Decrease of Nitrogen Fertilizer Application in Tomato Production in No-tilled Field with Hairy Vetch Mulch

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Abstract

Growth and yield of tomatoes were estimated when they were planted in a no-tilled field with hairy vetch (*Vicia villosa*) mulch (NT+HV) with 80, 160 and 240 kg/ha of nitrogen fertilizer, and compared with tomatoes grown in a tilled field with black polyethylene film mulch (Till+BP). Seed of hairy vetch (50kg/ha) was sown in the Field Center of Niigata University on October 21, 1999, and hairy vetch (3,200kg/ha in dry weight) was mowed on May 17, 2000, to make residue mulch. Twenty percent of nitrogen was applied by fast-effect fertilizer and the rest (80%) by slow-effect fertilizer. Tomato cv. Momotaro was planted in NT+HV and Till+BP on May 19, 2000, and grown until early in September. The nitrate concentration in the petiole of the leaves near 2-3cm fruit in diameter decreased from 50 or 60 days after planting in the Till+BP. However, it maintained more than 1,500 ppm until 70-80 days after planting in NT+HV. The growth index of tomatoes grown in NT+HV with 80 kg/ha of nitrogen became higher after 50 days compared with Till+BP. The tomato yield in NT+HV was lower than that of Till+BP in the first and second fruit cluster in 80 kg/ha of nitrogen, but was higher from third to 7th cluster. No definite effect of nitrogen fertilizer in the yield was recognized among 80, 160 and 240kg in NT+HV. In 80 kg/ha of nitrogen fertilizer application, the total marketable yield of NT+HV was higher than that of Till+BP. There was no difference in total yield between NT+HV and Till+BP in 160 and 240 kg/ha. In no-tilled field with hairy vetch mulch, even if nitrogen fertilizer is decrease to the 80 kg/ha, recommended level for 'N reduced tomato production', the marketable yield will be the same level obtained in conventional production with 160 and 240 kg/ha of nitrogen.

INTRODUCTION

Organic production in vegetables has been taken attention for avoid of NO_3^- pollution in groundwater and food safety. In the policy of Japanese government, vegetables produced in the field without any fertilizer and any agricultural chemicals (pesticide, fungicide and herbicide) for 3 years are recognized as 'organic products'. However, in practice, it is difficult to maintain the current level of crop productivity in organic production under the climate and soil condition in Japan.

The production system reduced nitrogen fertilizer and agri-chemicals is spreading gradually. In tomato production in open field, the recommended amount of nitrogen fertilizer is 80 kg/ha for fertilizer-reduced production in Japan (Table 1). It is necessary to establish tomato production system in which current yield is obtained under even 80 kg/ha of N fertilizer application. Cover cropping and use of slow-effect fertilizer are important for reducing N fertilizer.

Legume winter cover crops provide substantial amount of N to the succeeding crop.

Hairy vetch (*Vicia villosa*) is one of the promising legume winter cover crops and it decomposes rapidly and released N in the soil because of their high N concentration and low C:N ratio (Ranells and Wagger, 1996). Besides, cover crops improve the soil properties (Sainju and Singh, 1997; Araki and Ito, 1999) One method of managing winter cover crops in the spring is to kill them and leave their residue as dead mulch. The subsequent crop is then no-till (NT) planted into the plant residue. Hairy vetch is a good materials for covering ground surface.

In the present examination, slow-effect N fertilizer was used in the tomato field with hairy vetch residue mulch. Growth and yield of tomatoes grown in reduced nitrogen fertilizer in no-tilled field with hairy vetch residue mulch were investigated, compared with tilled field with black polyethylene mulch.

MATERIALS AND METHODS

Experimental Design

The experiments were conducted at the Shindori Station, Field Center for Sustainable Agriculture and Forestry, Niigata University, Niigata, Japan, on sandy roam, in 2000.

Growth and yield of tomatoes grown in the no-tilled field with hairy vetch-mulch were compared with those in conventionally tilled fields with black polyethylene film mulch as the main plot treatment, with 3 different nitrogen rates as sub plot factor. Nitrogen application rates were 80, 160 and 240 kg/ha. Treatments were arranged in a randomized block design with 3 replications. Each plot was 8 m wide and 3.5 m long.

