A New Indicator of Earliness of Maize Varieties for Whole Crop Silage, and Its Application to Varietal Combination in Hokkaido

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Introduction

The number of dairy cattle in Hokkaido is about 780,000, accounting for 37% of the total in Japan. To feed these cattle, maize for silage use is grown on farm fields of 65,000 ha, approximately a half of the total maize area of Japan. The maize for silage use is regarded as one of the most important self-sufficing forage crops in dairy management, and its acreage seems to increase further.

Recent cultivation of maize for silage use in Hokkaido aims at production of high-energy whole-crop silage. For that purpose, it is necessary to produce high-quality maize showing 25–35% of dry matter content in the whole crop at the harvesting date. At this date, grain dry matter occupies about 30–50% of the total dry matter of the whole crop.[4] TDN content of the silage prepared by using this material reaches about 70% on dry matter basis, or more than 20% on row matter basis. Thus, this material has high energy, comparable with usual concentrates, and good fermentative quality[1,10] (Table 1).

Because of a short frostless period and low temperature in Hokkaido, located in the northern part of Japan, it is necessary to fully gripe the climatic condition of the crop season, and to grow selected maize varieties with an early maturity fitted to the climatic condition in order to insure the stable production of high-quality materials shown above.

It is known that the major climatic factor influencing maize growth is heat unit accumulation. Particularly, as maize varieties growing in Hokkaido have high thermosensitivity, they show a strong positive correlation between growth duration and heat unit accumulation. Therefore, when the cropping season is given, and heat unit accumulation in the cropping season is preestimated, it is possible to select the varieties, which can reach proper harvesting time within a range of the estimated value of heat unit accumulation.

On the other hand, sowing and harvesting have to be done over a certain period of time, due to group utilization of farm machines or other farm management conditions, although their time depends on climatic factors. Therefore, it is necessary to postulate several different cropping durations, and to select varieties which can reach the proper harvesting stage in each cropping duration. This is called the combination of varieties with different growth duration (different earliness).

Indication of earliness of varieties

As mentioned above, the growth advancement of maize varieties growing in Hokkaido is primarily dependent on heat unit accumulation, and hardly influenced by yearly variations in light and soil moisture. This fact is called "a high conformity of heat unit accumulation to

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Table 1. Nutrient value and fermentative quality of whole crop silage made at different ripening stages of maize

Ripening stage of materials	DM content	Nutrient value		Fermentative quality		
		TDN % in DM	TDN % in RM	PH	VFA/T-A	VBN/T-N
Water	<15	63-65	<10	3.5 – 4.0	10.0 – 20.0	5.0 – 10.0
Milk	15-20	63-65	12			
Dough	20-25	65	15			
Yellow dent	25-35	70	20-25			
Overripe	>35	>70	>25			

DM=Dry matter, RM=Raw matter, TDN=Total digestible nutrient, VFA=Volatile fatty acid, T-A=Total acid, VBN=Volatile basic nitrogen, T-N=Total nitrogen.

Table 2. Errors (in days) in estimating the ripening progress by the use of RHU or the usual accumulated temperature

Location	RHU (over 0.1°C)			Usual heat unit accumulation (over 10.1°C)		
	1975	1976	1977	1975	1976	1977
Kunneppu	2.6	2.1	3.0	4.6	12.1	5.9
Tsukisamu	—	9.5	3.2	—	12.0	3.5
Memuro	0.7	1.0	0.9	1.6	2.3	3.6
Nakashibetsu	1.3	1.8	0.5	8.3	17.6	9.3
Average		2.4			7.3	

Cultivar: Wase-homare (double cross)

crop growth." The heat unit accumulation used in Hokkaido is the sum of mean daily temperature above 10.1°C, because the temperature below 10.0°C was regarded as ineffective for growth advancement of crops.[2,3,11]

However, the author found out that the sum of mean daily temperature above 0.1°C gives better conformity than that above 10.1°C.[5,7] The former is named the "revised or simple heat unit accumulation*" (RAT or SHU). Table 2 shows differences (errors) between actual progress of ripening and estimated one, calculated from the revised or the usual heat unit accumulation. The progress of ripening was expressed in terms of dry matter content (%) of whole crop. Errors of estimation against actual values were obtained as follows.

