All the male sterile lines and respective maintainer O type lines at the Nat'l Hokkaido Agr. Exp. Stn. are improved to be carriers of the *m* gene for monogerm seed, while pollen parents are improved to have high sugar content, high yielding ability and high combining ability with multigerm seed nature. Sugar beet breeders have a choice to develop diploid F_1 cultivars by using diploid pollen parents or triploid F_1 cultivars by using tetraploid pollen parents.

One of the objectives in sugar beet breeding is to reduce inhibiting factors for crystallization in a process of sugar refining, such as soluble nitrogen, potassium and sodium. Some breeding materials, which were developed for pollen parents at the Nat'l Hokkaido Agr. Exp. Stn., are evaluated as the lines containing the inhibiting factor least in the world, and being utilized as pollen parent for F_1 cultivars in Europe and USA.

3. Rape seed crop

There is two species in Rape: *Brassica campestris* and *B. napus*. Of them, *B. campestris* had been planted for a long time in Japan, but was completely replaced by *B. napus* which was introduced into Japan during Meiji era. *B. napus*, which is an amphidiploid possessing AACC genome, is considered to be a hybrid between *B. campestris* with AA genome and *B. oleracea* with CC genome. Of the parental species of *B. napus*, *B. campestris* is considered to be originated in Turkish highland areas, and *B. oleracea* is in coastal areas along the Mediterranean Sea. Then they produced an interspecific hybrids at coastal areas of the north Europe where both species exist together.

Rape in Japan was cultivated as a winter crop in paddy farms after rice. Farmers, therefore, were anxious to plant rape cultivars as early as possible to harvest it before transplanting rice seedlings.

B. campestris, which disappeared once from farms in Japan owing to its yield lower than that of *B. napus*, was used as a breeding material for improving maturity of *B. napus*, because *B. campestris* matures much earlier than *B. napus*. Earliness of *B. campestris* was successfully transmitted to *B. napus* through interspecific hybrids between the two species. Early cultivars, 'Chisaya natane' and 'Oumi natane' were developed from interspecific hybrids at Fukushima Agr. Exp. Stn in 1954 and at the Nat'l Tokai-Kinki Agr. Exp. Stn in 1964, respectively.

Decreasing consumption of rape oil in the world is mainly caused by increasing use of soybean oil, but another reason for this may be a high content of erucic acid in rape seed which is considered hazardous for human myocardium. Consequently, if the erucic acid is eliminated genetically from rape oil, such rape oil will be as superior vegetable oil as compared with olive oil, peanut oil, corn oil, sunflower oil and safflower oil. Of these, the former two are known as oleic acid rich oil, and latter three are known as rinoleic acid rich oil. As a result of a mass screening of world wide collections for erucic acid-less character, a germplasm for erucic acid-less rape was found in Canada, and the trait was confirmed to be controlled by two pairs of polymeric gene. Thus, erucic acid-less rape cultivars were developed one after another in Canada, France and West German, some of which were soon introduced into Japan. Erucic acid-less cultivars in Japan, 'Asakano natane' and 'Kizakino natane', were developed in 1990 at the Nat'l Tohoku Agr. Exp. Stn. from crosses between the introduced erucic acid-less cultivars and cultivars in Tohoku region. The new cultivars will contribute to improved a farming system in Tohoku region by adding a new component crop in the rotation.

Rape seed crop exhibits a remarkable heterosis in yield, and F_1 hybrids will increase the yield. F_1 hybrid seed production system using self-incompatibility is now popular in Japan for cabbage and Chinese cabbage, but it can not be applied to F_1 seed production of rape because of self-compatible nature of rape. The use of genetic male sterility, therefore, is essential for the F_1 seed production. As a result of mass screening for cytoplasmic male sterility of rape at the Nat'l Inst. Agr. Sci., it was revealed that 'Chisaya natane' had a male sterile cytoplasm (S) and a fertility restoration gene (*Rf*), and that 'Hokuriku 23' had a normal cytoplasm (N) and a recessive gene for fertility restoration (*rf*). Of 131 cultivars tested, 23 cultivars were confirmed to have *Rf* gene for (S) cytoplasm of 'Chisaya natane'. This cytoplasmic male sterility system will be utilized for the F_1 seed production in future.

4. Mint

Mint as an aromatic crop includes several species. The component of refined oil of Japanese mint (*Mentha arvensis*) is mainly menthol, and that of peppermint (*M. piperita*) consists of about 50% menthol and others including ester menthol etc., while that of spearmint (*M. spicata*) is mainly carvone.

The total production of menthol oil in Japan reached about 800t in 1937, and this amount shared 70 to 80% in the world market of menthol oil at that time. Owing to increasing supply of cheaper product from developing countries and competition with artificially synthesized products, menthol oil production in Japan was suddenly reduced. A new breeding program, therefore, aimed to increase menthol oil productivity up to 100kg/ha from 30kg/ha in 1935 by using wide genetic resources.

'Suzukaze' and 'Ouba' were developed from intervarietal cross between Japanese mint (*M. arvensis* var. *piperascense*) and Chinese mint (*M. arvensis* var. *glabrata*) at the Nat'l Hokkaido Agr. Exp. Stn. in 1954 and 1961, respectively, and their production level was raised to 60kg/ha from the original level of 30kg/ha. Then, 'Houyou' was developed from an interspecific cross with German spearmint (*M. spicata* var. *crispa*) in 1965. Its production level was raised up to the initially projected level of 100kg/ha. Furthermore, 'Wasenami' was developed from another interspecific cross between Japanese mint and Dutch wild spearmint (*M. spicata* var. *crispa*) in 1973, and its production level was tremendously raised to 170kg/ha which was much higher than the initially projected level and about six times the original production level.

