Studies on the Speedmister

Part I. Fundamental Experiments by Using Model Apparatus*

Akira ISHIHARA, Yoshinori NISHIKAWA and Junji MASUDA**

(*Laboratory of Agricultural Machinery, Faculty of Agriculture, Tottori University*)

Received September 13, 1968

In this paper, the authors proposed a new spraying method of liquid, called it "speedmister". The principle of "speedmister" was discussed theoretically and it looked as if the principle were possible to realize. Therefore, the fundamental experiment were done by using the knapsack type mistsprayer. Next, the authors designed a 1/10 model speedmister of the actual machine, and this model was used by way of trial. The results of the experiments by using this model were as follows. When the air volume of blast was 100 m^3/min, mistparticles were obtained by using liquid of 2 kg/cm^2, 2 l/min and compressed air 2 kg/cm^2.

Introduction

What we call the speedsprayer has a high performance as a pest control machine. But the method of spraying chemical liquids has still some defects. For example, the nozzle of the speedsprayer is an airless spray type, therefore the liquid particles are distributed by a strong blast made from the blower. These strong blasts cause a large loss of required power, and also since the particles are of a large size the particles distribution in the spraying is rough.

Therefore, in order to improve some of those defects the authors have attempted a new spraying method which they call "Speedmister". Here, the authors wish to emphasize particularly that the speedmister is different from the speedsprayer. In this report, the principle and the results of the fundamental experiments of this new spraying machine are reported.

Principle of the "Speedmister"

In modern farming, the mechanization of pest control work has been developed rapidly. The tendency of mechanization is directed towards large size machines as for example the airplane spraying machine. However, the airplane spraying method is not yet sufficient to control the pest of the farm crops. That is to say, large size ground sprayers are also required. Large size ground sprayers are classified into two groups. They are a) the spraying method of a pipe line system and b) the speedsprayer or the running type power sprayer with a large liquid tank. Among the spraying methods which are used on the ground, the speedsprayer is used extensively recently. But neither this method is perfect, are it has some faults. We think the defects of the speedsprayer, are as follows.

(1) The liquid particles are sprayed with strong blasts from the blower, therefore those strong

* Paper presented at the meeting of the Japanese Society of Agricultural Machinery at Tokyo, April 1966.

** Marunaka sprayer & duster mfg. Co., Ltd.

blasts injury young leaves or young fruits at the places near the nozzles.

(2) Because the air volume of the blower is small, the range of the deposit and the penetrability (the ability to flow out through the trees) is inferior. Especially, when particles are sprayed toward the wind, the effective arriving distance is only 5m from the nozzle.

(3) Required power is large, because the blasts of the blower are used under high pressure.

(4) The size of the particles is large and the particles' distribution in the spraying pattern is rough, because the atomization is done by using a pump but no air.

(5) As liquid is used to a large volume, a large liquid tank is needed for the machine. Therefore, the rendement is inferior and much time is taken up in supplying the chemical liquids to the tank.

Those faults must be improved as much as possible to make better machines in the future. According to this idea, the authors attempted to study the "Speedmister". In general, the air speed of the strong blast from the blower decreases rapidly in the air. So, it seems that if we hope to make the particles to arrive as far as possible from the nozzle, we must use a large volume blast rather than a large speed blast.

If we will be able to mix the particles with large volume blasts, the particles will be flown away by the blast and they will be carried as far as the blast goes. By this method, we hope to atomized particles as small as possible. For this atomization, the parallel flowing air is used to crush the liquid. This method is very simple and perfect and it is the main principle of "Speedmister" which has been tried by the authors.

In general, the free surface of the liquid has force to contract itself and to form a minimum surface and this is the surface tension.

$$P = \frac{2T}{r}$$

where P : pressure from the outside
r : radius of the particles
T : surface tension

T is balanced with P, so the larger P becomes, the smaller r will be. Therefore, the formation of particles in speedmister and the particle size are determined by the absolute speed of both the spraying particle and the parallel flowing air. But the possible air speed of blasts from a usual blower is limited to within about 100 m/s, so we must use air compressure if we hope to go beyond 100 m/s air.

