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Effect of Maize Residue Compost Application on Growth, Yield of Some Vegetables and Soil Properties

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Summary

Maize residue compost (MRC) was applied to komatsuna (*Brassica rapa* L. cv. 'Rakuten'), radish (*Raphanus sativus* L. cv. 'Radicula Pers'), and chingensai (*Brassica campestris* L. cv. 'Choyo No. 2') over three consecutive growing seasons of four months, as compared with the effect of inorganic fertilizer (IF) and control treatments. MRC and IF application were 30 Mg ha^{-1} 24 g kg^{-1} soil and 150 kg ha^{-1}, respectively. Additionally, P and K were applied at the rate of 120 kg ha^{-1} each per treatment. Plant growth, leaf chlorophyll content and N uptake index were higher in IF than MRC and control during all trials. The N uptake and yield of vegetables were significantly higher with the recommended inorganic N treatment. Our experiment showed that the changes caused by the MRC are relatively small. The soil EC was significantly increased by IF application, probably caused by nitrate accumulation of an excess amount of inorganic N in the soil.

Introduction

As well known, application of plant residues and compost to agricultural soil enhances organic matter content, increases crop production, improves soil physical structure, decreases the need for inorganic fertilizer and sustains the agriculture system[5]. Moreover, it is important in supplying nutrients, stabilizing chemical conditions (pH, EC, CEC, *etc.*), and trapping phytotoxic metals.

Maize (*Zea mays* L.) is a crop with the highest production in the world, and composting of maize residues is useful method of producing a stabilized product and substantial organic matter because a high C/N ratio also produces humus that can be used as a source of organic materials and slow the release of nutrients. Nitrogen mineralization kinetics of different type of composts have been studies[3].

In the previous study[4], we determine the effects of the application of maize residue compost on the nitrogen and carbon uptake by radish, komatsuna, and chingensai as compared with the effect of

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inorganic fertilizer. We found that the vegetables took up significantly ($P<0.05$) lower amounts of N from MRC than from inorganic fertilizers (IF) during the three cultivations. The values of the N uptake derived by fertilizer application to the plant exhibited significant differences among different vegetables. Radish, komatsuna, and chingensai recovered significant amounts of C from MRC in the first and second crops, with negligible C recovery in the third crop. In addition, we assessed the application effect of MRC on the fate of C and N in paddy soils used for rice cultivation[2].

In this study, the objective was as follows: (1) to elucidate the effects of application of maize residue compost and inorganic fertilizer on vegetables growth, (2) to determine their effects on the changes of soil pH and electrical conductivity, and (3) to compare the availability of P, K, Ca, and Mg in the soil.

Materials and Methods

Site and soil properties

The experiment was carried out in the Ehime University Experimental Farm (Matsuyama City) in Southwest Japan (33° 57′ N; 132° 47′ E). The soil used was upland soil (Low fertility, Brown Forest Soils, Dystric Regosol) [according to FAO/UNESCO]; Typic Udorthents [USDA]; collected from the top 0–20 cm and sieved, fraction (< 2 mm). The soil properties were as follows: pH (H_2O), 6.60; electrical conductivity (EC), 0.311 dS m^{-1}; total C, 1.12%; total N, 0.133%; cation exchange capacity (CEC), 16.5 cmol(+) kg^{-1}; C/N, 8.4; available phosphorus (P), 1897 mg kg^{-1}; exchangeable potassium (K), 623 mg kg^{-1}; Ca, 1349 mg kg^{-1}; and Mg, 325 mg kg^{-1}. Mean diurnal soil temperature of the pots during the cultivation period was (maximum/minimum) 35/12.7°C, and the mean ambient temperature was 22.7°C.

Plant growth and experimental setup

The trial was carried out during the vegetable cropping season from May to September 2005 under greenhouse conditions. Three vegetable species komatsuna (*Brassica rapa* L. cv. 'Rakuten'), radish (*Raphanus sativus* L. cv. 'Radicula Pers'), and chingensai (*Brassica campestris* L. cv. 'Choyo No. 2'), were raised in plastic pots of dimensions 83 cm (L) × 27 cm (W) × 20 cm (H) filled with 40 kg of soil (dry weight).