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Forage Plants

by

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CONTENTS

1. Forage plant breeding and use of ecotypes

1) Grass and legume breeding

At the beginning of Meiji Era, Japanese Government introduced temperate grasses and legumes from foreign countries and compared their adaptability to Japan. Many of them failed to adapt, but some adapted more or less to Japanese environmental conditions and through years of natural selection, their progenies were acclimatized to become ecotypes of Japan.

After the World War II, agricultural situations in Japan have changed. The Japanese Government, with aims to increase animal production, promoted forage plant culture. As the varietal improvement was recognized to be of primary importance, a breeding organization was set up by founding laboratories of forage plant breeding throughout Japan from 1950 to 1964. The National breeding program for forage grass and legume has now twelve laboratories located over Japan (Fig.1).

Selection of promising plants of adaptable species and populations were carried out. In the course of varietal comparison and breeding work, it was clarified that domestic ecotype populations have higher potential as the breeding materials when compared with foreign cultivars. The results of the national breeding work over 25 years indicate importance of selection of breeding materials according to each stage of the breeding work (Table 1). In the early period (1965-1970), six out of eight cultivars registered were bred from ecotypes in Japan which were collected at the starting of breeding work. In the next period (1971-1980), introduced foreign cultivars were used more frequently, but mixtures of both germplasms were also important. In recent years, combining exotic genetic resources with domestic germplasms or early-bred cultivars of Japan is becoming more and more important.

Experiments using Italian ryegrass proved existence of high concealed genetic variation in ecotype populations (FUJIMOTO *et al.* 1975). Ecotypes, which are usually highly uniform in the phenotypes within each population, showed a high response to selection by three generations of selection of dry matter weight in local varieties, while the response of a foreign material was low (Fig.2), in spite of its higher phenotypic variation. These results indicate the high potentiality of Japanese ecotypes as the materials for the further breeding work.

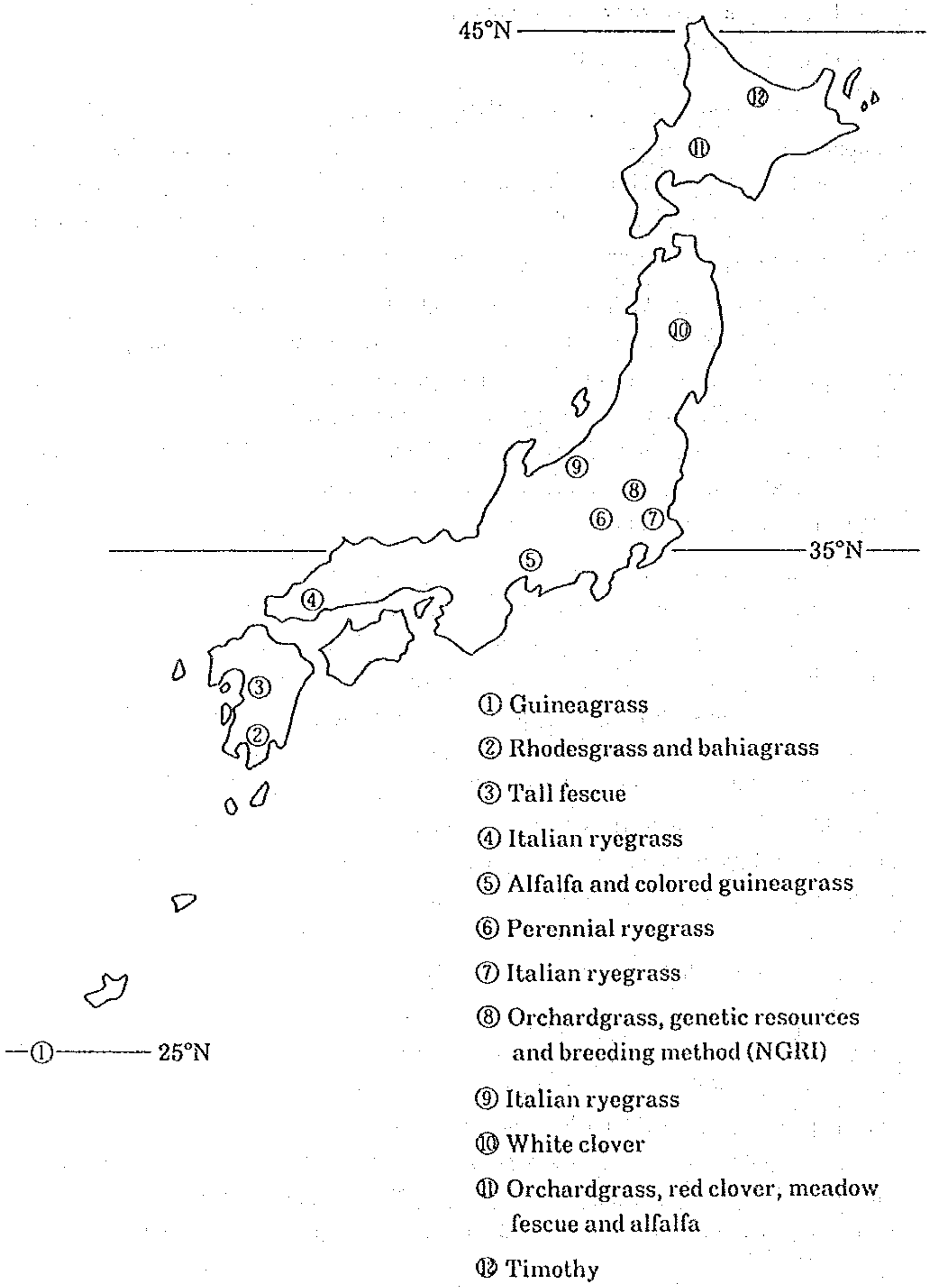

Fig. 1 Location of breeding stations for forage species in Japan.