First, from the data obtained during 12 years up to 1974, the RHU and the usual heat unit accumulations during the period from sowing to harvesting, and their regression equations to the harvesting time were calculated.[8] Next, by using these equations, errors in estimating the ripening stage against the actual (measured) ripening stage were calculated with three croppings from 1975 to 1977. Values of the error in Table 2 were converted into the number of days by using a daily climatic table.

The regression equations obtained from the data of 12 years up to 1974 are

$$Y = 1545.8 + 24.6\,X$$
$$Y' = 542.2 + 13.8\,X'$$

where Y and Y′: RHU and usual heat unit accumulation, respectively, during the period from sowing to harvesting date,
X and X′: dry matter content (%) of whole crop at harvesting date.

It is clear in Table 2 that the estimation of ripening progress by the use of RHU gives smaller errors in each location and each year, showing a higher conformity than the estimation by usual heat unit accumulation.

Reasons for the higher conformity of RHU

* Revised heat unit accumulation can simply be obtained by accumulating mean daily temperature, and hence referred to as simple heat unit accumulation.

Table 3. Germination rates (%) of five maize inbred lines under low temperature conditions

Temp. of germ. bed (°C)	Days after seeding (days)	Maize lines				
		To15	W79A	CMV3	CM37	N21
		%	%	%	%	%
	14	82	23	48	36	9
8±0.5	16	100	38	58	53	22
	18	100	47	64	53	53
	10	95	77	46	26	30
10±0.5	12	98	90	79	73	74
	14	98	98	80	73	81
	8	100	8	40	35	72
12±0.5	10	100	92	84	64	88
	12	100	95	88	76	95

The germination experiment was conducted on filter paper in petri-dish with two replications in a controlled room.

Table. 4. Increase of maize grain weight (A) under low temperature condition in the field (B)

(A) Increase of grain weight in the ripening period

Cultivar	Harvesting date	Grain yield	Weight/1000 kernels
		kg/10a	g
	Sept. 29	489	258
KO No. 4	Oct. 3	540**	278
	Oct. 12	562*	287*
	Sept. 29	451	224
Fukuko No. 4	Oct. 3	527**	249*
	Oct. 12	535**	269**

*, ** significant at 5% and 1% level. Replication=3, 1969

(B) Air temperature in the ripening period (°C)

Air temp.	Sept. 30	Oct.											
		1	2	3	4	5	6	7	8	9	10	11	12
Mean	5	6	12	11	7	6	7	5	5	10	12	9	10
Max.	12	11	16	15	15	13	14	12	14	16	17	14	13
Min.	−1	1	7	7	−2	−2	−1	1	−3	5	7	5	7

At Memuro-cho, 1969

are (1) even in the days with mean daily temperature below 10°C, there are several hours of temperature above 10°C, and (2) seed germination and ripening of seeds can proceed at the temperature below 10°C as shown in Table 3 and 4.

Earliness or lateness of maize varieties for silage use in Hokkaido are expressed by relative maturity (RM), such as early-, medium-, and late-maturity. However this expression is rough and not suitable for selecting a combination of varieties fitted to diverse cropping durations on a farmer's field in different regions. Therefore, the author proposes a new expression specific to Hokkaido, i.e., Hokkaido relative maturity (HRM).[8)]

$$HRM=\frac{RHU}{HU} \cdots\cdots (1)$$

where,

RHU: Revised heat unit accumulation during the period from sowing date to the stage when dry matter content reaches 30%,

HU: Mean daily temperature, 17.5°C, at a region representing an average of the whole Hokkaido.

Although the appropriate combination of varieties can be made by knowing RHU of each

Table 5. Revised heat unit accumulation (RHU) and Hokkaido relative maturity (HRM) of maize cultivars in Hokkaido

Cultivar	RHU(°C)	HRM(days)
Heigen-wase	2, 279	130
Wase-homare	2, 283	130
Wase-minori	2, 349	134
Liza	2, 352	134
C 535	2, 366	136
Brutus	2, 362	136
Essor	2, 390	136
P.A.G. 145	2, 485	142
Hokuyu	2, 499	142
Jx 844	2, 536	146
P 3715	2, 600	149
W 573	2, 691	154

RHU and HRM for the period from sowing to the stage when dry matter content of whole crop reaches 30%.

variety, this expression, as it is, is not easily utilized by farmers. Therefore, RHU is converted to the number of days (HRM) by dividing RHU by HU.

