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On-farm evaluation of the yield and nutrient content of high-altitude-profit-oriented leafy vegetable fields in Central Japan

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Abstract

High altitude leafy vegetable cultivation in profit-oriented fields in Japan are abundantly fertilized and characterized by plastic mulching. Our goal was to evaluate the close link between soil nutrient amendment, yield and nutrient uptake of three leafy vegetable production systems of small and middle scale producers characterized by an array of farm management practices. A participatory methodology using questionnaires together with on-farm and homestead discussions and observations were employed to obtained information about the farm management practices. Plant sampling was carried out at harvest and analyzed using standard methods. Results showed that yields for the same crop from high-nutrient input cropping system (B) was not significantly different ($p > 0.05$) to that of low-nutrient input systems (A, C and AFC). However, there was a significant difference ($p < 0.05$) in terms of nutrient content of the harvested parts indicating excess nutrient applied in high-nutrient input cropping systems. In addition, more of N, K, Ca and Mg taken up were left in the system as residues after harvest than was taken out in the form of harvested farm produce. P content of the harvested part was greater than that in the crop residue. Harvesting methods were not uniform (time, crop residue) resulting in some significant differences between nutrient content of the harvested parts and crop residues indicating that farm management practices may not necessarily result to any significant gain in yields but may lead to significant differences in the nutrient content.

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Introduction

The increasing gap between the world's total population and total food production has been one of the driving factors behind intensification of cropping systems in the 20^{th} century (Kimura and Hatano, 2007; Komatsuzaki, 2011). Intensification accelerated by the green revolution has been achieved through the introduction of high yielding varieties, use of high analysis fertilizers with high planting density and the adoption of best management practices. Intensive vegetable production systems predominates the lower volcanic slopes of the highlands in Central Japan. According to Maruyama (1992), the land use patterns on these highlands constitute mainly summer vegetable production, horticulture and animal husbandry. Small and middle scale Chinese cabbage, cabbage and lettuce based vegetable production systems have progressed rapidly on these highlands since 1956 by taking advantage of the large-scale farmland and favorable traffic conditions represented by the existence of railway (Komi Line) and Highway 141 (Maruyama, 1992).

In addition, the mean daily intake of vegetables in Korea (327.0 g/day) (Hansson *et al.*, 1994) and Japan (253.9 g/day) is higher than that of the USA (189 g/day) and northern Europe (104.6–119.1 g/day in men and 119.4–131.0 g/day in women) (Kim *et al.*, 2010). Inherited or rented profit-oriented vegetable production fields characterized by plastic mulching are abundantly fertilized to increase productivity per unit area (Mishima, 2001; Nishio, 2001).

The growth, yield and quality of leafy vegetable are remarkably influenced by organic and inorganic nutrients applied (Pour *et al.*, 2013).

The Utilization of inorganic fertilizer in contrast to organic amendments may result to human health and environment problems due to excessive use and residual effects (Takeuchi, 1997; Molitor, 1998; Bergström *et al.*, 2005). In addition, studies of N flow associated with agricultural production in Japan showed that there has been an increase in the use of chemical fertilizers per unit area of vegetables (Mishima, 2001; Nishio, 2001).

However, there has been a trend towards decreasing the rates of inorganic fertilizer application to soils by using organic fertilizers more efficiently since organic fertilizers will increase soil productivity as well as crop quality and yield (Pour *et al.*, 2013).

In developed countries, profit-oriented agricultural production systems are characterized by high nutrient input in the form of chemical fertilizer and organic sources of nutrients that may not necessarily lead to any significant changes in yield and are environmentally not benign (FAO, 1989; Heckman *et al.*, 2003; Heckman *et al.*, 2007).

These profit-oriented production systems make use of high yielding and disease resistant varieties as well as farm management practices at levels defined by the farmer's conception and experience. Most research studies focused on the impacts of soil nutrient amendments are conducted in research stations/institutions through experiments that may not replicate the abiotic and biotic environment of the real farms.