The three fertility treatments in five replicates were as follows: (1) Control treatment to which additional N was not applied. (2) IF pots to which N fertilizer labeled with 10.5 atom% was applied as ammonium chloride at 3.36 g pot^{-1} (84.4 mg N kg^{-1} dry soil) at only the first cropping. Further, P and K were supplied at a rate of 120 kg ha^{-1} as phosphorus pentoxide (P_2O_5, 13.4 g pot^{-1}) and potassium chloride (KCl, 2.68 g pot^{-1}), respectively. (3) Organic fertilizer pots supplied with ^{13}C (1.256 atom %) and ^{15}N (1.098 atom %) dual-labeled[10] MRC [73.0% moisture content; 35.2% T-C, and 2.9% T-N, (dry matter), and 12.1 C/N]. The compost was applied at a rate of 672.3 g (123.7 g dry matter) pot^{-1}, which corresponded to 3.66 g N pot^{-1} (91.5 mg N kg^{-1} dry soil). The normal organic fertilizer application rate ranges from 300 to 350 kg N ha^{-1} [1, 6] depending on the N requirement of the crop, and soil N availability.

Three consecutive crops of the three species were cultivated over four months from May 2 to

September 1 (2005) in their respective pots. Every crop was grown for 40 days. Non labeled nitrogen fertilizer was applied to the compost treatments in the second and third crops at half of the quantity applied to IF in each crop for improvement the shot-term effectiveness of MRC. The water content in the pots was maintained between 40% and 80% water-holding capacity (WHC).

Sampling and analysis

Plant growth parameters (plant height and leaf chlorophyll content) were measured weekly until harvest starting from one week after seeding. Chlorophyll content was measured with a chlorophyll meter (SPAD-502; Minolta Co. Ltd., Japan). Vegetables were harvested at the commercial maturity and only the edible portions were used for analysis.

The samples washed and then oven dried at 75℃ for 42 hrs. The dried samples were weighed and ground into a fine powder with an electric mill. After harvest the soil in the pots was homogenized before sampling. The dried soil subsamples were finely pulverized and ground. The EC and pH of the soil samples at harvest were also measured. All the treatments were carried out in five replicates.

Statistical analysis

Statistical analyses were conducted by analysis of variance and Fisher's protected significant difference ($P < 0.05$) and the differences among the means were analyzed by Tukey-Kramer test by using the software KyPlot (KyensLab Inc., Japan).

Results and Discussion

Effect of MRC and IF application on vegetables growth and N uptake index

Fig. 1a shows the changes in vegetables height with amendments. Vegetables height increased gradually until 28 days after sowing. No remarkable differences were found among vegetable species. There are some differences between the treatments at harvest but no significance difference was observed between IF and MRC. However, control was significantly lower than IF and MRC treatments. SPAD values in vegetables were increased gradually during cultivation period (Fig. 1b). SPAD value of IF was the highest during all cultivation period and followed by MRC and control. Fig. 1c shows the nitrogen uptake index (Vegetables height x SPAD values). Control was significantly lower than IF and MRC.

Dry matter production and N uptake by vegetables

Table 1 shows the dry matter yield and total N uptake by the vegetables. The effect of IF on vegetables dry matter was significantly higher than that of control and MRC treatment. However, no significant difference was observed between three treatments in radish leaf dry matter in the first or the third crop. The vegetables dry matter in the third crop was lower than in the first and second crops. Total N uptake in the vegetables had a similar pattern to dry matter production (Table 1). Total N was significantly higher in the first crop and decreased in the second and third crops.

Different N uptake responses were observed in the vegetable species, with komatsuna acquiring the greatest amount of N followed by chingensai and radish (Table 1). The vegetables responded differently to MRC and IF treatments. N uptake by the vegetables was highest with IF treatment.

