

Forage crops

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Chapter 4

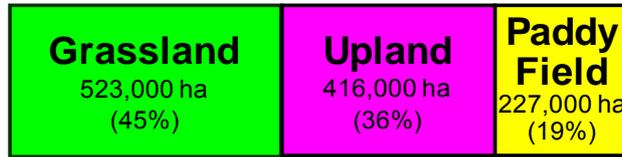
Forage Crops

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Grassland farming is one of the important activities in Hokkaido's agriculture. Grasslands cover 45% of cultivated area of Hokkaido. About 83% of the grasslands of Japan are in Hokkaido alone (Fig. 4-1). In eastern and northern Hokkaido where rice cultivation can not be undertaken due to cool climate, dairy farming based on grasslands is the major agricultural activity. It accounts for 91.5% of the total agricultural output. Size of dairy farms in these districts is comparable to those of European countries. Grasslands in Hokkaido consist of perennial forage grasses such as timothy and orchardgrass, and perennial forage legumes such as white clover, red clover and alfalfa. In upland areas such as Tokachi district, maize is grown as an annual forage crop for use as silage for animal feed. In this chapter, forage crops cultivated in Hokkaido are described.

1. History of Hokkaido's grasslands

The cultivation of forage crops in Hokkaido was first recorded in 1869. Gaertner, a Prussian (now German), cultivated some forage crops in Nanae near Hakodate. At the Sapporo Agricultural College (now Hokkaido University) the cultivation of forage crops whose seeds had been imported by Dr. William S. Clark from Massachusetts, USA was started in 1877. Dr. Edwin Dun (Fig. 4-2), who has been called the father of Hokkaido's dairy farming, established the Makomanai Livestock Farm in 1876. In 1887, forage crops were cultivated at several livestock farms in Hokkaido. In those days, forage grasses such as timothy and orchardgrass were grown in grasslands. Timothy was grown mainly for production of hay for use as feed of horses. Orchardgrass was used for both hay production and grazing by cattle. However, after the World War II, due to decrease in horse population cultivation of timothy declined. In 1955, the grassland area was only 80,000 ha. During 1960's, the consumption of animal



Cultivated area of Hokkaido 1,166,000ha
 (25% in Japan)

Fig.4-1. Cultivated area in Hokkaido.



Fig.4-2. Edwin Dun Memorial Museum at Makomanai, Sapporo. The materials used at Makomanai Livestock Farm in those days are displayed.

products such as milk and meats increased drastically due to the influence of western life-style and economic development. After 1956, grasslands were developed on a large scale in eastern Hokkaido with the support of Japanese government and World Bank. So called 'Pilot Farm Program' was carried out using big machinery to develop grasslands. Later, a number of grasslands were established every year, which had an area over 500,000 ha by the end of 1980's (Fig. 4-3). In the 1970's, for the establishment of grasslands in the eastern Hokkaido near Abashiri, orchardgrass was cultivated, because of its high forage yield. But, in 1975, severe winter conditions of the region killed orchardgrass plants in many swards. Subsequently, cultivation of timothy, a winter hardy species, was undertaken in this region, and now it covers more than 70% of the grasslands of Hokkaido. Timothy has high forage quality and is a suitable feed for high milk yielding cows (super cow); thus it is a preferred forage crop for grasslands.

2. Forage crops

Table 4-1 shows the current acreage of forage crops in Hokkaido. Perennial forage crops as well as annual maize are important for forage production in Hokkaido.

(1) Perennial forage crops

Timothy and orchardgrass are cool season grasses. These are cultivated as important perennial forage crops in Hokkaido. Hokkaido has two distinct climate zones. During winter, the western Hokkaido has thick snow cover (non-frozen soil zone); thus orchardgrass and perennial ryegrass are grown there. The eastern Hokkaido has less snow cover (frozen soil zone). Here winter hardy species such as timothy and meadow fescue are common (Fig. 4-4). Perennial forage legumes such as red clover, white clover and alfalfa are usually cultivated as a mixture with grasses. They play an expanded and invaluable role in the nitrogen economy, animal productivity and sustainability of grasslands.

Main perennial forage crops grown in Hokkaido are listed below.

1) Timothy:



Fig. 4-3. Grassland in the eastern Hokkaido -view from an observatory point, 'Kaiyou-dai' in Nakashibetsu-town.

Table 4-1. Acreage of forage crops in 2006 (ha).

