Proceedings of International Symposium on Recent Technology of
Chemical Control of Plant Diseases pp.70~87 (1998)

Current states and trends of chemical control of plant diseases in Japan

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Exceedindly bad weather fell on many Asian countries such as China, Korea and Japan this summer. It caused serious flood damages on not only human livings but also crop production in affected areas. It is well known that these bad weather, especially rainy and low temperature conditions, often invites severe and extensive occurrence of plant diseases. Actually, severe occurrences of leaf blast on rice, downy mildew on vine, scab on apple and canker on citrus were observed in Japan this year, too.

Agrocultural chemicals have contributed to stable and high quality production of crops, even under bad weather conditions, through their reliable and rapid control effects against diseases and insect pests for a long time. However, we have sometimes read and heard opinions which oppose making use and deny the role of agrochemicals for crop production from safety and environmental conservation points of view.

In 1993, Japan Plant Protection Association reported the results of field surveys which assessed yield and profit losses on fields without any application of agrochemicals.

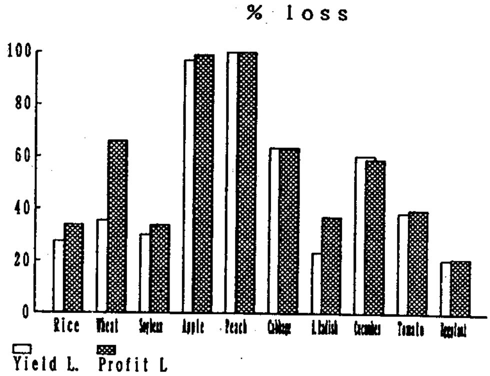

Fig. 1 Yield and profit loss on fields without application ofchemicals(JPPA, 1993)

As shown Fig. 1, availability of application of agrochemicals on crop production was clearly proved. In cases of fruits which are required high guality to sell, none was harvested and nearly 100% of profit was lost when chemicals had not sprayed at all. Even in cases of cereals such sa rice and wheat, yields decreased by 27.5~35.7% and 34.0~66.0% of profits were lost on un-applicated fields compared with commonly controlled fields by fungicides and insecticides.

We can realize that use of agrochemicals is indispensable to control plant diseases and insect pests through their surveys and have good future prospects on the better use of agrochemicals.

1. Present states of agriculture in Japan

Farmars in Japan are now faced with with various difficult problems. The situation surrounding farmers and farm management seems not to be getting better in the recent years. Problems to be solved are as follows.

① advancing age of farmer and shortage of inheritor(manpower)

Ratio of advanced aged population in farmhouse older than 65 has been increasing and is significantly higher than the average of total Japan as seen in Fig. 2. The government has intended to increse young wokers by the expenditure of subsidy for growing core farmers who cultivates more than 5 hectares and encouraging newly entered farmers or U-turned farmers.

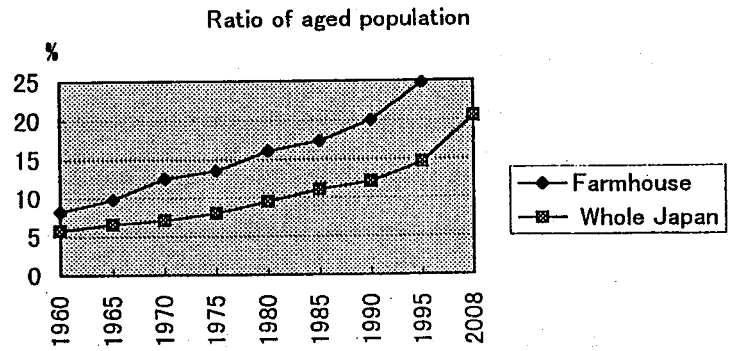

Fig. 2 Ratio of aged population in farmhouse
(Zennou, 1997)

Numbers of farmhouse with large scale management and newly entered farmers tend to increse gradually and slowly in the last few years, but it is insufficient to solve this issue.

② increase of interest in environmental conservation and food safty.

Following the increasing of world-wide interests in environmental conservation, farmers in Japan also come to take interests in safty of environment, food and operators themselves. Establishment of environmentally conscious agriculture is intended by the government and public research stations, and crop productions with organic materials, reduction of the number of application times of chemicals, production without any chemicals are intensively conducted by some farmers.

