Effect of application timing and incorporating way of manure on nutrient uptake and yields of sugar beet（*Beta vulgaris* L.）cultivated on Andosol

Nobuhiko FUEKI[*1], Osamu SAKAI[*2] and Yuji WATANABE[*3]

To clarify the effect of application timing（fall or spring）and incorporating way of manure（plow-down or rotary-hallow）on nitrogen and phosphate uptake and sugar yield of sugar beet, field experiment was conducted for three years（2014-2016）, on Andosol in Tokachi region, Hokkaido.

Spring application of manure tended to increase nitrogen uptake by sugar beet at early growth stage more than fall application, presumably because nitrate leaching during winter time from the fall-applied manure might decrease nitrogen uptake at early growth stage, while the spring-applied manure did not undergo the leaching. Phosphate uptake by sugar beet at early growth stage tended to be larger in spring application of manure than fall application, hypothetically due to the longer time for phosphate adsorption in fall application than spring application, on the allophanic soil of Andosol. These trends of the nitrogen and phosphate uptakes at early growth stage were consistent with the tendency of the higher sugar yields in spring application than in fall application.

On the other hand, the difference between the plow-down and the rotary-harrow（at both of spring）was no significant, or seemed nearly equal, in terms of the nitrogen and phosphate uptakes and sugar yield. This reason could be thought as：although the plow-downed manure was distributed at 10-25 cm depth, deeper than the rotary-harrowed manure（0-10 cm）, the bottom of paper-pot（length 13 cm）at which the tip of sugar beet root appears outside could reach the plow-downed manure and take up nutrients from it.

These results suggest that spring application of manure gives better nutrient uptake and yield of sugar beet. However, fall application of manure has several advantages such as the labor dispersion and the pest damage mitigation（e.g., magotts）, therefore we should choose the best timing of manure application with considering every aspects of agricultural practice totally.

Key words：application timing, incorporating way, manure, nutrient uptake, sugar beet

INTRODUCTION

A policy of environmental conservation agriculture was launched by Ministry of agriculture, forestry and fisheries of Japan in 1992. However, Hokkaido government, one of the local municipalities in Japan, has already advanced its original administrative strategy of the "Clean Agriculture" in 1991（Department of Agriculture, Hokkaido Government 2015）. One of the main pillars of the Clean Agriculture strategy is to minimize the usage of chemical fertilizer and agrochemicals by improving soil fertility through the proper application of organic matters. Based on this agricultural strategy, the application of organic matters（mainly cow manure）is widely encouraged in Hokkaido.

Farmers in Hokkaido are enthusiastic about the soil improvement through the manure application because they know well how effective the manure application is for their own agricultural practice, according to not

Received 29 Jul 2020

[*1] Hokkaido Research Organization Tokachi Agricultural Experiment Station,（Memuro, Hokkaido, 082-0081 Japan）
E-mail：fueki-nobuhiko@hro.or.jp
[*2] ditto.（Present；Hokkaido Research Organization Kitami Agricultural Experiment Station, Kunnepu, Hokkaido, 099-1496 Japan）
[*3] ditto.（Present；Paddy Agriculture Department, Hokkaido Research Organization Central Agricultural Experiment Station, Iwamizawa, Hokkaido, 069-0365 Japan）

only their own experiences but also the experimental scientific results which advocate the positive effects of the manure application on soil physical/chemical properties, plant nutrients and yields. For example, Nakatsu *et al.* (2000) suggests that the upper limitation of manure application is surmised as less than 30 Mg ha^{-1} per a year (every year), in order to make soil physical/chemical properties better and to ensure more amount and better quality of the agricultural products without any harmful effects, e.g., the nitrate pollution of groundwater. Nakatsu and Tamura (2008; 2009) also reported that the thirty-years continuous application of organic matters surely increased air-filled porosity of soil, available soil moisture, soil aggregates (more than 0.5 mm diameter) and upland crop yields, from the results of the long-term experiments of organic matter application. These positive effects of organic matter application are prone to be clear when the experimental crop is sugar beet, probably due to its longer growth periods (Nakatsu and Tamura 2009; Okumura *et al.*, 1989).

