Growth and Digestible Dry Matter Productivity of Sugar Cane in Warm Temperate Zone of Japan

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Cultivated area of sugar cane in Japan is about 30,000 ha at present, and is distributed mostly in Okinawa and Kagoshima prefectures. In recent years, the total sugar consumption in Japan is 3 million tons per year. Although sugar beet is grown as another sugar crop, 80% of the sugar consumption has to be imported. In addition, by-products of sugar cane, molasses, bagasse, and even the dried leaves of sugar cane, are imported for animal feeds.

Sugar cane was first introduced into Amami Oshima Island in 17th century. The species introduced at that time was *Saccharum sinense* Roxb from China.[7] Since then, the cultivation spread in southwestern areas or some southern parts of Pacific coast, and it was extended once to Kanto district at the latitude 36°N. The cultivated area reached approximately 13,000 ha, excluding Okinawa Islands, in 1921 with its distribution as shown in Fig. 1.[9]

Although the cultivation at present is limited to only restricted areas, much efforts have been made for breeding new varieties to increase and stabilize productivity of sugar cane, not only in subtropical part but also in warm temperate zone of Japan.[7] In the warm temperate zone, high temperature and strong solar radiation are usually expected to last for 7—8 months in a year, but sugar cane might not express it's high potential productivity without some invented cultivation methods.

Field trials to increase dry matter yield were carried out, therefore, using modern varieties of *S. officinarum*, with the purpose of getting better understanding and utilization of sugar cane productivity, as a sugar crop and a forage crop.[5,6] Results of the field trials and high feeding value of the product evaluated by laboratory test will be described in the present paper. It is hoped that the result might be applicable to other warm temperate areas in Japan as well as in similar areas overseas.

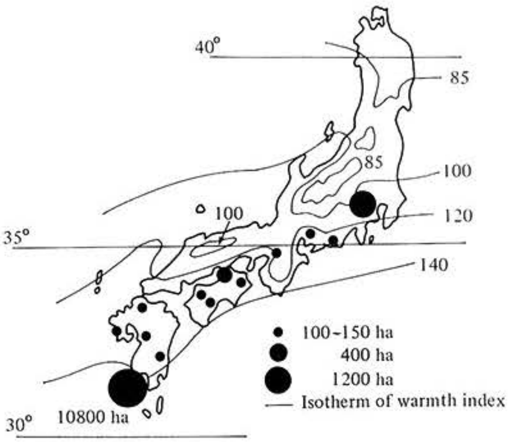

Fig. 1. Cultivated area of sugar cane in 1921 in Japan.[9]

Increase of yield by planting sprouted sets

Sugar cane, usually, requires high temperature (above 20°C) during its main growth period, with frost-free ripening and harvest seasons.[3,10]

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The Kyoto University Subtropical Plant Institute, where the present experiment was done, is located at the southmost part of Honshu Island, and shows the following climatic data for recent years; Annual mean temperature 16.8°C, the lowest mean temperature 7.5°C in January, daily mean temperature rises to 15°C first in the middle of April, and it maintains 20°—27°C in the summer, then decreases lower than 15°C in the middle of November. As is shown by the isotherms of warmth index (Fig. 1), there is a similarity between the site of the Institute and southern parts of Shikoku and Kyushu islands. Annual precipitation is 2700 mm, but not much rain in the winter.

In the first trial, using modern improved varieties, NiN 2 and N: Co 310, early planting was done in the middle of April, when mean temperature was just rising to 15°C, and growth characters and dry matter productivity of the April-planted crop were compared with those of May-planted crop and ratoon crop in 1977. The April-planted crop could start leaf growth and tillering at the same time as the ratoon crop, but earlier than May-planted crop. Final length and fresh weight of stems of the April-planted crop at the time of harvest in the middle of December were much greater than those of the May-planted crop. Estimated dry matter yields of NiN 2 per ha were 54.2 t (leaf 22.5 t, stem 31.7 t) for ratoon crop, 35.3 t (leaf 14.5 t, stem 20.8 t) for April-planting, and 16.1 t (leaf 8.8 t, stem 7.3 t) for May-planting. Sugar contents of stem were 17.2%, 16.0% and 15.8% in Brix for ratoon crop, April planting and May planting, respectively.

The result of this experiment indicated that the yield of ratoon crop was highest, but relatively high yield could also be expected by new planting at an earlier season. Concerning the climatic condition, 17°C seemed the minimum daily mean temperature for sprouting and initial growth, and leaf growth could continue until the middle of November, when daily mean temperature began to decrease below 15°C.

