加工用トマト果実の硝酸塩蓄積に関する研究

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Studies on the Accumulation of Nitrate in Tomato Fruit for Canning

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This study was carried out to investigate the factors concerning the accumulation of nitrate in tomato fruit and to find the preventive measures against heavy tin-dissolving in canned tomato juice caused by nitrate.

The factors determining the accumulation of nitrate in the plant were as follows : the levels of nitrate, potassium, and calcium in the soil, the application of plant growth regulators, the tomato cultivar, and the light intensity. For obtaining fruits containing less than 3 ppm of nitrate-nitrogen, low nitrate cultivars should be grown in a sunny place on weak acid soil with split application of slow-acting nitrogen fertilizer, and a high calcium level. By proper treatment with plant growth regulators, nitrate-nitrogen content in the fruit can be decreased still more. It is also important that any particular growing-conditons in every tomato-growing district should be taken in consideration in the cultivation management for preventing the accumulation of nitrate-nitrogen.

INTRODUCTION

Canned tomato juice is made from red ripe tomato fruit and the juice has generally been packed in plain cans, not in coated cans, for maintaining the quality of the juice. However, it was found several years ago in various parts of the world that the concentrations of tin dissolved in some canned tomato juices were over 150 ppm which is the upper concentration limit permitted by food sanitary law of Japan, so this raised a serious problem in the tomato juice industry from the point of view of foodhygiene[1,2]. It is well known that high tin concentration is caused by nitrate contained in tomato fruit[3~7], and it is assumed that when bivalent tin, a strong reducing agent, is formed by oxygen enclosed in a can, nitrate is reduced to nitrite which readily attacks metallic tin to form bivalent tin and thus a chain reaction proceeds until most of the nitrate is consumed. To prevent the heavy tin dissolving, the nitrate-nitrogen concentration in raw tomato fruit as canning material should be below 3 ppm[8,9].

It was also reported that high nitrate concentrations in foods and water caused methemoglobin in infants, and that high nitrate concentrations in grass caused cyanosis in ruminants[10~12]. Investigations are therefore urgently required to find the means of preventing the accumulation of nitrate in agricultural products and other foods.

The causes of nitrate accumulation in plants are generally attributed to the absorption of excessive amounts of nitrate by the plant and the inhibition of nitrate reductase activity in the plant[13~17]. Some reports concerning the accumulation of nitrate in tomato fruit are available[18~

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[23], but the effect of related factors and the means of prevention are not yet sufficiently elucidat. ed.

Features, factors and means of prevention of the accumulation of nitrate in tomato fruit investigated by the author and coworkers[24~36], are summarized in the following review.

FEATURES OF THE ACCUMULATION OF NITRATE-NITROGEN IN TOMATO FRUIT.

Nitrate-nitrogen content in tomato fruit.—Changes of nitrate-nitrogen contents in various parts of the tomato plant during the growing period are presented in Fig. 1. Nitrate-nitrogen content in the fruit was lower than that in other parts of the plant and was always in the range 0—5 ppm under any growing conditions. When a tomato plant free of nitrate-nitrogen was planted in the culture solution containing nitrate-nitrogen. nitrate-nitrogen was rapidly absorbed by the plant and detected in the stem and leaves within 1 h after planting, in the fruit stalks and calyxes after several hours, and in the fruits after 1 day.

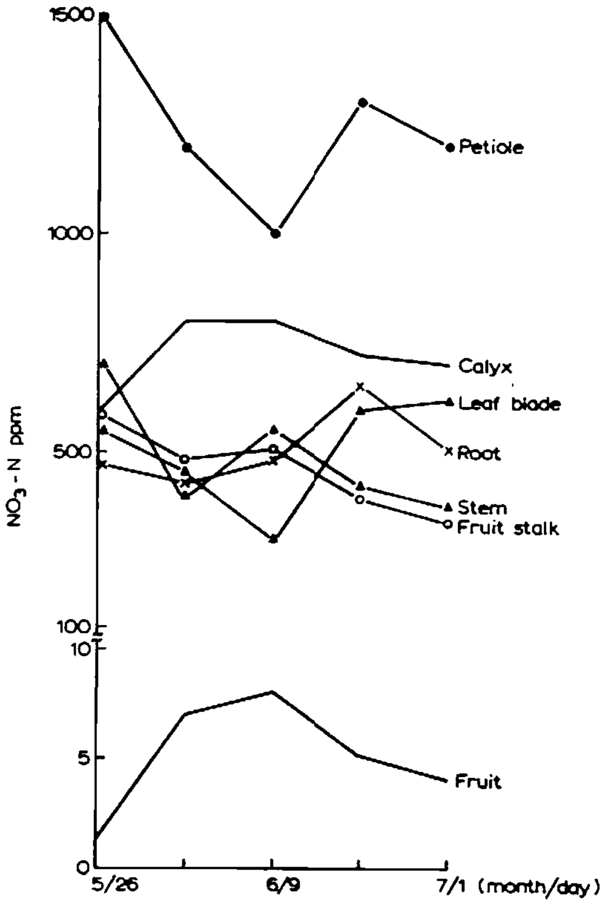

Fig. 1 Nitrate-nitrogen (NO_3-N) contents in various parts of tomato plant during the growing period ; planted on April 1st, fruit set on May 10 th, ripened on July 1st. 'Chico' in soil culture in greenhouse.

The sap entering into the fruit from the stalk was collected in the same way as the bleeding from the stem is usually performed, while conditions of lower temperature and higher humidity were adopted for preventing evaporation loss. The amount of sap collected was about 0.5ml/ fruit/10 h, and the nitrate-nitrogen content of the sap was at an unexpectedly high level during a some period of immature stage, reaching as much as 320 ppm, being very different from the low concentration in the fruit.