	Japan	Hokkaido
Forage grasses & legumes	787,300	569,700
Maize	85,200	36,600
Sorghum	34,300	158
Oat & Rye	62,080	45,618
Forage turnip	339	0
Others	27,381	10,024
Total	996,600	662,100

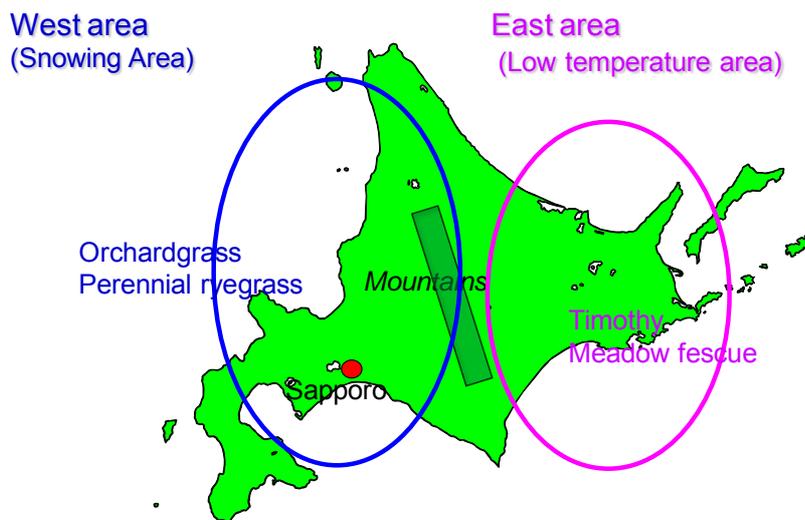


Fig. 4-4. Two different climate conditions in winter and distribution of cultivated grasses.

Scientific name: *Phleum pratense* L.

Japanese name: Oh-awagaeri

Timothy (Fig. 4-5) is the most important grass in the Hokkaido region and now occupies more than 70% of Hokkaido's grasslands. This species is well adapted to humid and temperate area with severe winters, and thus does not grow under dry or hot conditions. Timothy is one of the most winter-hardy cool-season grasses. LT₅₀ (the temperature at which half of plants are killed) was lower than -25°C for samples of timothy collected in December (Fig. 4-6). Thus timothy can be cultivated steadily in the coldest areas of the eastern Hokkaido. It is used mostly for hay and silage. Timothy has high palatability and forage quality. However, it has poor re-growth after cutting. It is not suitable for grazing pasture. It is very compatible with red clover.

In the past, early flowering cultivars of timothy had been popular in Hokkaido. Delayed harvest due to simultaneous heading and flowering often results in lower forage quality. Forage quality reduces drastically after flowering. Therefore, intermediate and late flowering cultivars of timothy have been developed. Now cultivars with different maturity periods are available (Fig. 4-7). Thus, now a farmer can harvest timothy grasslands at the optimal time.

2) Orchardgrass (Alias: Cocksfoot)

Scientific name: *Dactylis glomerata* L.

Japanese name: Kamogaya

Orchardgrass (Fig. 4-8) is well adapted to humid and temperate regions. It has moderate tolerance to heat and drought, and higher shade tolerance than most of other forage grasses. LT₅₀ of orchardgrass is higher than that of timothy (Fig. 4-6). It can not survive severe winters of the eastern Hokkaido. Orchardgrass shows high yield and good response to fertilizers. It has relatively good palatability and forage quality. Orchardgrass is used primarily for hay and grazing pasture. It is compatible with alfalfa, white clover and red clover.

Area under orchardgrass in Hokkaido has declined in the past three decades because of its relatively poor winter hardiness and decrease in the



Fig. 4-5. Timothy.

