15. TECHNICAL PROBLEMS IN THE MECHANIZATION

TAKASHI TAKENAGA*

General description

Pest control machinery in Japan has been mostly hand applicators which are small in size and light in weight. As agricultural modernization advances, however, hand aplicators have been gradually replaced by power machines which are much highly efficient in working area per day. Unlike those in Western countries, pest control machinery in Japan is available in paddy fields as well as in upland fields. Table 1 shows the characteristics of power applicators.

Table 1. Classification and charactor of pest control machines

Kind		Appli. rate/acre	Nozzle or blowhead	Discharge rate/min.	Work area/ machine (acre)	Swath width (ft.)	No. of opera.
Sprayer	trailer*	200 gal.	wide swath	15 gal.	30	66	5
	tractor mount	200 gal.	wide swath	18 gal.	34	66	4
	portable	200 gal.	boom**	5 gal.	10	50	5
Duster	trailer	27 lbs.	boom**	9 lbs.	120	250	3
	tractor mount	27 lbs.	boom**	13 lbs.	180	300	3
	self prop	27 lbs.	boom**	9 lbs.	120	200	3
	knapsack	27 lbs.	boom**	4.5 lbs.	80	100	2
Mist blower	knapsack	30 gal.	diffusion	0.5 gal.	5	15	2
Air spray	trailer*	400 gal.	diffusion	26 gal.	25	30	3
	trailer	200 gal.	shell	13 gal.	25	15	3
	tractor mount	400 gal.	diffusion	15 gal.	15	20	3
	self prop	400 gal.	diffusion	26 gal.	25	30	3
Granule appli.	knapsack	27 lbs.	boom**	4.5 lbs.	80	100	2
Soil fumi.	trailer*	20 gal.	blade	24 fl. oz.	3	2	2
	tractor mount	20 gal.	blade	1 gal.	20	20	2
Helico. appli.	sprayer	3 gal.	boom	10 gal.	590	60	5
	UL V	14 fl. oz.	boom	0.5 gal.	890	60	5
	duster	27 lbs.	diffusion	90 lbs.	590	60	5
	granule	27 lbs.	diffusion	90 lbs.	590	60	5

* Machine is trailed by the tiller.
** Boom is supported by hand.

* 1st Research Division, Institute of Agricultural Machinery, Omiya, Saitama, Japan.

Present situation of pest control machines

The machines in current use are classified as follows: sprayers, dusters, mist blowers, air sprayers, granule applicators, soil fumigators, ultra low volume applicators and helicopter application kids et al. These applying machines are driven with hands or motor power; and some of hand applicators are shoulder, hanging and knapsack type, and power applicators are divided into the knapsack, portable, and travelling type.

The sprayer is the most popular applicator among all farmers in Japan, and widely used for cereals, vegetables, citrus and deciduous fruits et al. The sprayed chemicals are high volume liquid such as insecticides, fungicides and herbicides. Power sprayers have a reciplocating pump, a pressure regulator, and nozzles for atomization. The pressure of liquid of portable type power sprayers, is comparatively high (200–300 lbs/sq. inch), and its application rate is about 70–200 gal/acre within 15–40 min. at the rice field. The nozzles of the sprayer are classified into spray guns, line types, boom types and wide swath nozzles. The spray guns is available only for orchard, and the line nozzle with a spray rod is for paddy and upland fields. In paddy fields, the boom nozzle is supported by 2 followers, but in upland fields, it is mounted on the tractor as the boom sprayer. The wide swath nozzle is widely used in paddy fields because by using the nozzle of 66 ft. in width, the farmer on the farm road or the foot path can spray chemicals on the other side without walking in the field.

Dust applicator such as dusters have been used for pest control since World War II, and have been gradually familiar to farmers. The dust application saves labor because the water supply for dilution is not needed. The applicator is available for rice and vegetables except citrus and deciduous fruits. The knapsack duster has a centrifugal blower, a boom type blow head and a small 2 cycle engine. This blow head is made of a plastic tube of 66 or 100 ft. in length. With a blow head travelling horizontally to the end of the field, the applicator can apply the dust chemicals evenly as wide at 66–100 ft. This is not only available for the dust application, but also for the granule application.