③ enlargement of ristriction area of rice cultivation and decline of rice producer's price

Producer's prices of rice grain fell more than 10% compared to those of the preceeding year on the volauntary trade market where most of rice grains classified with variety and producin place are buyed by bids recently. And competition among prefectures or producing places become more intense even in rice production.

Adjustment of rice production was strengthen this year, the average ristriction area of rice cultivation reached to 35.5% of total paddy fields due to increase of stored guantity of rice grain up to 300 million tons.
trade negotiation, imported rice should be increased to 0.8 million tons in 2000, is also a bueden to rice producing farmers.

④ Competition with oversea countries and among domestic crop producing places

Food supply in Japan deeply depends on foreign countries as before. As seen in Fig. 3 and Fig. 4, many kinds of food including meat and fish are in large quantities except rice. Citrus producing farmers are affected most by imported orange and grape fruit. In the case of vegetables, increse of imported quantity is remarkable in the last ten years. Major items of vegetable are pumpkin, asparagus, broccoli, garlic and ginger. It is thought that the quantity of inported vegetable will increse more for the purpose of adequatesupply all the year round and low cost strategy of food processors, and by established low temperature transportation system. The competition among domestic vegetable producing places is getting harder year by year for price, safety and quality under the stress of imported vegetables.

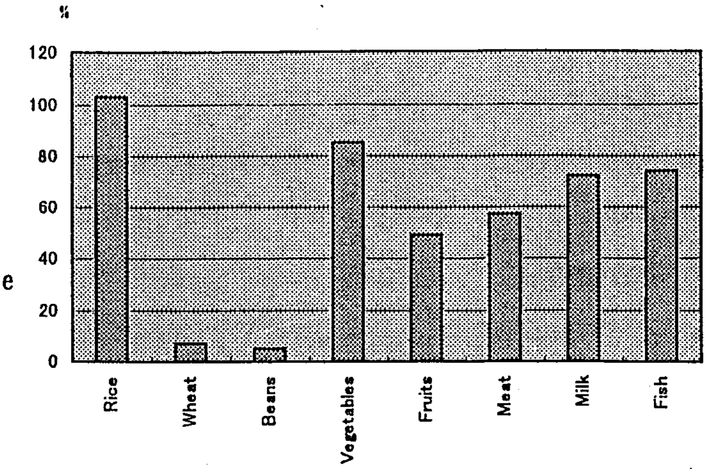

Fig. 3 Food self-support ratio in Japan(1995)
(MAFF, 1997)

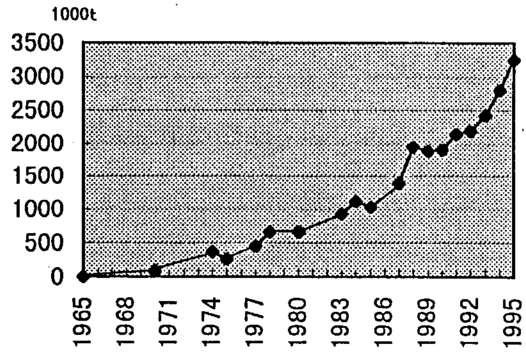

Fig. 4 Quantity imported vegetables
(MAFF, 1996)

To break through these problems mentioned above, the government and farrmers struggle how to establish labor-saving production, low cost production, high quality production, safer production and environmentary conscious and sustainable agriculture. And it is expected to meet their efforts that development of agrochemicals of effective with lower a. i. rate, higher safety against human being and livestock, non-effect against non target organisms and environment.

Agrochemicals launched have steadily been improved on toxicological property and foumulation type as shown in Table 1,2 and Fig.5.