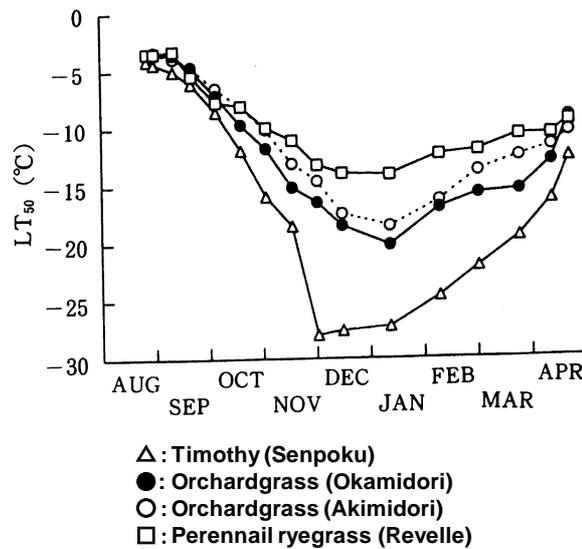
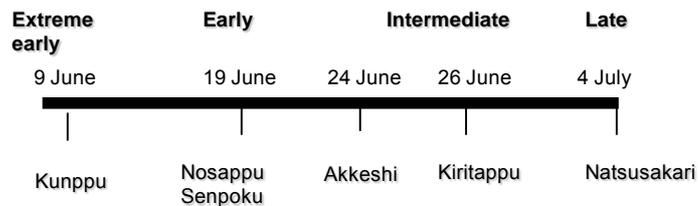


Fig. 4-6. LT₅₀ (the temperature at which half of plants is killed) in three species of grasses.



Data in Kunneppu-town

Fig. 4-7. Ear emergence in timothy cultivars released at the Hokkaido Pref. Kitami Agric. Exp. Station.

forage quality resulting from delayed harvest. However, recently orchardgrass has gained attention due to its high productivity and earlier heading time compared to timothy. Keeping in view the growing periods of timothy and orchardgrass, grasslands with a combination of these two may result in high herbage production.

3) Perennial ryegrass

Scientific name: *Lolium perenne* L.

Japanese name: Hosu-mugi

Perennial ryegrass (Fig. 4-9) is the most important grass species in western Europe and New Zealand. In Hokkaido, its use as forage has been limited to the northern Hokkaido, Tenpoku area which is a non-frozen soil zone due to heavy snow cover. It does not tolerate low fertility, drought and heat stress, as well as severe winters of eastern Hokkaido. LT₅₀ of perennial ryegrass is substantially poorer than that of timothy and orchardgrass (Fig. 4-6). This species has high digestibility and palatability as well as resistance to treading by grazing animals. It is grown in grazing pasture mainly as mixture with white clover, but is also used for hay and silage production.

4) Meadow fescue

Scientific name: *Festuca pratensis* Huds.

Japanese name: Hiroha-no-ushinokegusa

Meadow fescue (Fig. 4-10) has characteristic good re-growth after cutting and winter survival. This species is generally grown mixed with orchardgrass and timothy as a companion crop in Hokkaido. However, this is also a promising grass for grazing pasture in eastern Hokkaido where cultivation of perennial ryegrass is difficult.

5) Alfalfa (Alias: Lucerne)

Scientific name: *Medicago sativa* L.

Japanese name: Murasaki-umagoyashi

Alfalfa (Fig. 4-11) is called 'Queen of forage' because of its good forage quality and high protein content. It does best on soil with fine to medium



Fig. 4-8. Orchardgrass.



Fig. 4-9. Perennial ryegrass.



Fig. 4-10. Meadow fescue.

textures that are moderately to well drained and neutral or alkaline. It tolerates drought and is very winter hardy. Alfalfa is well adapted in the USA. However, it is not adapted so well in Hokkaido due to acidic and wet soil conditions. But breeding has led to the development of cultivars adapted to Hokkaido conditions. New cultivars, 'Makiwakaba' and 'Haruwakaba' have shown good performance in Hokkaido region and area under these cultivars has increased. Mono-cultivation as well as mix-sowing of alfalfa with grasses such as orchardgrass is practiced. Alfalfa is mainly used for silage production. It is not suitable for grazing.

6) White clover

Scientific name: *Trifolium repens* L.

Japanese name: Shiro-tsume-gusa

White clover (Fig. 4-12) is the most important forage legume for mix-sowing in temperate grasslands of the world. It is well adapted to humid temperate climate. White clover is grown throughout Hokkaido. Cultivars are classified for leaf size: small (wild), medium (common) and large (ladino). Small types are dwarf and have very prostrate habit, and are not very productive. These are used for intensive grazing pasture. Medium types are intermediate in size between small and large types, and are used for silage or grazing pasture. Ladino types have larger leaves and longer petioles, and are more productive. These are used for hay and silage production.

7) Red clover

Scientific name: *Trifolium pratense* L.