The mist blower is for the application of the concentrated liquid chemicals, and has a centrifugal blower, a mist blow head and a small 2 cycle engine. This applicator is a kind of knapsack power applicators, and convertible from the knapsack power duster or the granule applicator, only by changing parts such as the liquid tank and the blow head. The nozzle of a sprayer is for the atomization of liquid on the high pressure from small hole but the blow head of a mist blower atomizes the liquid by the breakable power of the high speed air flow, and the diffusion type blow head is available to apply the chemicals wide. This machine is available for rice, vegetables, citrus and deciduous fruits of small or medium areas.

The air sprayer used only for citrus and deciduous fruits runs about in orchard with 15–30 ft. swath wide. There are 3 types of these air sprayers; tractor trailing, tractor-mounted, and self-propelled types. The self-propelled type was invented by a Japanese maker, and others of foreign origion are licensed to be made in Japan. All of them have a huge liquid tank, an axial or a centrifugal blower and a blow head.

Granule applicators apply the granule chemicals such as insecticides and herbicides. They are divided into knapsack and travelling type; the knapsack type is a kind of knapsack power applicators such as dusters and mist blowers, and uses the boom type blow head of 66 or 100 ft. in length as well as the duster does. The applicator is available mainly for rice.

The soil fumigator is used to exterminate nematoda living in the roots of the crops in upland fields. It has one or two blades that horizontally move in the soil under the ground. Chemicals are vaporific liquid, and are discharged into the soil from the chisels

situated at the bottom part of the blades.

The depth of application is 0.3–0.5 ft. from the soil surface.

The ultra low volume applicator to which the advanced technique is applied has many merits in the pest control. It does not require water supply at all because 60% concentrated chemicals highten insect control effect. The application rate of chemicals by this machine ranges from 14 to 28 fl. oz per acre. The recent studies indicate that the machines are available for rice, vegetables, citrus and decidious fruits, and many trial machines are invented and improved at the research station. This technique is practically applied to the machines at the Institute of Agricultural Machinery.

Aerial application of the chemicals is mostly carried on by airplanes in America while in Japan mostly by helicopters. In Japan, there are not the airports for the airplane's landing or taking-off nearby the fields, and the farm area is too small for aerial application. But if a helicopter, which can land on or take off from a farm road, flies at an altitude of less than 15 feet, chemicals can be blown down to the bottom part of plants by making use of down oscillation generated by the rotation of the helicopter's roter. The attachment to the applicator is a duster, a sprayer, or a granule applicator. An extremely concentrated spraying of the ultra low volume applicator has recently been studied.

The evaluation and problems of the applicators

The application by the sprayer is an easy work to the farmers. The chemicals are diluted at 7–0.1% by the water nearby the water way. When the application rate is over 70 gal/acre, the evenness of the chemical deposits to the plants is comparatively available for pest control. The durability of the sprayer is higher than other applicators, because the revolution of the shaft is as slow as 600 or 800 rpm. The sprayer, however, is not utilized in the upland area where the water supply for mixing the chemicals is hardly available. Under the current situation, it has been difficult to collect even 4 or 5 farmers for the cooperative control works to use the power sprayer, because farm labor has been too short. The power sprayer that withstands high pressure is not light enough to be moved from place to place in the fields. The power sprayer is more expensive than others.

The duster that applies fine dust chemicals (the average diameter is about 15 micron) does not need the water supply for mixing the chemicals before the application. The work starts as soon as the operator fills up the chemicals in the tank at the rate of 27 lbs/acres. In the case of knapsack type power duster with a boom-type-blow-head that is over 66 ft. long, the application work at the rice field is exceedingly highly efficient (5–7 min/acre) and enormously saves the labor (2–3 operators in the work). The structure of the duster is comparatively simple and it is inexpensive because it has not any part of pressure resistance. But the drift hazard that is injurious to other crops as well as animal and human lives breaks out by the travelling of the toxic dust chemicals blown with the wind because of the very fine dust particles. The dust chemicals contain net agricultural chemicals at the rate of 3 to 5%, and the rest contained is almost fine powder of the clay that is not effective in pest control at all, so that they are more expensive than liquid chemicals. The durability of the duster with the blower of high speed revolution is smaller than other applicators. The knapsack type power duster makes an annoying noise and gives unpleasant vibration to the operator.