Table 1 Ratio of Ordinary Chemicals

(JPPS, 1998)

Year	Ordinary (%)	Poisonous and Deleterious(%)
1980	61.4	38.6
1985	61.6	38.4
1990	65.7	34.3
1995	72.8	27.2
1996	72.8	27.2
1997	76.4	23.6

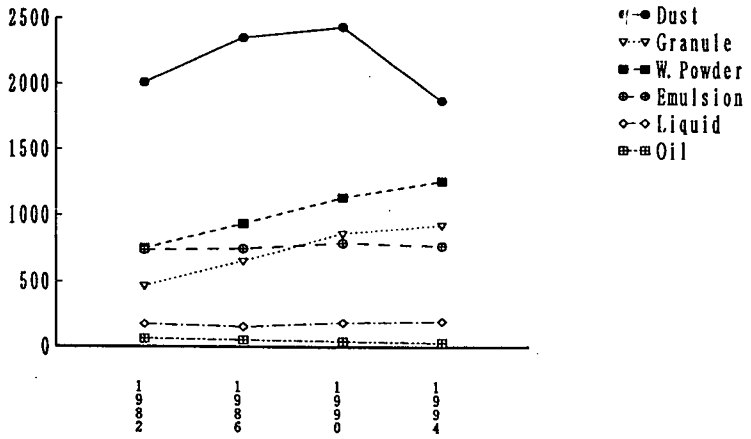

Fig.5 Change of Formulation Type of Chemicals

(H. Namae, 1996)

Table 2 Formulation Type of Resistered Dust and Wettable Powder

(H. Namae, 1996)

	Registeration No.	14,001 ~15,000	15,001 ~16,000	16,001 ~17,000	17,001 ~18,000	18,001 ~19,000
Dust	Dust	37.4%	21.9	8.9	2.7	2.7
	Low drift dust	62.6	78.1	91.1	97.3	97.3
WP	Wettable powder	90.1%	95.5	78.7	66.3	46.8
	Water dispersible granule	0.7	0.5	2.0	0.7	6.4
	Flowable	9.2	4.0	19.3	33.0	46.8

The ratio of ordinary chemicals in agrochemicals resistered has gradually risen and reached to 76.4% in 1997 from 61.4% in 1980. And it can be clearly recognized that the ratio of dust type chemicals is rapidly declining and granule and WP type of chemicals are increasing because of their easiness to applicate and less risk to environment and operators. As to dust and WP type of chemicals, low drift or driftless type of dust and flowable type and water dispersable granule type of WP show apparently increasing tendency.

2. Trends of chemical control of rice diseases

Rice diseases usually controled by fungicides are blast and sheath blight by foliar application and bacterial grain rot, bacterial seedling blight, bacterial brown stripe, bakanae disease, blast and brown spot by seed disinfection.

Seedborne diseases caused by bacteria are serious problems to raise rice seedlings even at present. Although seeds are usually disinfected with oxolinic acid or kasugamycin , rarely with acetic acid or cupper, which are only four active ingredients of seed disinfectants resistered, occurrences of severe damage by these diseases often reported from many prefectures every year. Further development of available chemicals and establishment of control measures are expected. Researchers in NARC proceed to study on artificially coating of husked rice grain with resin, that is production of aseptic rice grain.

Recently, remarkable changes occur on the control measures of blast and sheath blight as follows.

① increase of controled area by remote controlled helicopter

Since 1989, one year after the year of a severe and broad occurrence of panicle blast in the northern parts of Japan, treated acreage by manned helicopter is constantly decreasing as shown in Fig. 6

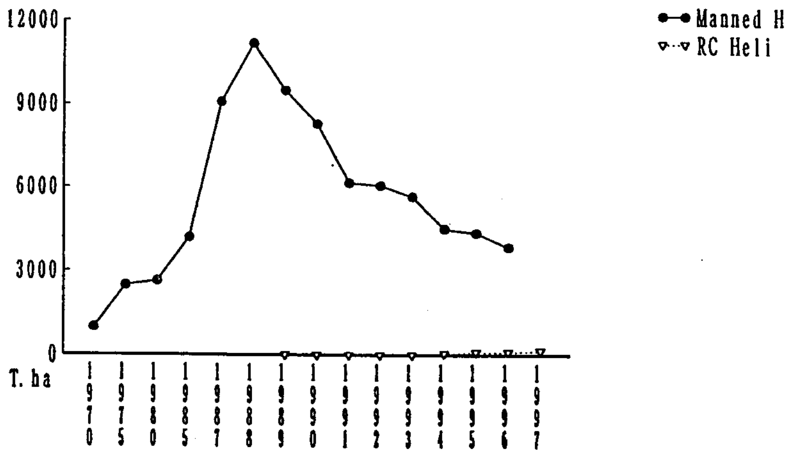

Fig. 6 Treated acreage by manned helicopter (Thousand ha.)