In Hokkaido where the arable crop rotation system is widely prevailing, most of the arable farmers implements manure application at fall season (after harvesting winter wheat), before planting sugar beet at spring, because the period from after harvesting winter wheat (early half of August) until the continuous snow cover starts (approximately middle of November), gives the farmers better feasibility to apply manure (JA network Tokachi Agricultural Technology Council 2013). Usually the applied manure is going to be plowed down at a time before the continuous snow cover starts, but some farmers espouse conventionally incorporating the applied manure with topsoil (approximate 0-15 cm) by rotary hallow before plowing, with intending to accelerate organic matter decomposition and to suppress odor volatilization. Moreover, there are farmers who have no time to apply manure at fall season, and they are forced to apply manure at spring time of the busy farming season. Furthermore, there are two ways of the spring-time manure application, the one is “plowing down the applied manure” and another is “applying the manure after plowing, then incorporating the manure with topsoil by rotary hallow”.

These differences of applying timing (fall or spring) and mixing (plow-down or rotary-hallow) would affect plant growth, nutrient uptakes and yields, but there are no tangible data answering these questions. Such knowledge would be indispensable to promote the proper usage of cow manure in the arable fields.

Based on these backgrounds, authors implemented a field experiment in order to clarify the above questionable issues and obtained the results which should be published.

MATERIALS AND METHODS

Experimental field

All the experiments were conducted in the experimental fields of Tokachi Agricultural Experiment Station (latitude: 42.89° north, longitude: 143.07° east), which is located in Memuro, Kasai-gun, Hokkaido, Japan. Soil type is Andosol (Low-humic Andosol) classified by *Classification of Cultivated Soils in Japan, Third Approximation* (Cultivated Soil Classification Committee 1995). Chemical properties of the topsoil were as follows; soil pH: 5.7 (glass-electrode method, dried soil : water = 1:2.5), available phosphate (Truog method): 140 mg P_2O_5 kg^{-1}, cation exchange capacity (CEC, Schorenberger method): 140 mmol$_c$ kg^{-1}, available nitrogen (autoclave method): 26 mg N kg^{-1}.

Autoclave method (AC-N) proceeded as follows: air-dried soil (10 g) was put in a 100 mL conical flask with 100 mL distilled water and autoclaved for 60 min at 105℃. After autoclaving, the suspension was percolated and the total N content in 50 mL of the percolated solution was measured by Kjeldal method.

Exchangeable cations extracted by neutral ammonium acetate solution were: 260 mg K_2O kg^{-1}, 380 mg MgO kg^{-1}, 2090 mg CaO kg^{-1}, respectively.

Determination of rotary-harrowed or plow-downed depth of applied matter

To determine the vertical depth of rotary-harrowed or plow-downed matters, we examined the following experiment. In an experimental field of Tokachi Agricultural Experiment Station, 20 kg of the soybean seed (cultivar: “Yukihomare R”) were spread uniformly by hand to a 4 m^2 (2 m × 2 m, 3 plots) square area, and then the plow-down (depth: 25 cm), or the rotary-hallow (depth: 15 cm), or the combination of the both (plow-down + rotary-hallow) were treated to each plot of 4 m^2, on 6th November 2012. Immediately after the treatment, as shown in Figure 1, soil sample

Figure 1 Distribution of applied soybean seed which was plowed down. The soybean seed was eccentrically located along with the moldboard of plow.

was taken from each plot as a block (length 30 cm × width 10 cm × depth 5 cm) and was loosened and sieved by 4.75 mm mesh for picking up the added soybean seed. This investigation was done for each 5 cm of 0–30 cm depth as three repetitions, for each plot of 4 m^2 (plow-down, rotary-hallow or combination of the both). The picked-up soybean seed was weighed and the vertical distribution rate was calculated as the percentage of weight (soybean seed weight of the each 5cm depth / soybean seed weight of the total 0–30 cm depth × 100, %).

Studied crop

Sugar beet (*Beta vulgaris* L.) was employed as the studied crop in this experiment. The cultivar was "Lycka", which was introduced from Sweden and has tolerance against one of a serious disease of the cercospola leaf spot (Yamazaki *et al.*, 2013).