The change in nitrate-nitrogen content in the fruit during ripening.—Nitrate-nitorogen content in the fruit of the first cluster increased during the thickening growth period, and reached a maximum at the breaker stage ; two types of change, a sharp decrease and no change, followed during the transition from the breaker stage to the red ripe stage as shown in Fig. 2. It was consequently considered that type A fruit became a high nitrate-nitrogen type, and type C fruit a low nitrate-nitrogen type in the red ripe fruit. That is, nitrate-nitrogen content in red ripe fruit depends on nitrate-nitrogen content at the breaker stage and the type of change during the transition from the breaker stage to the red ripe stage. When a tomato plant was grown under shading, which is regarded as a condition to inhibit nitrate reductase activity, the fruit contained a re-

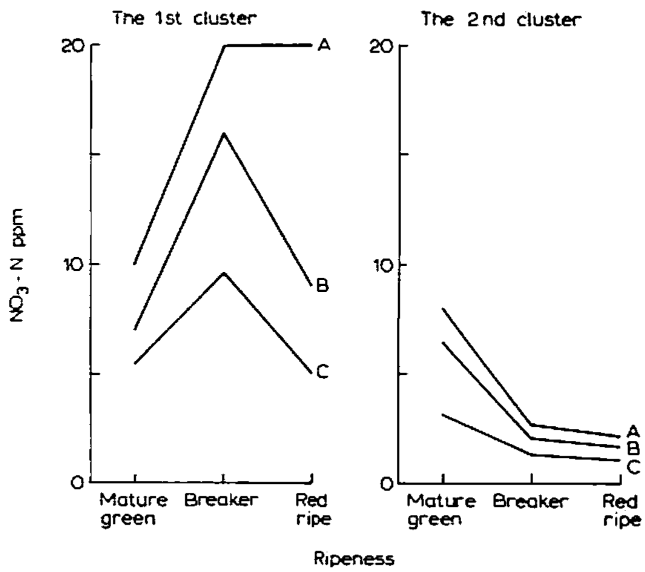

Fig. 2 The change in nitrate-nitrogen (NO_3-N) cont^nt of tomato fruit during the ripening (sand culture). A : tomato plant with a high content of NO_3-N in the fruit ; B : tomato plant with a medium content of NO_3-N in the fruit ; C : tomato plant with a low content of NO_3-N in the fruit.

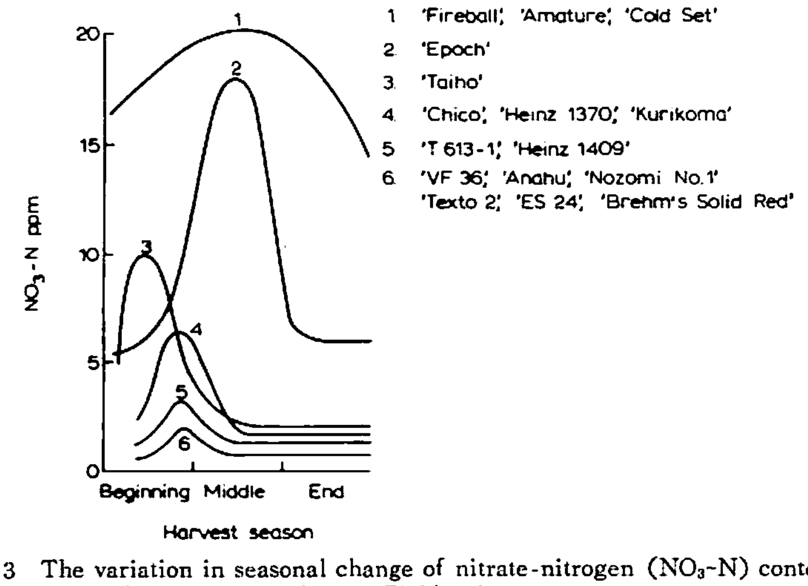

Fig. 3 The variation in seasonal change of nitrate-nitrogen (NO_3-N) content in tomato fruits among cultivars. Field culture.

markably large amount of nitrate-nitrogen at the breaker stage showing the pattern of type A.

Seasonal change of nitrate-nitrogen content in the fruit during the harvest season.—Seasonal change of nitrate-nitrogen content during the harvest season was found in the red ripe fruit grown in the field. The pattern of change varied among tomato cultivars, which were classified according to the pattern shown in Fig. 3. Remarkably large amounts of nitrate-nitrogen were observed throughout the harvest season in such extremely early ripening cultivars as 'Fireball', 'Amature' and 'Cold Set', regardless of growing time and district of production. The cultivars 'Taiho', 'Chico', 'Heinz 1370', and 'Kurikoma', which were at one time typical for canning in Japan, contained a considerable amount of nitrate-nitrogen only at the beginning of the harvest season. No appreciable amounts of nitrate-nitrogen were found throughout the harvest season in 'VF 36', 'Nozomi' and others. In sand culture, nitrate-nitrogen content in the fruit of the first cluster (early harvest) was higher than that of the second cluster (late harvest), as shown in Fig. 2.

