H. & Atkin, P.M., 1986. Natural occurrence of naphthoquinones in cereals and animal feed stuffs. *In* International biodeterrioration, Vol:22, supplement, proceedings of the biodeterrioration society on spoilage and mycotoxins of cereals and other stored products', B. Flannigan, ed., pp:71-82.

Shepherd, M.J. & Gilbert, J., 1986. Fusarium mycotoxins in cereals and other stored products. *In* International biodeterrioration Vol:22, supplement, proceedings of the biodeterrioration society on spoilage and mycotoxins of cereals and other stored products, B. Flannigan, ed., pp:61-70.

Shildbah, R. 1989. Problems relating to infestation with micro organism on malting barley and malt. Brauwelt international.

Skerritt, J.H., Hill, A.S., Edward, S.L. Beasley, H.L., Lee, N., McAdam, D.P. and Rigg, A.J., 1997. Rapid testing for insecticide residues in stored products using immuno-and ezyme assays. *In* Proc. 6th Intern. Working. Conf. Stored Prod. Protection E. Highley, E.J., Wright, H.J. Banks and B.R. Champ eds., CAB International, University Press, Cambridge, pp. 843-847.

Somel,K., Mazid, A.,Hallajian, M., 1984. Survey of barley producers Northern Syria (1981/1982). Volume III Descriptive Statistics, Research Report 12-111, Farming System Program. ICARDA, Syria.

Srivastava, J.P., 1977. Barley production, utilization and research in the Afro-Asia region. Proc. of the fourth regional winter cereal workshop, Vol.2, Amman, Jordan.

Starks, K.J. and Webster, J.A., 1985. Insect and related pests, Chapter 12. *In*< Barley, Rasmusson, D.C. ed., Number 26 in the series Agronomy, American Society of Agronomy, pp.337-360.

Donald, B.R., pp. 335-365, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Wisconsin, 1985, pp.522.

Tetik, M., 1982. Grain losses and rates of broken grains of batter threshing. *In* Seminar on pre and post harvest proceeding, 13-17 Dec. 1982, Printing house of Ministry of Agriculture and Forestry, Central Logistic Directory, Yenimahalle, Ankara (in Turkish).

TMO, 2003. Long term data of purchased commodities and their storage capacities. Ankara.

Tuite, J.F. & Christiensen, C.M., 1955. Grain storage studies, XVI: Influence of temperature conditions upon the fungus flora of barley seed. *Cereal Chem.,* 32:1-11.

Ulger, P., 1982. Effects of various mechanizations systems used for wheat harvest and threshing on the crop losses. *In* Seminar on pre and post harvest proceeding, 13-17 Dec. 1982, Printing house of Ministry of Agriculture and Forestry, Central Logistic Directory, Yenimahalle, Ankara (in Turkish).

Varnava, A., Navarro, S. and Donahaye, E., 1995. Long-term hermetic storage of barley in PVC covered concrete platforms under Mediterranean conditions. *Postharvest Biol. & Technol.* 6: 177-186.

Vickerman, G.P. and Wratten, S.D, 1979. The biology and pests status of cereal aphids (Hemiptera, Aphidedae) in Europe: A review. *Bull. Entomol. Res.* 69:1-2.

Wendorf, F., Schild, R., Hadidi, N.E., Close, A.E., Kabusıewicz, M., Wieckowska, H., Issawı, B. and Haas, H., 1979. Use of barley in the Egyptian late paleolithic. *Science*, 205: 1341-04 1347.

WHO, 1993. IARC Monographs on the evaluation of carcinogenic risks to humans, Volume 56, 397-444.

Wilkin, D.R. & Hurlock, E.T., 1986. Stored grain pests and their management. *In* International biodeterrioration Vol:22, supplement, proceedings of the biodeterrioration society on spoilage and mycotoxins of cereals and other stored products', B. Flannigan, ed., pp: 1-6

Wilkin, D.R., 1975. The effects of mechanical handling and admixture of acaricides on mites in farm stored barley. *J. Stored Prod. Res*., Vol.11, pp.87-95.