Field Preparation and Chemical Fertilizer Application

For the no-tilled field with hairy vetch-mulch, 50 kg/ha of N, P_2O_5 and K_2O was applied to the field for hairy vetch growth and hairy vetch was drill-sown at a seeding density of 50 kg/ha after rotary tillage in October, 1999. The plots received no water, herbicide or any other treatment until the hairy vetch was mowed by a bush cutter 3 to 5 cm above the ground surface in next May. In the hairy vetch-mulched field, mowed hairy vetch was scattered over the soil, and the soil was left untilled to maintain the hairy vetch residue mulch**.** Chemical fertilizers for tomato growth were applied on the ground surface in May 17, 2000.

In the tilled field, hairy vetch was not produced and the soil was rotary tilled with 3 rates of chemical fertilizers before tomato planting in May 17, 2000, then covered with black polyethylene film mulch.

In each field, 3 rates of nitrogen fertilizer were applied, i. e., 80, 160 and 240 kg/ha. In all N rates, 20% and 80% of total N fertilizer was applied by fast-effect and slow-effect fertilizer, respectively (Table 2). In every plot, 240 kg of P_2O_5 and K_2O were added per ha.

Biomass Yield and N Concentration of Hairy Vetch

Above-ground biomass yield and nitrogen concentration of hairy vetch were determined just before mowing at 3 randomly selected 1 m^2 locations outside of the plot area. Hairy vetch samples were dried at 70 in a forced air oven to determine dry matter yield.

Production of Tomato Seedlings and Plantin*g*

Fresh market tomato 'Momotaro T93' seeds were sown in sowing boxes in a greenhouse in March and seedlings were transferred into plastic pots of 12 cm-width. Two month-old tomato seedlings were transplanted in test fields on May 19, 2000 after the first flower cluster appeared.

All plants were staked at the planting and tied 4 or 5 times during the tomato growing. Pesticides and fungicides were applied 3 times and 2 times, respectively, before the harvesting of tomatoes. Weeds were removed by hand.

Nitrate Analyses in Petiole Sap

The NO_3^- concentrations in leaf petioles were determined about every 2 weeks from May 25 to August 25 in 1999. Petioles closed to the fruit cluster with a 2-3 cm tomato in diameter were collected. The petioles were crushed and petiole sap was used. Twenty μliter of the petiole sap was diluted with 1980μliter distilled water. NO_3^- concentration in diluted solution of petiole sap was measured with a reflection photometer RQ flex (Merck Co., Ltd.).

Tomato Growth and Yield Determination

The plant length, number of expanded leaves and stem diameter of tomatoes tested was measured for calculation of growth index (GI) every 2 weeks from May 25 to August 2. Tomatoes were harvested from 8 plants per plot every 3 days at the pink stage, and then the fruit was weighed. The harvest season was July 7 to September 7 in 2000.

RESULTS

Above-ground Biomass

At the time of hairy vetch mowing in May of 2000, the above-ground biomass (dry weight basis) was 3,200 kg/ha.

NO_3^- concentration in Petioles

In all N rates, the NO_3^- concentration in the petiole peaked on June 29, 41 days after transplanting and the season of 3rd-4th cluster enlargement, and gradually decreased after June 29 (Fig. 1). NO_3^- concentration in the petiole of the tomatoes grown in NT+HV with 80 kg/ha N was higher than that in Till+BP with 80 kg/ha N and same as those in Till+BP with 160 and 240 kg/ha N. At July 31, the season of 6th cluster enlargement, NO_3^- concentration decreased below 700 ppm in Till+BP with 160 and 240 kg/ha N, whereas it maintained 1,600ppm in NT+HV with 80 kg/ha N.

Tomato Growth and Yield

The growth index (GI) in Till+BP was larger than that in NT-HV before June 21, 33 days after transplanting, in all N rates (Fig. 2). All plots showed more than 40,000 at July 5, beginning of harvest. After July 19, GI in NT+HV with 80 kg/ha N was higher than that in Till+BP with 80 kg/ha N and same as that in Till+BP with 160 kg/ha N.

Fruit weight in NT+HV with 80 kg/ha N was smaller than that in Till+BP with 80 kg/ha N in 1st and 2nd cluster, however, it was larger than that in Till+BP with 80 kg/ha N upper from 3rd cluster (Fig. 3). Tomato yield per cluster in NT+HV with 80 kg/ha N was similar to those of Till+BP with 160 and 240 kg/ha N upper from 3rd cluster.