Table 1 Effects of nitrate-nitrogen (NO_3-N) level in the culture solution used in sand culture on the contents of nitrogen, carbohydrate, organic acid, and mineral in red ripe fruit, and leaf. CV. 'Fireball' in sand culture. *1 N is 210 ppm of standard NO_3-N level. **Total amount of nitrogen in a whole plant including fruits, leaves, roots, and other parts

Treatment		Nitrogen				Carbohydrate	Organic acid	Mineral	
		NO_3-N** absorbed (mg/plant)	NO_3-N (ppm)	Total N (ppm)	NO_3-N / Total N (%)	Reducing sugar (%)	Total organic acid (mg/100g)	K_2O (ppm)	CaO (ppm)
Fruit	¼ N	1,827	2.4	1,210	0.2	2.69	345.1	2,560	101
	½ N	2,918	4.2	1,331	0.3	1.81	—	2,680	98
	1 N*	4,014	9.7	1,374	0.7	1.73	394.2	2,720	95
Leaf	¼ N		76	1,467	4.9	0.33	—	2,783	4,223
	½ N		313	1,866	14.6	0.41	—	3,508	3,886
	1 N*		734	2,664	27.4	0.59	—	4,648	3,759

EFFECT OF NITROGEN FERTILIZER ON THE ACCUMULATION OF NITRATE-NITROGEN IN TOMATO FRUIT

Effect of nitrate-nitrogen level in the culture solution used in sand culture on the accumulation of nitrate-nitrogen in tomato fruit.—Nitrate-nitrogen content in the fruit is remarkably affected by nitrate-nitrogen level in the sand culture solution, as shown in Fig. 4. When tomato was grown on lower nitrate-nitrogen levels in the culture solution, the nitrate-nitrogen contents of the fruit and the petiole decreased. Nitrate-nitrogen contents of the fruit and the petiole in the third cluster were lower than those of the first cluster on any nitrate-nitrogen levels in the culture solution.

Nitrate-nitrogen levels in the culture solution also had some influence on the concentration of other chemical compounds in the fruit and leaf of the first cluster, as shown in Table 1. With decreasing nitrate-nitrogen levels, the concentrations of reducing sugar in the fruit and calcium in the leaf increased, while the concentrations of free amino acid, organic acid, and potassium decreased. These phenomena at low nitrate-nitrogen levels would result from a decrease in amounts of nitrate-nitrogen absorbed by the plant.

Many studies concerning the influence of the amount of applied nitrogen fertilizer on the accumulation of nitrate-nitrogen in the fruit have been reported, and very often no significant cor-

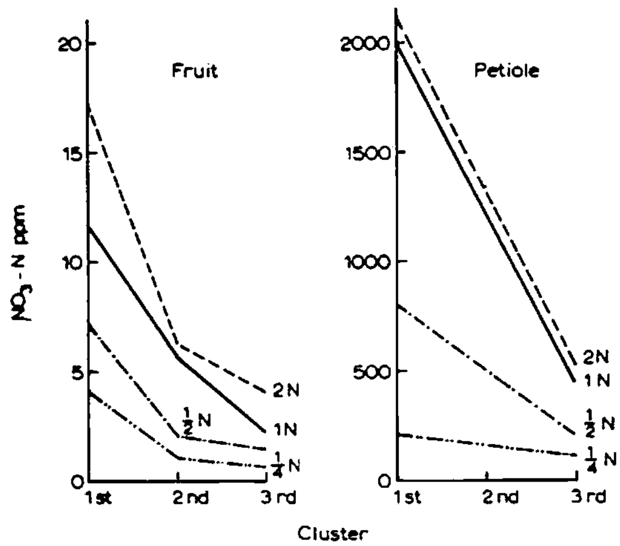

Fig. 4 Effect of nitrate-nitrogen (NO_3-N) level in culture solution used in sand culture on the accumulation of NO_3-N in tomato fruit and petiole. CV. 'Fireball'. 1N=210 ppm of standard NO_3-N level.

relation has been found between them[1,2,18~20]. In our experiment, too, the nitrate-nitrogen content in the fruit grown in the field treated with large amounts of nitrogen fertilizer wast not always at a high level, suggesting that the amount of nitrogen fertilizer applied did not directly reflect on the nirate-nitrogen level in the soil. Nitrate-nitrogen level in the soil is apt to be influenced by various factors such as nitrifier activity, levels of ammonium, some trace elements, acidity, water content, temperature, and rainfall[37,38]. However, it was clear that the nitrate-nitrogen content of the fruit grown in the field containing a considerably high level of nitrate-nitogen was at high level. When tomato was grown in the field containing over 100 ppm of nitrate-nitrogen for over 2 weeks during the growing period, the nitrate-nitrogen concentration in the fruit was always over 5 ppm.

Means of lowering nitrate-nitrogen level in the soil.—It is known that the applications of reduced amounts of nitrogen fertilizer, stable manure, slow-acting nitrogen fertilizer, and nitrogen fertilizer containing nitrification controller[39~41] can be used to control the nitrate-nitrogen level in the soil.

When stable manure was applied in our experiments, nitrate-nitrogen level in the soil was lowered, but the level was still often found to be over 100 ppm and then the concentration of nitrate-nitrogen in the fruit became very high. On the other hand, the application of quick-acting nitrogen fertilizer brought about a extremely high level of nitrate-nitrogen in the soil, but the nitrate-nitrogen content of the fruit was rather lower than that with stable manure. Any unsuitable use of stable manure, therefore, may cause a significant accumulation of nitrate-nitrogen in the fruit.

Nitrogen fertilizers containing thiourea, dicyandiamide, 2-chloro-6-trichloro-methylpyrimidine or 2-amino-4-chloro-6-methylpyrimidine as inhibitors of nitrification in the soil are being used in Japan. When these fertilizers were split-applied during the growing period, nitrate-nitrogen contents both in the soil and the fruit clearly decreased. By increasing the application ratio of inhibitors, both nitrate-nitrogen contents were more lowered further still, but tomato growth and yield deteriorated considerably.