The former RM concerns a period from field emergence to maturity or silking date. On the contrary, HRM indicates a period from sowing date to the stage when dry matter content of whole crop reaches 30%. As the field emergence occurring under low temperature takes long time after sowing, showing remarkable varietal differences in germinability at low temperature, the number of days required for field emergence is not neglected, so that sowing date is taken as a start of growth duration. On the other hand, the stage when dry matter content of whole crop reaches 30% was taken as the end of growth duration, because dry matter content at the appropriate harvesting time for high-quality material is 25–35% with an average of 30%. At the stage of full maturity, the whole crop becomes over-matured to get high quality material. The silking stage is also not appropriate to be taken as the end of the growth duration, because varietal differences in progress of ripening after the silking stage are neglected, and the silking stage itself is not fit for the concept of growth duration. Thus, the growth duration adopted by HRM is more rational than that used by the former RM.

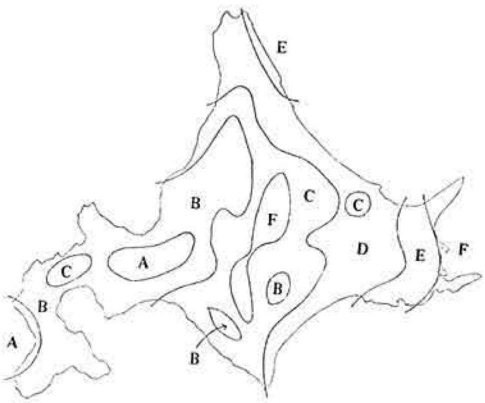

Fig. 1. Regional classification of Hokkaido by revised heat unit accumulation (RHU) during the maize cropping season (May 1 to October 5, 1966–1977)

Note: RHU for each region is as follows:
A: 2,751–2,900°C B: 2,601–2,750°C
C: 2,451–2,600°C D: 2,301–2,450°C
E: 2,151–2,300°C F: below 2,150°C

Table 5 gives RHU and HRM of selected cultivars of maize in Hokkaido.

Regional variation of RHU of maize growing season in Hokkaido

Regional classification of Hokkaido by RHU is necessary for selecting an appropriate combination of maize varieties to be grown at each location of Hokkaido. The author recognized, from the data on maize growth obtained by 1977 in many experimental stations, and other locations that the RHU required for early-, medium-, late-, and very late-varieties in their growth durations is ca. 2300, 2450, 2600, and 2750°C, respectively.[5] These values were used as standards for the classification. As the result, Hokkaido was classified into 6 regions shown in Fig. 1.[6] The regions from A to E are maize areas.

Combination of maize varieties at a given locality

It is desirable to employ a certain standard in selecting an appropriate combination of varieties

Table 6. The standard shown in terms of HRM for selecting maize varieties to be grown in varying cropping durations in different regions of Hokkaido

Region	Harvesting date	Sowing date					
		May 1	May 11	May 16	May 21	May 26	June 1
A	Sept. 25	152	146	142	139	130	—
	Sept. 30	157	150	147	142	134	—
	Oct. 5	161	154	151	147	138	—
B	Sept. 25	144	138	135	132	—	—
	Sept. 30	148	142	139	136	—	—
	Oct. 5	152	146	143	139	131	—
C	Sept. 25	141	135	132	—	—	—
	Sept. 30	145	139	136	133	—	—
	Oct. 5	148	143	140	136	—	—
D	Sept. 25	—	—	—	—	—	—
	Sept. 30	132	—	—	—	—	—
	Oct. 5	136	131	—	—	—	—
E	Sept. 25	—	—	—	—	—	—
	Sept. 30	—	—	—	—	—	—
	Oct. 5	131	—	—	—	—	—

at the farmer's level. This standard is prepared on the basis of the earliness (HRM) of varieties, regional classification, and allowable time range of cropping durations. Needless to mention, the time range of cropping durations, caused by varying sowing date and harvesting date, is determined by climatic and edaphic conditions as well as varying sequence of farm operations in a farm or a village. By taking these factors into consideration, it can be said that the sowing date is within a period from early to mid-May throughout Hokkaido, except a part of it where sowing is made until late May. The range of sowing time in a given region is about 2 weeks. RHU for that period is ca. 100–200°C. On the other hand, the range of harvesting time, which is determined by the climatic factor such as the first frost in early October followed by soil freezing, and working capacity of machines used in the current harvesting system, is from mid-September to early October.