Wilson, D.M., Abramson, D., 1992. Mycotoxins, *In* Storage of cereal grains and their products, D.B.Sauer, ed., American Association of Cereal chemists, Inc., pp.341-391.

Wisniewska, H., Adamski, T., Chelkowski, J. And Surma, M., 1997. Susceptibility of two and six rowed barley DH lines to Fusarium head blight. *In* Proceedings of the 5th European Seminar, Szeged, Hungary, 26 August-5 September, 1997; Cereal Research Communications Vol.25, No.3/2: 833.

Yaltirik, A., 1982. Methods for measuring grain loss at combine harvest and grain loss in Ankara province in: Seminar on pre and post harvest proceeding, 13-17 Dec. 1982, Printing house of Ministry of Agriculture and Forestry, Central Logistic Directory, Yenimahalle, Ankara (in Turkish).

Yasar, B., 1996. Depo zararlilari. 100th Year University, Agricultural Faculty Pres, No:16, Van, Turkey, 76 pp. (in Turkish).

Yildirim, E., Özbek, H. and Aslan, İ., 1997. Turkiyedeki önemli depolanmıs urun zararlıları ve mucadeleleri. Ataturk University Pres, No:191, Erzurum, Turkey, 95 pp. (in Turkish).

Yurdakul, O., O. Erkan, I. Genc, c. Bedestenci, Y. Kırtok, M. Direk, 1987. Barley production economy of Southestern Anatolia. Cukurova Universitesi basımevi, Adana, 1987, (in Turkish).

7. Annex

Annex 1. Recipes of barley foods containing barley products

(Saari. K. and Hawtin, L., 1977. Back to barley, recipes for the world's oldest food crop. Forth regional winter cereal workshop - Barley, Amman, Jordan, April 24-28, 1977).

<u>Soups:</u>

Scotch broth

Ingredient	Amount
Lamb or mutton, cubed	3 lbs
Water	-
Salt	1 table spoon
Pearl barley	1/2 cup
Carrots	2
Turnips, diced	2
Onions, diced	3
Chopped parsley	1/2 cup

Place cubed mutton in deep kettle. Cover with water. Add salt, bring to boil and reduce heat to low. Add salt. Bring to boil and reduce heat to low. Skim off scum when necessary. Simmer, covered, for 1 hour. Add barley and vegetables except parsley. Simmer, covered 1 1/2 - 2 hours. Skim fat and before serving, stir in parsley. Serves 6.

Barley yogurt soup (Turkey)

Ingredient	Amount
Pearl barley	1 cup
Beef broth	6 cups
Yogurt	4 cups
Onion, chopped	1
Butter	1/4 pound
Parsley	1 bunch
Dried mint	1 sweet spoon
Salt	1 tea spoon
Pepper	1/2 tea spoon

Soak barley overnight in cold water. Drain and cook in broth until tender. Fry onion in butter until lightly brown and add to barley. Add parsley, mint, salt, pepper and simmer 1 1/2 hours. Add well-beaten yogurt and cook 5 minutes more, stirring constantly in one direction only. Serve at once.

Barley soup -Krupnik (Poland)

Ingredient	Amount
Cracked soup bone (joint) with some meat	1/2 pound
Diced mixed vegetables	1/2 pound
Mushrooms, dried	2
Medium potatoes, diced	3-4
Pearl barley	1/2 cup
Butter	1 table spoon
Dairy sour cream	1 cup
Salt and pepper	1 tea spoon
Egg yolks	1-2
Chopped parsley	1 table spoon

Put soup bone, mixed vegetables and mushrooms in kettle and cover with water. Bring to boil, reduce heat, and simmer until meat is half done. Skim occasionally, add potatoes and cook until done. Cook barley separately, adding half the butter. When meat and potatoes are done, remove bones and meat and add vegetables and stock to barley. Cut mushrooms in strips and return to soup. Bring to boil. Add sour cream and seasoning. Stir in youlks a little at a time to prevent curdling. Pour into tureen, and add remaining butter and parsley. Serves 6. For a less filling soup, omit sour cream and egg youlks.

