Original Article

Improvement in Distribution of BPMC Deposits and Classification of Dust Particles*

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A power duster of large maximum air volume (DMD11E) provides faster airflow in the blow head and at the blow holes. With its capacity, such as DMD11E contributes to improve distribution of *o*-sec-butylphenyl methylcarbamate (BPMC) deposits. High control of brown rice planthoppers was possible when insecticidal dusts were applied with such a DMD11E. Buprofezin having vapor action and high insecticidal activity could be applied with a DMD11E with a boom-type blow head. The relationship between the horizontal and vertical deposits of BPMC at the base of rice plant was improved by the use of a power duster of large air volume, and the slope of the regression line of less-drifting dust (DL) was about the same as that of regular dust (RD). Application with a shortened blow head, in contrast, resulted in extremely small deposits of BPMC and in inferior insect control at the end zone of the blow head. Deposition of BPMC in rice plants decreased at the heading stage, but increased at the yellow-ripe stage. The diameters of deposited dust particles of RD were mostly less than 10 μm , while particles of 20 to 40 μm diameter were predominant in DL. The amount of BPMC per 1 mm^2 surface area of a particle deposited on a horizontal surface was 0.11 $\mu\text{g}/\text{mm}^2$ in RD and 0.03 $\mu\text{g}/\text{mm}^2$ in DL, and that on a vertical surface 0.20 $\mu\text{g}/\text{mm}^2$ in RD and 0.05 $\mu\text{g}/\text{mm}^2$ in DL. This may be the reason for high control of brown rice planthoppers by RD.

INTRODUCTION

Application of chemicals to rice plants with a power duster with a boom-type blow head saves labor, but nonuniformity in deposition is a major problem for control of pests that inhibit at the base of rice plant. In the previous paper,¹⁾ we reported that the deposit distribution of an insecticide varied according to the dust forms and boom-type blow heads used even with the same power duster. In 1986, brown rice planthoppers infested a Hiroshima area, seriously damaging a rice

crop. Damage was severer where less-drifting dust (DL) was applied than where regular dust (RD) was applied. The reasons were the differences in the deposition of insecticide (BPMC) on the rice plant base and in floatability between RD and DL in the space between the bases of rice plants.

We examined two kinds of power dusters different in maximum air volume in order to improve insect control, to clarify serial changes in BPMC deposit as rice plants grow and to classify dust particles applied with boom-type blow heads.

MATERIALS AND METHODS

1. Insecticide

Regular dust (RD) and less-drifting dust (DL) of BPMC (Bassa,[®] *o*-sec-butylphenyl methylcarbamate, *a.i.* 2%, RD: Takeda Chemical industries Ltd., DL: Nihon Nohyaku

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Table 1 Physical properties of insecticidal dusts used.^{a)}

Physical property	RD	DL
Bulk density	0.64	0.92
Dispersibility index	71	95
Drift index	13	9
Fineness (<45 μ m)	94.9	94.9
Moisture content (%)	0.18	0.17

^{a)} Data supplied by Nihon Nohyaku Co., Ltd.

Co., Ltd.) were applied at 40 kg/ha throughout this experiment. The physical properties of the dusts are shown in Table 1. A mixture of buprofezin and BPMC (Applaud-Bassa,[®] 2-tert-buthylimino-3-isopropyl-5-phenyl-3,4,5,6-tetrahydro-2H-1,3,5-thiadiazin-4-one, *a.i.* 1%, plus BPMC, *a.i.* 2%, Nihon Nohyaku Co., Ltd.) was also used at 40 kg/ha.

2. Power Dusters and Boom-type Blow Heads

Two kinds of knapsack-type power dusters were used: DMD11E (Kyoritsu Co., Ltd.) of 24 m³/min maximum air volume and DMD350AE (Kyoritsu Co., Ltd.) of 16 m³/min maximum air volume. The DMD11E was operated at the 8/10 position of engine lever and at the 3/7 (RD) or 2/7 (DL) position of shutter lever. The DMD350AE was operated at the 7/10 position of engine lever and the 6/10 position of shutter lever.