On-farm assessment through participatory research provides findings representing the state-of-art of a typical farm within an actual agro-ecosystem. This study focused on profit-oriented fields of leafy vegetables characterized by the high use of machinery, an array of soil nutrient amendment and farm management practice located on the lower volcanic slopes of the highlands in central Japan. The main objective was to evaluate the close link between yield, nutrient uptake and soil nutrient amendments of profit-oriented fields of leafy vegetable production systems to obtain information representing the-state-of-art of prevailing farm management practices.

Materials and methods

Study site

The study was carried out at the Nobeyama plateau located at the foot of the Yatsugatake mountains (35°57`N, 138° 28`E), Nagano prefecture, Central Japan, adjacent to the Kanto region. This region is a famous production area of vegetables, horticulture and animal husbandry (dairy farming and calf production) in the Nagano Prefecture.

The cropping season runs from April to October. The soil characteristics, nutrient management and the climatic conditions of the studied fields are found in Chotangui *et al.* (2015). Vegetable production systems in this area are based on Chinese cabbage (*Brassica rapa* L. ssp *pekinensis*), cabbage (*Brassica oleracea* L.), crisp-head type lettuce (*Latuca sativa* L.) and others.

Farm management practice

A participatory inventory and monitoring procedures was implemented to obtain primary data on crop and farm management practices (crop rotational patterns, land preparation, crop types, and nutrient management, nursery, mulching material, tillage and schedule of all farm management events). Information of the selected fields was obtained through on-farm or in-situ and homestead observations and discussions. The initial stages of the study involved diagnoses of the soil physical properties of the selected fields (Chotangui *et al.*, 2015).

Field selection, plant sampling and analysis

In this study, 12 fields belonging to four farm management practices (A, B, C and AFC) were selected following the establishment of a collaborative research relationship with Shinshu University in Nagano. Amongst the fields were profit-oriented fields of three farmers (A, B, and C) recommended by an agricultural extension worker of the Saku centre of the Nagano Prefecture and research-oriented fields of the Education and Research Centre of Alpine Field Science (AFC) owned and managed by Shinshu University (Chotangui *et al.*, 2015).

Three fields per farm/farmer were randomly selected as sampled representatives of the prevailing cropping systems.

Aboveground plant parts in triplicates were randomly sampled at harvest, placed in a portable cooler and taken to the laboratory for analysis the next day.

Harvested plant samples were separated into harvested (inner leaves) and crop residues (outer leaves) according to the harvesting procedure demonstrated by each farmer at the level of the field. Fresh weight and dry weight of plant parts after drying in an air-circulating oven at 80°C for 72 hours was determined using a top-load electronic balance. Dried plant materials were ground using an electric mill (MILLSER-720-G-W, Iwatani Japan), sieve through a 2 mm mesh and the N content analyzed using a C/N analyzer (CN CORDER MT-700, Shimadzu, Japan). Elemental content of plant material were obtained through wet acid digestion using 60% perchloric acid and subsequent analysis using the atomic absorption spectrophotometer (Ca, K, Mg) and UV spectrophotometer (P).

Data analysis

All data obtained were entered into Microsoft Excel 2007 and spreadsheets created. The spreadsheets were imported into SPSS version 21 statistical package and analysis of variance was done with the means separated by Tukey HSB test.

Results and discussion

Characteristics of selected farms

In this region, farmer's fields have been established on the plateau with an elevation ranging from 1120 to 1350 m (a.s.l). Information obtained through on-farm assessment using semi-structured questionnaires/interviews was used to diagnose the structural set-up of the four systems studied. Table 1 shows the basic information of the farm management systems selected. A farm represents a management system owned by a farmer and each farm constitutes several fields amongst which three were selected for the purpose of this study. Two of the farmers selected for this study were full-time middle-scale (farm size of about 5-10 ha) and small scale (< 5 ha) vegetable growers managing family fields (Table 1). The labour force generally comprised of family members and trainees (A, B and C) performing all farm management operations throughout the cropping season (Table 1).