Crotonyliden diurea, isobutyliden diurea and ureaform are also used as slow-acting nitrogen

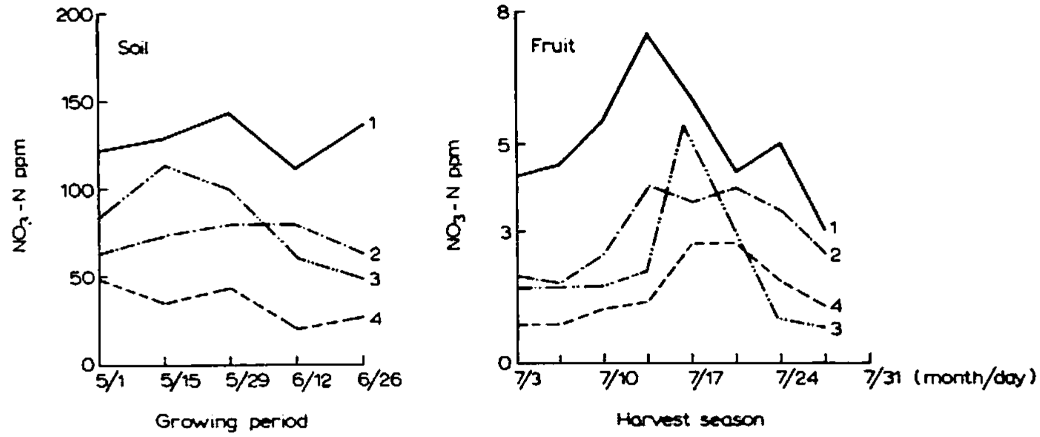

Fig. 5 Effects of flooding and Crotonyliden diurea (CDU) application on nitrate-nitrogen (NO_3-N) contents in the soil and in tomato fruit. Cv. 'Chico' in field culture.
1 : Split-application of $(NH_4)_2SO_4$ on the unflooded field ; 2 : Split-application of $(NH_4)_2SO_4$ on the flooded field ; 3 : Split-application of CDU on the unflooded field ; 4 : Split-application of CDU on the flooded field.

fertilizers. When these fertilizers were split-applied during the growing period, nitrate-nitrogen contents in the soil and the fruit decreased considerably.

To control the pathogenic fungi, we used to grow tomato plants in the field which was flooded during the winter season and drained in early spring. It was then found that under these conditions nitrate-nitrogen contents in the soil and the fruit were obviously lowered. Furthermore, when slow-acting nitrogen fertilizer was split-applied in the previously flooded field, the nitrate-nitrogen content in the fruit was at a fairly low level, being below 3 ppm throughout the harvest period as shown in Fig. 5.

EFFECT OF POTASSIUM AND CALCIUM FERTILIZERS ON THE ACCUMULATION OF NITRATE-NITROGEN IN TOMATO FRUIT.

Effect of potassium level in sand culture solution on the accumulation of nitrate-nitrogen in tomato fruit.—When tomato plants were grown in culture solution with a low potassium concen-

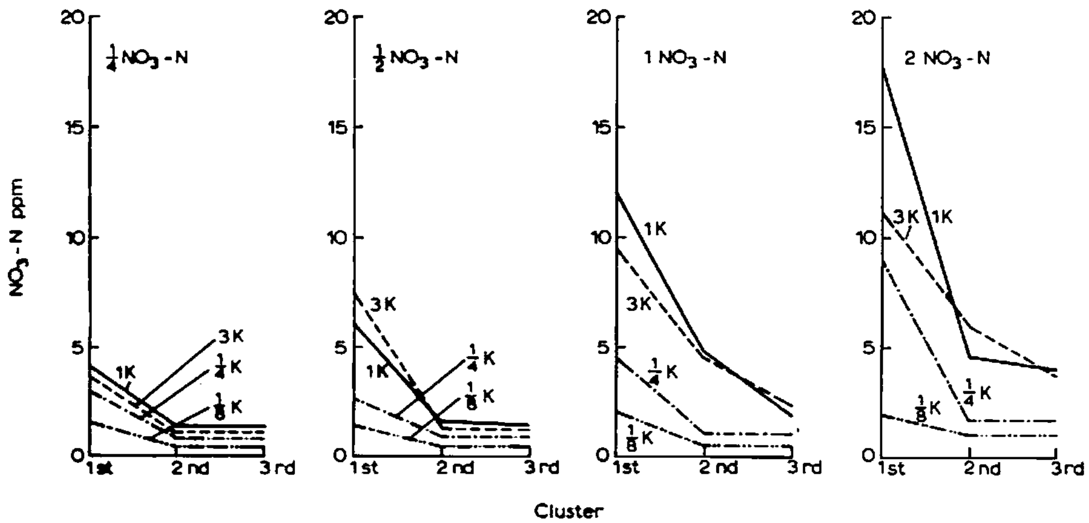

Fig. 6 Effects of potassium levels combined with nitrate-nitrogen (NO_3-N) levels in culture solution on the accumulation of NO_3-N in tomato fruit. 1 N=210 ppm of standard NO_3-N level. Cv. 'Fireball' in sand culture.