The standard for selecting varieties to be grown in different regions of Hokkaido is shown in terms of HRM in Table 6. The regions in Table 6 correspond to those in Fig. 1. The following is an example how to use this standard. As for the region A, when the sowing date and harvesting date are expected to be 11 May and 30 September, respectively, a variety with HRM of 150 days has to be selected. However, when the sowing date ranges from 11 to 16 May, varieties of 150 to 147 days have to be combined at an appropriate proportion. Similarly, the variety combination has to be done according to the range of harvesting date.

By looking through all the regions in Table 6, it is summarized as follows. In the regions from A to C, high-quality materials can be produced by combining maize varieties with HRM between 130 days (early) and 161 days (very late), if they can be sown by mid-May. In the region D, it is necessary to grow varieties with 130 or little more than 130 days of HRM by early sowing and late harvesting. In the region E, it is difficult to get materials with dry matter content of 30%, even if an early variety with 130 days of HRM is used. The horizontal bars in the table indicate that very early varieties with HRM less than 129 days are needed. Breeding for these varieties is now in progress.

Conclusion

In Tokachi district of Hokkaido, a combination of varieties differing in earliness has been established by applying RHU and HRM described in this paper[9] for 21 cropping durations composed of 7 different sowing dates and 3 harvesting dates, for each village or community. It has been contributing a great deal to the production of high-quality whole crop silages. It is desirable to apply this method to other districts.

References

1) Abe, A. et al.: Influence of variety and harvesting date on the nutritive value of corn plants and investigation of the nutritive value of corn silages prepared from 7 varieties of corn. *J. Jpn. Grassl. Sci.*, **21**, 291–299 (1975) [In Japanese with English summary].
2) Brown, D. M.: Heat units for corn in southern Ontario. Ontario Minist. Agr. Food, Order No. 75-077 (1972).
3) Iwata, F.: Studies on high-yielding culture in corn —theory and practice—. *Res. Bull. Tohoku Nat. Agr. Exp. Sta.*, **46**, 63–129 (1973) [In Japanese with English summary].
4) Kushibiki, H.: Studies on productivities of corn as silage materials and cropping combination of varieties different in maturation dates for north-eastern areas of Hokkaido. I. Characteristics of cultivar groups at ripening periods and cropping combinations of those cultivars. *J. Jpn. Grassl. Sci.*, **25**, 128–135 (1979) [In Japanese with English summary].
5) Kushibiki, H.: Studies on productivities of corn as silage materials and cropping combination of varieties different in maturation dates for north-eastern areas of Hokkaido. III. Constancy and requirement of some heat unit accumulations for varieties. *J. Jpn. Grassl. Sci.*, **25**, 144–149 (1979) [In Japanese with English summary].
6) Kushibiki, H.: Studies on productivities of corn as silage materials and cropping combination of varieties different in maturation dates for north-eastern areas of Hokkaido. IV. Distribution map based on the heat unit accumulation and combination varieties in Hokkaido district. *J. Jpn. Grassl. Sci.*, **26**, 7–13 (1980) [In Japanese with English summary].
7) Kushibiki, H.: Studies on productivities of corn as silage materials and cropping combination of varieties different in maturation dates in north-eastern areas of Hokkaido. V. On the reasons in the good effects of applying the simple heat unit accumulation to the cropping. *J. Jpn. Grassl. Sci.*, **26**, 14–18 (1980) [In Japanese with English summary].
8) Kushibiki, H.: Studies on productivities of corn as silage materials and cropping combination of varieties different in maturation dates in north-eastern areas of Hokkaido. VII. A proposition of Hokkaido relative maturity scale. *J. Jpn. Grassl. Sci.*, **26**, 131–136 (1980) [In Japanese with English summary].
9) Kushibiki, H.: Cropping combination maps of silage corn cultivars together with locations in Tokachi area. Tokachi Unit Agr. Coop. (1980) [In Japanese].
10) Nakui, T. et al.: The influence of varieties and weather on nutritive value and yield of corn silages. *Res. Bull. Hokkaido Nat. Agr. Exp. Sta.*, **126**, 149–162 (1980) [In Japanese with English summary].
11) Toda, S. et al.: Studies on classification of growing season distributed based on effective heat unit accumulation in Hokkaido district. *Hokuno Kenkyu Shuho* 2, 84–85 (1955) [In Japanese].

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