Application timing and incorporating way of manure (experimental plots)

Experimental treatments of this study consisted of 4 different ways of the application timing and the incorporating way of manure, as follows. Additionally, the dates of agricultural works related to this experiment were shown in Table 1.

Fall-Plow plot (control): Manure was applied by hand at the end of October (27–29th October), and then was plowed down (depth: 25 cm) at the early November (2–11th November).

Table 1 Date of agricultural works related to this experiment

Trial plots	Year	Previous fall			Spring		
		Manure application	Rotary harrowing	Plowing down	Manure application	Plowing down	Rotary harrowing
Fall-Plow	2014	29-Oct-13	—	11-Nov-13	—	—	23-Apr-14
	2015	29-Oct-14	—	5-Nov-14	—	—	22-Apr-15
	2016	27-Oct-15	—	2-Nov-15	—	—	25-Apr-16
Fall-Rotary-Plow	2014	29-Oct-13	7-Nov-13	11-Nov-13	—	—	23-Apr-14
	2015	29-Oct-14	5-Nov-14	5-Nov-14	—	—	22-Apr-15
	2016	27-Oct-15	2-Nov-15	2-Nov-15	—	—	25-Apr-16
Spring-Plow	2014	—	—	—	15-Apr-14	18-Apr-14	23-Apr-14
	2015	—	—	—	21-Apr-15	22-Apr-15	22-Apr-15
	2016	—	—	—	19-Apr-16	20-Apr-16	25-Apr-16
Spring-Rotary	2014	—	—	11-Nov-13	15-Apr-14	—	23-Apr-14
	2015	—	—	5-Nov-14	21-Apr-15	—	22-Apr-15
	2016	—	—	2-Nov-15	19-Apr-16	—	25-Apr-16

Fall-Rotary-Plow plot: Manure was applied by hand at the end of October (27-29th October), and then, was rotary-harrowed (depth: 15 cm) at the early November (2-7th November) and plowed down at the early November (2-11th November).

Spring-Plow plot: Manure was applied by hand at the mid-late April (15-21st April), and then was plowed down later (18-22nd April).

Spring-Rotary plot: Topsoil was plowed down (without manure) at the early November (2-11th November). Then the manure was applied by hand at the mid-late April (15-21st April).

In every experimental plot, the topsoil was rotary-harrowed at the mid-late April (18-25th April). The amount of the applied manure was 50 Mg ha^{-1} (2014) or 30 Mg ha^{-1} (2015, 2016). Every year these experimental plots were set up on the different experimental fields (after wild oats), to avoid continuous cropping. In terms of the studied manure, water content was 0.6 kg kg^{-1} (fresh matter base), nitrogen content was 8 gN kg^{-1} (fresh matter base), phosphate content was 6 gP_2O_5 kg^{-1} (fresh matter base), potassium content was 13 gK_2O kg^{-1} (fresh matter base), measured by Kjeldal method.

Field management

The field trials were done for three years, 2014-2016. Row width was 60 cm, plant distance was 23 cm, plant density was 72,460 plant ha^{-1}. Nitrogen fertilizers (2014: 90 kg ha^{-1}, 2015-2016: 130 kg ha^{-1}) were applied on 23-25th April as the band application by hand. Phosphate and potassium fertilizer were not applied because phosphate and potassium were supposed to be sufficiently supplied from the applied manure (Department of Agriculture, Hokkaido Government 2015). The paper-pot nursery of sugar beet (approximate 40 days after sowing) was transplanted along the band-applied fertilization line, 1-4 days after fertilization (24-28th April). Herbicides, fungicides, germicides and pesticides were sprayed as the conventional way of Tokachi agricultural experiment station.

Statistical analysis

Microsoft Excel, with the add-in software Ekuseru-Toukei (Social Survey Research Information Co., Ltd. Tokyo, Japan) was used for the statistical analysis.