(JAAA, 1998)

Major reasons of this decreasing tendency are considered that (a) unstable control effects under rainy conditions. As almost of all flights are usually scheduled early in the cropping season, helicopters often could not work coresponding to actual incidence of disease occurrence and it is thought that this unflexibility may induce severe occurrence of panicle blast. (b) air pollution by aearial application. Farmers are compelled to change to another control measure by demands from environmental preservatio points of

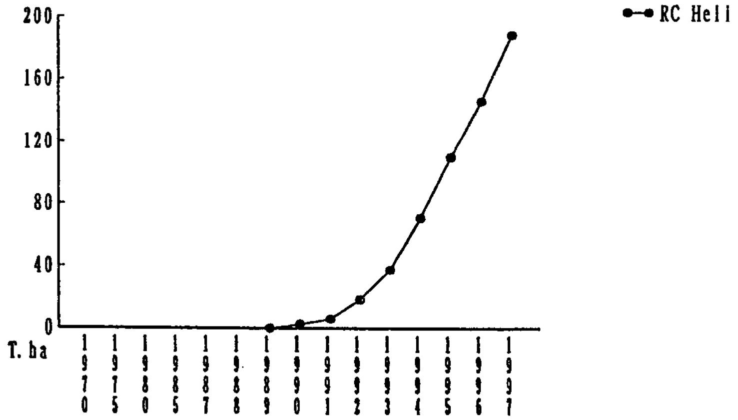

Fig. 7 Treated acreage by remote controlled helicopter (Thousand ha.)

(JAAA, 1998)

view in some prefectures.

② remarkable increase of use of remote controlled helicopter

As seen in Fig.7, treated acreage by remote controlled helicopter is distinctly rising, though it's acreage is very small compared to that by manned helicopter.

A remote controlled helicopter has lower capacity to conduct treatment than manned helicopter because of it's small size. It can cover paddy fields of 30 ha.per day and it is one tenth of manned helicopter.However, it has advantages of certainity on covering foliage with fungicide and reduction of drift. At present, remote controlled helicopter takes partial charge of two roles in aerial treatment: one is a supplementary work around the fields treated with manned helicopter and the other is the work for fields which are too small to apply by manned helicopter. The number of operators reaches up to 4,874 in 1997.

Pan-Cru-Sprayer, ride on type ground sprayer for a large scale paddy field, was also developed for labour saving works, but it has not yet popular.

③ development new fungicides with long residual effect

Recently new fungicides effective to blast and/or sheath blight and some new formulation of current chemicals have developed and launched one after another. Those are as follows:

Blast (a.i., company, target, application method, mode of action etc.)

Amistar(azoxystrobin);ZENECA. Blast, effective for 50 days after nursery box application, ground application, inhibition of mitchondorial electron transportation

Bion(benzothiadizole);Novartis. Blast, effective for 70 days after nursery box application, induce systemic acqired resistance

Coratop pack(pyroquilon 24%);Sankyo, Blast, throw into paddy, 10~13 pack/10a wrapped by water soluble film.

Dr. Oryzae(probenazole 21%);Meiji. Blast, effective for 70 days after nursery box application

Oribright(methominostrobin);Shionogi. Blast, submerged application, inhibition of mitchondorial electron transportation

Win(carpropamid);Bayer. Blast, effective for 70 days after nursery box application, inhibition of melanin biostnthesis and induce production of phytoalexin

Sheath blight

Amistar(azoxystrobin);ZENECA. Sheath blight and(Brown spot). effective for 70 days after nursery box application, ground application, inhibition of mitochondrial electron transportation

Greatam(thifluzamide);Rohm and Haas. Sheath blight, nursery box and submerged application, inhibition of succinate dehydrogenase in tricarboxylic acid

Limber(furametpyr);Sumitomo. Sheath blight, nursery box and submerged application, inhibition of succinate oxidation in mitochondria but not oxidation of NADH

RAKUO Moncut(flutolanyl 21%);Nichino, Sheath blight, throw into paddy, 20 pack per 10a, wrapped by water soluble film.