Japanese name: Aka-tsume-gusa

Red clover (Fig. 4-13) is a short-lived perennial forage legume widely distributed in temperate grasslands. It has good winter hardiness, but poor tolerance to high temperature and drought. This species is grown throughout Hokkaido. Cultivars are classified into two growth habits, medium and mammoth. Medium types flower earlier and produce two or three harvests, while mammoth types flower much later and typically produce a single harvest. Red clover has high palatability and nutritive value. Its poor persistence (only



Fig. 4-11. Alfalfa.



Fig. 4-12. White clover.



Fig. 4-13. Red clover.

two to three years), however, is disadvantageous. It is used for hay and silage production, and also for grazing.

8) New forage species

A new forage legume ‘Galega’ (*Galega orientalis* Lam.) has been recently introduced from Estonia and registered as a recommended forage cultivar for Hokkaido (Fig. 4-14). This species shows good persistency and high adaptability under mixed cultivation with timothy in Hokkaido. However, it has slow establishment, which needs to be improved through breeding.

(2) Annual forage crops

In Japan, corn (maize) and sorghum are important annual forage crops. Maize is grown mainly in Hokkaido in an area of 36,600 ha. It is mainly cultivated on uplands in the Tokachi district. In Hokkaido, sorghum is grown in a very limited area because it requires warm temperature in summer. Rye and oat are also cultivated as forage crops, but currently their acreage is not large. Therefore, only corn is described here.

1) Corn (Alias: Maize)

Scientific name: *Zea mays* L.

Japanese name: Toumorokoshi, Toukibi

Corn (Fig. 4-15) is world’s third leading cereal crop, after rice and wheat. However, unlike rice and wheat, corn is consumed mainly as feed for livestock rather than as human food. Corn is often classified into six groups based upon endosperm characteristics. These are dent, flint, flour, pop, sweet and waxy corns. Sweet corn has high sugar in kernels and is grown for human consumption. Dent and flint corns are mainly used for animal feeds. About 40% of the world’s corn is grown in the USA, and mainly (over 90%) for grain. But in Japan including Hokkaido, corn is cultivated for the production of silage. The whole plants are harvested when kernels are in yellow-ripe stage. All commercial cultivars are hybrids. Mainly early maturing (75-110 days) hybrids are grown because in Hokkaido accumulated temperatures during growing season (16 May–10 Oct) are low (2,000 – 2,500 °C). In eastern Hokkaido, very



**Fig. 4-14. New forage legume Galega in Hokkaido
(Photograph by Dr. K. Okumura).**



Fig. 4-15. Corn field in Tokachi district (Photograph by Dr. K. Koinuma).

early maturing types (75 days) are cultivated. Seeds of many hybrid cultivars come from the USA and Europe. Sweet corn is also cultivated in Hokkaido.

3. Breeding program

Plant breeding is the intentional genetic manipulation of plant species in order to create desired phenotypes for specific purposes. Improvement of various agronomical characters such as yield, quality, and disease and insect resistance by breeding is essential for stable and high production.

Breeding programs on orchardgrass, meadow fescue, alfalfa, red clover, and white clover are now carried out at the National Agricultural Research Center for Hokkaido Region (NARCH). Breeding of timothy is done at the Hokkaido Pref. Kitami Agric. Exp. Station (timothy), and also by some private companies. Main breeding objectives for perennial forage crops are winter hardiness, yield, forage quality, persistency and disease resistance. Evaluation of plants/accessions introduced or collected from Hokkaido region and foreign countries is undertaken at experimental fields (Fig. 4-16), and superior genotypes with desired characteristics are selected. New breeding lines thus developed at the breeding stations are tested for local adaptation and specific characteristics such as suitability for grazing and cold tolerance etc., at several experimental sites throughout Hokkaido (Fig. 4-17). Based on the data from these evaluations, high performing breeding line(s) are registered as a recommended variety(ies) for general cultivation in Hokkaido.

(1) Perennial forage crops

Many forage crops are polyploids and obligate out-breeders. Conventional breeding of forage crops is mainly based on synthetic varieties developed through poly-crosses among superior selected genotypes (Fig 4-18).

1) Timothy

Recent breeding objectives of timothy are lodging resistance, mix-sowing ability with forage legumes, re-growth in summer and good seed production. Lodging results in bad forage quality. Lodging resistance is also essential for mechanical harvesting.



Fig. 4-16. Experimental field for selection of timothy. Hokkaido Pref. Kitami Agric. Exp. Station.