Table 1. Characteristics of selected farms.

Farm	Number of fields	Labor force	Status	Scale	Main crops	Longevity (yrs)
A	16*	4: Family	FF	Mddle scale vegetable grower	Lettuce, C. cabbage, Cabbage	>30
B	11	5: 2 Trainees, 3 family	FF	Middle scale vegetable grower and cattle production	Lettuce, C. cabbage, Cabbage	>30
C	5	3: Family	FF	Small scale vegetable grower	Lettuce, Cabbage, C. cabbage, Sweet corn and Flower bean	>15
AFC&	11	Not fixed: 2(3) Permanent and students	R	Field experiments and cattle production	Cabbage, Buckwheat and Flower bean	>15

* Three of the fields were rented; FF= Full-time farmer; R= Research; C. cabbage= Chinese cabbage; & Education and Research Center of Alpine Field Science, Faculty of Agriculture, Shinshu University.

Table 2. Basic crop rotation type.

Farm	Time		1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year	7th Year
A	Single cropping-GM/catch crop		Timothy	Timothy	Timothy	C. cabbage-Oat$	Lettuce-Rye$	C. cabbage-Oat$	Lettuce-Oat$
B	Type 1	Continuous cropping	Lettuce	Lettuce	Lettuce	Remark: Continuous cropping of lettuce in high elevation fields			
	Type 2	Double cropping	Lettuce-Cabbage*						
			Lettuce-C. cabbage						
			Lettuce-Cabbage*						
C	Single and double cropping		Lettuce-Lettuce	Lettuce-C. cabbage/ Cabbage	Lettuce-C. cabbage/ Cabbage	Sweet corn/Flower bean			
AFC&	Single cropping		Cabbage	Flower bean	Sorghum				

C. cabbage: Chinese cabbage, * A cabbage called a green ball, $ Green manure/Catch crop, & Education and Research Center of Alpine Field Science, Faculty of Agriculture, Shinshu University.

Fields varied in sizes usually (0.1-0.7 ha) and the three major vegetables cultivated were lettuce, Chinese cabbage and cabbage. The older farms (A and B) were larger in size shown by the number of fields and were managed by the farmer's household and trainees (Table 1). Interestingly, organic manure was also applied in farms A and B annually and this reflected the soil nutrient composition as shown in Chotangui *et al.* (2015)

Basic crop rotation and cultivated varieties

The cropping history of selected fields for the past five years was used to diagnose the basic crop rotation type (Table 2).

Basically, the crop rotation types in the assessed farms vary with the farmer's decision at the beginning of each cropping season. Crop rotation pattern involved leafy vegetables lettuce, cabbage and Chinese cabbage (A, B, C, and AFC), leguminous crops (flower bean) in C and AFC, green manure species (A and AFC) and gramineous crops (timothy, sorghum and sweet corn) in A, C and AFC. Continuous cropping of lettuce was a typical practice in high elevation fields in farm B (B1).

Table 3. Cultivated varieties.

Crop	Variety		A	B	C	AFC&
	Farm					
Lettuce	Ordinary varieties		*Lalaport	*Senior	Haru-P	-
				*Finegreen	Laputoru	-
				Summerace		-
				*Venus		-
	Resistant varieties for root rot of lettuce	Race 1	Wizard	Starlei	Starlei	-
					Choya No.45	-
		Race 2	-	-	*Rushina66	-
					*Rushina67	
		Race 1 and 2	Escort	Escort	Escort	-
Chinese cabbage	Ordinary varieties		*Shinshudaifuku	*Kishin	*Shinriso-megumi	-
	Resistant varieties: Clubroot and Verticilium yellow		Akimeki G1-4	-	-	-
Cabbage	Ordinary varieties		*Seirin	*Seirin	*Sogetsu. GB	Shinshu868
	Resistant varieties for clubroot			Teruyoshi		*Teruyoshi

*Leading varieties in each farm; &Education and Research Center of Alpine Field Science, Faculty of Agriculture, Shinshu University.