Control methods adopted by farmers tend to shift from dust and WP to granule and field spraying to nursery box application by launching of these fungicide because of their reliable and excellent effecacy and easiness to apply.

3. Issues on current horticulure productions in Japan

Stable production of horticulture crops deeply depends on agrochemicals at present. Many times of spraying were commonly performed on vegetables and fruit trees. In an extreme case, chemicals are applied once a week to control diseases and insects.

There are some issues on these control system of horticulture crops.

① to establish new control systems by use of registered existing chemicals instead of methyl bromide

Methyl bromide is well known as one of causal agents for destruction of ozone layer. Japan has a responsibilty to stop use of methyl bromide as a soil fumigant perfectly by 2005 as confirmed in Montreal in 1997.

As any new active ingredient which has the broad spectrum as a true fumigant has not yet found, researchers repeat experiments for establishment of a substitutional control method for methyl bromide.

Matsunaga(1998) evaluated MITC, chloropicrin and dichloropropene and showed high efficacy of MITC against nematoda, fungi and weeds as shown in Table 3. However, Takeuchi(1989) reported that effects of Dazomet and chloropicrin was insufficient to control pepper mild mottle tobamovirus and cucumber green mottle mosaic virus. Yamada(1997) reported conrol effect against tomato bacterial wilt by soil treatment of Dazomet combinrd with soil solarization. In this experiment, the combined treatment showed a superior effct to methy bromide and single treatment of soil solarization as seen in

Table 3 Efficacy comparison of soil fumigants (M. Matsunaga, 1998)
(a. i. rate need to control)

Chemical	Nematoda	Fungi	Weeds
MITC *	10	60	25
Chloropicrin	40	50	125
Dichloropropene	30	300	200
Methyl Bromide	40	100	50

*: methyl isothiocyanate

Table 4.

To utilize these chemicals for the control of soilborn diseases, further improvement on protection system will be needed because they are more expensive and complicated to treat than methyl bromide.

Table 4 Control of tomato bacterial wilt combined with soil solarization

(Yamada, M. et. al. 1997)

	Sept. 25	Oct. 5	Dec. 11
Soil solarization	16.3	32.9	37.5
Dazomet+Solarization	2.5	9.6	12.5
Methy bromide	5.8	20.8	40.0

*: tetrahydro-3, 5-dimethyl-1, 3, 5-thiadazine-2-thione 30Kg/10a

② safer protection on horticulture under structure

Vegetable, flower and fruit production in glass house and vinyl house have been continuously increasing as shown Table 5. The ratio to total cultivation acreage of reached to 9.0% on vegetable, 44.0% on flower and 2.2% on fruit in 1995.

Table 5 Cultivation acreage in glass and vinyl house

(T. Kondo, 1998) (ha.)

	1975	1985	1991	1993	1995
Vegetables *	24,353	41,376	48,496	50,191	51,026
Flowers	2,486	4,934	8,451	8,330	9,611
Fruits trees	1,596	4,575	5,871	6,330	6,750
Total	28,435	50,855	62,818	64,851	67,387

*: major crop; melon, tomato, cucumber, strawberry, spnach water melon, sweet pepper, eggplant

As diseases are easy to occur and prevail on all plants rapidly and severely after the onset in glass and vinyl houses due to their closed and high humidity conditions, chemicals are applied many times through a cropping season. For example, chemicals commonly applied 11~15 times for a semi-forcing culture of tomato. It is often pointed out that such current protection system is highly risky to operators and consummers.

To improve these situations, various non-manned protection machines have been developed such as self-propelled type power duster/sprayer, steam fog generator and non-heat type fogging machine. But these machines have not yet been popular, because chemicals applied by these machines showed lower efficacy caused by insufficient deposition of active ingredient on the reverse side of leaves.