Table 2 Effects of potassium and calcium levels in the culture solution used in sand culture on the contents of nitrogen, carbohydrate, organic acid, and mineral in red ripe tomato fruit, and leaf. Cv 'Fireball' in sand culture. 1 Ca is 200 ppm of standard level ; 1 K is 234 ppm of standard level. *Total amount of nitrogen in a whole plant including fruits, leaves, roots, and other parts

Treatment		Nitrogen				Carbohydrate	Organic acid	Mineral	
		NO_3-N* absorbed (mg/plant)	NO_3-N (ppm)	Total N (ppm)	NO_3-N / Total N (%)	Reducing sugar (%)	Total organic acid (mg/100g)	K_2O (ppm)	CaO (ppm)
Fruit	1 K/1 Ca	4,014	9.7	1,374	0.7	1.73	394.2	2,720	95
	1 K/3 Ca	3,080	3.4	1,269	0.3	2.24	402.0	2,810	127
	1/6 K/1 Ca	2,646	1.8	1,257	0.2	2.57	327.0	1,500	104
	1/6 K/3 Ca	2,223	1.7	1,249	0.1	2.63	279.4	1,550	132
Leaf	1 K/1 Ca		734	2,664	28	0.59	—	4,648	3,759
	1 K/3 Ca		330	2,334	14	0.46	—	4,034	4,990
	1/6 K/1 Ca		280	2,209	13	0.32	—	1,181	4,693
	1/6 K/3 Ca		240	2,183	11	0.51	—	1,230	5,495

tration, the nitrate-nitrogen content of the fruit was very low at the red ripe stage and even at the immature stage. It was found that the influence of high nitrate-nitrogen level in the culture solution was controlled by the potassium level, and the nitrate-nitrogen content was very low in the fruit grown in culture with a high nitrate-nitrogen level combined with a lower potassium level, as shown in Fig. 6. The contents of reducing sugar and potassium decreased in the fruit and the leaf grown at a lower potassium level as shown in Table 2, and these phenomena were similar to those regarding the lower nitrate-nitrogen level which resulted in decreased nitrate-nitrogen content in the fruit (see Table 1).

Effect of calcium level in sand culture solution on the accumulation of nitrate-nitrogen in tomato fruit.—Application of high levels of calcium decreased nitrate-nitrogen contents in tomato fruit considerably, and when this was combined with low levels of nitrate-nitrogen or potassium, the decreasing effect was even more conspicuous, as shown in Fig. 7. With increase in calcium

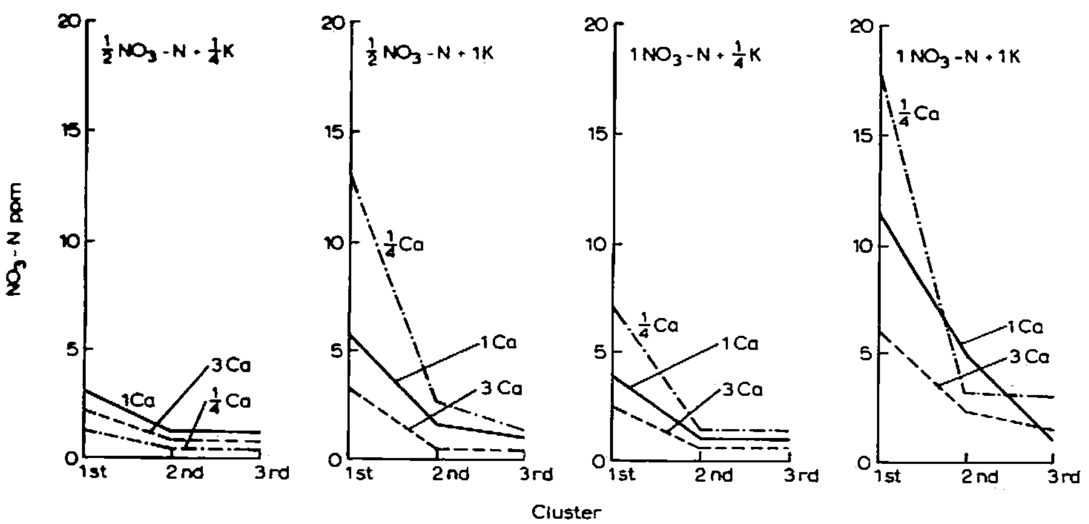

Fig. 7 Effect of calcium levels combined with nitrate-nitrogen (NO_3-N) and potassium levels in the culture solution on the accumulation of NO_3-N in tomato fruit. Cv. 'Fireball' in sand culture. 1 N=210 ppm of standard NO_3-N level ; 1 K=234 ppm of standard K level ; 1 Ca =200 ppm of standard Ca level.

level, the decreases in nitrate-nitrogen absorption by the plant and in contents of organic acid and potassium, together with the increase in contents of reducing sugar and calcium were found in the fruit and the leaf, as shown in Table 2. These tendencies coincided with those at low levels of nitrate-nitrogen or potassium of the culture solution which lowered the nitrate-nitrogen content of the fruit.

In the field test, too, a low nitrate-nitrogen content was found in the fruit grown with a high concentration of applied calcium fertilizer and this treatment did not affect the yield of fruit.

Effect of potassium and calcium on the accumulating velocity of nitrate-nitrogen in the fruit. —In order to investigate the influences of potassium and calcium on the accumulating velocity of nitrate-nitrogen in the fruit, tomato plants free from nitrate-nitrogen were grown on each of 1×10^{-2} M KNO_3, $\frac{1}{2}\times10^{-2}$ M $Ca(NO_3)_2$ and 1×10^{-2} M $KNO_3+2\times10^{-2}$ M $CaCl_2$ solutions containing standard levels of phosphate, magnesium, and micro elements. The plants free of nitrate-nitrogen were prepared by growing on 1/4 times as much as the standard culture solution until the early mature green stage of the fruit of the first cluster, and then on water for 2 weeks until the nitrate-nitrogen in the plant had disappeared. Nitrate-nitrogen contents of the fruit, calyx, and petiole of the first and third clusters were analyzed 1 and 5 days after the initiation of treatment. Among the different treatments, the highest nitrate-nitrogen content was detected even in the fruits of the upper as well as of the lower cluster of the plants grown on KNO_3 solution, and the nitrate-nitrogen content of plants grown on $Ca(NO_3)_2$ solution was very low, as shown in Fig. 8. The nitrate-nitrogen content of plants grown on KNO_3+4 Ca solution was intermediate between nitrate-nitrogen contents of plants grown on KNO_3 and $Ca(NO_3)_2$ solution. From these results, it is suggested that potassium accelerates the accumulation of nitrate-nitrogen in the tomato fruit, and more likely in the leaf.