Table 4. Fertilizer application rates.

Farm	Field	Quantity applied (kg ha^{-1})							(t ha^{-1})
		Fertilizer (form)	N	P_2O_5	K_2O	CaO	MgO	Salicyclic Acid	Cattle manure
A	A_1	Inorganic	90.0	60.0	60.0	120.0	-	120.0	40
		Organic	24.0	28.0	12.0	-	-	-	
	A_2	Inorganic	90.0	60.0	60.0	120.0	-	120.0	40
		Organic	24.0	28.0	12.0	-	-	-	
	A_3	Inorganic	340.0	-	120.0	1800.0	200.0	120.0	40
		Organic	-	-	-	-	-	-	
B	B_1	Inorganic	264.0	328.0	204.0	504.0	468.0	-	30
		Organic	-	-	-	-	-	-	
	B_2	Inorganic	234.0	302.0	180.0	504.0	462.0	-	30
		Organic	-	-	-	-	-	-	
	B_3	Inorganic	356.0	354.0	228.0	756.0	672.0	-	30
		Organic	-	-	-	-	-	-	
C	C_1	Inorganic	165.3	95.0	127.3	320.0	427.8	-	10
		Organic	36.3	94.8	32.6	-	-	-	
	C_2	Inorganic	87.0	50.0	67.0	-	307.8	-	10
		Organic	28.8	76.8	33.6	-	-	-	
	C_3	Inorganic	165.3	95.0	127.3	320.0	427.8	-	10
		Organic	28.8	76.8	33.6	-	-	-	
AFC	AFC_1	Inorganic	150.0	100.0	100.0	800.0	360.0	-	20
		Organic	-	-	-	-	-	-	
	AFC_2	Inorganic	64.4	78.2	59.8	800.0	300.0	-	10
		Organic	-	-	-	-	-	-	
	AFC_3※	Inorganic	171.0	114.0	114.0	800.0	368.4	-	10
		Organic	-	-	-	-	-	-	

Double cropping system was a common practice in the commercial fields of farm A, B, and C (Table 2). Double cropping in these farms is characterized by early planting of the first crop immediately after the melting of snow in spring, aimed to maximize production during the short cropping season. Crop rotation pattern in the assessed fields can be summarized as; 7 years rotation (A), 4 years rotation (C), continuous cropping (B) and 3 years rotation (AFC) (Table 2).

Generally, the cropping systems involved the use of ordinary and resistant varieties (Table 3). These varieties are cultivated in association with disease and pest management practices depending on the farmer's perception and experience.

Table 5. Aboveground biomass (yield) in 2012 and 2013 cropping seasons For each year, numbers within a column, followed by a common lowercase letter are not significantly different ($p > 0.05$) according to Tukey HSD; #2 Second crop in a double cropping sequence; ※Experimental field for club-root disease.