Fig. 4-17. Experimental field for local adaptability test of timothy. Hokkaido Pref. Kosen Agric. Exp. Station.

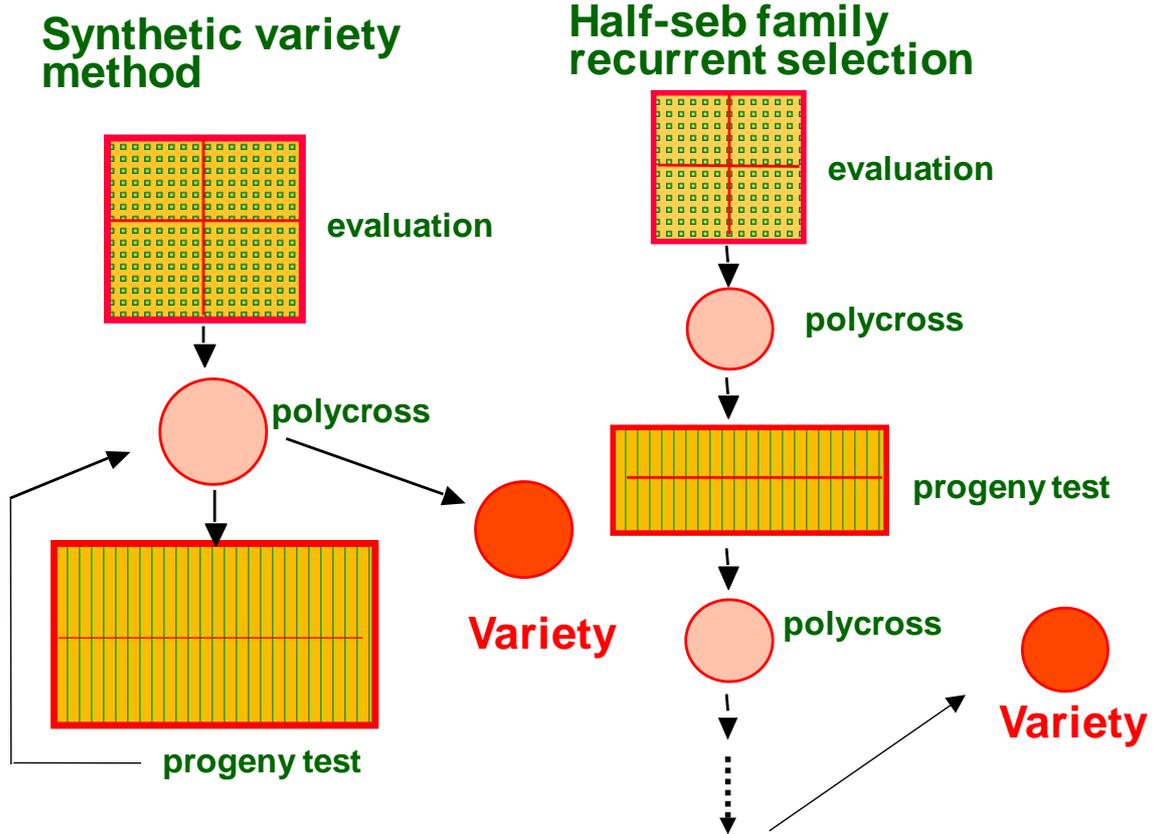


Fig 4-18 Breeding methods in perennial forage crops.

2) Orchardgrass

Water soluble carbohydrate (WSC) is an important trait for the nutritive value of forages because of its relation to palatability, digestibility and fermentation quality of silage. The WSC content and its composition are also correlated with freezing tolerance. The WSC content of orchardgrass is lower than that of other temperate grasses. Thus at NARCH the breeding program aims at increasing the content of WSC, and some promising breeding lines with high content of WSC have been developed. A new orchardgrass cultivar with high WSC content is likely to be released soon. There is generally a negative correlation between freezing tolerance and plant vigor in autumn (Fig. 4-19). Recently, a new cultivar 'Harunemidori' with both good winter hardiness and high production in autumn has been released. This cultivar showed a rapid increase in freezing tolerance in late autumn (Fig. 4-20). 'Harunemidori' is an ideal cultivar for Hokkaido region, which is located at mid latitude and has severe winter cold.