RESULTS

Vertical distribution of rotary-harrowed or plow-downed matter

Figure 2 shows the vertical distribution rate of the surface-applied soybean seed after rotary-harrowing and / or plowing down. In the case of plow down, the soybean seed converged around 15-25 cm depth and 16 % of the soybean was found at 10-15 cm depth. In the case of the rotary harrow + plow down, even though no significant difference among the depths, the soybean seed converged around 10-20 cm depth, 5 cm more shallowly than in the case of plow down. In the case of rotary harrow, the soybean seed converged around 0-5 cm depth, most shallowly among the plots.

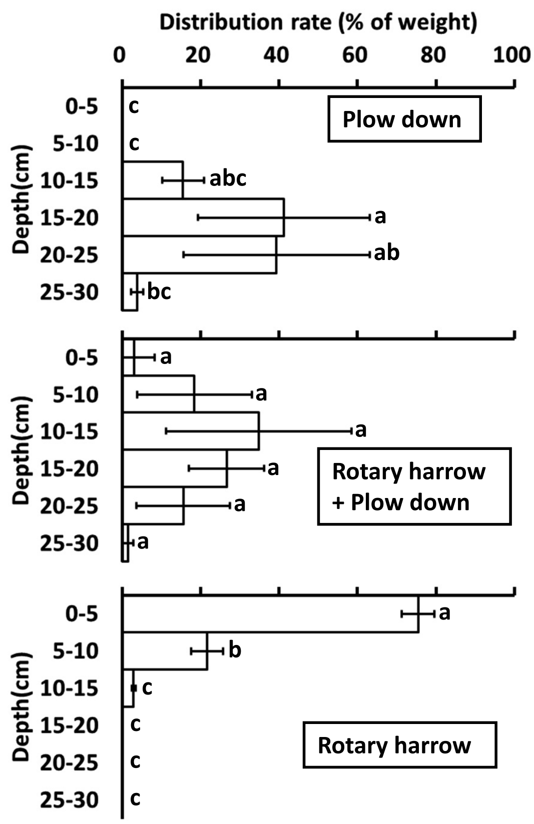

Figure 2　Vertical distribution rate of surface-applied soybean seed after rotary harrowing and/or plowing down (% of weight). Different letters are significantly different between the depths within each plot by Tukey-Kramer's honestly significant difference (HSD) test at $P < 0.05$. Error bars indicate standard deviations.

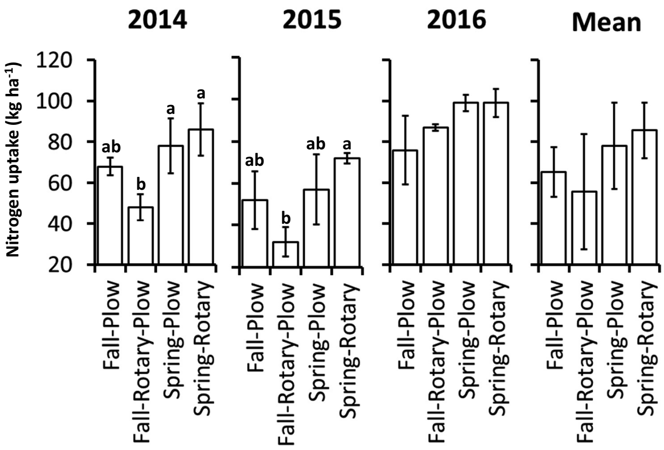

Figure 3 Nitrogen uptake by sugar beet in each experimental plot at early growth stage (late June). Different letters are significantly different between the experimental plots by Tukey-Kramer's honestly significant difference (HSD) test at $P < 0.05$. Error bars indicate standard deviations.

Effect of the experimental treatments on nitrogen uptake by sugar beet at early growth stage

Figure 3 shows nitrogen uptake by sugar beet at the early growth stage, late June. Nitrogen uptake was significantly smaller in Fall-Rotary-Plow plot than in both of Spring-Plow plot and Spring-Rotary plot, and Fall-Rotary-Plow plot was apt to be smaller than Fall-Plow plot, even though no significant difference, with referring the results of 2014 and 2015. When looking at the wholly 3-years results, the difference between Spring-Plow plot and Spring-Rotary plot was unclear, but spring application of manure (Spring-Plow plot and Spring-Rotary plot) seems larger than fall application (Fall-Plow plot and Fall-Rotary-Plow plot), even though no significant difference.