Table 1 Changes in number of Japanese cultivars in three periods, when grouped according to their breeding materials.

Species	Regist. Year / Origin	1965-70 E.	M.	F.	1971-80 E.	M.	F.	1981-90 E.	M.	F.	Total
Italian ryegrass		3	0	0	1	3	2	1	2	0	12
Orchardgrass		2	0	0	0	1	1	0	2	0	6
Timothy		1	0	0	0	2	1	0	0	0	4
Tall fescue		0	0	0	1	0	1	0	1	0	3
Meadow fescue		0	0	0	0	0	0	0	1	0	1
Perennial ryegrass		0	0	0	0	0	2	0	2	0	4
Smooth bromgrass		0	0	0	0	0	0	0	0	1	1
Alfalfa		0	0	0	0	0	2	0	1	0	3
White clover		0	0	0	0	1	1	0	1	1	4
Red clover		0	1	0	0	1	0	0	2	0	4
Bahiagrass		0	0	1	0	0	1	0	0	1	3
Rhodesgrass		0	0	0	0	0	0	0	0	1	1
Dallis grass		0	0	0	1	0	0	0	0	0	1
Guineagrass		0	0	0	0	0	0	0	0	2	2
Colored guineagrass		0	0	0	0	0	0	0	0	2	2
Total		6	1	1	3	8	11	1	12	8	51

Note : E ..... Ecotypes of Japan.
M ..... Ecotypes, varieties bred in Japan and foreign cultivars.
F ..... Foreign cultivars.

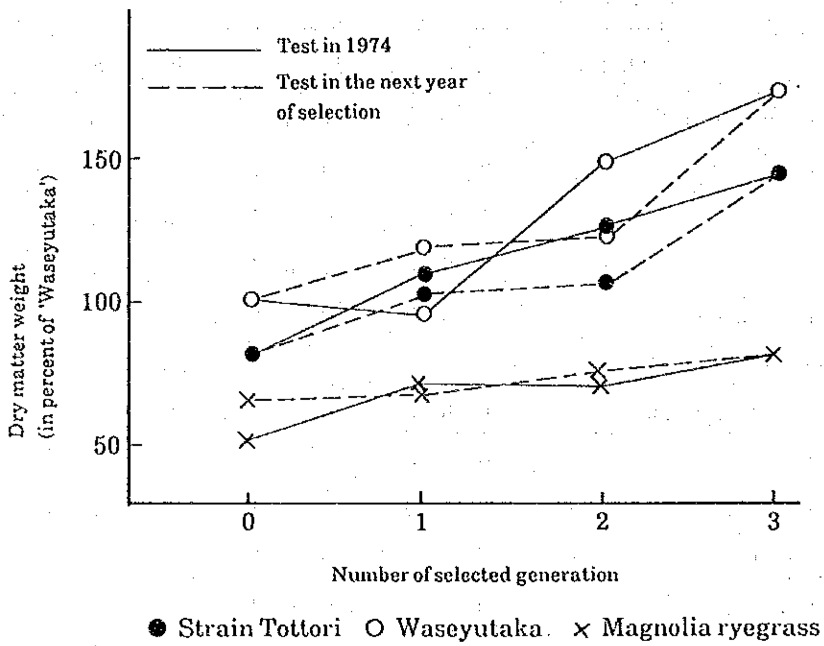

Fig. 2 Increase of dry matter weight as generations of selection advanced in Italian ryegrass.

2) Maize breeding

Maize is considered to have been introduced to Japan in the periods of Oda-Toyotomi (1573-1591) by the Portugueses. They were Caribbean flint type of maize and spread in Japan from Kyushu to Tohoku region during Edo Era. At the beginning of Meiji Era, Japanese Government introduced maize mainly from USA to cultivate it in Hokkaido. They were northern flint type and dent type cultivars. The introduced germplasms have received natural and artificial selection under local environments and differentiated many local varieties in Japan.

From 1953 to 1968, about 700 local varieties were collected by National Institute of Agricultural Sciences, NIAS (now reorganized to National Institute of Agrobiological Resources, NIAR). As the facility of seed storage was very poor at that time, many of the collections before1960 were not maintained owing to loss of germinability. But, 216 are preserved in the Center Gene Bank in Tsukuba.

The evaluation of their characteristics were conducted in the Division of Genetics, NIAS, and their results showed that some of these local varieties had strong resistance to diseases; for examples, Caribbean type varieties from the hill foot of Mt. Fuji such as 'Kamigane-1' and 'Narusawaseiko-3' had a high level of resistance to maize streaked dwarf virus. For detailed information refer to Dept. Physiol. and Genet., NIAS (1979) and YAMADA (1989).