Main dishes:

Barley Casserole

Ingredient	Amount
Butter or margarine	6 table spoons
Pearl barley	1 cup
Large onion, minced	1
Sliced raw or canned mushrooms	1 cup
Chicken bouillon	3 cups
Salt and pepper	-

Heat two table spoon butter and saute barley. Transfer barley to heavy casserole. Heat two more table spoon butter and saute onion. Add to barley. Saute mushrooms in remaining butter and add to casserole. Stir in hot consomme. Salt and pepper to taste. Cook, covered, over lowest possible heat until barley is tender and consommé absorbed, 25-45 minutes, depending on type of barley. Stir occasionally. Serves 6.

Mushroom and Kasha (Poland and Russia)

Ingredient	**Amount**
Pearl barley	1/2 lb.
Dried (1 oz) or cultivated mushrooms (1/2 lb)	1 oz 1/2 lb
Butter	1-2 oz
Salt and pepper	1/2 taste
Greated chese	2 table spoon
Egg	1

Beat up the egg and stir into barley so tht the grains are well coated, and leave to dry. Soak the mushrooms (if dried) in one pint warm salted water, then simmer them, covered, in the same water for 1/4 hour or until tender. With cultivated mushrooms, wipe and slice them, then simmer in one pint salted water, covered for 1/4 hour. In both cases, Simmer the butter in a pan till melted, add the barley, cover and simmer very slowly for 10 minutes, stirring from time to time. Then transfer the content of the pan to a small, heavy casserole with a lid. Mix in the mushrooms, cut into small strips, a pinch of salt and a sprinkle of pepper. Put on the lid and bake in a moderate oven (180 °C) for one hour. Before serving, stir in another lump of butter and greated cheese. Serves 3-4.

Chicken livers and barley

Ingredient	**Amount**
Butter or margarine	1/2 cup
Onion, minced	1
Mushrooms, sliced	1/2 pound
Pearl barley	1 cup
Chicken boullon	2 cups
Chicken livers	1 pound
Salt and pepper	

Heat 1/4 c. butter in heavy saucepan. Add onion and cook for 2-3 minutes. Add mushrooms and cook for 5 minutes. Add barley and brown lightly. Stir in bouillon. Cover, and simmer for about 25 minutes, or until barley is tender and liquid is absorbed. Saute chicken livers in remaining butter. Season to taste. Stir into barley. Serves 4-6.

Desserts:

Birthday cake

Item	Amount
Barley flour	1 cup
Sugar	1/2 cup
Baking powder	3 tea spoon
Salt	1/4 tea spoon
Shortening	4 table spoon
Milk	2/3 cup
Egg replacer	1 tea spoon
Vanilla	1/2 tea spoon

Sift flour, baking powder and salt together. Cream shortening. Add sugar to shortening, continuing to beat. Beat milk, egg replacer, and vanilla. Add milk mixture and then the sifted dry ingredients. Bake in two greased 6 inch pans at 375 °F. for about 40 minutes. When cool, smooth on your favorite frosting on both layers. Serve immediately or chill.

Barley fudge

Item	Amount
Flaked barley	1 tea cup
Chopped dates	2 table spoons
Golden syrup	1 table spoon
Cocoa	1/2 table spoon
Margarine	1 oz
Salt	1 pinch
Water	4 tea cup

Mix the ingredients well and put into a well greased pudding bowl and steam for 2 1/2 hours.

Boiled barley -Iyouk (Syria)

Item	Amount
Yellow barley	1 cup
Sugar	1 cup
Raisins (soaked 1/2 hour)	1 cup
Anise seeds	1 tea spoon
Walnuts, chopped	1/2 cup

Boil barley in quart of water on low fire for 30 minutes, adding more water during cooking. Add sugar and stir well. Add raisins and anise seed. Simmer 10 minutes. Garnish with walnuts. This dessert is served especially on the feast day of S. Barbara, which falls on December 4.