Effect of the experimental treatments on phosphate uptake by sugar beet at early growth stage

Figure 4 shows phosphate uptake by sugar beet at the early growth stage, late June. Phosphate uptake was significantly smaller in Fall-Rotary-Plow plot than in both of Spring-Plow plot and Spring-Rotary plot with referring each result of 2014-2016. When seeing the data of 2014 and 2015, Fall-Rotary-Plow plot was apt to be smaller than Fall-Plow plot even though no significant difference. When looking at the wholly 3-years results,

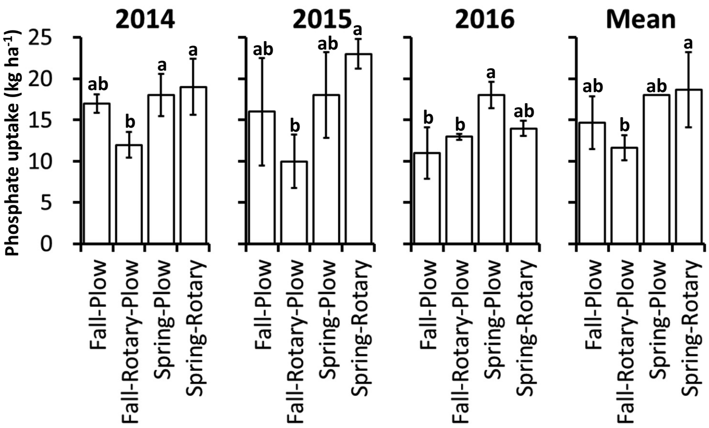

Figure 4 Phosphate uptake by sugar beet in each experimental plot at early growth stage (late June). Different letters are significantly different between the experimental plots by Tukey-Kramer's honestly significant difference (HSD) test at $P < 0.05$. Error bars indicate standard deviations.

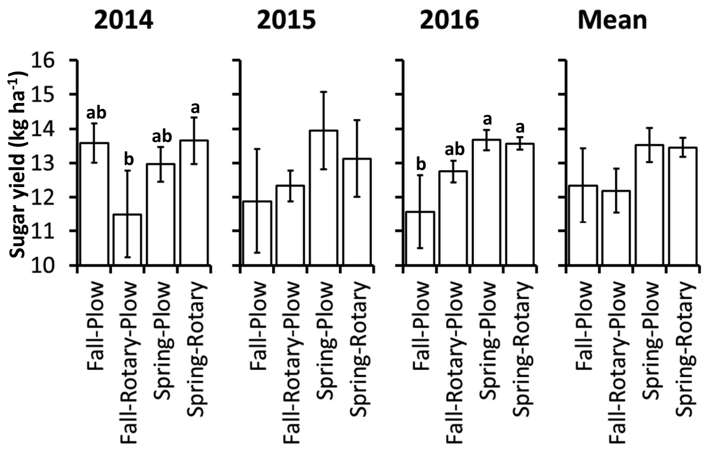

Figure 5　Sugar yield in each experimental plot（investigated at middle of October）. Different letters are significantly different between the experimental plots by Tukey-Kramer's honestly significant difference（HSD）test at $P < 0.05$. Error bars indicate standard deviations.

Spring-Rotary plot was significantly larger than Fall-Rotary-Plow plot, and as a tendency, spring application of manure（Spring-Plow plot and Spring-Rotary plot）seems larger than fall application（Fall-Plow plot and Fall-Rotary-Plow plot）, even though the cases of no significant difference was included.

Effect of the experimental treatments on sugar yield

Figure 5 shows sugar yield at the harvest time, investigated at the middle of October. In 2014 Fall-Rotary-Plow plot was significantly smaller than Spring-Rotary plot. On the other hand, in 2016 Fall-Plow plot was significantly smaller than spring application of manure plot（Spring-Plow plot and Spring-Rotary plot）. When looking at the wholly 3-years results, spring application of manure（Spring-Plow plot and Spring-Rotary plot）seems larger than fall application（Fall-Plow plot and Fall-Rotary-Plow plot）, even though no significant difference.