Year		DW	Fresh weight ($g\ plant^{-1}$)			Dry weight ($g\ plant^{-1}$)		
	Cultivated crop	Field	Harvested	Residue	Total	Harvested	Residue	Total
2012	Lettuce	A_1	357.70c	398.47bcd	756.17de	15.99de	19.22d	35.20de
	Lettuce	A_2	343.23c	357.90bcd	701.13de	16.86de	21.51cd	38.37de
	Lettuce	B_1	533.70c	447.89bcd	981.59de	16.09de	18.46d	34.55de
	Lettuce	B_2	345.90c	271.03cd	616.93e	14.48de	15.79cd	30.27de
	Lettuce	B_3	509.75c	337.49bcd	847.24de	30.64cd	21.90d	52.54de
	Lettuce (S)	B_3#2	613.75c	351.14bcd	964.89de	21.11de	12.45d	33.56d
	Lettuce	C_1	420.86c	261.42d	682.28de	17.02de	14.04d	31.06de
	Lettuce	C_1#2	302.30c	292.54bcd	594.84e	9.50e	10.78d	20.28e
	Lettuce	C_3	379.65c	227.03d	606.68e	12.07de	12.21d	24.27de
		Mean	422.98	327.21	750.19	17.08	16.26	33.34
	Cabbage	AFC_1	1326.77b*	629.74bc	1956.50c	84.12b*	57.46ab	141.58bc
	Cabbage	AFC_3※	538.69c	643.71b	1182.40d	45.04c*	69.28a	114.32c
	Cabbage	B_3#2	2077.38a*	547.54bcd	2624.92b	129.37a*	42.37bc	171.74a
		Mean	1314.28	606.99	1921.28	86.18	56.37	142.55
	Chinese cabbage	A_3	2442.24a*	1730.89a	4173.13a	73.01b	72.78a	145.79ab
2013	Lettuce	A_3	521.34d	308.42de	829.75de	17.27d	12.66c	29.93c
	Lettuce	B_1	417.88d	288.27de	706.15de	15.10d	13.65c	28.74c
	Lettuce	B_2	580.57cd	325.22de	905.79cde	23.65cd	17.26c	40.91c
	Lettuce	B_3	723.90cd	379.64de	1103.54cde	19.35cd	14.81c	34.16c
	Lettuce	C_1	521.70d	202.74e	724.44de	20.77d	13.48c	34.25c
	Lettuce	C_3	475.94d	182.11e	658.05e	27.15d	15.81c	42.96c
		Mean	540.22	281.07	821.29	20.55	14.61	35.16
	Cabbage	C_2	1326.83bc*	501.81cde	1828.63bcd	84.77ab	49.59ab	134.36ab
	Cabbage	AFC_2	1444.55b	867.46bc	2312.02b	88.74ab	66.78ab	155.52ab
	Cabbage	AFC_3※	752.16cd	527.78cde	1279.94bcde	66.40bc	58.13ab	124.53b
	Cabbage	A_3#2	1354.13bc*	655.66cd	2009.79bc	77.59ab	54.02ab	131.61ab
	Cabbage	B_3#2	1422.99b	884.96bc	2307.94b	79.99ab	71.23ab	151.21ab
		Mean	1695.19	886.00	2581.19	87.06	61.80	148.86
	Chinese cabbage	A_1	2492.72a*	1252.97ab	3745.69a	92.05ab	56.32ab	148.37ab
	Chinese cabbage	A_2	3073.00a*	1511.33a	4584.33a	119.91a*	76.51a	196.42a
		Mean	2782.86	1382.15	4165.01	105.98	66.41	172.39

The leading variety cultivated for lettuce was ordinary varieties in farms A and B, and resistant varieties in C. For Chinese cabbage and cabbage, the leading varieties cultivated were ordinary varieties in farms A, B and C, and resistant varieties in farm AFC (Table 3). The cultivation of resistant or ordinary varieties influenced or reflected the integrated pest management practice of these commercial vegetable production systems. Farm AFC was a research-oriented producing more of cabbage and Chinese cabbage while the profit-oriented-farms A, B, and C produced more of lettuce.

Soil nutrient amendment

Chemical fertilizers applied differ with cultivated crops and farm management. Total fertilizer application rates ranged from 64.4-356 kg ha^{-1} for N, 0-354 kg ha^{-1} for P_2O_5 and 59.8-228 kg ha^{-1} for K_2O (Table 4). There was high application of soil conditioners particularly lime in the form of calcium carbonate to maintain the soil pH at an optimum level that will minimize or eradicate the occurrence of root diseases.

Application rates were generally higher in farm B and lowest in farm C and AFC in 2012 and 2013 (Table 4). N fertilizer input was lowest in farm A for lettuce (90 kg ha^{-1}) (Table 4). The nutrient inputs and crop rotation type played an important role in the soil fertility status for agronomy and the environment. Application rates of chemical fertilizers were determined not only by recommendations from agriculture extension workers but by the farmers experience as well.

Table 6. Nutrient content of cultivated crops in 2012.