Table 6 New protection system with consciousness for environment proposed by Chiba Prefecture for tomato production in houses

(Y. Takeuchi, 1998)

Treatment Time	Target	Chemicals and others
	Soil disinfection	solarization
Transplanting	White fly, Aphid	imidacloprid
End of Nov.	Leaf mold	triflumizole
Middle of Jan.	White fly	pyridaben
Early of Mar.	Grey mold	mepanipyrim
	Aphid	flufenoxuron
	Legume leafminer	pirimicarb
Middle of Mar.	Grey mold	fludioxonil
	White fly	parasite(*Encarsia formosa*)

Chiba Prefecture proposed a new protection system as Table 6 for a semi-forcing production of tomato in houses combined with use of natural enemy and soil solarization after three years experiments. Application of chemicals can be reduced to 9 times from 13 ay present by this system. Simultaneous with their proposal, they rmphasized the importance of studing on ecology of diseases to dicide proper applicationtiming of chemicals.

③ combat with fungicide resistance

Chemicals are applied so many times in horticulture production that the history of plant protection is also the history of combats with fungicide resistance.

Occurrences of resistant strains to fungicides have been confirmed on many fungi and many crops : grey mold, powdery mildew, downy mildew, and anthracnose of vegetables, black spot and scab of pear, scab and alternaria leaf spot of apple and so on.

Nakazawa and Yamada (1997) reviewed current states of fungicide resistant strains of *Botryotinia fuckeliana* (anamorph:*Botrytis cinerea*), the causal organism of gray mold which is one of most damaging diseases of fruiting vegetables such as tomato, cucumber and strawberry. Systemic chemicals effective to gray mold were launched one after another after 1971. Those are resistant to benzimidazoles(thiophanate-methyl and benomyl) ,dicarboximides (procymidone, iprodion and vinchlozolin) and diethofencarb (as mixed formulation;Getter and Sumibrend). Strains resistant to these fungicides are major problems in Japan at present. There are three phenotyp es of strains to benzimidazole , three phenotypes to dicarboximide and four phenotypes to diethofencarb. There are totally fifteen combinations of phenotypes with respect to sensitivity to these three classes of fungicides. The effectiveness of these fungicides against *B. fuckelinia* is shown in Table 7. Diethofencarb still exhibits good activity against weakly resistant strains though the period of effectiveness seems to be shorter than against sensitive strains .

1052 isolates , which were collected from tomato, cucumber, strawberry and others in Kanto area from the winter of 1994 to the spring of 1995, were assessed sensitivity to benzimidazole, dicarboximides and diethofen-carb. Seventy-two percent of tested isolates were benzimidazole resistant and 52 percent were resistant to dicarboyimide. And 42% of isolates were resistant to both of benzimidazole and diethofencarb and 49% were resistant to dicarboximides and diethofencarb as shown in Fig. 8. They also reported that there were a few cases in which a drastic reduction of efficacy of diethofencarb-mixtures occurred. These results show that resistance to diethofencarb-mixtures have already developed to a considerable degree.

Table 7 Penotypes of *Botryotinia fuckeliana* isolates with respect to sensitivity to benzimidazole, dicarboximide and diethofencarb and effects of fungicides (Nakazawa, Y. et. al., 1997)

Penotype *			Effect of fungicide **				
Ben	Dic	Dec	Ben	Dic	Den	Ben+Dec	Dic+Dec
S	S	HR	○	○	x	○	○
S	MR	HR	○	x	x	○	x
S	HR	HR	○	x	x	○	x
HR	S	S	x	○	○	○	○
HR	MR	S	x	x	○	○	○
HR	HR	S	x	x	○	○	○
MR	S	HR	x	○	x	x	○
MR	MR	HR	x	x	x	x	x
MR	HR	HR	x	x	x	x	x
HR	S	WR	x	○	△	△	○
HR	MR	WR	x	x	△	△	△
HR	HR	WR	x	x	△	△	△
HR	S	HR	x	○	x	x	○
HR	MR	HR	x	x	x	x	x
HR	HR	HR	x	x	x	x	x

*: Ben;benzimidazol, Dic;dicarboximide, Dec;diethofencarb
S;sensitive, WR;weakly resistant, MR;moderately resistant
HR;highly resistant
**: ○;high, △;moderate, x;low

Basic strategies mentioned by them against fungicide resistance are:

(a) use methods other than chemical control such as traditional practices. The frequency of fungicide spraying should be reduced so as to minimize oppotunities for selecting resistant individuals.