Evaluation of Japanese landraces of Caribbean flint type and the world-wide collection from USA for resistance to southern corn leaf blight (*Bipolaris maydis*) was conducted recently in the National Grassland Research Institute, NGRI. Wide varietal variability existed for the resistance to southern corn leaf blight (INOUE *et al.* 1989). Selection of breeding materials among local varieties was considered to be highly possible. More resistant materials were found among varieties in the southern part of Japan (Fig.3 and 4). In comparison with the resistant world-wide collections, resistant local varieties possessed a very high level resistance to southern corn leaf blight. As for resistance to smut and lodging, however, local varieties were generally weak, and accumulation of resistant genes by population improvement methods was considered necessary for improvement of these traits.

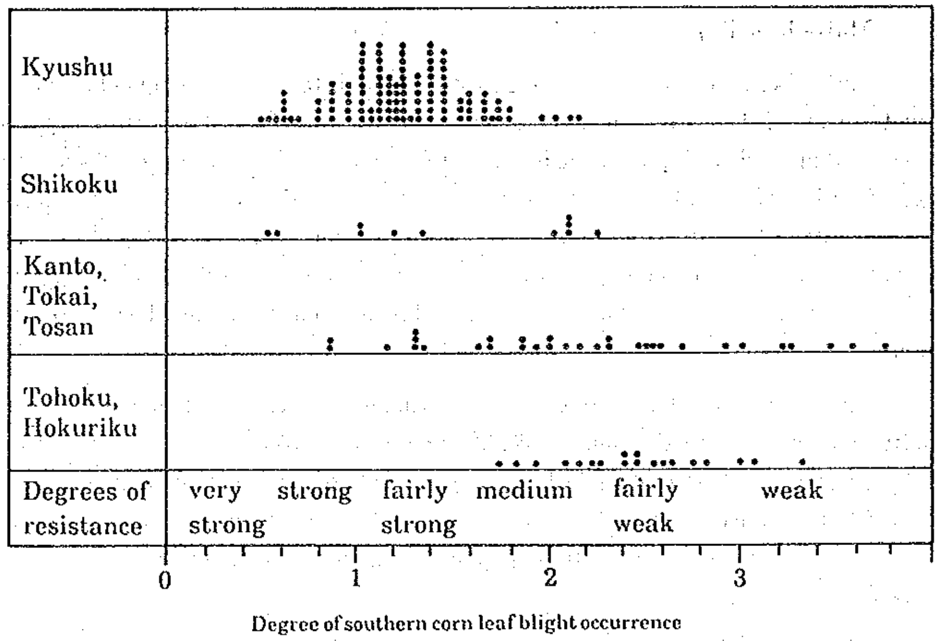

Fig. 3 Frequency of landraces by southern corn leaf blight index under artificial inoculation from 1983 to 1988 - comparison by collection regions in Japan -. (INOUE *et al.* 1989)

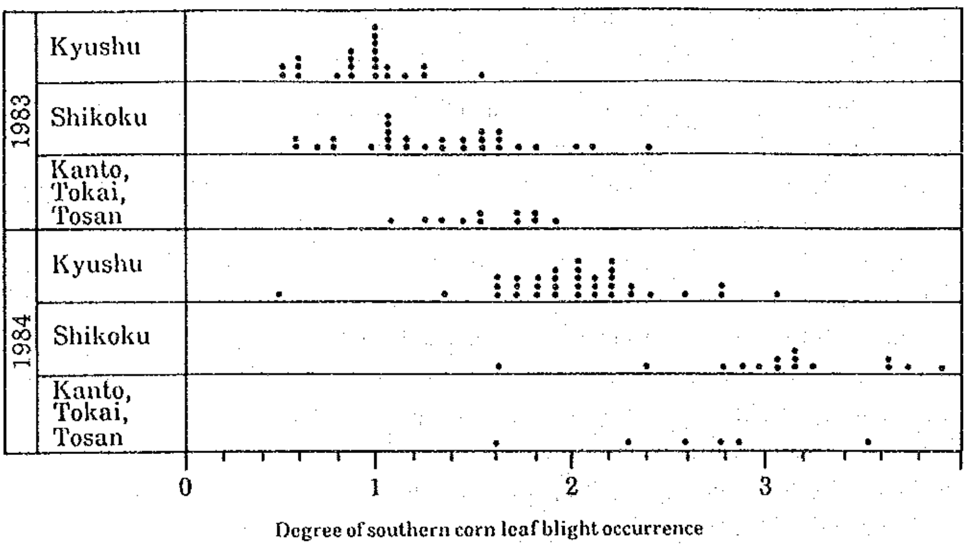

Fig. 4 Frequency of landraces by southern corn leaf blight index observed under natural occurrence in 1983 and 1984 - Comparison by collection regions in Japan -. (INOUE *et al.* 1989)

Public maize breeding in Japan is conducted in five laboratories (Table 2). As the production of maize for silage use has been increasing, recent objectives of breeding are directed toward higher yield of total digestible nutrients (TDN). Lodging resistance and disease resistance are important characters for realizing the higher yield under mechanized harvesting, and hybrid varieties which combine the domestic flint type with the introduced dent type as parents are promising.

Table 2 Stations and covering areas of maize breeding in Japan.

Station	Covering area
Tokachi Prefectural AES	Northern and eastern Hokkaido
Hokkaido National AES	Central and southern Hokkaido, and northern Tohoku
Nagano Chushin Pref. AES	Cool and temperate areas of Honshu
Kyushu Nat'l AES	Kyushu and warm areas of southwestern Japan
Nat'l Grassl. Res. Inst.	Warm and cool areas of Honshu, and breeding methods

2. Evaluation of orchardgrass genetic resources and its implication in plant breeding

1) Populations collected in Japan

Collection of genetic resources of grass and legume populations from all over Japan were carried out as a part of the new project from 1984 to 1986. The names of species, number of materials collected and some results of the evaluation were already reported by NAKASHIMA (1991). In the present paper, more recent results on collected populations of orchardgrass (*Dactylis glomerata* L. subsp. *glomerata*) and some implication and problems in their utilization for forage plant breeding are given (FUJIMOTO *et al.* 1991a).