Cultivated crop	DW	N (%)		P_2O_5 (%)		K_2O (%)		CaO (%)		MgO (%)	
	Field	Harvested	Residue	Harvested	Residue	Harvested	Residue	Harvested	Residue	Harvested	Residue
Lettuce	A_1	2.37de	2.76de	1.17cdef	0.95bcd	5.04d*	8.14ab	0.65e*	2.29c	0.38abcd*	0.99ab
Lettuce	A_2	2.39de	2.76de	1.57b*	1.05bcd	5.67cd*	8.70a	0.65e	1.73c	0.37bcd*	0.61f
Lettuce	B_1	2.78cd*	4.05bc	1.05defg	0.77d	6.32cd*	9.24a	0.65e*	2.46c	0.37bcd*	0.97ab
Lettuce	B_2	1.65e	2.31ef	1.35bcd	1.29ab	5.71cd*	9.00a	0.70e*	2.12c	0.28cd*	0.68ef
Lettuce	B_3	3.24c	3.77c	1.52bc	1.25abc	7.83ab	9.17a	1.36bcd	2.19c	0.52ab*	0.75def
Lettuce	B_3#2	4.05b	3.28cd	1.32bcde	1.21abcd	8.54a	8.66ab	1.41bc	2.29c	0.55a*	0.76def
Lettuce	C_1	2.83cd	3.41cd	1.13defg	0.80cd	6.78cd*	8.90a	0.93de*	2.99c	0.43d*	0.93ef
Lettuce	C_1#2	4.10b	4.71ab	0.98efg*	1.55a	5.42bc*	8.69a	0.88cde*	2.50c	0.25abc*	0.66abc
Lettuce	C_3	3.27c*	3.93c	0.78g	1.13abcd	6.34cd*	8.97a	0.78e*	2.67c	0.39abcd*	0.84bcd
Mean		2.96	3.44	1.21	1.11	6.41	8.83	0.89	2.36	0.39	0.80
Cabbage	AFC_1	1.93e	1.84f	0.93fg	1.02bcd	2.75e	2.71c	1.17bcde*	5.00b	0.35bcd*	0.92abc
Cabbage	AFC_3※	4.05b	3.90c	1.04defg	1.09abcd	3.15e	2.64c	1.04cde*	4.79b	0.31abcd*	1.01a
Cabbage	B_3#2	2.71cd	3.30cd	0.90fg	1.11abcd	3.21e	2.71c	1.63ab*	7.84a	0.48ab*	1.08a
Mean		2.90	3.01	0.95	1.07	3.04	2.69	1.28	5.89	0.42	1.02
Chinese cabbage	A_3	5.01a	5.27a	2.61a*	1.33ab	6.74bc	7.30b	1.97a*	6.81a	0.55a*	1.05a

Numbers within a column, followed by a common lowercase letter are not significantly different ($p > 0.05$) according to Tukey HSD;

#2Second crop in a double cropping sequence; *Significant difference between the harvested parts and the crop residue for that field; ※Experimental field for club-root disease; DW: Dry weight basis.

Yield

Analysis of yield in both 2012 and 2013 showed that Chinese cabbage has the highest water content followed by lettuce (Table 5). Fresh and dry weight of the aboveground biomass partitioned into harvested (inner leaves) and residues (outer leaves), showed no significant difference between the same crops of different management system (Table 5).

This is similar to observed results on the effects of N and P fertilization on plant growth and nitrate accumulation in vegetables (Simmone *et al.*, 2001; Wang and Li, 2004).

This indicates that excess nutrients applied in the form of fertilizers or organic manure will not be taken up by crops above the optimum level of crop nutrient requirements. Chinese cabbage had the highest yield for both years, followed by cabbage. One of the fields AFC_3 generally had a low yield for the two years of evaluation due to clubroot disease that destroyed the roots affecting nutrient uptake (Table 5).

Nutrient content of aboveground biomass

The nutrient content for all the elements evaluated was higher in Chinese cabbage, followed by cabbage (Table 6 and 7).