In theory, the relationship between the maximum diameter of particles and the air speed is shown in Table 1. It is clear from this table that if we will obtain particles with 10μ diameter, by using 3 kg/cm^2 compressed air we can obtain it. But the particles with 10μ diameter are not suitable for farming, so the authors selected 20μ particles as standard size of particles for farming. In this case, we can make 20μ particles by using 1.5kg/cm^2 compressed air.

Now, the authors put the standard sizes as follows,

particle diameter of speedmister 100μ
particle diameter of speedsprayer 20μ

and the particle radius in the adhesion area are r_1 and r_2 as follows,

Table 1

Air velocity (m/sec)	Maximum diameter of particle ($\times 10^{-4}$cm)	Air velocity (m/sec)	Maximum diameter of particle ($\times 10^{-4}$cm)
10	4700	120	33
20	1188	130	28
30	528	140	24
40	296	150	21
50	190	160	18
60	132	170	16
70	96	180	14
80	74	190	13
90	58	200	11
100	47	218	10
110	39		

for speedmister r_1
for speedsprayer r_2

and so, $r_1 : r_2 = 1 : 5$

$$r_2 = 5\, r_1 \cdots\cdots(1)$$

The particle volumes are V_1 and V_2, i. e.,

for speedmister V_1
for speedsprayer V_2

and,

$$V_1 = \frac{4}{3} \pi r_1^3 \cdots\cdots(2)$$

$$V_2 = \frac{4}{3} \pi r_2^3 \cdots\cdots(3)$$

now put equation (1) in equation (3),

$$V_1 : V_2 = 1 : 125 \cdots\cdots(4)$$

this is the volumetric ratio.

Also, if the diameter of the particles is d_1 for speedmister and d_2 for speedsprayer,

$$2\, r_1 = d_1$$
$$2\, r_2 = d_2$$

then $d_2 = 5\, d_1$

therefore, covering area a_1 and a_2 it becomes,

$$a_1 = \frac{\pi d_1^2}{4} \text{ for speedmister}$$

$$a_2 = \frac{\pi d_2^2}{4} \text{ for speedsprayer}$$

if the covering area is equal, that is to say $a_1 = a_2$, then we have,

$$V_1 : V_2 = 1 : 25$$

this is the covering area ratio.

As a result, it can be said that the required liquid volume for using in speedmister is 1/25 of that for using in speedsprayer. So, by using speedmister a concentrated low volume spraying and an economical spraying are possible.

Experiments by Using the Knapsack Type Mistsprayer

1) Purpose of the experiment.

In order to prove the possibility and the exactness of the principle of speedmister, the authors have made experiments in conection with the atomization and the arriving performance on the airless spraying and air injection spraying method by using the knapsack type mistsprayer and by testing the nozzles.

2) Experimental machine and apparatus.

Knapsack type mistsprayer : Made by Marunaka sprayer & duster mfg. Co., Ltd. in Japan (Fig. 1)

Dimension:
- engine : air cooling, 2 cycle, 1.2 ps
- weight : 17.9 kg
- air velocity : 85 m/s
- air volume : 7.3 m^3/min
- tank of liquid : 11.5 l

Nozzle used experiment : (Fig. 2)

for speedmister:
- compressed air used, 3 holes type,
- dia. of hole for liquid : 0.8 mmϕ
- dia. of hole for comp. air : 2.5 mmϕ

for speedsprayer:
- mistsprayer nozzle with 3 holes,
- dia. of hole for liquid : 0.8 mmϕ

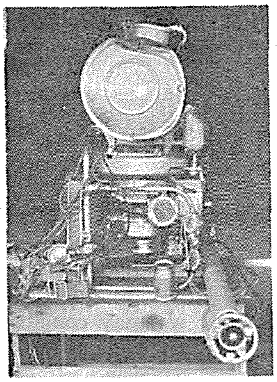


Fig. 1 Knapsack type mistsprayer and nozzle used the experiment.