Based on these results, sprouted sets, and young tillers of NiN 2, besides non-treated usual stem cuttings, were planted in the middle of April in the next year (1978), with an aim of more effective utilization of the whole period with temperature enough for the growth of sugar cane. The sprouted sets were prepared by placing stem cuttings in a nursery in a frame covered by vinyl film. The air temperature inside the frame was kept around 20°C by controlled electric heater to facilitate the sprouting. Young tillers were taken from sugar cane stubs preserved in a green house during the winter. In addition to these planting materials, the first and the second ratoon crops (the second and third year of the original plants) were also used. Planting space of sprouted sets was same as that in 1977, 1 m between rows and 0.3 m between hills, and 20 kg N+15 kg P_2O_5+15 kg K_2O/ha was applied with some manures and slaked lime. The sprouted sets had 2 buds in 1977, and one bud in 1978.

Leaf growth and tillering started earlier in both the sprouted set and young tiller plots than the control plot (non-treated stem cutting plot). Number of tillers began to increase rapidly at the beginning of June in both the sprouted set and young tiller plots, and it was 30 days earlier than the control plot. As a result, number of stems/hill, number of elongated internodes, mean length of stems, and total fresh weight/hill at the harvest time were greatest for the sprouted set plot, which was almost similar to the first ratoon crop (Table 1). The young tiller plot also gave slightly increased number of elongated internodes and stem length than the control, and the largest stem diameter and higheat sugar content among all plots.

The dry matter yield/ha, calculated from fresh weight/hill (Table 1) was 38.4 t (leaf 10.7 t, stem 27.7 t) for the sprouted set plot, and 30.9 ton (leaf 9.1 t, stem 21.8 t) for the control, planted in April (Table 2). Although the ratoon crops of both varieties showed significantly high yields, as given in Table 1, they occupied the fields for longer time, and had to be protected against the coldness of winter for their survival. On the other hand, the newly planted crops could express their high potential of dry matter production, whenever their early growth was promoted by any means.

Table 1. Mean yield components of sugar cane (1978)

Variety and plot	Number of stem	Diameter of stem	Number of elongated Internode	Length of stem	Fresh weight/hill Leaf	Stem	Total	Sugar content of juice (Brix %)
[NiN 2]	/hill	cm		cm	kg	kg	kg	
Planting:								
Control	5.0	2.19	10.4	132	0.98	3.30	4.28	15.7
Sprouted set	7.4	2.18	12.5	164	1.16	4.19	5.35	15.3
Tiller planting	5.0	2.36	11.5	155	0.85	3.79	4.64	16.3
Ratooning:								
1st year	6.6	2.42	12.2	170	1.07	4.38	5.45	16.0
2nd year	9.8	2.27	11.2	164	1.45	6.69	8.14	15.2
[N: Co 310]								
Ratooning:								
1st year	4.0	2.48	15.6	196	0.85	3.72	4.57	16.6
2nd year	11.4	2.43	13.6	197	2.12	9.61	11.73	16.9

(Harvest: December 15)

Table 2. Digestible dry matter productivity of sugar cane (1978) var. NiN 2

Plot	Dry matter				DMD				DDM		
	August*		December*		August*		December*		December*		
	S.	L.	S.	L.	S.	L.	S.	L.	S.	L.	Total
	(kg/10a)				(%)				(kg/10a)		
Control	265	271	2178	906	65.0	47.5	77.9	54.2	1699	491	2190
Sprouted set	767	592	2765	1072	70.3	43.9	—	—	(2157)	(579)	(2736)
Tiller planting	558	660	2501	785	67.3	44.1	76.3	53.6	1908	421	2329

Note *Harvest time
S.: stem
L.: leaf

Evaluation of sugar cane as a forage crop

High nutritional value of sugar cane as a forage or silage crop was already reported: TDN is 60.8 and content (%) of crude protein and fat is as high as that of maize.[6] To know more precisely the feeding value of sugar cane under different cultural methods and at different growth stages, its digestibility was analyzed by in vitro cellulase method, and neutral and acid detergent insoluble fibers were also analized.[1,2,4]

Dry matter digestibility (DMD) of stems is higher than that of leaves, and both of them increase as the plants grow from August to December (Table 2). In general, stem DMD of grasses begins to decrease more or less with the panicle formation or flowering, but that of sugar cane continues to increase gradually to the end of plant growth. For example, DMD of other grassses, like ryegrass, wheat or barley, is as high as 60—70% at the younger stage, but it decreases with growth and flowering.[8] On the contrary, DMD of sugar cane is maintained at a high level with the increase of dry matter of stems, even though stems and leaves grow very slowly after the middle of October. The value of DMD of sugar cane ranges 55 to 75% for stems and 35 to 55% for leaves, though it fluctuates with seasons and years.