Three kinds of boom-type blow heads were used: DL30A (common type used for RD and DL, Maruyama Mfg. Co., Ltd.), DMH30A (special type for RD, Kyoritsu Co., Ltd.), and DLH30A (special type for DL, Kyoritsu Co., Ltd.) were used. All the blow heads were 30 m long.

3. Examination of Insecticide Deposit Distribution

Paddies (39 m $\times$ 30 m) with rice plants (*Oryza sativa* cultivar Nakate shinsenbon) at the young panicle-formation to the yellow-ripe stage were fumigated. The horizontal and vertical deposition distributions of BPMC were determined as described elsewhere.¹⁾ To examine the horizontal deposition, glass slides coated with silicone grease were placed at crossing points 5, 10, 15, 20 and 25 m from

the blow head base to the end, at 8, 16, 24 and 32 m longitudinally, and at 3 cm above the ground. To examine the vertical deposition, glass slides were placed at crossing points 5, 15 and 25 m from the blow head base to the end, at 8, 16 and 24 m longitudinally, and at 15 cm above the ground.

4. Airflow Velocity

The velocity of the airflow penetrating the blow head and discharged at the blow holes was measured with a micro-manometer equipped with a pitto tube 3 mm in diameter (DP-1000A, Okano Works Co., Ltd.). The DMD11E power duster was operated at the 8/10 position of engine lever, and the DMD350AE at the 7/10 position. The airflow rate from the pipe base to the end was measured every 5 m to compare the two power dusters and every 3 m to examine a shortened blow head.

5. Insecticidal Effect of Buprofezin-BPMC Mixture on the Brown Rice Planthopper

To determine the insecticidal effects of BPMC and buprofezin-BPMC mixture, we counted the number of brown rice planthoppers (*Nilaparvata lugens* Stål) before and after applications of the insecticides and calculated the mortality 1, 4, 7 and 14 days after application as described elsewhere.¹⁾

6. Gas Liquid Chromatography

Quantitative analysis of BPMC was done with a gas-liquid chromatograph (Shimadzu GC-15A, Shimadzu Co., Ltd.) equipped with an FTD-8 detector (Shimadzu Co., Ltd.). A 3 mm ϕ $\times$ 1.5 m glass column packed with 1.5% silicone OV-17 plus 1.95% silicone DC QF-1 on Chromosorb W(HP) (80-100 mesh) was used at 170°C. The flow rates of carrier gas (helium) of air and of hydrogen were 50, 200 and 3 ml/min, respectively. The injection volume was fixed at 2 μ l.

7. Measurement of Diameters of Dust Particles

To measure the diameters of dust particles deposited on the horizontal and vertical surfaces of rice plant bases, glass slides were placed at crossing points 5, 15 and 25 m from the blow head base to the end and at 24 m longitudinally. After applying dust, we

photographed particles deposited on the glass slides and calculated the average diameter from the maximum and minimum diameters of the particles. The surface areas of the particles deposited were calculated on the basis of the particles being spherical.

RESULTS

1. Comparison in Velocity of Airflows Penetrating the Blow Head and Discharged at the Blow Holes

The velocity of the airflow penetrating the DL30A blow head (30 m) decreased gradually toward the pipe end in both power dusters tested, but the airflow was faster in the DMD11E of 24 m³/min maximum air volume than the DMD350AE of 16 m³/min maximum air volume (Fig. 1-A). The velocity of the discharged air at the blow holes was also faster with the DMD11E than with the DMD350AE (Fig. 1-B), and so was the case with other blow heads, as described elsewhere.¹⁾

2. Improvement in Uniformity of BPMC Deposit Distribution in Paddies

A larger amount of BPMC dust was deposited horizontally at rice plant bases when RD was applied with a DMD11E equipped with a DL30A blow head than when it was applied with a DMD350AE (Fig. 2). The uniformity of deposition distribution at the end zone of the pipe was improved by the use of the DMD11E. A similar tendency was observed when DL was applied with the DMD11E equipped with a DL30A blow head. The deposits of BPMC were also uniform on the vertical surface, sufficient to produce a control effect when BPMC was applied with the DMD11E as described in Section 3.