The mist blower to apply concentrated liquid chemicals (30 gal/acre) does not need water supply so much compared with the sprayer operated in upland fields. The rate of effective deposits in the total applied chemicals is over 60%, which is noticeable compared with other applicators. The application of concentrated chemicals, however, occasionally fails to keep the deposits even. The noise and vibration of the knapsack

mist blower are as upleasant as those of the knapsack power duster.

The air sprayer is excellently effective to save labor in orchard because the working efficiency is very high by means of the use of huge machines. As many studies on it show, the number of men needed for working in orchard has decreased to one twentieth. However, the hours for the miscellaneous works such as supplying the liquid tank with water, mixing chemicals and travelling from field to field cannot be reduced in sloping orchard.

Recently the technique of the granule applicator is most interesting in the light of the herbicide and insenticide application. The applied granules of herbicides immediately show the control effect on weeds, and the systemic insecticides that are absorbed into the roots of plants and circulate in the plants owing the osmosis are effective without bringing on the drift hazard. So the granule application is safer to the neighborhood than the dust application. The granule chemicals, however, are comparatively more expensive than other chemicals made of dust and liquid.

For the extermination of nematoda over the wide area of upland fields by agricutural chemicals, there are no available applicators except the soil fumigator. The use of the expensive chemicals, however, is unprofitable for the crops of low commercial value. When the packing of soil after the application is imperfect, the applied liquid to the soil volatilizes in the atmosphere throughout the porous soil without giving perfect effect.

The knapsack type ultra low volume applicators that have 10~14 fd. oz of liquid tank are light enough to carry on the operator's back. The chemicals applied to the crops by this machine remain effective in pest control longer than other formulated ones. So this technique is reliable at present. But, if the non-diluted liquid of the chemicals is more or less toxicant and the applied chemicals flow out to the other area, drift hazard breaks out after the application.

The helicopter application kid is the most efficient of all the pest control machines. When the ultra low volume application kid is used in the rice field at the rate of 14 fd. oz/acre, one flight takes about 20 minutes for 90 acres. However, the drift hazard of the chemicals used affects the neighbourhood because the altitude of the helicopter is about 25 ft. high.

The problems in the applying technique and machines

Agricultural productivity has increased owing to the extermination of agricultural insects, disease, weeds et al. The application of the chemicals has brought more income than before, but the labor cost, which has increased at a higher rate than that of the products, does not bring profits so much. Although one of the applicators that need enomous labor shows an excellent pest control effect, it is not advantageous to the farm economy. The applicators and their applying technique should be devised for saving labor and for cutting down agricultural production cost. For this purpose producers' prices of the chemicals should be also lowered.

The chemicals used should be applied and spread to all the parts of plant population necessary to exterminate weeds, fungi, and insects. The herbicide has to be dropped on the ground surface rather than on the crops; the fungicide should be applied normally to the back side of leaves; and the borer in the rice stem should be exterminated by the deposits not to the leaf but to the rice stem. There are many kinds of the nozzles of the sprayer; the blow head of duster, the mist blower, the granule applicator and the air sprayer for each case. For instance, the nozzle that has a wide spray pattern is effective to exterminated by the applying chemicals from the blow head of the helicopter kid without penetrating inside because of its wide swath.

The application of concentrated chemicals not only serves working efficiency, but

also saves the labor of the application, or the volume of chemicals and the chemical tank can be designed to light weight and to lessen capacity. The ultra low volume applicator is finally devised for this purpose. However, when exceedingly concentrated chemicals are applied too rapidly, the uneven deposits in the field or the imperfect pest control effect tends to be passed over. The distance of the drift is an important problem to study as Fig. 1 shows. The radio active analysis now under study is an