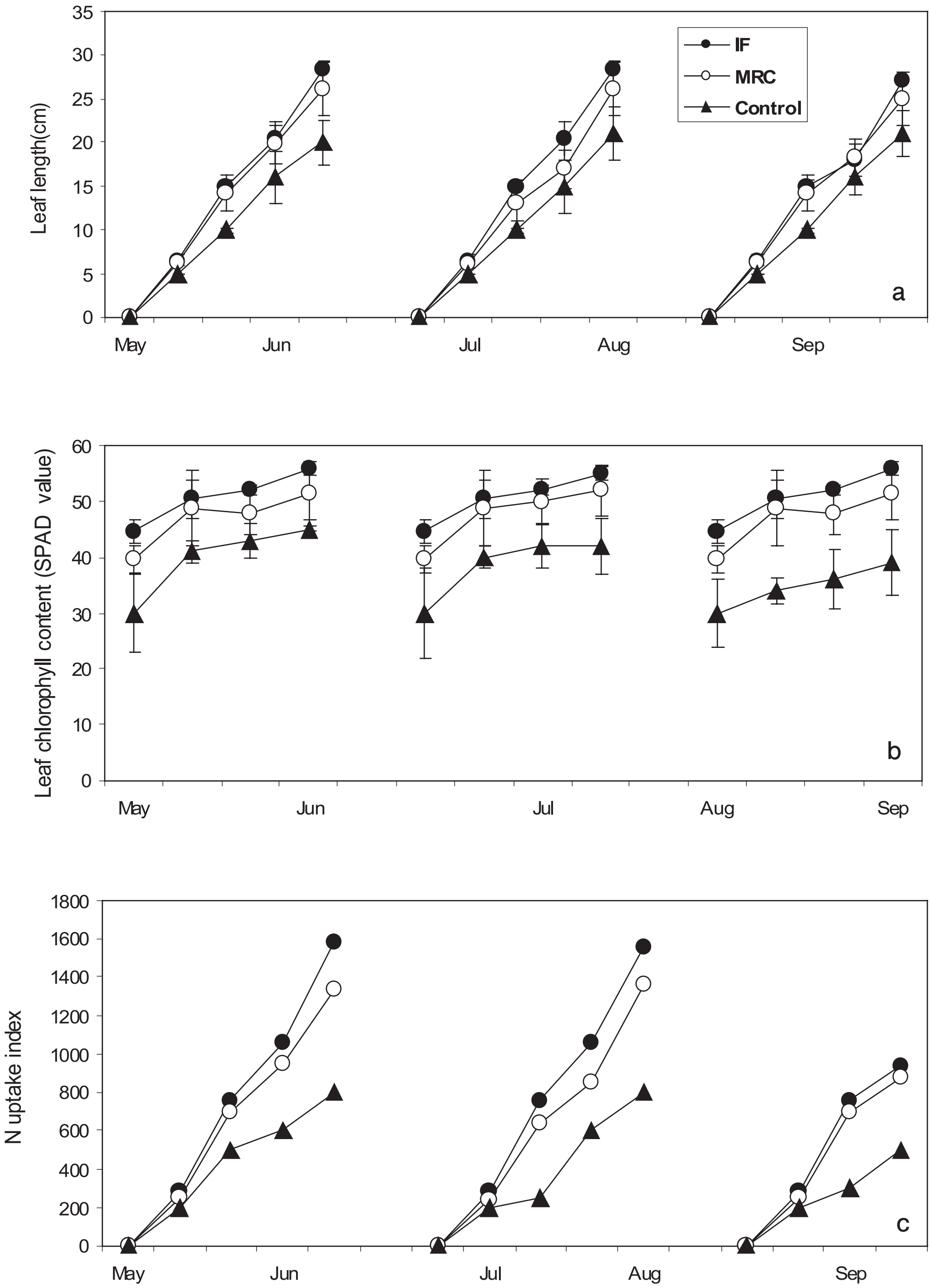

Fig. 1. Changes in leaf growth (a), chlorophyll content (b) and N uptake index (c) during 1st, 2nd and 3rd crop of radish. Bars represent ± SD (n=5).

In this study, we used the harvestable portion of vegetables to provide the evidence for whether compost-fertilizer blends are more efficient in providing N than fertilizer alone. Data indicated that neither yield nor N uptake increased when MRC was blended with N fertilizer. Neither vegetable yield nor total N uptake increased with MRC treatment in agreement with Sikora and Enkiri[7], who reported that the compost blended with N fertilizer did not supply sufficient additional available N to increase yields.