3) Perennial ryegrass

Recently, the Hokkaido Pref. Tenpoku Agric. Exp. Station has released a variety, 'Pokoro', which has moderate winter hardiness and high herbage production for grazing pasture. Figure 4-21 shows perennial ryegrass attacked by snow mould fungus, which is a major winter disease in Hokkaido. The new cultivar is resistant to snow mould and thus yields higher than susceptible ones.

4) Forage legumes

The breeding objectives of forage legume, white clover are winter hardiness and persistency. Red clover is improved for persistency, winter hardiness and compatibility for mix-cultivation with timothy. Breeding of alfalfa is aimed at improving persistency, yield, resistance to pepper spot and tolerance to trampling by heavy agricultural machinery. These legumes are pollinated by insects, mainly bees.

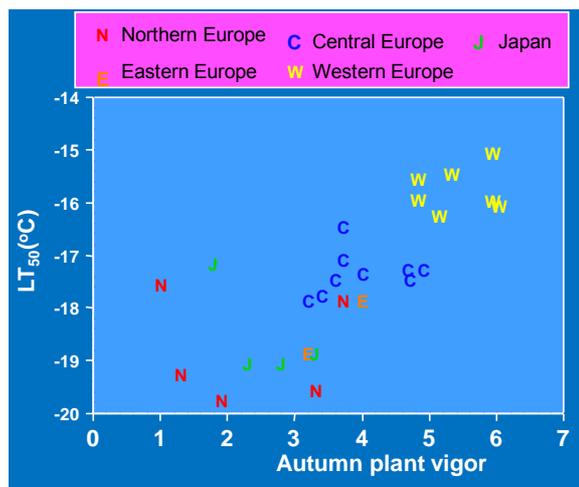


Fig. 4-19. Relationship between freezing tolerance (LT₅₀) and plant vigor in orchard grass populations during autumn (from Nakayama et al. 1997).

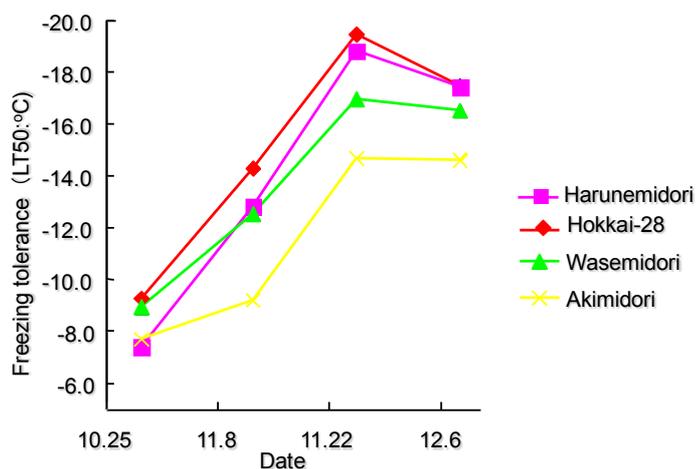


Fig. 4-20. Change of LT₅₀ in four cultivars of orchardgrass during autumn



Fig. 4-21. Winter pathogen, snow mould disease in perennial ryegrass. Left two rows: resistant cultivar, right two rows: susceptible cultivar.

(2) Corn

All corn cultivars are hybrids. Hybrid is the first generation progeny from a cross involving inbred lines. The objectives of corn breeding in Hokkaido are improvement in growth at low temperature, yield, lodging resistance and forage quality. Hybrids have been developed from single crosses between high yielding inbred lines of dent corn and northern flint having good growth at low temperature (Fig. 4-22).

4. Utilization of forage crops

(1) Grazing management

Grazing (Fig. 4-23) management involves manipulation of the soil-plant-animal complex to achieve the desired results. Grazing is not common in Japan including Hokkaido because it is not feasible to produce enough milk from limited lands. An intensive grazing system has been developed at NARCH combining short rotational grazing with silage production. Herbage production differs from season to season; from spring flush to summer slump. Utilization of sward for short rotational grazing and silage production in time of spring flush is reliable and efficient (Fig. 4-24). Such an intensive grazing system using 'Harusakae', a new winter-hardy meadow fescue cultivar has been established for eastern Hokkaido under a research project supported by the Ministry of Agriculture, Forestry and Fisheries (Fig. 4-25).