Total marketable yield increased as N fertilizer was added in Till+BP, but did not increased in NT+HV (Fig. 4). Total marketable yield in the tomato grown in NT+HV with 80 kg/ha N reached 33 t/ha. It was higher than that of Till+BP with 80 kg/ha N and was same as those of Till+BP with 160 and 240 kg/ha N.

DISCUSSION

NO_3^- concentrations in the petiole of tomato was reported as indicator of vegetative growth (Roppongi, 1991; Takebe and Yoneyama, 1995) and topdressing is necessary to add if NO_3^- concentrations decreased below 1,000-1,500 ppm (Yamada et al., 1995). In NT+HV with 80 kg/ha N, NO_3^- concentrations showed more than 1,500 ppm at July 31 though it decreased below 700 ppm in all N ratesin Till+BP. Thus, high NO_3^- concentration led vigorous growth of tomato plant and contributed high GI and maintaining green color leaf.

As to GI, it is necessary to ensure 40,000 GI at the beginning of a harvest for obtaining an average yield (Soma, 1993). All plots showed more than 40,000 at July 5, beginning of harvest. GI of tomato plant grown in NT+HV has a tendency of increase in late period. This phenomenon showed the possibility to accelerate the fruit enlargement in high cluster.

The marketable yield increased after 3rd cluster in NT+HV with 80 kg/ha N was higher than that in Till+BP with 80 kg/ha N. Thirty Three t/ha of marketable yield was expected in NT+HV with 80 kg/ha N. From these results, there is a possibility that nitrogen fertilizer can reduce to 80 kg/ha, recommended level for ‘N reduced production’, in tomato production in open field, by using slow-effect fertilizer and hairy vetch residue mulch, as Abdul-Baki et al (1997) reported hairy vetch can reduce N requirement for tomato production at least one-half.

Further researches are needed on NO_3^- concentration in soil, yield stability in reduced N fertilizer. Besides, hairy vetch residue mulch in greenhouse will be used because more than 60% tomatoes were produced in greenhouse in Japan.

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Literature Cited

Abdul-Baki, A.A., Teasdale, J.R. and Korcak, R.F. 1997. Nitrogen requirements of fresh-market tomatoes on hairy vetch and black polyethylene mulch. HortScience 32 (2): 217-221.

Araki H. and Ito, M. 1999. Soil properties and vegetable production with organic mulch and no-tillage system. Japan. J. Farm Work Res. 34 (1):29-37.

Ranells, N.N. and Wagger, M.G. 1996. Nitrogen release from grass and legume cover crop monocultures and bicultures. Agron. J. 88:777-782.

Roppongi K. 1991. Studies on nutritional diagnosis in fruit vegetables. 1. The diagnosis of nitrogen nutrition in cucumber on nitrate density of petiole juice. Bull. Saitama Hort. Exp. Stn. 18:1-15. (In Japanese)

Sainju, U.M. and Singh, B.P. 1997. Winter cover crops for sustainable agricultural systems: Influence on soil properties, water quality and crop yields. HortScience 32:21-28.

Soma, A. 1993. Growth Index. In Nogyo-gijutsu taikei, Dojo and Sehi No.4:165. Nobunkyo, Tokyo (in Japanese)

Takebe M. and Yoneyama, T. 1995. An analysis of nitrate and ascorbic acid in crop exudates using a simple reflection photometer system. Jpn. J. Soil Sci. Plant Nutr. 66 (2): 155-158. (In Japanese)

Yamada R., Kato, T., Ido, Y., Seki, M. and Hayakawa, I.. 1995. Rational manualing management of greenhouse tomatoes based on real-time nutritional diagnosis of plant and soil. 1. Diagnostic standard according to nitrate concentration of petiole juice. Res. Bull. Aichi Agric. Res. Ctr. 27: 205-211. (In Japanese)

Tables

Table 1. N fertilizer application.

Cropping	N fertilizer (kg/ha)
Conventional	200-300
Reduced fertilizer	80
Organic	0

Table 2. Fertilizer application in the present examination.