Characteristics of 28 orchardgrass populations collected in seven regions of Japan were investigated for four years in NGRI. Significant differences in fresh weight and other traits were recognized between populations from the second year of harvest. Kanto populations displayed the highest yield through three years (Fig.5). Dry matter weight in the fourth year was the highest in Kanto populations and the lowest in Hokkaido populations. Kanto populations showed earlier spring growth and best regrowth in summer and in addition, occurrence of summer blight was the lowest among them (Table 3, Fig.6).

These results of collected populations of orchardgrass demonstrated that adapted ecotypes are superior to unadapted populations in persistency of dry matter production. Regrowth vigor under humid summer conditions and disease resistance were considered important in differentiation of ecotypes in Kanto region. These characteristics of ecotypes can be incorporated to new cultivars which are to be recommended in the warmer region of Japan.

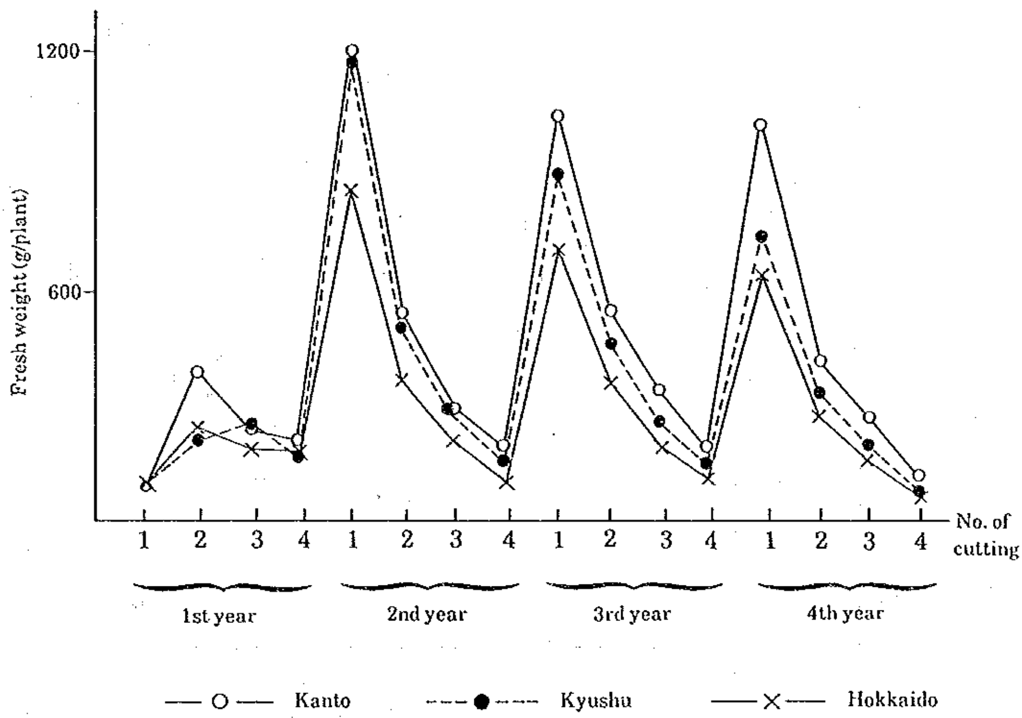

Fig. 5 Change of fresh weight by the year of harvest in orchardgrass populations collected in Japan.

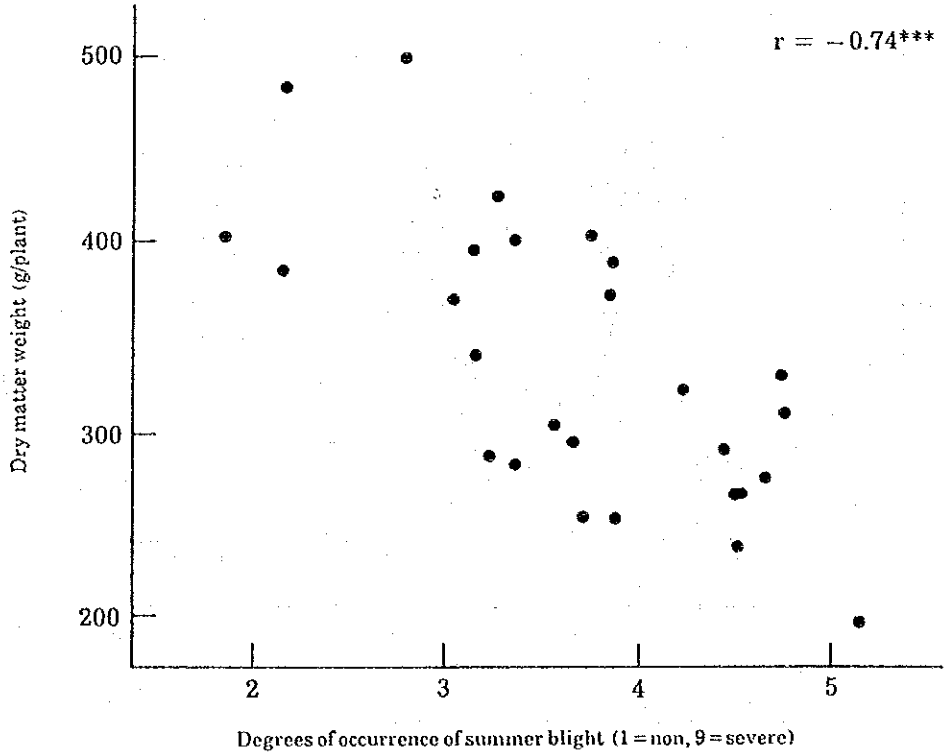

Fig. 6 **Correlation of dry matter weight in the 4th year with leaf blight occurrence in the previous year.**

Table 3 Characteristics of populations grouped by regions.