(b) Fungicides with high risk of resistant isolates should be used in

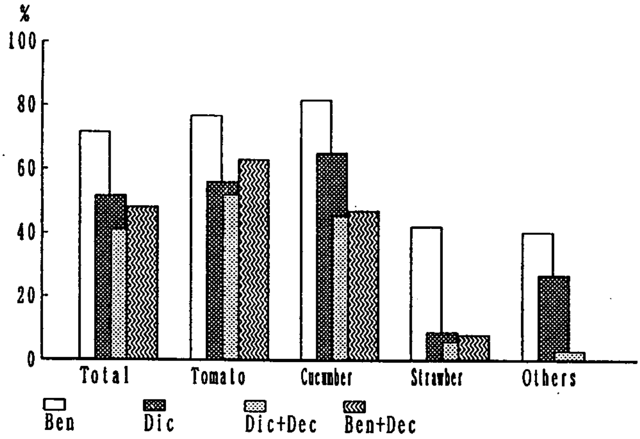

Fig. 8 Percentage of *Botryotinia fuckeliana* strains resistant to benzimidazole, dicarboximide and diethofencarb

(Nakazawa, Y. et. al., 1997)

alternation or in combination with fungicides having different modes of action.

And they expected that agricultural experiment stations and tension services will establish an integrated disease management system for each crop and disease. Furthermore they exspected that pesticide manufactures will develop fungicides possessing novel mode of action and release informations regarding their new fungicides, such as mode of action, risk of resistance development, monitoring method of sensitivity and base-line sensitivity data on target organisms.

Chemicals recentry registered and launched for diseases of fruits and vegetables are as follows:
(a. i., company, target, mode of action etc.)

Amistar(azoxystrobin);ZENECA, rust, powdery mildew, downy mildew, etc.
systemic, inhibition of mitochondrial respiration
Bellkute(iminoctadine-albesilate);DIC, scab, anthracnose, gray mold etc.

inhibition of lipid biosynthesis and affect activity of cell membrane

Frupica(mepanipyrim);Kumiai, gray mold and powdery mildew, inhibition of secretion of host cell degrading enzmmes

Manage(imibenconazole);Hokko, rust, alternaria, scab, powdery mildew etc., systemic, EBI and direct destruction of fungal cell

Savior(fludionyl);Novartis, gray mold, inhibition of glucose phosphorylation

Score(difenconazole+ manzeb);Novartis, scab, alternaria, fruit spot of apple systemic, inhibition of ergosterol biosynthesis

Stroby(kresoxim-methyl);BASF, rust, powdery mildew, downy mildew etc., redistribution by vapour phase, inhibition of mitochondrial respiration

4. Prospects of chemical control in future

The human population of the was 5.8 billion in 1996, and it is estimated if the world population continues to grow, it will be 8.3 billion in 2025 and 9.8 billion in 2050 at the medium increasing rate by World Population Prospect. It is said that over 800 million people do not have adequate food and growing population will need food more and more. To respond to social demands, increase of agricultural production is needed as a matter of urgency. In the past, increase of food production was supported by ① cultivation more land, ② irrigation more land, ③ use of fertilizer, ④ mechanization of cultural practice and ⑤ progress of crop protection.

According to the estimation by FAO, we can not expect so much contribution of cultivatig and irrigating more land toward increase of food production in future. On the other hand, crop protection is clearly essential for food production and will be able to contribute to perform stable and adequate food supply in the future.

Chemical control has played a important role in disease management and occasionally has been the only control method available and effective. Recently, studies on biological control, producing of gene engineered plant related to host resistance and new method of cultural practice such as solarization are actively conducted by many researchers. The results obtained by these studies will be available to build up a new integrated disease management system. It is also thought that chemical control will keep its important role in the IDM, because diseases rapidly increse after their onset and cuasal organisms are easy to mutate to adapt to new circumstances. Development of novel compounds with high efficacy, low toxicity, no effect to the environment and non-target organisms, and better formulations will be required to meet a new control system with consciousness of environmental conservation.

At the end of my presentation, I would like to say that researches on ecologies of plant diseases are indispensable to perform effective and proper application of chemicals and for better use of chemicals.

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