Generally, N, K, Ca and Mg contents were higher in the crop residues compared to the harvested parts in both 2012 and 2013 (Table 6 and 7). In some cases, this difference was significant ($p < 0.05$) and this may have been due to the difference in the harvesting methods of the farming house hold. P content of the harvested parts was higher than the crop residues for all the cultivated vegetables in both years (Table 6 and 7).

Table 7. Nutrient content of cultivated crops in 2013.

Cultivated	DW	N (%)		P_2O_5 (%)		K_2O (%)		CaO (%)		MgO (%)	
crop	Field	Harvested	Residue	Harvested	Residue	Harvested	Residue	Harvested	Residue	Harvested	Residue
Lettuce	A_3	4.4a	4.65a	1.65c*	0.87bcd	10.30ab	11.80de	0.57de	1.72d	0.54abc	0.70d
Lettuce	B_1	4.0ab	4.65a	1.07def*	0.62de	8.12bcd*	13.35cd	0.50de	2.51d	0.42cd*	0.92bcd
Lettuce	B_2	3.38bc*	4.36ab	1.24d*	0.78cde	9.18bc*	16.26ab	0.26e*	2.88cd	0.47cd*	1.00bcd
Lettuce	B_3	4.3a	4.98a	1.70bc*	0.99abc	12.164a*	17.37a	0.57de	2.03d	0.48bcd*	0.97bcd
Lettuce	C_1	3.24b	3.64bc	1.5de*	0.74cde	7.01cde*	11.67de	0.39e	2.15d	0.36d*	0.87bcd
Lettuce	C_3	2.70cde	3.45c	0.71fg	0.72cde	7.68bcd*	14.61bc	0.37e*	2.46d	0.44cd*	0.87bcd
Mean		3.68	4.29	1.25	0.79	9.08	14.18	0.44	2.29	0.45	0.89
Cabbage	C_2	2.18e	2.64de	0.77efg	0.61def	4.85ef	4.91fg	0.85cd*	7.20ab	0.43cd*	1.28bc
Cabbage	AFC_2	2.48de*	3.52c	0.84defg	0.69cde	5.67def	6.38f	1.20bc*	8.12ab	0.53abc*	1.09bcd
Cabbage	AFC_3※	2.97cd	2.50e	0.65g	0.30f	3.65f	3.49g	0.92cd*	7.47ab	0.46cd*	1.77abcd
Cabbage	$A_3^{\#2}$	2.74cde	3.3cd	0.84defg	0.63de	5.85def	5.66fg	1.15bc*	5.49bc	0.43cd	0.80cd
Cabbage	$B_3^{\#2}$	2.98cd*	3.83bc	0.72fg	0.47ef	4.29f	4.59fg	1.37b*	8.06ab	0.48bcd*	1.19bc
Mean		2.67	3.16	0.76	0.54	4.86	5.00	1.10	7.27	0.47	1.22
C. cabbage	A_1	4.42a	4.62a	2.24a*	1.19a	8.03bcd	10.56e	2.24a*	7.50ab	0.64a*	1.34ab
C. cabbage	A_2	4.33a	4.99a	2.09ab*	1.13ab	9.87ab*	13.69bcd	2.07a*	8.53a	0.62ab*	0.98bcd
Mean		4.37	4.81	2.16	1.16	8.95	12.12	2.16	8.02	0.63	1.16

Numbers within a column, followed by a common lowercase letter are not significantly different ($p > 0.05$) according to Tukey HSD;

$^{\#2}$Second crop in a double cropping sequence; *Significant difference between the harvested parts and the crop residue for that field; ※Experimental field for club-root disease; DW: Dry weight basis.

Ca and Mg were significantly higher in residue than harvested parts for all the three vegetables irrespective of the management system. This confirms the rate of liming is almost the same and it is a common practice in the region. This is because liming material is mostly dolomitic quicklime containing Ca and Mg cations. In terms of management, farm A has a sustained system as observed by no significant difference in the N content of the harvested and residual material in both fields (Table 6 and 7). This can be confirmed by the fixed fertilizer input and green manure to maintain the systems inorganic N from leaching in fall after harvesting and land preparation for the next cropping system.