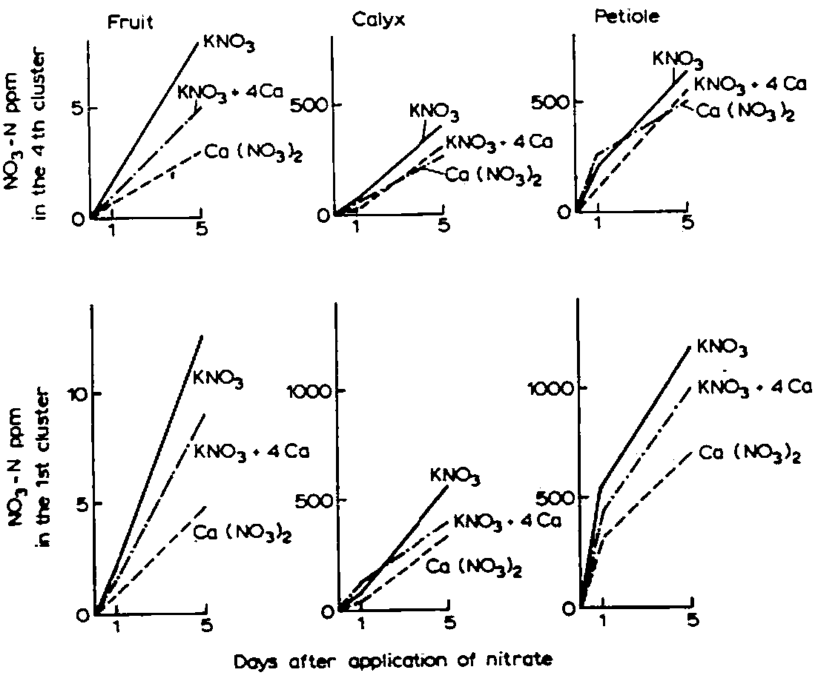

Fig. 8 Effects of potassium, and calcium on the accumulating velocity of nitrate-nitrogen (NO_3-N) in tomato plant. Cv 'Fireball' in sand culture. Plants free of NO_3 were grown on each of KNO_3 (1×10^{-2}MKNO_3), $Ca(NO_3)_2$ ($\frac{1}{2}\times10^{-2}$M $Ca(NO_3)_2$) and KNO_3+4 Ca (1×10^{-2}M $KNO_3+2\times10^{-2}$M $CaCl_2$) solution.

EFFECT OF PLANT GROWTH REGULATORS ON THE ACCUMULATION OF NITRATE-NITROGEN IN TOMATO FRUIT

p-Chlorophenoxy acetic acid (PCPA) is widely used for tomato growing as a parthenocarpy inducer, and gibberellin (GA_3) is another chemical used to induce parthenocarpy. 2-chloroethyl phosphonic acid (Ethrel) is known to have an accelerating effect on the ripening of tomato fruit.

When 50 ppm of GA_3 was applied to the flower, cluster, or whole tomato plant, nitrate-nitrogen content in the fruit decreased as shown in Fig. 9. Diminished fruit size and yield, and delayed maturation were also observed.

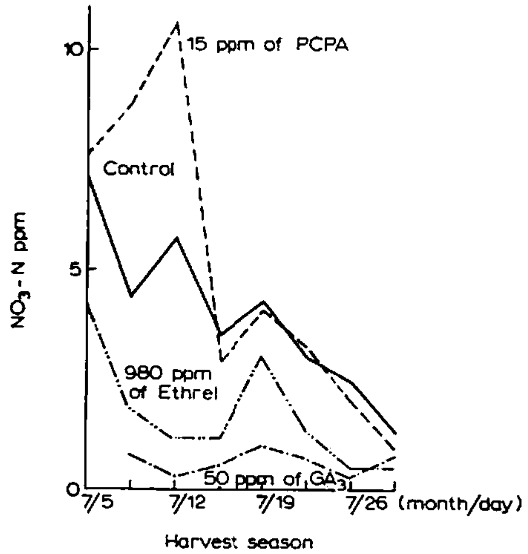

Fig. 9 Effects of some plant growth regulators on seasonal change of nitrate-nitrogen (NO_3-N) content in tomato fruit. Cv 'Chico' in field culture.

On the contrary, when tomato flowers and clusters were treated with 15 ppm of PCPA, higher nitrate-nitrogen contents in the fruit were found. Fruit size and yield were also increased and maturation was accelerated.

By treating clusters with 25 ppm of GA_3 and 7.5 ppm of PCPA together, it was found that the effects on fruit growth, yield, and maturation time were intermediate between those caused by single treatments of GA_3 or PCPA, and nitrate-nitrogen contents in the fruit decreased, with a higher percentage of the fruit containing less than 3 ppm of nitrate-nitrogen.

Spraying of 980 ppm ethrel on the whole plant shortly before the beginning of the harvest season accelerated the maturation considerably and shortened the harvest season. Nitrate-nitrogen contents in the fruit decreased with this treatment, but the fruit yield was lowered.

The effects of these regulators varied among the cultivars and 'Chico' was found to be more sensitive to PCPA and GA_3 than 'Heinz 1370'.

The mechanism of the effects of these regulators on the nitrate-nitrogen content of tomato fruit is not yet clear. For practical purposes, however, by treating the flowering cluster with GA_3 and PCPA together, and the whole plant with ethrel, shortly before the beginning of the havest time, it seems likely that nitrate-nitrogen content in the fruit will decrease without lowering the fruit yield.