Table 1. Dry matter yield and total nitrogen (N) uptake by vegetables grown in soil amended with either inorganic fertilizer (IF) or maize residue compost (MRC)

		Dry matter ($g\ pot^{-1}$)			Total N ($mg\ pot^{-1}$)		
Plant part	Treatment	1st crop	2nd crop	3rd crop	1st crop	2nd crop	3rd crop
Radish root	Control	3.52a	2.72a	2.37a	90.4a	69.5a	54.9a
	IF	5.75b	4.60b	4.07b	208.6b	187.3b	132.0b
	MRC	5.21c	3.75c	3.03c	173.1c	100.4c	86.9c
Radish leaf	Control	3.34a	2.16a	2.05a	168.3a	91.9a	68.2a
	IF	3.98a	3.49b	2.76a	208.2b	193.9b	137.1b
	MRC	3.81a	2.92c	2.37a	197.3c	127.6c	112.1c
Komatsuna	Control	12.72a	10.46a	7.38a	549.1a	374.2a	188.8a
leaf	IF	15.74b	14.88b	11.26b	908.2b	856.8b	622.3b
	MRC	14.02c	13.03c	8.24c	636.9c	423.5c	219.9c
Chingensai	Control	10.07a	5.28a	4.17a	433.4a	122.8a	119.9a
leaf	IF	13.05b	11.82b	10.92b	723.8b	653.7b	520.8b
	MRC	11.62c	8.15c	6.47c	493.0c	246.8c	181.0c

Different letters in each column denote significant differences within treatments (Tukey-Kramer test, $P < 0.05$, n = 5).

The effect of compost application on the changes of soil pH and electrical conductivity

Soil pH (H_2O) and EC at harvest are shown in Fig. 2 and 3. The pH of soil is important because it can alter the availability of nutrients to the plant, thereby affecting the activity of the roots and microbes. Fig. 2 shows the effect of IF and MRC application on the soil pH during the cultivation period. Our experiment showed that the changes caused by the MRC are relatively small. The initial pH of the soil was 6.6 and the measured changes in Fig. 2 are in the range of +0.2. This is a normal deviation in measurements of soil pH. The decrease of 0.6 unit under IF treatment in the first crop is probably a result of the nitrification of the added ammonium in the NH_4Cl fertilizer and acidification of the root rhizosphere due to ammonium uptake. The increase of the pH back to 6.6 in the end of the second crop is probably a result of nitrate uptake by the plants and the buffer capacity of the soil. This is in agreements with Stanford and Smith[8]. The soil used in this study might have a lower ability to stabilize soil pH, *i.e.* CEC or organic matter content.

However, the EC of soil (Fig. 3) with MRS was lower than that of soil with IF. These results possibly reflect the concentration of the mineralized nutrients (NO_3, available P, K, Ca, Mg, *etc.*) and certain water-soluble compounds (organic acids or low-molecular weight organic compounds) in the soil after inorganic fertilizers were applied.

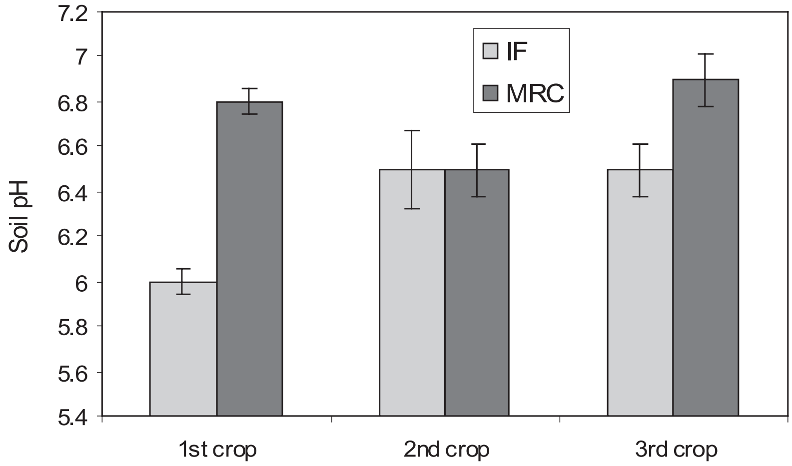

Fig.2. The pH for soil as affected by inorganic fertilizer (IF) and maize residue compost (MRC) application. Bars represent ± SE (n = 5).