Nutrient management practices in farms A, B, C and AFC were similar but differ in the quantity and quality of nutrient-input materials (Chotangui *et al.*, 2015). This resulted to varying nutrient use efficiency and environmental impacts of the farms. The significant difference of the nutrient content between the same crop type of different farms is due to the difference in quantity and quality of nutrient-input materials. Plants take up nutrients in the soil when available but if the amount of readily available nutrients is above the rate of uptake, there will be excess in the soil vulnerable to losses or other chemical and biological processes of the biogeochemical cycles.

In the developed countries where there is intensive vegetable production through various soil nutrient amendments, scientific information based on experimentation varies with the farmer's conception and experience. This results to an array of farm management practices some of which affects key sustainability issues. Thus, participatory evaluation of farmer's fields is important to expose the state-of-art in intensive production systems.

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References

Bergström L, Bowman BT, Sims JT. 2005. Definition of sustainable and unsustainable issues in nutrient management of modern agriculture. Soil Use and Management **21,** 76-81.

FAO. 1989. Guidelines on Communication for Rural Development - A brief for development planners and project formulators. FAO, Rome, 3-5 P.

Heckman JR, Sims JT, Beegle DE, Coale FJ, Herbert SJ, Bruulsema TW, Bamka WJ. 2003. Nutrient removal by corn grain harvest. Agronomy Journal **95,** 587–591.

Heckman JR. 2007. Sweet corn nutrition uptake and removal. Hort Technology **17,** 82–86.

Kimura SD, Hatano R. 2007. An eco-balance approach to the evaluation of historical changes in nitrogen loads at a regional scale. Agricultural Systems **94,**165-176.

Komatsuzaki M. 2011. Agro-ecological approach for developing a sustainable farming and food system. Journal of Developments in Sustainable Agriculture **6,** 54-63.

Maruyama H. 1992. Agricultural land use patterns on the lower volcanic slopes in Central Japan. Geographical review of Japan **62,** 104-128.

Mishima S. 2001. Quantitative evaluation of environmental risk associated with nitrogen flow in agricultural production and mitigation plan for two typical prefectures in Japan. Soil Science and Plant Nutrition **47,** 157-166.

Molitor H. 1998. Environmentally sound production in horticulture- The European way (Sustainable Horticulture, For Further Development of Horticulture in East Asia). Journal of the Japanese Society for Horticultural Science **67,** 1224-1228.

Nishio M. 2001. Analysis of the actual state of nitrogen application in arable farming in Japan (in Japanese with English abstract). Japanese Journal of Soil Science and Plant Nutrition **72,** 513-521.

Pour AA, Moghadam ARL, Ardebili ZO. 2013. The effects of different levels of vermicompost on the growth and physiology of cabbage seedlings. International Research Journal on Applied and Basic Sciences **4,** 2726-2729.

Takeuchi M. 1997. Nitrate and phosphate outflow from arable land. (in Japanese) Japanese Journal of Soil Science and Plant Nutrition **68,** 708-715.

Hansson LE, Nyren O, Bergstrom R, Wolk A, Lindgren A, Baron J, Adami HO. 1994. Nutrients and gastric cancer risk. A population-based case-control study in Sweden. International Journal of Cancer **57,** 638–44.

Kim HJ, Lim SY, Lee J, Park S, Shin A, Choi BY, Shimazu T, Inoue M, Tsugane S and Kim J. 2010. Fresh and pickled vegetable consumption and gastric cancer in Japanese and Korean populations; A meta-analysis of observational studies. Cancer Science **101,** 508-516.

Simmone E, Simmone A, Wells L. 2001. Nitrogen source affects chrunchiness but not lettuce yield. Journal of Plant Nutrition **4-5,** 743-751.

Wang Z, Li S. 2004. Effects of nitrogen and phosphorus fertilization on plant growth and nitrate accumulation in vegetables. Journal of Plant Nutrition **3,** 539-556.