Belila

Item	Amount
Barley (Soaked overnight)	1/2 lb.
Sugar	-
Orange blossom or rose water	-
Pistachios, chopped	2 oz
Flaked almonds	1/4 lb.
Pine nuts	1 oz.

Simmer the barley in about 2 pints of water until only just tender, about 1/2 - 3/4; hour. Add sugar to taste and cook a few minutes, stirring well-dissolved. Add orange blossom or rose water and nuts. Add more water, if necessary, so that the barley and nuts remain suspended in a light, scented syrup. This dessert is served especially on the occasion of the appearance of the first tooth of babies.

Beverages

Barley water:

Mix 1 oz of patent barley into a smooth paste, pour into a stewpan containing 1 quart of boiling water and thinly-pared rind of 1/2 small lemon, and two - three lumps of sugar, and stir over the fire for about 5 minutes. When cold, strain and use. This forms a nutritious, agreeable drink, and is also largely used to dilute milk, thus making it easier of digestion.

Barley drink:

Item	Amount
Pearl barley	1/ 4 cup
Water	1 qt.
Rind and juice of lemons	2
Sugar	To taste

Combine barley, water and lemon rind in a saucepan. Bring to boil and simmer, covered, over the lowest possible heat for two hours. Strain and add lemon juice and sugar to taste. Chill before serving. Makes 1 quart.

Breads

Unleavened barley bread - Rieska (Finland)

Item	Amount
Buttermilk (or any other liquid)	1/2 cup
Cream	1/2 cup
Salt	1/2 tea spoon
Sugar	1/2 tea spoon
Barley flour	1 cup
Melted butter	1 table spoon

Mix together the buttermilk, cream, salt and sugar. Stir in the flour and beat until smooth. Add the butter. Pour the batter into a well-buttered and floured 9 inch round cake pan, or spread the dough on raw cabbage leaves and place on a lightly greased baking sheet. Bake at 450 °F for about 30 minutes or until lightly browned. Serve hot with butter. Serves 4-6.

Kyrsa whole-grain bread (Vahakyron Ohrakyrsa) bread

Item	Amount
Dry yeast	2 packages
Warm water	1/4 cup
Salt	2 tea spoon
Barley flour	4 cups
Milk	2 cups

Sprinkle the yeast into the mixing bowl and add water. Stir until the yeast dissolves. Add the milk, salt, and part of the flour, stirring well. Add the remaining flour slowly, beating until the dough is smooth and stiff. Let the dough rest in the bowl for 15 minutes. Turn out unto a lightly floured board and divide into 2 equal parts (the dough will be slightly sticky). Shape each part into a ball and pat out into around 8 - 10 inches in diameter. Place on a lightly buttered baking sheet. Let rise until the loaves look puffy (about 45 minutes - 1 hour). Prick all over with a fork and bake a 375 °F. for 30 minutes or until lightly browned. Brush with butter while hot. To slice, cut into wedges and split each wedge into 2 parts. Makes 2 loaves.

Barley/Whole Wheat Bread - Canada (www.albertabarley.com/recipes)

Ingredient	Amount
whole barley flour	3 cups
whole wheat flour	3 cups
all-purpose flour	5-6 cups
water	5 cups
vitamin C	1000 mg
regular yeast	2 Table spoons
sugar	2 Table spoons
salt	1 Table spoons
canola oil	1/3 cup

In a separate bowl, combine 1cup warm water, sugar and yeast. Let stand until yeast becomes visibly active. In a large mixing bowl, combine yeast mixture with remaining ingredients, except for 4 cups of all-purpose flour. Mix together well and let sit for approximately 30 minutes, until a sponge is formed and doubled in bulk. Mix in enough of the remaining flour to produce a soft, smooth dough and knead for 15 minutes (12 minutes by mechanical dough hook). Separate into 4 loaves, cover and let rise in a warm place until doubled in bulk. Bake for 20 to 25 minutes in a 375 °F (190° C) oven. *From Donna Hamilton, Hamilton's Barley Flour, Olds, Alberta, Canada.*

Annex 2: List of figures