Region	Greenness[1]	Plant length (cm) in 1989					Regrowth[2] '89 Jul.27
		Apr.13	May 31	Jul.20	Sep.20	Nov.16	
Hokkaido	2.16	16.4	97	59	58	22	3.5
Tohoku	2.65	22.3	103	60	55	24	4.0
Hokuriku	3.17	20.4	101	61	57	23	4.3
Kanto	3.60	25.5	114	73	68	25	5.0
Tokai	3.56	23.7	105	69	64	26	4.5
Chugoku & Shikoku	3.72	25.0	108	65	62	25	4.3
Kyushu	3.17	21.3	102	67	62	26	4.0
Check-1(Sap)	2.13	18.0	93	61	60	23	4.2
Check-2(Nas)	3.17	22.1	102	75	67	29	5.0
Check-3(For)	2.40	15.6	91	60	56	27	3.4
Check-4(Kum)	3.36	20.4	94	69	63	27	4.6

Note: 1) Greenness in early spring (mean of '88 Mar.7 and '89 Mar.20); 1 = yellow ~ 5 = green.
2) Regrowth; 1 = very poor ~ 9 = very good.

2) Populations collected in Morocco and Portugal

Orchardgrass and its relative (subspecies of *D. glomerata*) are widely distributed in the temperate regions of the world. Differentiation of subspecies in warmer regions such as southwestern Europe and north Africa has been reported by several authors (STEBBINS and ZOHARY 1959, BORRILL 1977, LUMARET 1988). A Japanese exploration team collected populations of *Dactylis* in Morocco and Portugal in 1986, and evaluation of them was conducted at NGRI from 1989 to 1991 (FUJIMOTO *et al.* 1991b).

Diploid and tetraploid populations exist in *D. glomerata* and differences in adaptation of these populations have been reported (LUMARET 1988). In order to use collected materials for grass breeding in warmer region, it was necessary to clarify variations in characteristics and polyploidy levels of these populations.

Fresh weight of the populations from Morocco (region of severe dry summer) was low, but populations of Portugal, especially those of the north coast area of higher rainfall, displayed high fresh weight throughout the year (Table 4 and 5). In late autumn growth, many populations of Portugal were better than cultivars of Japan. Populations of Morocco had narrow and short leaves and were very susceptible to anthracnose in summer. Chromosome numbers of several Portugal populations were found to be 14 (diploid level) and it was considered that they were *D. glomerata* L. subsp. *lusitanica*.

Table 4 Climate of collection districts and evaluation station. (NGRI)

District	City	Latitude	Rainfall(mm)		Temperature(℃)		
			Annual	Apr.-Sep.	Y.mean[1]	Oct.-Mar.	Apr.-Sep.(Aug.)
Morocco	Casablanca	33°34'	493.1	68.5	17.4	14.8	20.0 (22.4)
Portugal							
Interior	Campo Maior	39°00'	518.8	135.6	16.5	11.8	21.2
Center Coast	Lisbon	38°46'	707.5	154.8	16.6	13.3	19.8 (22.5)
North Coast	Port	41°10'	1149.6	310.5	14.4	11.4	17.5
Japan	Nishinasuno	36°55'	1631.8	1208.1	12.3	5.9	21.2 (24.8)

Note: [1] yearly mean.

Table 5 Characteristics of populations grouped by districts of different climates.

District	Number of population	Fresh weight (g/pl)				Leaf size (cm)		Anthracnose[1]
		1st	2nd	3rd	4th	length	width	
Morocco Highland	26	134	38	92	53	15.3	0.75	5.4
Portugal								
Interior	2	234	74	156	53	16.7	0.92	4.6
Center coast	5	494	154	261	82	22.7	1.13	2.3
Middle coast	10	573	257	273	90	26.7	1.13	2.4
North coast	4	818	434	368	108	30.8	1.18	1.6
Japan, bred by NGRI								
Nishinasuno Akimidori		518	335	330	70	22.7	1.32	3.7
Makibamidori		533	409	303	46	32.1	1.18	3.4
Subspecies from Welsh PBS, UK								
mairei (NE Algeria)		47	21	22	11	13.9	0.50	2.1
santai (W.Algeria-Morocco)		88	32	72	35	14.2	0.75	4.8
lusitanica (Portugal)		204	166	170	86	23.9	1.21	3.1

Note: 1) Degree of occurrence; 1 = very slight ~ 9 = very severe.

Examination of the characteristics of the populations in relation to local climates pointed out that total amount of growth and leaf size of a population increased in accordance with increase of rainfall of its indigenous place. These results suggest the adaptive changes of *Dactylis* populations to the climatic conditions of their indigenous places. Populations from humid districts of Portugal seemed to have a high possibility as breeding materials in Japan.