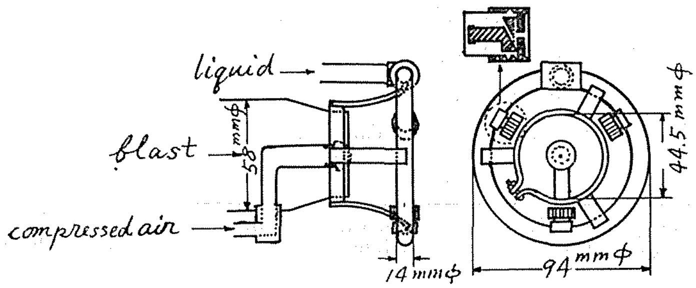


Fig. 2 Dimensions of nozzle parts of knapsack type mistsprayer.

3) Conditions of experiments.

Experiments were carried out under the following conditions,

a. Measuring the discharge rate.

b. Arriving performance of particles (measuring the range of deposit).

c. Atomizing performance of nozzle (measuring the mean diameter of particle by taking photographs using microscope).

4) Results and discussion of experiments.

a. Discharge rate.

The results are as follows.

Table 2

Liquid pressure (kg/cm²)	1.5	2.0
Discharge rate (l/min)	0.75	0.87

b. Arriving performance.

The nozzle fixed on the table height 1 m above the ground surface and the liquid was sprayed to a horizontal district. The experiments have been done under the following conditions.

liquid pressure : 2 kg/cm^2

discharge rate : 0.87 l/min

revolution of blower : 4500 rpm

compressed air was changed 0, 2, 4 kg/cm^2 step by step.

The experimental results are given in Fig. 3.

From this figure, following values were obtained.

Table 3

Compressed air (kg/cm^2)	Maximum distributed point of liquid. (m)
0	4
2	5
4	4.5~5

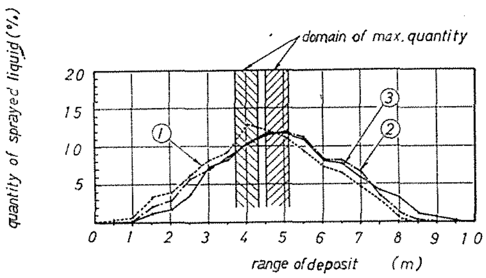


Fig. 3 Quantity of sprayed liquid to the range of deposit.
① : Pa = 0 kg/cm^2
② : Pa = 2 kg/cm^2
③ : Pa = 4 kg/cm^2

c. Atomizing performance of nozzles.

The particles were caught on the preparate glass to which oil was applied at the position of 1 m from the nozzle horizontally.

A microphotograph was taken of these samples, and the mean diameter of particles were calculated by the authors.

These results are given in Table 4.

Table 4

Compressed air (kg/cm^2)	Mean diameter of particle (μ)
0	40
2	20
4	18

From the above experiments, we may conclude what follows ;

(1) The mean diameter of particles in the case of using compressed air was smaller than that of those in the case of not using compressed air.

(2) The range of deposite is also further in the case of using compressed air than in the case of not using compressed air.

(3) But in these experiments, the air volume of the blast was not changed, therefore the effect of the wind was not investigated.

Experiments Using the 1/10 Model Speedmister by Applied Axial Flow Blower

1) Purpose of the experiment.

As a theoretical consideration, we can decrease liquid volume of spraying in the case of using speedmister more than in the case of using speedsprayer. From the results of experiments of using knapsack type mistsprayer, it was recognized that compressed air of 2 kg/cm^2 was enough for fine atomization.

Therefore, by applying those results the authors attempted to make a 1/10 model of the machine for the future.

By using this model, the experiments of the arriving performance and the atomization in relation to liquid pressure, discharge rate, air volume from the blower, air pressure and air volume of compressed air etc. were planned by the authors.

2) Design and making of the 1/10 model speedmister.