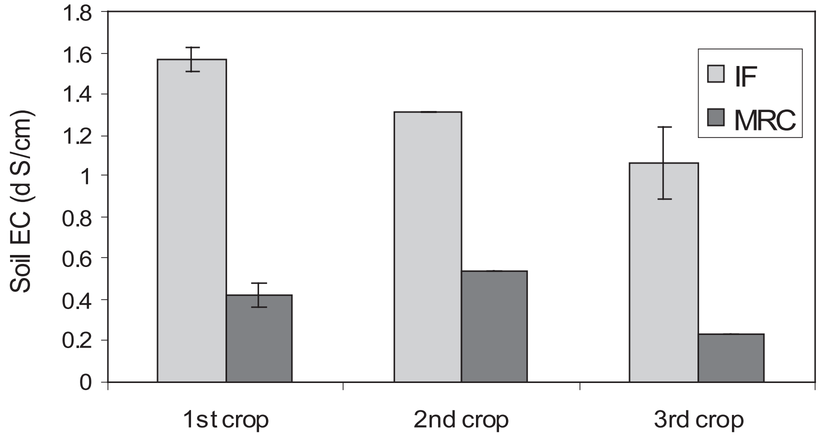

Fig. 3. EC for soil as affected by inorganic fertilizer (IF) and maize residue compost (MRC) application. Bars represent ± SE (n = 5).

Availability of P, K, Ca, and Mg in soil as affected by MRS and IF application

The concentration of available Ca, K and Mg released from the composts in the soil was measured after first, second and third crop and shown in Fig. 4a, b and c, respectively. With regard to Ca, K and Mg, IF demonstrated the highest concentration after the third crop and it had significant differences with MRS treatments. In addition, the Ca concentration of MRS plots in the first crop was significantly higher than IF, although only a slightly greater concentration was observed in the second crop. The concentration of Mg as affected by MRS and IF application had a similar pattern after first and second crop. In this study, identical release patterns for K, Mg, and Ca could not be obtained in MRS and IF, but the wide variation in the changes in concentration may be related to immobilization by soil microbes and compost materials. Stewart *et al.*[9] noted an occurrence of extreme immobilization of S, K, Ca, and Mg during incubation when the compost was amended with an N fertilizer. They also conducted a kinetic study on the release of S, P, Ca, and

Mg from spent mushroom compost and found that the amount of all the elements released increased with time. The discrepancies between these results and those obtained in our study may be attributed to the differences in the extraction methods and solutions used.