Total amount of Nitrogen (kg/ha)	Nitrogen (kg/ha)		Phosphate (kg/ha)	Potassium (kg/ha)
	Fast -effect	Slow -effect		
80	16	64	240	240
160	32	128	240	240
240	48	192	240	240

Figures

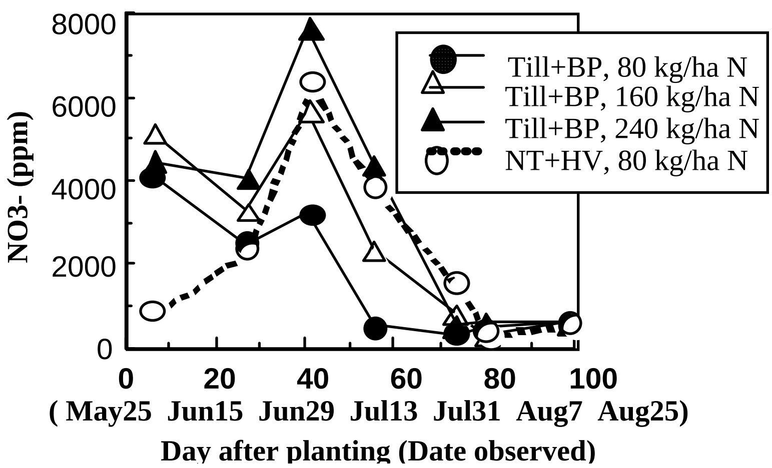

Fig. 1. Change of NO_3^- in the petioles of tomatoes grown in Till+BP and NT+HV.

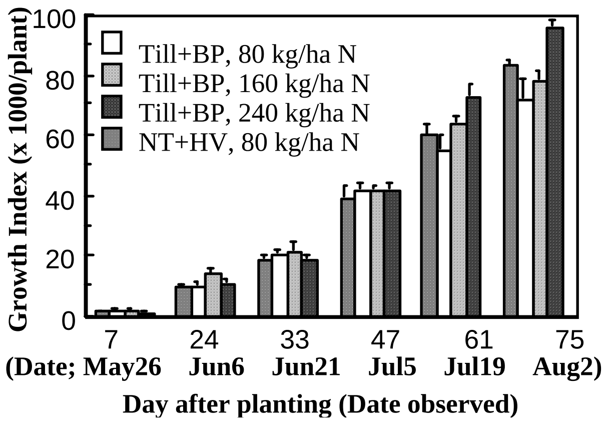

Fig. 2. Change of Growth Index (GI)n of tomato plants grown in Till+BP and NT+HV. GI=Plant length x stem diameter x Number of leaves expanded.

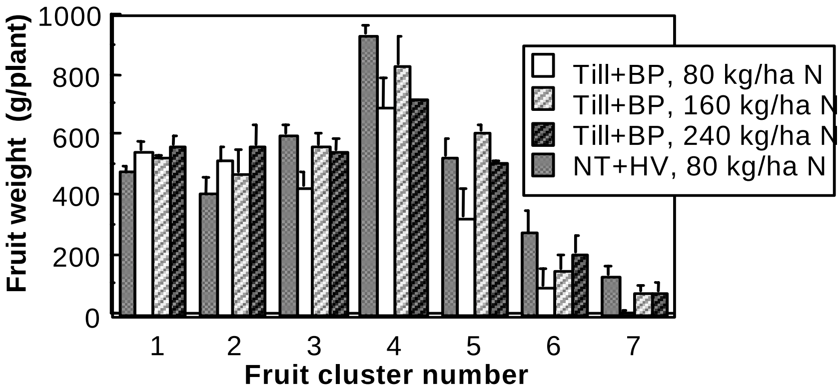

Fig. 3. Fruit weight of tomatoes grown in Till+BP and NT+HV in each cluster.

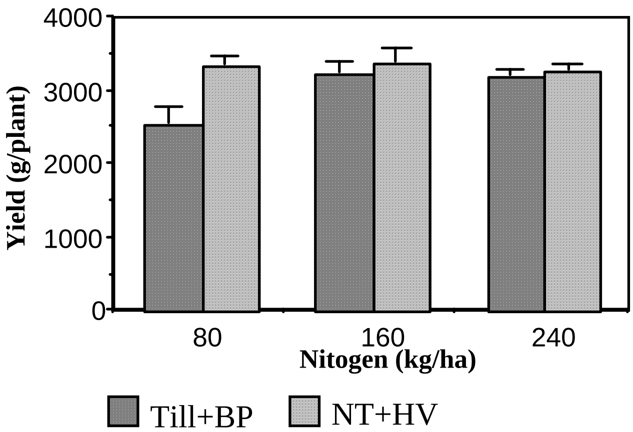

Fig. 4. Effect of nitrogen fertilizer on marketable tomato yield in Till+BP and NT+HV.