(2) Preservation of forage as hay and silage

Forage crops are harvested two or three times in a year, and stored for use as a consistent, reliable and predictable feed supply system for confinement feeding to dairy and beef animals. Common forms of storage are hay (usually with less 20% moisture) and silage preserved by anaerobic fermentation. Maturity stage at harvest is considered to be the primary factor affecting forage quality. Generally, forage quality declines with increase in growth stage of forage crops. Fig. 4-26 illustrates a typical relationship between quality and maturity stages based on cell wall components (fibrous constituents) and digestibility. The general trend is that digestibility declines with increase in maturity, while fibrous constituents increase. The best harvest time for good forage quality with

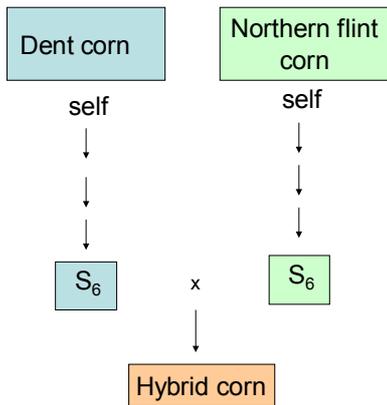


Fig. 4-22. Single cross hybrid corn seed production (Breeding program at NARCH).



Fig. 4-23. Grazing (Photograph by N. Sato).

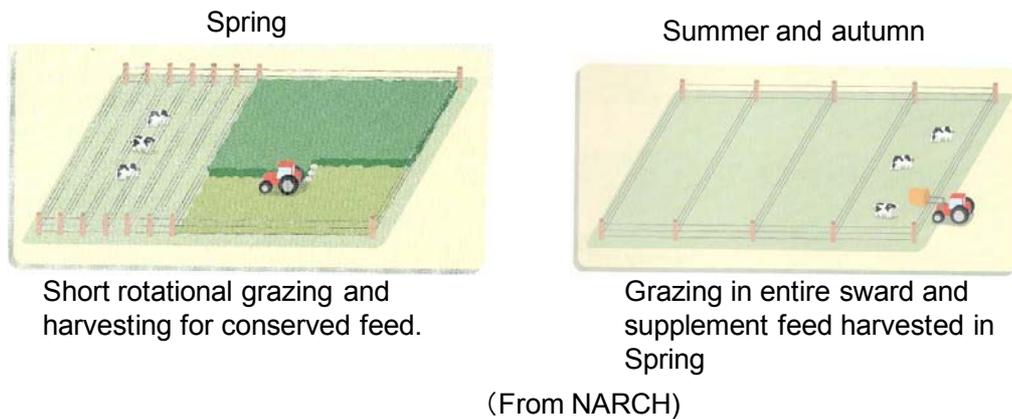


Fig. 4-24. Intensive grazing system.



Fig. 4-25. Experiment on intensive grazing system using meadow fescue in Tokachi district (Photograph by T. Matsumura).

high herbage production is heading stage. In Hokkaido, relatively earlier harvest at booting to heading stage has been recommended for cultivation of timothy.

1) Hay harvest

Moisture content in fresh forage crops is often 75 to 85%. Thus a large amount of water must be removed to produce hay. Weather is one of the important factors for drying. First crop-cutting time in Hokkaido is the middle of June to early July. Unlike other parts of Japan, Hokkaido normally does not have rains in June-July and thus has relatively low humidity. Therefore, timothy is harvested in June-July to produce high quality of hay.

2) Silage production

Silage is forage preserved by anaerobic storage, usually under conditions that encourage fermentation for conversion of sugar to organic acids such as lactic, acetic and propionic acids. The lactic acid bacteria are mainly involved in fermentation. Silage system is widely used for preserving forage in Hokkaido. Corn is harvested for whole crop silage. Fig. 4-27 shows corn harvest and making of whole crop silage in Tokachi district. Silage production is easier than hay production because there is no requirement of several good weather days for drying. The production of chopped silage has been mechanized; so labor inputs are lower than for hay. Because of lower mechanical losses in silage production, harvest losses are lower than in hay production. Wrapped round bales (Fig. 4-28) and bunker silos (Fig. 4-29) are often seen in Hokkaido.