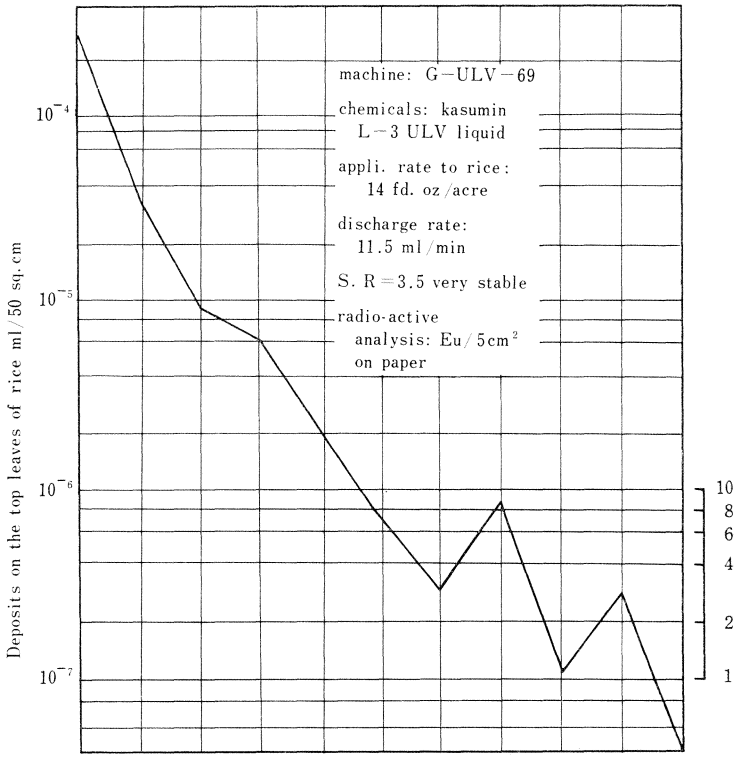

Fig. 1. The drift of a knapsack type power ULV applicators by radio active analysis: the element used was Europium.

advanced measure which should be a new subject for research. The relation between the applicator and the chemicals used can be compared to the relationship between a gun and a ball. A gun should be made fit for a ball so that it may be loaded easily for a shot. When the granule chemicals of irregular particle size are used, the granule applicator with a boom-type-blow-head whose swath width is as long as 66 ft. cannot deposit chemicals evenly from one side to the other of rice fields. Fig. 2 shows the even deposit of 3 kinds of granule chemicals, and the machine used is a knapsack power applicator with a boom-type-blow-head, which can deposit the chemicals evenest of all the granule applicators. On the contrary, some of the boom type blow heads for the granule application cannot deposit them so even as the illustration shows. Therefore applicators and the chemicals used are asked earnestly for the improvement.

It is desirable to avoid the use of the poisonous agricultural chemicals as far as possible but the chemicals include more or less some toxic compound in themselves. Some

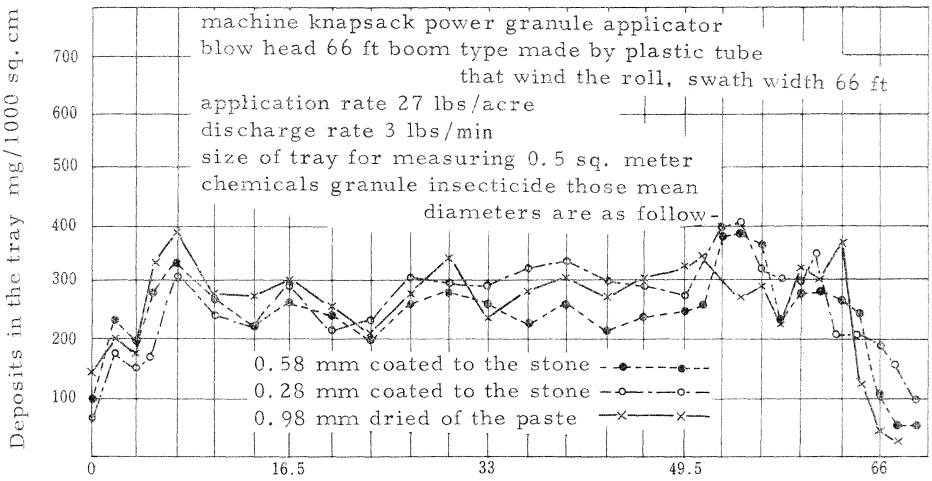

Fig. 2. The even deposits of granule chemicals used by knapsack power granule applicators.