The authors designed the dimensions to make the machine speedmister in future as follows ;

tank of liquid : 150 l
discharge rate : 10 l/min
application rate : 30 l/10 a
arriving radius in the bush of orchard trees 10 m. (effective radius 7.5 m)
air volume : 1000 m^3/min
air velocity : 30 m/s

For this design, several type speedsprayers which are used in general in Japan were investigated, and from these results following values were received as speedsprayer's standard dimensions ;

Table 5

Air volume (m^3/min)	Discharge rate (l/min)
200	30
400	65
900	120

Therefore, the authors fixed the standard of the design for the 1/10 model as follows :

air volume : 100 m^3/min
discharge rate : 2～5 l/min
liquid pressure : 2 kg/cm^2
compressed air : 2 kg/cm^2

For the apparatus of the 1/10 model speedmister, following parts of the machine were used. (Fig. 4)

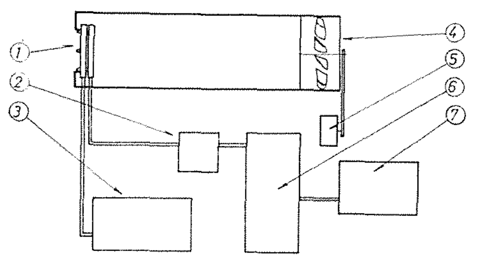


Fig. 4 Diagram of experimental apparatus for the 1/10 model speedmister.
① : nozzle
② : low pressure adjusting apparatus
③ : air compressure
④ : axial flow type blower
⑤ : moter
⑥ : power sprayer
⑦ : liquid tank

blower : axial flow type blower, 1 ps, 1800 rpm, air volume 106.2 m^3/min

pump : horizontal type 3 plunger power sprayer 2 { large size : 3 ps; small size : 1 ps }

low pressure adjusting apparatus : made by way of trial by authors

air compressure : 3 phase 2.2 kw, 1200 rpm, pressure 10 kg/cm^2, air volume 460 l/min

test nozzles : (Fig. 5)

for speedmister { trial type nozzle for speedmister, 4 nozzle heads }

for speedsprayer { whirl nozzle, 4 nozzle heads, nozzle hole 4 mmϕ }

3) Conditions of experiments.

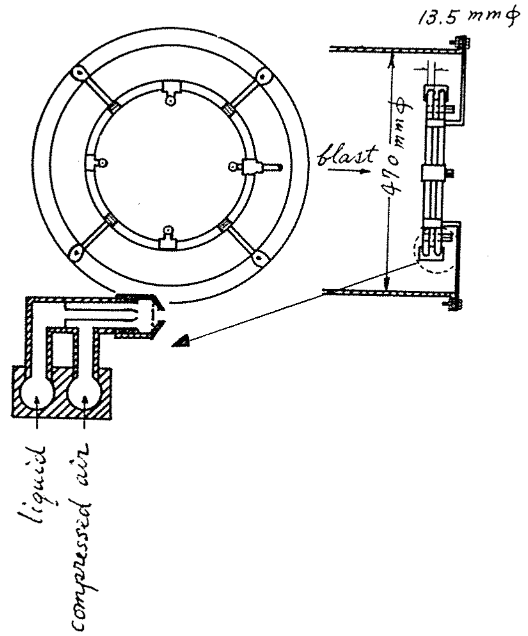


Fig. 5 Dimensions of nozzle parts of the 1/10 model speedmister.

Experiments were carried out under the following conditions,

a. Measuring the discharge rate.
b. Measuring performance of blower.
c. Arriving performance of particle.
d. Atomization performance of nozzle.

And as experimental conditions, following three conditions were given.

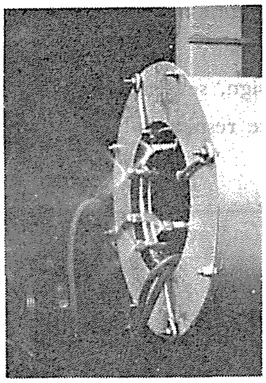


Fig. 6 Nozzle parts of the 1/10 model speedsprayer.