Effect of the experimental treatments on nitrogen uptake by sugar beet at harvest time

Figure 6 shows nitrogen uptake by sugar beet, investigated at the middle of October. Although no significant difference was observed, fall application of

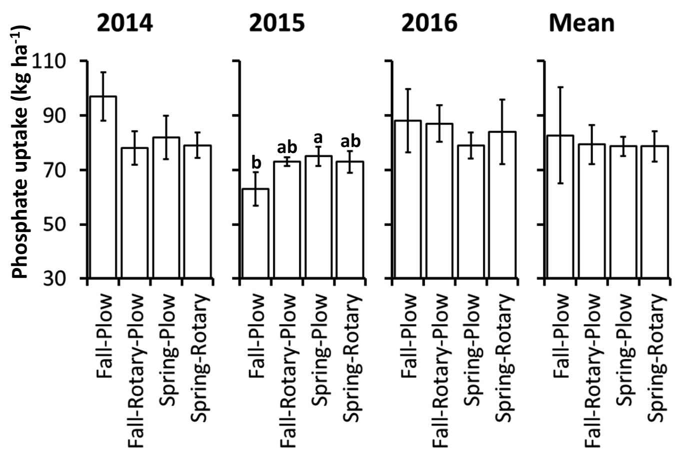

Figure 6　Nitrogen uptake by sugar beet in each experimental plot（investigated at middle of October）. Different letters are significantly different between the experimental plots by Tukey-Kramer's honestly significant difference（HSD）test at $P < 0.05$. Error bars indicate standard deviations.

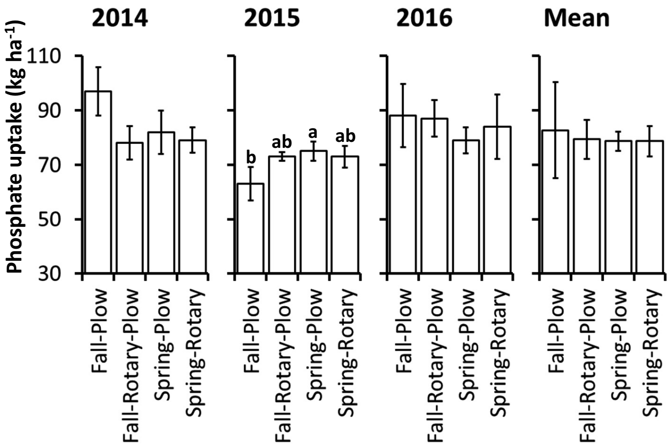

Figure 7 Phosphate uptake by sugar beet in each experimental plot (investigated at middle of October). Different letters are significantly different between the experimental plots by Tukey-Kramer's honestly significant difference (HSD) test at $P < 0.05$. Error bars indicate standard deviations.

manure (Fall-Plow plot and Fall-Rotary-Plow plot) looked larger than spring application (Spring-Plow plot and Spring-Rotary plot).

Effect of the experimental treatments on phosphate uptake by sugar beet at harvest time

Figure 7 shows phosphate uptake by sugar beet, investigated at the middle of October. The difference among the experimental plots was unclear and insignificant wholly, except for that Spring-Plow plot was significantly larger than Fall-Plow plot (2015).

DISCUSSION

Nitrogen uptake by sugar beet at the early growth stage tended to be larger in spring application of manure than in fall application, even though there were the cases of no significant difference (Figure 3). Normally, nitrate leaching occurs during the winter season in Tokachi and Abashiri area of Hokkaido (Sato et al., 2008), therefore it could be thought that nitrate leaching from the fall-applied manure might decrease nitrogen uptake at the early stage, while the spring-applied manure did not undergo the leaching.

However, not only nitrogen, but also phosphate uptake at the early growth stage tended to be larger in spring application of manure than in fall application (Figure 4). The reason of this fact is not clear, but could be thought that the manure was applied approximate six months earlier in fall application than in spring application, in Andosol which has the high phosphate adsorption due to allophane (Fueki *et al.*, 2004), i.e., phosphate released from the fall-applied manure had much more time to be absorbed and immobilized by the high-P-adsorption soil, than from the spring-applied manure. These trends of nitrogen and phosphate uptakes at the early growth were consistent with the tendency of the higher sugar yields in spring application than in fall application, though including the cases without significant difference (Figure 5). Nutrient uptake such as nitrogen at the early growth stage of sugar beet is supposed to be positively associated with sugar yield (Fueki, 2008), this citation would support the results of this study.