However, in order to utilize them in orchardgrass breeding in warmer region, investigation of their performance under sward conditions, including competitive ability with weeds had to be examined; widely distributed subspecies of *D. glomerata* are tetraploids and competitive advantage of tetraploids over diploids in *D. glomerata* was reported (MACEIRA *et al.* 1989).

3. Accomplishments of forage plant breeding, using domestic ecotypes and selections from introduced genetic resources

1) Use of ecotypes and introduced germplasms in orchardgrass breeding

The performance tests of newly-bred Japanese varieties of orchardgrass for nine years in NGRI proved, in addition to their high dry matter productivity, high stability of yield of newly bred Japanese varieties over foreign cultivars (Table 6). Yearly variation CV of the best cultivar, 'Akimidori', was 7.2% (range was 2.6), while that of foreign cultivars was 12.8% (range was 4.3), even though the mean of the best three foreign cultivars were used for comparison. The germplasm of 'Akimidori' are derived 75% from ecotype, 12.5% from France and 12.5% from USA. As a synthetic variety, 'Akimidori' well combines good persistency and regrowth vigor of domestic ecotype germplasms and high growth ability under short day length from a French cultivar as well as disease resistance from a USA cultivar.

Table 6 Variation by years in DM yield (ton/ha) of orchardgrass cultivars bred in NGRI and Hokkaido NAES, as compared with foreign cultivars.

Cultivars	1977	'78	'79	'84	'85	'86	'87	'88	'89[1]	Mean	CV(%)
Akimidori	11.5	12.7	12.4	11.0	11.2	11.2	13.6	12.4	12.4	12.0	7.22
Cultiv.NGRI[2]	10.4	11.4	12.3	10.2	10.4	10.9	12.9	11.3	11.8	11.3	8.17
Cultiv.HNAES[3]	9.7	9.1	10.5	9.4	9.0	9.7	12.0	10.2	10.9	10.1	9.58
Foreign C[4]	10.2	9.5	10.5	10.6	9.3	10.4	13.6	9.7	10.8	10.5	12.08

Note: 1) From 1977 to '79 and from '84 to '86; performance tests of newly-bred strains and cultivars. From '87 to '89; tests in collaborate research between Japan and France.
2) Mean of 'Akimidori', 'Aonami' and 'Makibamidori', bred in NGRI.
3) Mean of 'Kitamidori' and 'Okamidori', bred in Hokkaido NAES.
4) Mean of best three of foreign cultivars used in each tests.

2) Effect of repeated selection on introduced germplasm of alfalfa

Alfalfa (*Medicago sativa* L.) has been used as a common forage in arid regions in the world from old ages, and was considered unadapted to conditions in regions of high rainfall. Actually, production of alfalfa in Japan was not successful when introduced cultivars were used. But recently, two cultivars, 'Natsuwakaba' and 'Tachiwakaba' was bred in the Aichi Prefectural Agricultural Research Center, AARC, for alfalfa production in the warmer region in Japan. The breeding materials of 'Natsuwakaba' were five cultivars, three from USA and two from France and those of 'Tachiwakaba' were four cultivars, one from France and three from Italy. These foreign germplasm received selection for four or five generations under humid conditions of warmer Japan to create improved and adapted populations.

Table 7 Results of performance tests in eight locations in warmer region of Japan

Varieties	Regress. Coef.[1]		Degree of occurrence[2]		
	A	B	Lodging	Spring black stem	Anthracnose
Tachiwakaba	−9.5	−2.6	1.4	1.6	2.0
Natsuwakaba	−16.1	−7.9	2.9	1.9	2.4
Williamsburg	−19.9	−14.6	2.7	1.8	2.8
Moapa	−23.2	−11.8	3.2	3.3	2.6

Note: 1) Number of cutting per year; 6-8 times in A, and 4-5 times in B.
Temperature in March; 7.4-10.8℃ in A, and 2.1-5.4℃ in B.
Yearly rainfall; 1627-2290mm in A, and 1102-2367mm in B.
2) Scores; 1 = non or slight, 3 = medium, 5 = severe.

The response to selection was remarkable, although it took 8 to 14 years to breed up these two cultivars. They showed excellent persistency of dry matter yield through years in performance tests in AARC and other locations in the warmer region (Table 7, FUJIMOTO *et al.* 1989). In the evaluation at NGRI using French cultivars which have the same germplasm origin as the Japanese cultivars, 'Tachiwakaba' and 'Natsuwakaba' maintained good yield for three years, while the French cultivars were as good as them only in the first year (Fig.8). Reduction of yield of foreign cultivars was great in the second year (1988) when sunshine duration in summer was very low. These results indicate their low adaptability to humid climate of Japan; weaker regrowth under humid conditions are critically detrimental in competition with weeds. Difference in weed percentage is recognized between cultivars after summer (Fig.9). Japanese varieties which received selection under humid environments for generations could cope with weed invasion and showed few loss of stands.

The stability of yield under unfavorable climate and persistency of newly bred Japanese varieties suggest the differentiation of a new varietal group from introduced germplasms through population improvement carried out in the warmer region of Japan.