Exp.I speedsprayer I type (Fig. 6)

blower : 2000 rpm (90 m^3/min)
liquid pressure : 10 kg/cm^2
discharge rate : 10∼15 1/min
air speed : 23.6 m/s
nozzle : 4 head whirl nozzle, nozzle hole 4 mmφ
outlet of blower : cover used

Exp.II speedsprayer II type

blower: 2000 rpm (110 m^3/min)
liquid pressure : 10 kg/cm^2
discharge rate : 15 1/min
air speed : 11.7 m/s
nozzle : 4 head whirl nozzle, nozzle hole 4 mmφ
outlet of blower : not cover used

Exp.III speedmister type (Fig. 7)

blower : 2000 rpm (110 m^3/min)
liquid pressur : 2 kg/cm^2
discharge rate : 2∼5 1/min
air speed : 11.7 m/s
compressed air : 2 kg/cm^2
nozzle : trial type nozzle for speedmister, 4 nozzle head, nozzle hole 4 mmφ

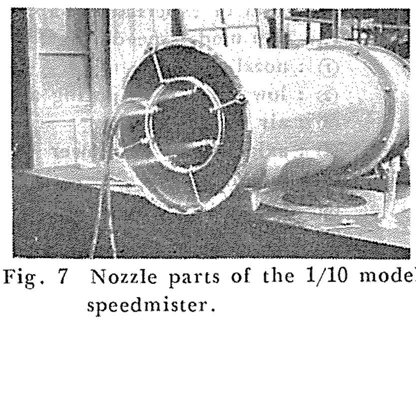


Fig. 7 Nozzle parts of the 1/10 model speedmister.

outlet of blower : not cover used

4) Results and discussion of experiments.

a. Discharge rate.

The results of the experiment are given in Fig. 8.

b. Performance of blower (characteristics of blower).

The characteristic experiments carried out by basing of "blower testing method JIS B 8330", and these experimental results were given in Fig. 9.

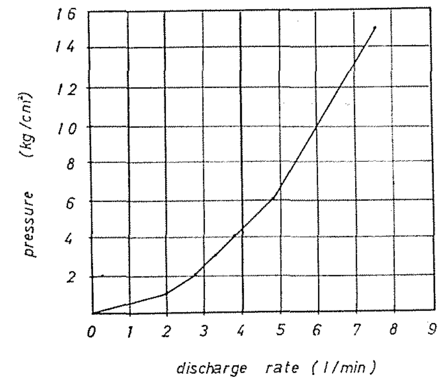


Fig. 8 Discharge rate of nozzle.

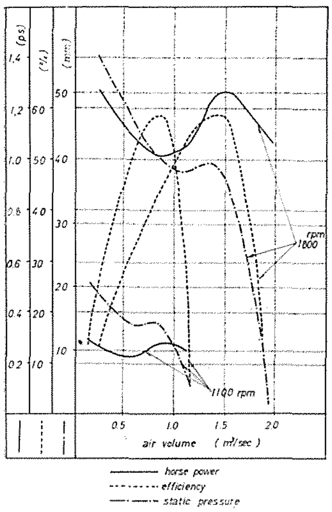


Fig. 9 Characteristics curves of the axial flow type blower.

c. Arriving performance of particle.

The same experimental method was applied as used in the experiment of knapsack type mistsprayer described above. The results of experiments are given in Fig. 10.

From these results the maximum distributed point of liquid was obtained as follows.

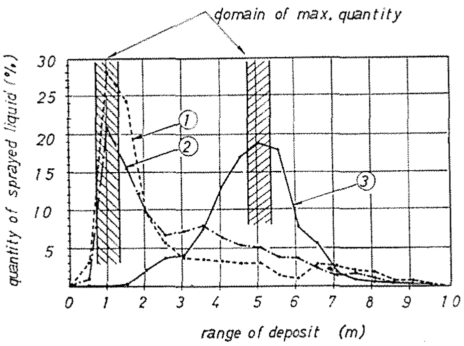


Fig. 10 Quantity of sprayed liquid to the range of deposit.
① : Exp. I
② : Exp. II
③ : Exp. III

Table 6

Outlet of blower	Compressed air (kg/cm^2)	Maximum distributed point of liquid (m)
No cover	0	5
Cover used	2	1
No cover	2	1

d. Atomization performance of nozzle.