crops, when covered with toxic dust, are withered up, and some operators suffer from a headache after the application and the neighbours are exposed to the injurious smell for health. So the application should be done under the safe conditions of the environment, and the operators must put on the clothes and a mask not to be covered with toxic chemicals. The cholinesterase (anti-toxin) values in the blood of rabits at the various dust/air ratio in the environment are shown in Table 2. The value before this test is 100, so the lower value in the table means the injurious effect. The chemicals used are the dust of carbamate insectcides, and are blown out from the boom several times to keep the constant dust/air ratio in the closed room (3,600 m^3). This ratio is measured by the velocity of air flow and the residues on the fine filter at the inlets of 5 suction blowers. The dust applicator used is a travelling type power duster with-boom-type-blow-head of 130 ft. long. The results obtained are that the rabits perfectly recovered after a week, and that therefore the chemicals used are clearly proved to be poisonous.

The biological pest control that exterminates agricultural insects by means of other useful insects or the attractant is not yet widely utilized because they cannot be mass-produced at a low price.

Although there are many insecticides and fungicides for pest control, their applying techniques are not quite the same. The granule formulation suits insecticides because osmetic chemicals move up to the leaves and stems through the roots of crops without drift hazard. But the application of the same formulation to fungicides cannot completely prevent the outbreak and spread of crop diseases.

Therefore, the spraying of fungicides was more effective applying technique than the granule application before many systemic fungicides appeared. To select and use chemicals and applicators properly is troublesome for farmers. Although the sprayer is available for fungicides and the granule applicator for insecticides, yet a knapsack type power applicator may be more recommended to the farm of medium-sized management because it can be used as a substitute for the duster, the mist blower, the granule

Table 2. The antitoxin values in the blood of rabits at the various dust/air ratio in the environment

Situation of measured	Dust/air		Exposed times			Progress of days		
	(mg/m³)	30 min.	1 hr.	2 hr.	3 hr.	3 day	7 day	14 day
Applicator side	530	85				—	—	—
			65			81	93	110
				62		76	99	95
					65	60	62	65
70 ft. from applicator along boom	800	73				88	102	101
			61			82	87	97
				50		54	91	99
					55	65	103	103
130 ft. from applicator, end of boom	730	91				82	91	117
			59			85	101	98
				32		76	102	101
					41	66	103	91

1) dust air ratio varied in each situation because the swath width was 130 ft. long.
2) numbers of tested rabits were 12, a rabit that was exposed in dusty air was released to the outside of the applying room after in each time.
3) these values after 7 days were irregular, but almost all rabits recovered within this day.

applicator or the ultra low volume applicator.

Although the evenness of deposits in the field is complicated to indicate, the coefficient of variation (C.V.) is usually put to practical use.

$$V.C=\frac{\sqrt{\sum(x-\bar{x})^2}}{\bar{x}}$$

x=deposit on the sample
$\bar{x}$=average of the deposits
n=number of samples

The materials used, for instance, are absorbable papers, glass plates painted in oils, and square trays respectively in the case of liquid, dust and granule. There is a problem in this C.V. method of indication. In the case of granule application, C.V. calculated by using the small scale tray cannot be exactly compared with C.V. done by using the large scale tray, because the former is always more precise. Therefore, the size of samples should be defined among all the experts of pest control.

In the near future the granule applicator for the paddy field and the low volume or ultra low volume applicator for the upland field will be highly evaluated because of the saving of labor, the high efficiency of working and the excellent effect of pest control. Power sprayers for the high volume application will still remain because they can easily work where labor and water supplies are abundant. The air sprayer which can be also used for high volume or ultra low volume application will be of considerable utility for pest control in orchard. But the use of dust applicators that cause the drift of toxic dust chemicals are produced.

All the other applicators will be made more efficient; hand applicators will be replaced by power applicators, and portable power applicators, by travelling type applicators to

save labor and to highten working efficiency.

In conclusion, applicators and the chemicals used should be studied in close connection with each other, as shown so far in the reciprocal development of the two. The rapid improvement of both will result in an excellent benefit to farmers.