3. Control Effects of BPMC and Buprofezin on Brown Rice Planthoppers

BPMC caused greater mortality in brown rice planthoppers when applied with a DMD11E than with a DMD350AE one day after application (Table 2). Insect mortality by a buprofezin-BPMC mixture was more than 90% at almost all points on the blow head one to 14 days after application (Table 3). An application of BPMC alone did not always result in high insect mortality.

Fig. 1 Airflow rates in a blow head (DL30A) (A) and at blow holes (B).

●, DMD11E; ○, DMD350AE.

Fig. 2 Horizontal distribution of BPMC (RD) deposits applied with two kinds of power dusters equipped with a boom-type blow head (DL30A).

A, DMD350AE; B, DMD11E.

4. Effect of Pipe Shortening on Deposit Distribution and Control of Brown Rice Planthoppers

When the blow heads were shortened to 20 m (from the original 30 m) by squeezing the blow head tip, the distribution of BPMC was not uniform, and the amount of BPMC deposited was extremely small at the pipe

Table 2 Effect of BPMC on control of brown rice planthoppers when DL dust was applied to paddies with DMD11E and DMD350AE power dusters with boom-type (DL30A) blow heads.^{a)}

Power duster	Observed position at blow head	No. of brown rice planthopper (Mortality %)		
		Before application	1 day after application	3 days after application
DMD11E	Base	602	53 (91.0)	8 (98.7)
	Middle	550	23 (96.1)	9 (98.7)
	End	456	62 (84.5)	103 (77.2)
	(Ave.)		(90.5)	(91.5)
DMD350AE	Base	365	34 (89.0)	12 (96.3)
	Middle	242	22 (87.6)	16 (91.2)
	End	208	44 (76.6)	23 (88.1)
	(Ave.)		(84.4)	(91.9)

^{a)} Paddies in the experiments measured 30 m×30 m. The number of brown rice plant-hoppers were counted for groups of five rice plant hills. Values shown are the averages of three groups at each observation position.

Table 3 Effect of DL dust mixed with buprofezin and BPMC, and of BPMC dust on control of brown rice planthoppers in paddies.^{a)}

Days after application	Buprofezin+BPMC				BPMC			
	Base	Middle	End	Ave.	Base	Middle	End	Ave.
1	96.7 ^{b)}	92.1	91.1	93.3	96.4	72.7	85.4	84.8
4	91.1	84.6	89.0	88.2	82.7	68.0	83.5	78.1
7	89.8	92.0	96.0	92.6	78.6	55.8	84.4	72.9
14	95.6	97.4	99.2	97.4	95.1	85.7	91.1	90.6

^{a)} Dust was applied to a paddy with a DMD350AE duster equipped with a DL30A at 40 kg/ha.

^{b)} Mortality (%) of brown rice planthoppers.

Fig. 3 Horizontal distribution of BPMC deposits applied with a power duster (DMD350AE) equipped with boom-type blow heads shortened to 20 m from the original 30 m.

A, RD-DL30A; B, DL-DL30A; C, RD-DMH30A; and D, DL-DLH30A.

Table 4 Effect of BPMP on control of brown rice planthoppers when the boom-type blow head (DL30A) was shortened to 24 m from original 30 m.^{a)}

Dust form	Power duster	Observed position at blow head	No. of brown rice planthoppers (Mortality %) ^{b)}		
			Before application	1 day after application	3 days after application
RD	DMD11E	Base	310	46 (85.9)	50 (84.1)
		Middle	424	19 (95.5)	21 (95.3)
		End	363	166 (50.1)	161 (53.1)
	DMD350AE	Base	179	25 (79.8)	29 (77.7)
		Middle	366	25 (90.2)	9 (97.4)
		End	247	83 (66.0)	76 (70.3)
DL	DMD11E	Base	134	18 (87.2)	5 (95.5)
		Middle	966	89 (90.8)	14 (98.5)
		End	1156	916 (22.0)	324 (70.6)
	DMD350AE	Base	151	17 (88.4)	5 (96.3)
		Middle	631	37 (92.4)	6 (98.7)
		End	845	483 (54.9)	395 (56.5)

^{a)} Paddies measured 24 m × 40 m.^{b)} The number of brown rice planthoppers was counted for groups of 10 rice plant hills. Values given are the averages of three groups at each observation position.