As the result, the total yield of digestible dry matter (DDM) of sugar cane is significantly high even in the warm temperate zone (Table 2). Because of lack of DMD values for stems and leaves in December, DDM of the sprouted set plot was calculated using DMD values of the young tiller plot and shown in parenthesis in this table. DDM of stems and leaves of sugar cane is more than 20 t and 5 t/ha, respectively, giving a total of 25 t/ha/crop within a period of 8 months.

By further chemical analysis, using neutral and acid detergents method by Van Soest (1963), NDF (Neutral detergent fibre), ADF (Acid detergent fibre) and ADL (Acid detergent lignin) were separated and measured.[4] NDF is the cell wall constituents and includes both digestible and indigestible fibrous fractions by ruminants. ADF is ligno-cellulose fraction insoluble by acid detergent and almost indigestible by ruminants.[1,2]

It was shown that DMD of stem has negative correlations with NDF and ADF, and its relation with NDF changed by the growth stages (Fig. 2). The data shown in this figure includes all samples collected by the experiments in 1977 and 1978, and it was indicated that the rate of NDF–ADF/NDF decreased in the winter harvest (Table 3). Indigestible fibrous fraction of NDF of stem increased with it growth and the different relations between DMD and NDF of stem in different seasons were caused by these changes. The relations of DMD and NDF or ADF of leaf were somewhat different from those of stem. DMD changes from 35 to 55% with seasons and with leaf positions though NDF does not change much. DMD of upper leaf is higher than that of lower leaf and DMD of each leaf increases with growth, and though NDF of leaf is higher than that of stem but this fibrous fraction usually includes much digestible fibres than in stem. (Table 3).

Conclusion

Although the area cropped to sugar cane is limited to only southern parts in Japan in these days, it was proved that relatively high yields can be obtained even in the warm temperate zone of the country.[6] By planting stem cuttings in April, 20 t/ha (in dry matter) of stems was obtained, and that yield was further

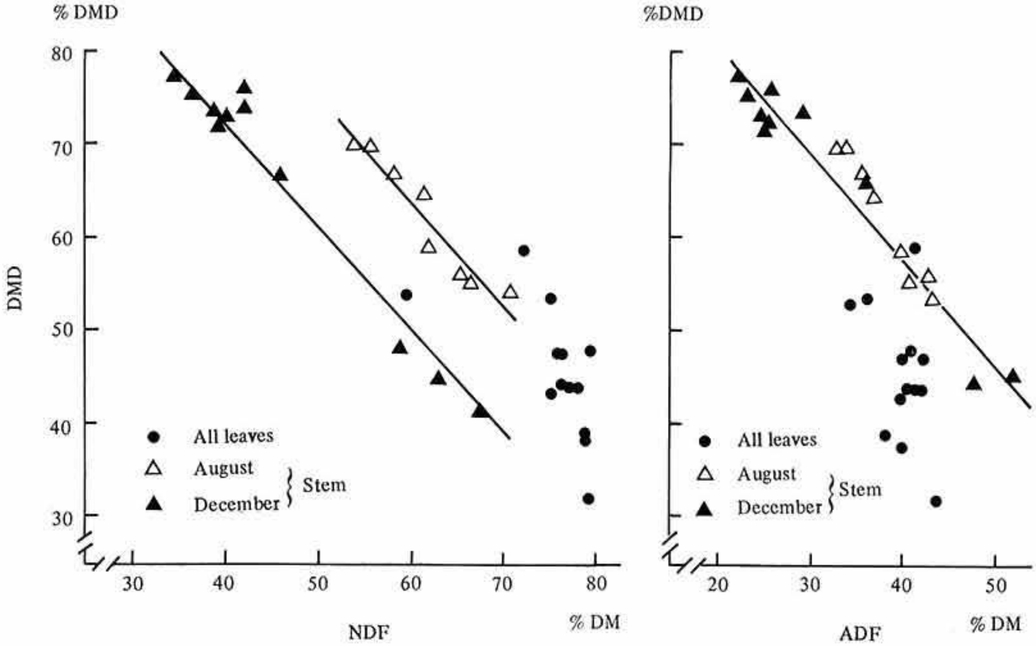

Fig. 2. Relationship of dry matter digestibility (DMD) to neutral and acid detergent fibers (NDF, ADF) of sugar cane (1977, 1978)

Table 3. Digestibility and fiber contents of leaf and stem of sugar cane at different harvest times (1978) var. NiN 2