On the other hand, the difference between Spring-Plow and Spring-Rotary was no significant, or seemed nearly equal (Figure 3-7). As shown in Figure 2 (figure at the bottom), the rotary-harrowed matter (soybean) was converged at the depth of 0-5 cm, and almost all of them distributed at the depth of 0-10 cm, while the plow-downed matter (soybean) was converged at the depth of 15-25 cm, and almost all of them distributed at the depth of 10-25 cm, deeper and more widely-ranged than in the case of rotary harrow. The plow-downed matter (soybean) seemed to distribute obliquely along with the cut-surface of plow board, i.e., the plow-downed manure also distributed obliquely and convergently as same as the plow-downed soybean in Figure 1. Additionally, in terms of the sugar beet nursery which was transplanted, the length of the paper-pot which wraps soil and sugar beet root is 13 cm, therefore, the bottom of the paper-pot at which the tip of the sugar beet root appears outside would reach under 13 cm depth of the soil immediately after transplanting, and the sugar beet root could take up nutrients from the plow-downed manure. This interpretation might explain the reason why the difference between Spring-Plow and Spring-Rotary was no significant, or seemed nearly equal（Figure 3-7）.

Based on the above discussion, spring application of manure would be more reasonable than fall application, for accelerating nitrogen and phosphate uptakes by sugar beet, and the difference of incorporating way of manure, whether rotary harrow or plow, would be not very critical. However, as mentioned in **INTRODUCTION**, fall application of manure（after harvesting winter wheat）is the most popular way in Hokkaido, and has a few advantages such as: 1）farmers can secure the sufficient time to apply manure to field during August（harvest time of winter wheat）to November（beginning of snow fall）, 2）farmers can reduce too much burdens of the agricultural works in spring, 3）risk of the pest damage by such as magotts（Aoki, 2013）can be reduced. Therefore, if taking into every aspects of the actual agricultural practice totally, we cannot simply decide that spring is the best timing of manure application, and we should choose the best timing of manure application with considering the own condition of each field and the agricultural style.

ACKNOWLEDGMENTS

Authors would like to give sincere gratitude to Mr. Akihiro Hurudate, Mr. Harunobu Takeuchi and Mr. Naoki Nishimura, who gave us their profound suggestions to this article.

REFERENCES

Aoki, M. Control of the damages caused by seedcorn maggot, *Delia platura* and Soybean dwarf virus disease in organic farming of green soybeans. *Bull. Hokkaido Pref. Agr. Exp. Stn*., 97, 39-44（2013, in Japanese with English summary）

Cultivated Soil Classification Committee. Classification of Cultivated Soils in Japan, Third Approximation, Vol. 17. National Institute of Agro-Environmental Sciences, Tsukuba（1995, in Japanese）

Department of Agriculture, Hokkaido Government. *Hokkaido Fertiliser Recommendations* 2015, Sapporo（2015, in Japanese）

Fueki, N. Studies on effective soil and nutrient management for stable sugar beet production. *Bull. Hokkaido Pref. Agric. Exp. Stn*., 120, 5-51（2008, in Japanese with English summary）

Fueki, N., Tani, M., Higashida, S., Nakatsu, S. Effect of soil acidity and nitrification of fertilizer introduced by row application on sugar beet growth in several soil types. *Soil Sci. Plant Nutr*., 50, 321-329（2004）

JA network Tokachi Agricultural Technology Counsil. Investigative report of precise picture of soil fertility management in Tokachi arable region（2013, in Japanese）

Nakatsu, S., Higashida, S., Yamagami, M. Effects of continuous manure application on yield and quality of upland crop and soil in light colored Andosol. *Jpn. J. Soil Sci. Plant Nutr*., 71, 97-100（2000, in Japanese）