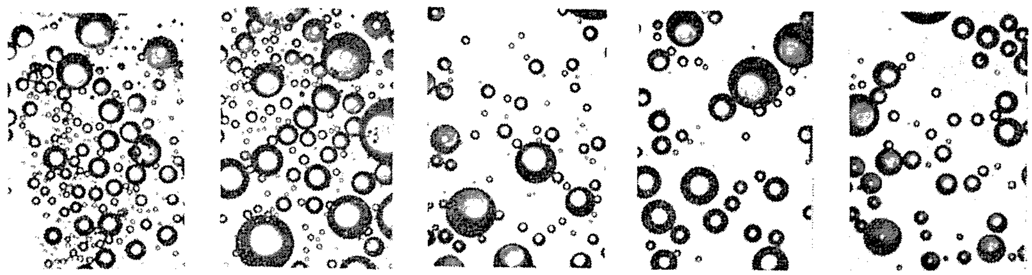
The particles were caught on the preparate glass and a microphotograph was taken of these samples, and the mean diameter of particles was calculated by the authors.

These results are given in Table 7.

Table 7

Outlet of blower	Compressed air (kg/cm^2)	Mean diameter of particle (μ)
No cover	0	80
Cover used	2	100
No cover	2	60

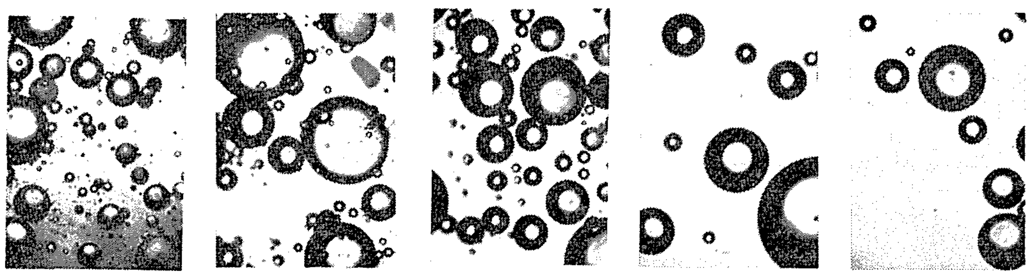
Also, some microphotographs of particles are shown in Fig. 11.



1 = 1 m 1 = 2 m 1 = 3 m 1 = 4 m 1 = 5 m

compressed air Pa = 4 kg/cm^2

(a) speedmister



1 = 1 m 1 = 2 m 1 = 3 m 1 = 4 m 1 = 5 m

compressed air Pa = 0 kg/cm^2

(b) speedsprayer

Fig. 11 Microphotographs of the particles.

From the above experiments, we may conclude as follows ;

(1) For an air volume of blast 100 m^3/min, mistparticles (mean diameter was 60μ) were obtained by using liquid chemicals of 2 kg/cm^2, 2 l/min and compressed air of 2 kg/cm^2.

(2) By using compressed air, the arriving performance had been increased largely.

(3) But after this, the particles must be more atomized by improving the nozzle structure until the mean diameter is 20 μ.

Conclusions

In this paper, the authors proposed a new spraying method of chemical liquids, and called it "speedmister".

As the first stage, the principle of speedmister was discussed theoretically. In conclusion, it appears that this principle of speedmister was possible to realize.

Therefore, fundamental experiments have been done continuously by using knapsack type mist-sprayer which is used in usual farming.

As for results, it is clear that the mean diameter of particles in the case of using compressed air was smaller than in the case of not using compressed air.

Next, the authors designed the 1/10 model speedmister of the machine for the future. This model was made by way of a trial.

The experiments by using this model speedmister were carried out with the following resuluts : When the air volume of blast was 100 m^3/min, mistpartcles (mean diameter was 60μ) were obtained by using liquid of 2 kg/cm^2, 2 l/min and compressed air 2 kg/cm^2.

But these mistparticles must be atomized more by improving the nozzle structure.