Plant part	Plot	DMD (%)		NDF (%)		ADF (%)		ADL (%)		(NDF-ADF) /NDF (%)	
		S*.	W.*	S.	W.	S.	W.	S.	W.	S.	W.
Stem	Control	65.0	77.9	62.2	34.4	36.8	21.7	7.1	5.1	40.8	36.9
	Sprouted set	70.3	—	56.0	—	33.7	—	6.0	—	39.8	—
	Tiller planting	67.3	76.3	58.8	36.5	35.5	23.2	6.4	4.9	39.6	36.4
Leaf	Control	47.5	54.2	76.9	60.1	42.4	35.9	7.3	5.2	44.9	40.3
	Sprouted set	43.9	—	77.2	—	41.8	—	6.6	—	45.9	—
	Tiller planting	44.1	53.6	77.1	75.8	41.0	34.5	7.0	5.8	46.8	44.5

Note *Harvest time
S.: summer (August)
W.: winter (December)

increased by 25% by planting pretreated stem cuttings (sprouted sets). As the result, the highest yield of 140 t/ha of stems (in fresh weight) with 15–16% of sugar content (in Brix) was obtained within a 8-month period by the new planting method. Maximum crop growth rate (CGR) in this case was 40 $g/m^2/day$ and net assimilation rate was 0.99 $g/dm^2/10$ days in the mid-summer. This value of CGR is comparable to 38 $g/m^2/day$ observed in Hawaii,[11] though the period which permits such a high CGR is short in Japan.

Dry matter digestibility (DMD) of stems and leaves of sugar cane was as high as 55–75% for stems and 35–55% for leaves, and DMD of stems increased until the end of stem growth. As the result, the total digestible dry matter (DDM) production amounting to 25 t/ha was obtained from one crop; this is significantly higher than 10–15 t DDM/ha of maize and wheat.[8] Such a high productivity of sugar cane should be utilized as a forage crop for feeding ruminant.

In spite of such a high dry matter productivity, clipping of this crop is not practical, because the ability of rapid growth is expressed only after the initiation of stem growth which occurs usually more than one month after the planting, so that there is not enough time for the regrowth of the plants under the warm temperate condition.

Pretreatment of stem sets for sprouting has been practiced and recommended at some places in tropical Asia and also in southern Japan to obtain uniform stands of sugar cane crop.[9,10,12] This method is particularly important in warm temperate areas with relatively short period of high temperature and strong solar radiation. The growth characteristics of sugar cane shown above may be manifested in areas where temperature higher than 15°C continues at least 6 to 7 months, and such areas may easily be found out in Japan and elsewhere.

References

1) Abe, A., Horii, S. & Kameoka, S.: Development and application of cellulose hydrolysis for predicting digestibility of roughage III. *Jap. J. Zootech. Sci.*, **43**, 175–180 (1972) [In Japanese].
2) Barnes, R. F.: Laboratory methods of evaluating feeding value of herbage. *Chemistry and Biochemistry of Herbage*, 3, Academic Press. 179–191 (1973).
3) Cobley, L. S.: Sugar cane. An introduction to the botany of tropical crops, Longman 64–70 (1977).
4) Committee of Crop Analysis Technique, ed.: Methods of analysis of cultivated plants, Yokendo 482–500 (1975) [In Japanese].
5) Ehara, K.: Sugar cane as forage crop. Forage crop science (Shiryo sakumotsugaku) II, Yokendo 353–354 (1954) [In Japanese].
6) Mizushima, T. & Kobayashi, K.: Utilization of crops as forage II. Sugar cane. *Bull. Okayama Agr. Exp. Station*, No. 2, 66–69 (1977) [In Japanese].
7) Nagatomi, S.: Introduction and breeding of sugar cane in Japan. *Japan J. Trop. Agr.*, **24**, 69–76

(1979) [In Japanese].

8) Nishida, M. & Nakano, H.: Comparative study on forage productivities of wheat, barley and rye. *Bull. Kinchyu branch, Jap. Soc. Grassland Sci.*, **6**, 18–21 (1977) [In Japanese].
9) Ouchiyama, S.: Sugar cane. Sakumotsutaikei, Part 8. Sugar producing crops. Yokendo, 1–26 (1963) [In Japanese].
10) Purseglove, J. W.: Saccharum. Tropical crops, Longman 214–256 (1972).
11) Togari, Y., ed.: Photosynthesis and Organic Matter Productivities of Crop Plants, Yokendo (1971) [In Japanese].
12) Tropical Agr. Res. Center: Sugar cane. *Nettai-noken Shyuho*, No. 28, 128–147 (1976) [In Japanese].

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