Fig. 4 Airflow rate in a blow head (●, ○) and at blow holes (▲, △) of DL30A.

●, ▲, 30 m; ○, △, 20 m.

end, except for when it was applied with a DMH30A (Fig. 3). The airflow rates in the blow head and at the blow holes were lower when the blow head (DL30A) was shortened (Fig. 4). When dusts were applied from this shortened blow head the number of insects killed was also smaller at the pipe end where BPMP deposits were small in amounts (Table 4).

Fig. 5 Relationship between horizontal (X) and vertical (Y) deposits of BPMP.

●, RD: $Y = 109.6 + 0.58X$ ($n = 36$, $r = 0.567^{**}$); ○, DL: $Y = 127.2 + 0.53X$ ($n = 36$, $r = 0.325^{*}$).

5. Relation between Horizontal and Vertical Deposits of BPMP

The horizontal and vertical deposits of BPMP when a DMD11E (maximum air volume

Fig. 6 Serial change in the horizontal (A, B) and vertical (C, D) deposits of BPMC as rice plants grow.

A and C, DMD11E; B and D, DMD350AE. ■, RD; □, DL.

24 m³/min) was used were correlated; the correlation coefficient was smaller for DL than for RD (Fig. 5). The amount of BPMC deposited on the horizontal surface, however, was more than 40 g/ha and on the vertical surface more than 90 ng/cm².

6. Serial Changes in the Amount of BPMC Deposited on Rice Plant Bases

The amount of BPMC deposited on the horizontal surface with power dusters with a boom-type blow head gradually decreased as rice plants grew from the young panicle formation (8/7–8/14) to the heading stage (8/25–9/1), and it increased toward the yellow-ripe stage (9/16–9/29) (Fig. 6-A, B). Serial changes in the BPMC deposit on the vertical surface were not as clear, but the amount deposited was relatively small from the heading to the yellow-ripe stage (9/16–9/29) (Fig. 6-C, D).

7. Classification of Dust Particles Applied with Boom-type Blow Heads

After dust was applied with a power duster with a DMH30A or DLH30A attachment, the diameters of particles deposited on the horizontal surface were measured (Fig. 7). The number of particles having a diameter of less than 10 μ m was 87–90% of the total RD particles deposited at all positions (Fig. 7-B). Particles 40–50 μ m in diameter were found at the end of the pipe. In contrast, when DL

Fig. 7 Ratio of the number of particles of each size to the total number of dust particles deposited on a horizontal surface.

A, DL; B, RD. ■, Blow head base; ▨, Blow head middle; □, Blow head end.

was applied, the ratio of the number of particles having a diameter of less than 10 μ m to the total number was 51% at the base, 49% at the middle, and 26% at the end of the pipe (Fig. 7-A), the number of particles having a diameter of more than 10 μ m increasing at the middle and end of the pipe. Results were

Table 5 Classification of dust particles applied with a DMD11E power duster with boom-type blow heads.^{a)}

Dust form	Observed position at blow head	Average diameter of particles (μm)		Average surface area of particles (μm^2)		Number of particles ($\times 10^3/\text{cm}^2$)		Amount of BPMP carried on 1 mm ² of particle surface ($\mu\text{g}/\text{mm}^2$)	
		Hori-zontal ^{b)}	Ver-tical ^{c)}	Hori-zontal	Ver-tical	Hori-zontal	Ver-tical	Hori-zontal	Ver-tical
DL	Base	12.3	16.2	800.0	1133.9	7	0.6	0.025	0.042
	Middle	14.8	18.0	1242.6	1776.1	6	0.6	0.026	0.054
	End	19.6	20.6	1698.2	1791.5	7	0.7	0.040	0.053
	(Ave.)	(15.6)	(18.3)	(1246.9)	(1567.2)	(6.7)	(0.6)	(0.030)	(0.050)
RD	Base	5.3	6.5	138.7	269.7	55	4	0.073	0.070
	Middle	5.5	7.6	191.5	376.5	23	2	0.194	0.342
	End	7.1	7.9	295.3	322.0	31	2	0.063	0.201
	(Ave.)	(6.0)	(7.3)	(208.5)	(322.7)	(36.3)	(2.7)	(0.11)	(0.204)

^{a)} Boom-type blow heads used; DMH30A for RD application and DLH30A for DL application.