5. Status and future prospects

In a couple of past decades in Hokkaido as well as in other parts of Japan, number of cow and cattle per farm has increased and number of farmers has decreased. Thus dairy farming and beef production in Japan depend largely on imported feed (Table 4-2). Some mega-farms (annual production 1,000 t milk per farm), which use mainly imported feeds have appeared in Hokkaido recently. Due to this a large number of problems have arisen in animal production including environmental pollution by animal wastes and serious animal diseases such as foot and mouse disease and bovine spongiform encephalopathy (BSE). The self-sufficiency rate of animal feed has been decreasing. The fundamental

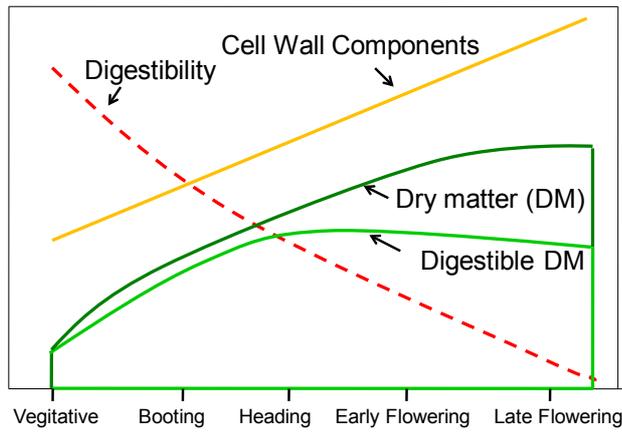


Fig. 4-26. Effect of maturity on forage quality in grasses.



Fig. 4-27. Harvest of corn to make whole crop silage in Tokachi district (Photographs by Dr. N. Fujita).



Fig. 4-28. Wrapped round bales for grass silage (Photograph by M. Takayama).



Fig. 4-29. Bunker silo for grass silage covered with polyethylene and used tires.

of dairy farming is nutrient cycling based on the involvement of the soil-plant-animal complex. Most of the nutrients contained in the forages and consumed by the animals are recycled to soil as urine and dung (Fig. 4-30). The dependence on concentrated imported feeds has caused too much accumulation of nutrients in soil leading to environmental pollution such as volatilization and nutrients runoff to rivers. During 2007-2008, the price of imported corn grains for animal feed had drastically increased. This was due to shortage in supply from USA as grains were used for ethanol production. Thus self-sufficiency in forage production is essential for secure and safe animal production. This requires developing new forage cultivars with higher productivity and quality. There is an urgent need to establish an efficient system for utilization of animal waste. Biogas systems with methane fermentation have been installed in some farms of Hokkaido (Fig. 4-31). Methane gas is used for fuel and electricity generation. Establishment of a sustainable grassland-farming system is essential in Hokkaido.

**Table 4-2. Demand-supply of animal feed in Japan.
(TDN base unit: 1,000 t)**

Demand				25,529
Supply	Domestic	Roughage		4,272
		Concentrate	Domestic materials	1,905
			Imported materials	4,076
			total	5,981
		Total		10,253
	Imported	Roughage		1,269
		Concentrate		14,007
		Total		15,276
		Roughage total		5,541
		Concentrate total		19,988
		Feed self-sufficiency rate		40.2 %
		Net domestic feed self-sufficiency rate		24.2 %

TDN: total digestible nutrients

(From MAFF)

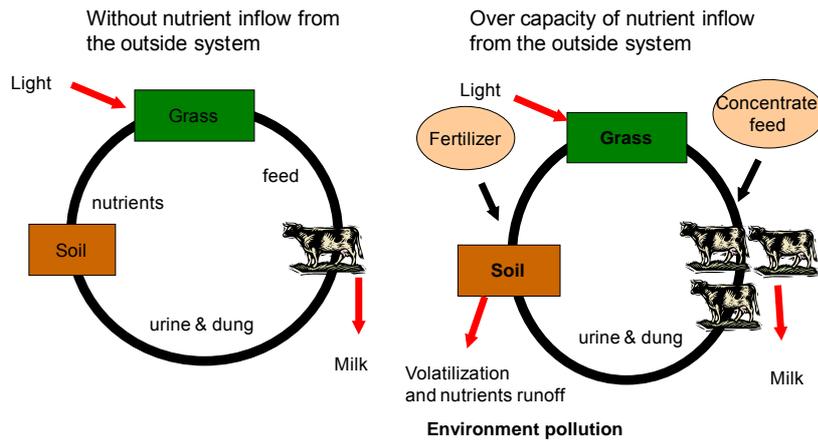


Fig. 4-30. Nutrient cycling systems in dairy farm.



Fig. 4-31. Biogas system with methane fermentation.