THE VARIANCE OF NITRATE-NITROGEN CONTENT IN TOMATO FRUIT AMONG CULTIVARS

As mentioned above, nitrate-nitrogen content in the fruit varied among cultivars. The physiological difference between the low nitrate-nitrogen 'Chico' and the high nitrate-nitrogen 'Fireball' was investigated in more detail.

Nitrate-nitrogen content in 'Fireball' fruit was high at the breaker stage, and the content remaind unchanged throughout the ripening period and stayed at a high level in the red ripe fruit. In 'Chico' fruit, the nitrate-nitrogen content was very high at the breaker stage, but decreased thereafter and resulted in a low level at the red ripe stage. Fruits and leaves of 'Chico' showed a lower ratio of nitrate-nitrogen to total-nitrogen and lower contents of organic acid and potassium, but higher contents of free amino acid, reducing sugar, and calcium as compared with 'Fireball', as shown in Table 3. This relation between 'Fireball' and 'Chico' was similar to that between the standard tomato fruit and the fruit with reduced nitrate-nitrogen content produced by growing at lower nitrate-nitrogen or potassium levels or a higher calcium level of the culture solution.

Table 3 The contents of nitrogen, carbohydrate, organic acid, and mineral in red ripe tomato fruit, and leaf of 'Fireball' and 'Chico' cultivars. In soil culture.

Cultivar		Nitrogen			Carbohydrate	Organic acid	Mineral	
		NO_3-N (ppm)	Total N (ppm)	NO_3-N / Total N (%)	Reducing sugar (%)	Total organic acid (mg/100g)	K_2O (ppm)	CaO (ppm)
Fruit	'Fireball'	9.6	1,721	0.3	2.13	469.2	3,324	83
	'Chico'	2.3	1,867	0.2	2.83	372.4	2,558	118
Leaf	'Fireball'	774	2,535	30.5	0.53	—	4,034	4,709
	'Chico'	560	2,494	22.1	0.70	—	2,780	5,780

It is well known that tomato fruitp, icked at an immature stage, ripen during subsequent storage showing drastic changes in color, texture, ethylene production, respiration rate, etc. Changes of nitrate-nitrogen content in the course of ripening after harvest was investigated in our experiment. The fruits of the first and the fourth clusters of 'Chico' and 'Fireball' were harvested at the mature green stage and stored at 25°C. To find out the effects of ethrel and gibberellin (GA_3), other harvested fruits were immersed in 980 ppm of ethrel or 500 ppm of GA_3 solution for 30 min and then stored at 25°C. The nitrate-nitrogen contents in untreated 'Chico' fruit of the first and fourth clusters decreased considerably during storage, while in 'Fireball' fruit only the nitrate-nitrogen content of the fourth cluster decreased, and not that of the first cluster as shown in Fig. 10. Nitrate-nitrogen content in 'Fireball' fruit of the first cluster decreased slighly with GA_3 treatment, but not with ethrel. Tests were performed using treatments with ascorbic acid, maleic acid, glucose, kinetin, molybdenum, and several amino acids (methionine, alanine, proline and leucine), contents of which had been found to differ between 'Chico' and 'Fireball' ; no significant effect was observed in 'Fire-ball' fruit of the first cluster.

EFFECT OF SHADING ON THE ACCUMULATION OF NITRATE-NITROGEN IN TOMATO FRUIT

It is known that nitrate reductase activity is inhibited and therefore nitrate-nitrogen content increases in the plant grown under conditions of light deficiency[22,42~44].

In our experiments, when tomato plants were grown under shading using cheese cloth, nitrate reductase activity and ascorbic acid content in the fruit decreased and nitrate-nitrogen content increased, as shown in Table 4. It was also found that the plants became spindly and that fruit size was small. The influence of light intensity on nitrate-nitrogen content in the fruit varied a-

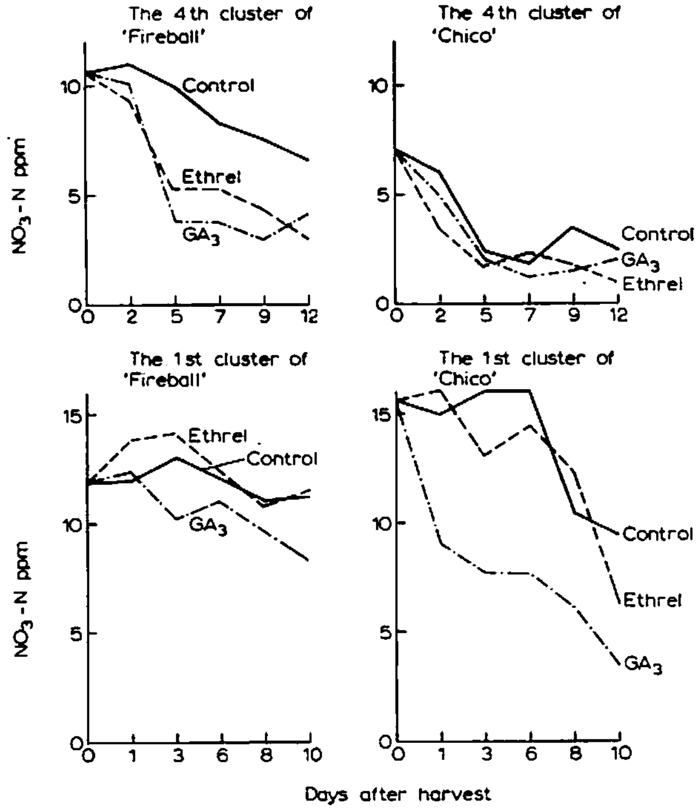

Fig. 10 The change in nitrate-nitrogen (NO_3-N) content in the ripening process of harvested tomato fruit. Fruits were harvested at mature green stage, immersed in each of 980 ppm ethrel and 500 ppm GA_3 for 30 min and stored at 25°C. The fruits of the first cluster were harvested on July 3rd, and those of the fourth cluster on July 18th.