^{b)} Horizontal surface.

^{c)} Vertical surface.

Fig. 8 Ratio of the number of particles of each size to the total number of dust particles deposited on a vertical surface.

A, DL; B, RD. ■, Blow head base; ▨, Blow head middle; □, Blow head end.

Fig. 9 Ratio of the surface area of individual particles to the total area of all particles deposited on a horizontal surface.

A, DL; B, RD. ■, Blow head base; ▨, Blow head middle; □, Blow head end.

similar for the particles deposited on the vertical surface (Fig. 8-A, B). The average diameters of particles deposited on the hori-

zontal surface were 15.6 μm for DL and 6.0 μm for RD, and on the vertical surface 18.3 μm for DL and 7.3 μm for RD (Table 5). The

Fig. 10 Ratio of the surface area of individual particles to the total area of all particles deposited on a vertical surface.

A, DL; B, RD. ■, Blow head base; ▨, Blow head middle; □, Blow head end.

number of RD particles deposited on 1 cm² of horizontal surface was 55,000 at the base, 23,000 at the middle, and 31,000 at the end of the pipe, and was 7000 at the base, 6000 at the middle, and 7000 at the end for DL. On the vertical surface, the number was 4000 at the base, 2000 at the middle, and 2000 at the end for RD, and 600, 600 and 700 for DL.

A surface area of RD particles having a diameter of less than 20 μm was 56.8–87.9% of the total surface of particles deposited on the horizontal surface (Fig. 9-B). A surface area of DL particles having a diameter of less than 10 μm accounted for only a few percent, while an area of those having a diameter of 20 to 40 μm made up 66.3–75.2% of the total area (Fig. 9-A). Results were similar on the vertical surface (Fig. 10-A, B). For the RD deposited on the horizontal surface, the amount of BPMC on 1 mm² of particle surface area was 0.073 μg at the base, 0.194 μg at the middle, and 0.063 μg at the end of the pipe (Table 5), and for DL, the amount was 0.025 μg at the base, 0.026 μg at the middle, and 0.040 μg at the end of the pipe. The average value for RD (0.11 μg/mm²) was

greater than that for DL (0.030 μg/mm²), and so was the case with RD and DL particles deposited on the vertical surface.

DISCUSSION

Elsewhere¹⁾ we reported that the deposit distribution of insecticidal dust applied with the power duster DMD350AE (maximum air volume of 16 m³/min) equipped with boom-type blow heads differed according to the combination of dust form and boom-type blow head used, the control of brown rice planthoppers emerging from around the rice plant bases being inferior where the deposits were small in amounts. In order to improve the distribution of insecticidal dust deposits, we tested a DMD11E that has a maximum air volume of 24 m³/min and obtained the following results.

When a DMD11E power duster with a DL30A blow head was used the amount of BPMC deposited was generally greater than when a DMD350AE was used, and the deposit distribution was more uniform (Fig. 2). Deposit distribution was also improved at the end zone of the pipe. Results were similar when the DMD11E duster was used with a DMH30A or DLH30A head.

The horizontal and vertical deposits of BPMC applied with the DMD11E were correlated, and the slopes of the equation were nearly the same for RD and DL (Fig. 5). Moreover, when the DMD11E was used the horizontal and vertical deposits of BPMC exceeded the LD₅₀ value for the brown rice planthopper: 39.8–34.3 g/ha for horizontal deposits and 46.2–39.3 ng/cm² for vertical deposits.¹⁾ Insect mortality was higher with the DMD11E than with the DMD350AE (Table 2).