Nakatsu, S., Tamura, H. Effects of thirty years continuous application of organic materials（bark manure and crop residues）on total carbon, total nitrogen and physical characteristics of upland field soil in light colored andosol in Hokkaido. *Jpn. J. Soil Sci. Plant Nutr*., 79, 139-145（2008, in Japanese with English summary）

Nakatsu, S., Tamura, H. Effects of thirty years of continuous application of organic matter（cattle manure with bark and crop residues）on yield and quality of upland crops in light colored andosol in Hokkaido. *Bull. Hokkaido Pref. Agr. Exp. Stn*., 94, 81-88（2009, in Japanese with English summary）

Okumura, M., Matsuzaki, Y., Nomura, N., Souma, S. The effect of nitrogen fertilizer and manure application on the sugar yield of sugarbeet. *Bull. Hokkaido Pref. Agr. Exp. Stn*., 59, 21-29（1989, in Japanese with English summary）

Sato, K., Nakatsu, S., Miki, N., Nakamura, R., Fueki, N., Shiga, H. Recommendation of nitrogen fertilizer application for winter wheat based on using diagnosis of soil nitrate-N in early spring in Hokkaido. *Jpn. J. Soil Sci. Plant Nutr*., 79, 45-51（2008, in Japanese with English summary）

Yamazaki, H., Yamada, S., Nishida, T. A new sugarbeet variety "Lycka". *Bull. Hokkaido Pref. Agr. Exp. Stn*., 97, 53-57（2013, in Japanese）

堆肥の施用時期と混和方法が，黒ボク土で栽培されたテンサイ（*Beta vulgaris* L.）の養分吸収量と収量に及ぼす影響

笛木　伸彦[*1]　　酒井　　治[*2]　　渡辺　祐志[*3]

要　　　旨

堆肥の施用時期（秋および春）ならびに混和方法（プラウ鋤き込みおよびロータリー混和）がテンサイの窒素・リン酸吸収量と糖量に及ぼす影響を明らかにするため，3カ年（2014-2016年）に亘る圃場試験を，北海道十勝地域の黒ボク土を供試して行った。

堆肥の春施用は，秋施用よりもテンサイ生育初期の窒素吸収量を高める傾向があった。この理由は，秋施用された堆肥は冬期間に硝酸溶脱を受けるため生育初期の窒素吸収量が低下するのに対し，春施用された堆肥はこの溶脱を受けないと推察された。

テンサイ生育初期のリン酸吸収量についても，堆肥の秋施用よりも春施用で高まる傾向にあった。この理由は，一つの仮説ではあるが，アロフェン質土壌である黒ボク土におけるリン酸吸着の時間が，春施用よりも秋施用でより長くなるためと考えられた。テンサイの糖量も秋施用よりも春施用で高まる傾向にあり，このことは生育初期における窒素およびリン酸吸収量が示した上記傾向と一致した。

一方，堆肥のプラウ鋤き込みとロータリー混和（両者とも春施用）間の差については，窒素・リン酸吸収量および糖量に関しては，有意差はないかほぼ等しかった。この理由は次のように考えられる：プラウで鋤き込まれた堆肥は深さ10-25cmに分布し，ロータリーで混和された堆肥（0-10cm）より深いけれども，テンサイ苗の根の先端が露出する紙筒（長さ13cm）の底はプラウで鋤き込まれた堆肥に到達可能で，養分を吸収することができると考えられる。

以上のことから，堆肥の春施用はテンサイの養分吸収および収量の面から見て秋施用に優ると考えられた。ただし，堆肥の秋施用には労働分散や害虫被害の軽減（タネバエ等）などいくつかの利点があるので，営農実践上の諸条件を総合的に考慮した上で最良の堆肥散布時期を選択すべきと考えられた。

キーワード：混和方法，施用時期，堆肥，テンサイ，養分吸収

[*1]　（地独）北海道立総合研究機構十勝農業試験場（082-0081　河西郡芽室町）
[*2]　同上（現：同北見農業試験場，099-1496　常呂郡訓子府町）
[*3]　同上（現：同中央農業試験場水田農業部，069-0365　岩見沢市）