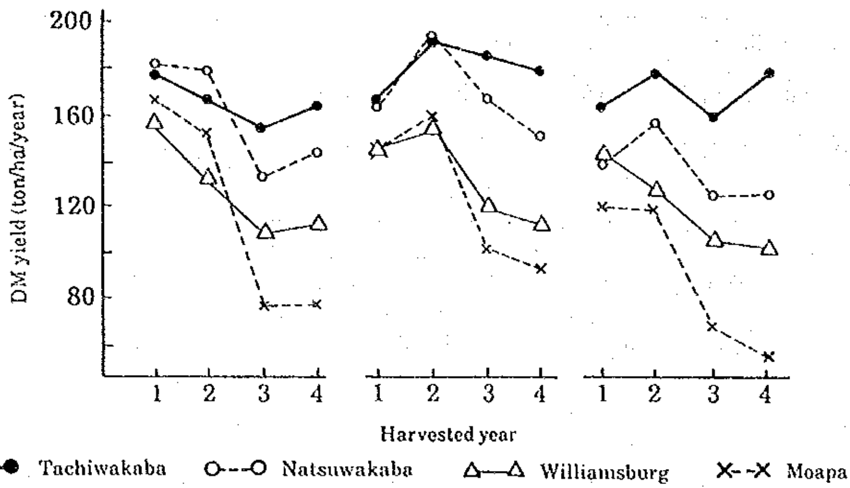

Fig. 7 Persistency of alfalfa varieties under three cutting treatments
- Dry matter(DM) yield for four years from 1978 to 1981 -.

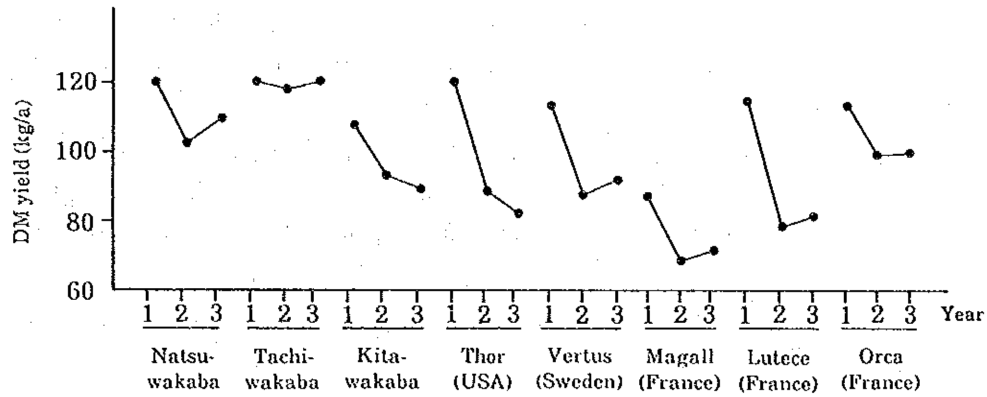

Fig. 8 DM yield of alfalfa cultivars in NGRI during three years including years of low sunshine duration.

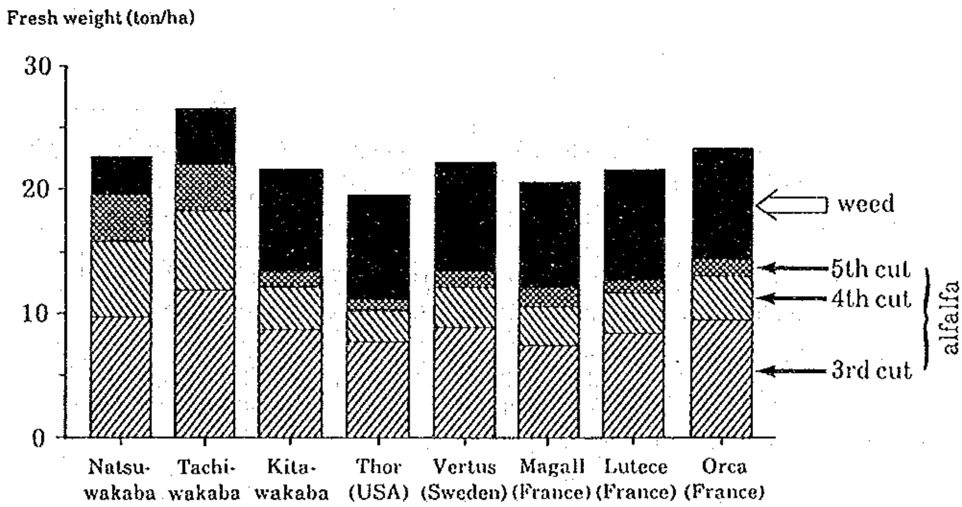

Fig. 9 Difference between cultivars in summer-autumn of the 3rd year, NGRI.

- Weed percentage within alfalfa sown in 30cm rows -.

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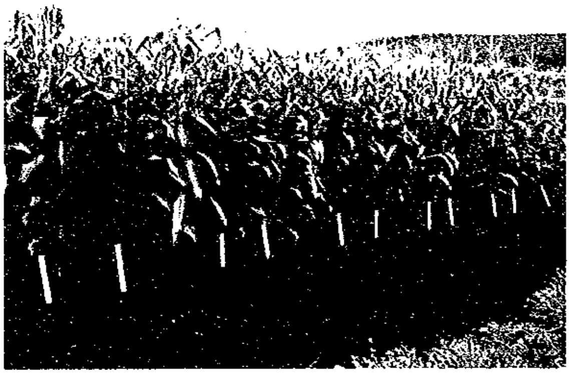

Photo 19. Mass screening of indigenous corn varieties against maize streaked dwarf virus. (E. SODEYAMA)

Photo 20. A resistant maize cultivar to streaked dwarf virus, which was identified out of several hundreds. (E. SODEYAMA)

Photo 21. Newly developed Guinea grass variety, 'Natsukaze'(left), is selected from several thousand materials introduced from Kenya, and is suitable for summer forage in the southern Japan, having a.a ability to propagate by apomixis. Right is a traditional variety. (H.SATO)

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