The blowing pressure of DMD11E, which has a large air volume, was greater than that of DMD350AE at the blow holes (Fig. 1). Our view is that a power duster of large air volume is more useful for control of insects and for the improvement of deposit distribution. Tabaru *et al.* have reported that elevation of the engine lever to a higher position resulted in high blowing pressure, large deposit and effective control of brown rice planthoppers.²⁾

Rice plants that had reached maximum length at the heading stage were thick with

leaves, which prevented insecticidal dust from reaching the plant bases (Fig. 6). During a ripening period, however, the leaves at the bases of rice plants were dying off, and the space between plant bases was widened.³⁾ Once the dust penetrated the plant canopy and was blown into the plant base space it floated for a long time and was effectively deposited on the bases of the plants. Nonaka *et al.* also have reported increased deposition during the late stage of rice cropping.⁴⁾

In practice, the shape of rice field often necessitates us to shorten a boom-type blow head. But, when we shortened a blow head, the deposition of BPMC was not uniform and the amount deposited at the end of the pipe was extremely small (Fig. 3). We believe that the amount of dust carried out of the pipe end greatly decreased because the airflow rate decreased in the shortened pipe (Fig. 4). Control effect on brown rice planthoppers was also low at the pipe end position (Table 4). This result showed that the blow head should be used, if at all possible at the original length.⁵⁾ If the pipe need to be shortened, however, it would be better to shorten it at the base, not at the blow head tip.⁶⁾

The use of buprofezin, a new insecticide that has vapor and high insecticidal actions, was advantageous for control of planthoppers resistant to carbamate and organophosphorus insecticides. Its use also countered the inferior control of planthoppers caused by the non-uniformity of insecticide deposition (Table 3).

Theoretically, the specific surface area of particle is small in DL of large particle size, and so the amount of a chemical carried by the unit area is large. But the amount of a chemical carried on 1 mm² of particle surface was smaller for DL (0.03 µg/mm²) than for RD (0.11 µg/mm²), when particles were actually deposited on the plant base (Table 5), which indicates that ingredients might not be distributed effectively by carriers of DL. In addition, the number of particles deposited on the rice plant base was much larger for RD than for DL (Table 5), and the RD particle size was small (Figs. 7 and 8). The results showed that RD were advantageous in floatability and deposition. The factors noted above may account for better control of brown rice plant-

hoppers by RD than by DL.¹⁾

In order to improve insecticide deposition, we examined the relation of power dusters to boom-type blow heads. Physical properties of insecticidal dusts and dust formulation techniques, however, also affect the distribution of dust deposits. Both types of factors must be taken into account if the distribution of dust deposits and the control of insects are to be improved.

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要 約

散布むらの改善と粉剤粒子の分級*

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パイプダスタ散布において散粉機の風量を大きくすると、ホース内、噴孔部の風速が高くなり、BPMCの散布むらやトビイロウンカ防除効果が改善された。また、ブプロフェジンのように、ガス効果を示し、かつ高い殺虫力をもつ薬剤では、散布むらによる防除むらもある程度改善された。単位平面落下量当りの垂直面付着量の関係を見ると、風量の大きな散粉機では、普通粉剤 (RD)、DL 粉剤 (DL) とともにその回帰式はほぼ同じ勾配を示し、DL での付着性の改善がみられた。一方、ホース先端を短縮すると、先端部における薬剤落下量が著しく減少し、防除効果も大きく減退した。水稻生育時期別の平面落下量をみると、茎葉の繁茂する幼穂形成期から出穂期にかけて減少した。その後、登熟期にかけては、下葉の枯れ上がりに伴い、落下量は徐々に増加した。パイプダスタ散布された粉剤の落下粒子の粒径分布をみると、

* パイプダスタによる水稻病害虫防除法に関する研究 (第2報)

RD では、粒径 $10\text{ }\mu\text{m}$ 以下のものがほとんどを占めていたが、DL では、 $20\sim 40\text{ }\mu\text{m}$ の粒径のものが多く落下していた。平面落下粒子の粒子表面積 1 mm^2 当りの薬量をみると、RD が $0.11\text{ }\mu\text{g/mm}^2$ 、DL が $0.03\text{ }\mu\text{g/mm}^2$ 、垂

直面付着粒子では RD $0.2\text{ }\mu\text{g/mm}^2$ 、DL $0.05\text{ }\mu\text{g/mm}^2$ となり、いずれも RD が多く、このことが DL より RD のほうが高い殺虫効果を示す一因と思われた。