Table 4 Effect of shading on the accumulation of nitrate-nitrogen (NO_3-N) in tomato fruit. Cv. 'Taiho' in sand culture. Shaded plants were grown under 2 sheets of cheese cloth. Nitrate reductase activity expressed in μg NO_2-N produced/3 g fruit/h.

		Fruit in first cluster			Fruit in second cluster		
		Mature green	Breaker	Red ripe	Mature green	Breaker	Red ripe
Non-shaded	NO_3-N (ppm)	5.1	9.8	2.9	3.2	2.1	0.5
	Nitrate reductase activity	3.8	6.2	0.5	2.4	0.5	0.6
	Ascorbic acid (mg/100 g)	—	—	14.6	—	—	12.1
Shaded	NO_3-N (ppm)	12.1	15.2	14.1	7.5	8.3	4.9
	Nitrate reductase activity	0.5	0.6	0.6	2.3	0.4	0.1
	Ascorbic acid (mg/100 g)	—	—	9.0	—	—	8.8

mong cultivars, and 'Heinz 1370' was found to be insensitive to shading.

MANAGEMENT PRACTICE FOR PREVENTING THE ACCUMULATION OF NITRATE-NITROGEN IN TOMATO FRUIT AND THE QUALITY OF CANNED TOMATO JUICE

The prevention of the accumulation of nitrate-nitrogen in the fruit.—The investigated phenomena and factors concerning the accumulation of nitrate-nitrogen in tomato fruit have been summarized above. On the basis of the knowledge obtained, a practical means of prevention of the accumulation of nitrate-nitrogen in tomato plants was tested. 'Chico', a low nitrate-nitrogen cultivar, was grown in the field which had been flooded during winter, using a high calcium level and split application of crotonyliden diurea which is a slow-acting nitrogen fertilizer. The results obtained were satisfactory, that is, nitrate-nitrogen content in the fruit was always below 3 ppm throughout the harvest season, as shown in Fig. 11, and the fruit yield did not decrease.

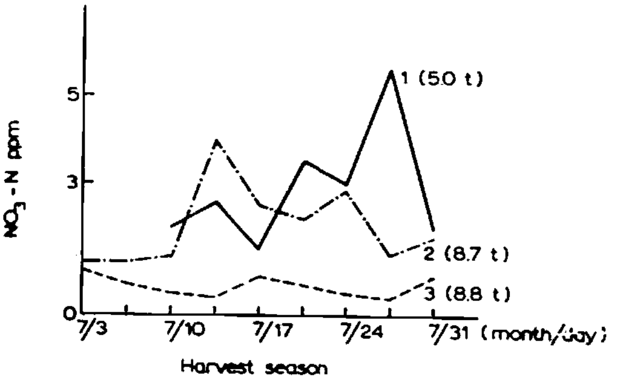

Fig. 11 Management practices for lowering nitrate-nitrogen (NO_3-N) content in tomato fruit. Cv 'Chico' in field culture. 1 : Application of $(NH_4)_2SO_4$ and standard Ca level on the unflooded field ; 2 : application of $(NH_4)_2SO_4$ and standard Ca level on the flooded field ; 3 : split-application of Crotonyliden diurea and 4 times standard Ca level on the flooded field. The figures in parenthesis indicate : fruit yield (ton/10 ares).

The quality of canned tomato juice.—Tomato fruits grown under the conditions mentioned above were processed into canned tomato juice and the contents of tin, nitrate-nitrogen, and other substances were analyzed.

When tomato juice containing nitrate-nitrogen below 3 ppm was packed in plain cans, nitrate-nitrogen in the juice disappeared in 3 months of storage at 37°C, and tin was dissolved to some extent with a concentration of about 100 ppm after 6 months of storage at 37°C as shown in Fig. 12. By packing the juice containing 5 ppm nitrate-nitrogen in plain cans, it was found that the dissolved tin concentration exceeded 200 ppm after 6 months at 37°C. In the coated cans, tin was not dissolved even when the juice containing 5 ppm of nitrate-nitrogen had been packed, and a great deal of nitrate-nitrogen remained. However, the ascorbic acid content in the juice decreased considerably and the development of browning as well as off-flavor was observed.

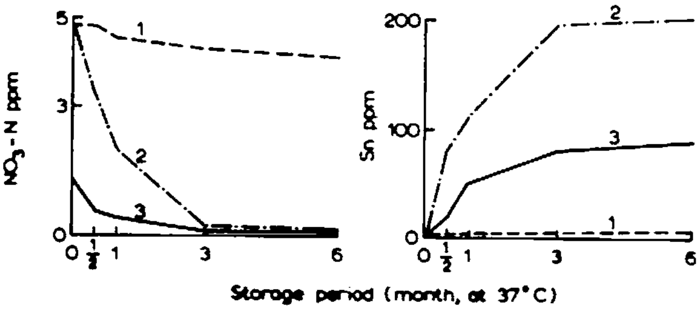

Fig. 12 The dissolving of tin and disappearance of nitrate-nitrogen (NO_3-N) contents in canned tomato juice stored at 37°C. 1 : Tomato juice initially containing 4.8 ppm NO_3-N packed into coated can. 2 : Tomoto juice initially containing 4.8 ppm NO_3-N packed into plain can. 3 : Tomato juice initially containing 1.4 ppm NO_3-N packed into plain can.

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