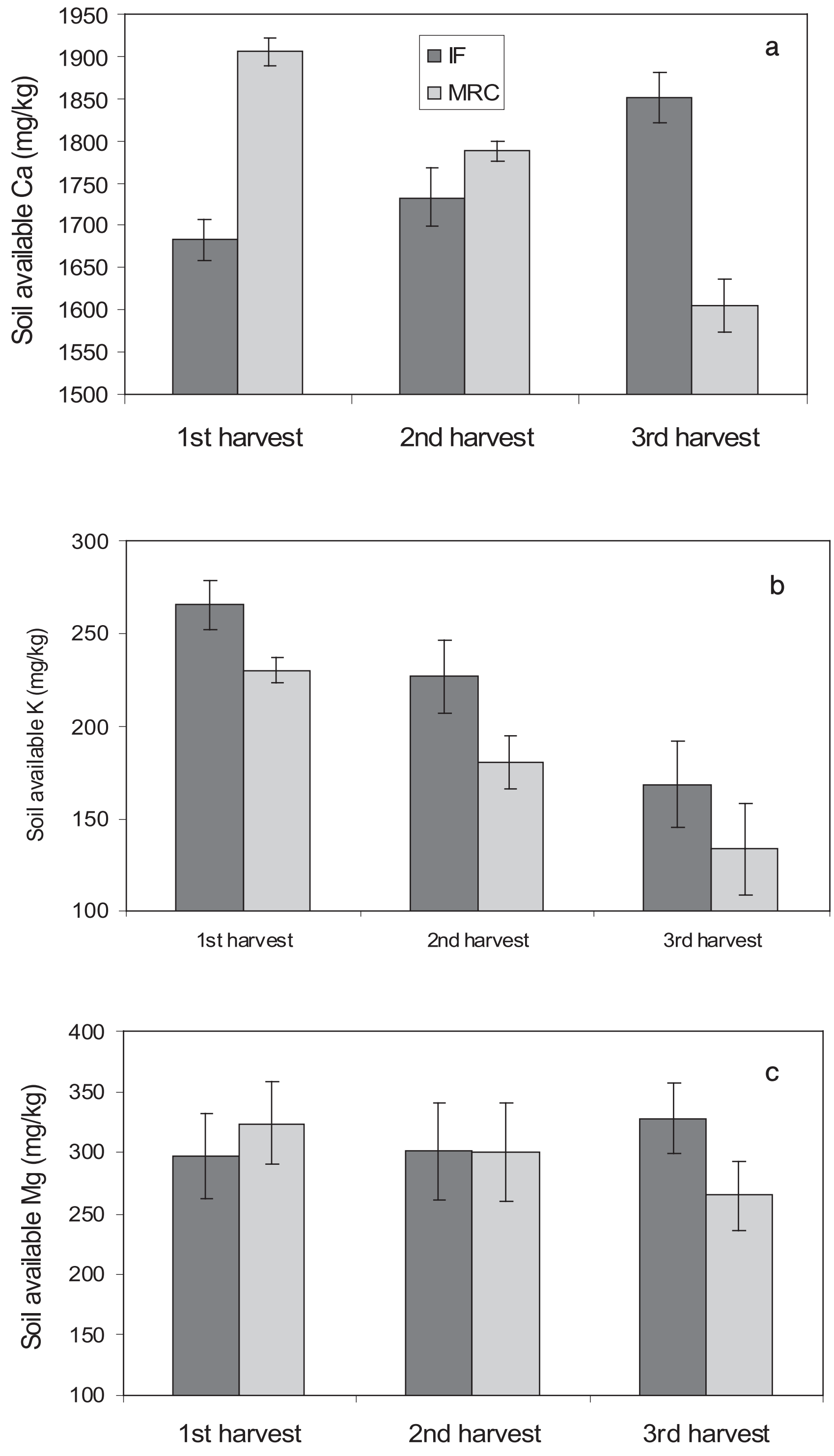

Fig. 4a, b and c. Ca, K, and Mg-remained in the soil from inorganic fertilizer (IF) and maize residue compost (MRC) after the 1st, 2nd and 3rd crop. Bars represent ± SE (n=5).

Conclusion

The results obtained in this experiment suggest that the application of maize residues compost at the appropriate rate and time is crucial to maximize their beneficial effects. In particular, increased immobilization by compost amendments application in early stage and subsequent gradual re-mineralization allowed plants to utilize inorganic inorganic-N more efficiently.

Future studies should attempt to identify the factors affecting N immobilization-mineralization, such as organic amendment application rate and quality, and soil properties. Proper management of organic amendments in intensive cropping systems can play an important role in maximizing production efficiency and minimizing negative environmental impacts.

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トウモロコシ残渣堆肥の施用が数種野菜の生育、収量および土壌特性に与える影響

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摘　　要

トウモロコシ残渣堆肥（MRC）の土壌への施用が、コマツナ（*Brassica rapa* L. cv.'Rakuten'）ハツカダイコン（*Raphanus sativus* L. cv.'Radicula Pers'）およびチンゲンサイ（*Brassica campestris* L. cv.'Choyo No. 2'）の生育、収量および土壌特性に与える影響を無施肥（Control）または化学肥料（IF）を施用した場合と比較した。栽培は３回、連続して行った。MRC区にトウモロコシ残渣堆肥を30 Mg ha^{-1}、IF区に化学肥料Nを150 kg ha^{-1}、さらにP，Kを各120 kg ha^{-1}施用した。IF区の各野菜生育、葉色値および窒素吸収インデックスは、３回の栽培ともMRC区およびControl区より高かった。さらにIF区のN吸収量および収量は、MRC区、Control区に比べ有意に高かった。IF区の土壌ECは、MRC区に比べ有意に高かった。これは、IF施用により土壌中に余剰の化学肥料窒素が硝酸態窒素の形態で残存したためと考えられた。MRCはIFに比べ土壌中で緩効的に無機化したため、土壌ECに与える影響が比較的低かったと推察された。

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