J. Trop. Agric and Fd. Sc. 25(2) (1997): 239–248

Spraying performance of lever-operated and motorised knapsack sprayers, and motorised mistblower on rice crop

(Prestasi penyemburan alat penyembur galas beroperasi tuil dan yang bermotor serta penyembur kabus bermotor pada tanaman padi)

M. Md. Jusoh*

Key words: insecticide spraying, knapsack sprayer, mistblower, rice crop

Abstrak

Parameter fizikal semburan bagi tiga teknik menyembur tanaman padi dengan menggunakan penyembur galas beroperasi tuil dan yang bermotor serta penyembur kabus bermotor dengan pelbagai gabungan muncung telah ditentukan. Hasil daripada kajian menunjukkan bahawa penyembur galas bermotor yang dipasang dengan joran 5 muncung memberikan isipadu semburan yang tertinggi iaitu 284 L/ha serta liputan dan resapan sembur yang terbaik. Akan tetapi, penggunaannya menyebabkan pencemaran titik sembur pada para penyembur. Isipadu semburan terendah mungkin (0.06 L/ha) dicapai dengan menggunakan penyembur kabus bermotor yang dipasangkan muncung isipadu ultrarendah. Kadar kerjanya tertinggi 6.96 ha/orang sehari dengan kecekapan menyembur 100% dicapai apabila penyembur kabus ini dikendalikan pada injap penuh, pembatas aliran nombor 3 dan kelajuan berjalan 28 m/min. Pencemaran paling tinggi di bahagian paha dan tangan kanan tak kira apa gabungan penyembur dan muncung yang digunakan. Teknik menyembur tanpa mengayun menghasilkan liputan dan resapan sembur yang lebih baik dan mengurangkan pecemaran sembur sebanyak 60%. Walaupun mengayun joran penyembur ke kiri dan kanan terutama pada 160 ° meningkatkan kadar kerja sebanyak 50%, cara ini mengurangkan kecekapan menyembur dan meningkatkan pencemaran. Penyembur kabus bermotor yang dipasangkan muncung standard atau muncung peresap sudut lebar telah memberi jalur sembur yang paling lebar sehingga 10 m hemburan mendatar. Kelajuan berjalan yang paling berkesan (dari segi liputan dan kadar kerja yang amat baik) apabila mengendalikan penyembur kabus ialah 36 m/min. Pada isipadu semburan 143 L/ha, penyembur kabus bermotor menghasilkan liputan yang ketara lebih baik pada bahagian atas pokok padi. Dengan demikian, isipadu 143 L/ha dapat mengurangkan populasi bena hijau dengan lebih berkesan daripada isipadu semburan terendah 27 L/ha. Tiada perbezaan yang ketara dari segi liputan titik sembur di bahagian bawah pokok padi apabila isipadu sebanyak 27–147 L/ha digunakan. Dengan demikian, tiada pengurangan yang ketara dalam populasi bena perang.

*Strategic, Environment and Natural Resources Research Centre, MARDI Headquarters, P. O. Box 12301, 50774 Kuala Lumpur, Malaysia
Author's full name: Md. Jusoh Mamat

Abstract

The physical spray parameters of three rice crop-spraying techniques using lever-operated and motorised knapsack sprayers, and motorised mistblower in combination with various nozzles were determined. Results showed that motorised knapsack sprayer fitted with a 5 nozzle boom gave the highest application volume of 284 L/ha as well as the best penetration and coverage of spray droplets. However, it was the worst in terms of contamination of spray droplets on operators. The lowest possible application volume (0.06 L/ha) was achieved with the motorised mistblower fitted with an ultra-low volume nozzle. Such mistblower gave the highest work rate of 6.96 ha/man-day with 100% spraying efficiency when operated at full throttle, restrictor number 3 and a walking speed of 28 m/min. Regardless of sprayer-nozzle combinations, contamination was highest on the right thigh and right hand. The no-swing spray technique gave better coverage as well as penetration, and reduced spray contamination by 60%. Although swinging the lance left and right especially at 160 ° increased the work rate by 50%, it reduced spray efficiency and increased contamination. The mistblower fitted with either a standard nozzle or a wide-angle diffuser nozzle achieved the widest effective swath of up to 10 m of horizontal throw. The most effective walking speed (in terms of having very good coverage and work rate) when operating a mistblower was 36 m/min. At a spray volume of 143 L/ha, the mistblower resulted in significantly better coverage of the upper parts of rice plants. Thus correspondingly, it resulted in better reduction of the green leafhopper population than the lowest application volume of 27 L/ha. No significant difference in terms of spray droplet coverage of the lower part of rice plants was recorded when spray volumes of 27–143 L/ha was used. Hence, there was no significant reduction in the brown planthopper populations.

Introduction

In Malaysia, insecticides for the control of rice insect pests are mostly applied by foliar spray technique (Zam 1980; Lim et al. 1983; Md. Jusoh et al. 1985). Such applications are done almost exclusively using the lever-operated knapsack sprayer (80%), motorised mistblower and motorised knapsack sprayer (2%) (Heong et al. 1992).

However, there is limited information on the mechanics of how these equipment are being used in rice crops, especially the physical spray parameters (flow rate, spray volume, walking speed, swath width, work rate, coverage of spray droplets on sprayed surfaces, penetration and spray droplet contamination on the spray operator's body). Such information is essential to the extension officials and field technicians for effective training of the spray operators who are either farmers, farm hands or plantation workers, to do the job efficiently and safely. A study was, therefore, carried out for this purpose.

Materials and methods

This study comprised four experiments. In the first experiment, rice plots of 100 m x 50 m were sprayed with irrigation canal water using 14 combinations of sprayers and nozzles commonly used locally *(Table 1)*.

Sprayings were done at 45 and 90 days after transplanting (DAT), using three spraying techniques: 160 ° and 70 ° swing, and no swing *(Figure 1)*. Four different spray operators replicated each treatment. Before the plot was sprayed, 20 hills within the plot were randomly chosen for the sampling of spray droplet coverage. Each hill was tagged with water-sensitive papers on the upper leaf surface, stem surface of outer tillers and stem surface of inner tillers.

Table 1. Fourteen combinations of sprayers, nozzles and operational settings used in the first experiment to spray insecticide on rice crop

Sprayer-nozzle combination	Sprayer	Nozzle	Operational setting
LOK-SCN	Lever-operated knapsack	Standard (1/16") hollow-cone	–
LOK-VLVN	Lever-operated knapsack	Very low volume (1/32") hollow-cone	–
LOK-SOAN	Lever-operated knapsack	Single orifice (3/64") adjustable hollow-cone	–
LOK-QOAN	Lever-operated knapsack	Quadruple orifice (3/64") adjustable solid-cone	–
MM-SN T3R1	Motorised mistblower	Standard	Throttle no. 3 and restrictor no. 1
MM-SN T3R3	Motorised mistblower	Standard	Throttle no. 3 and restrictor no. 3
MM-ULVN T3R3	Motorised mistblower	Ultra-low volume	Throttle no. 3 and restrictor no. 3
MM-ULVN T3R6	Motorised mistblower	Ultra-low volume	Throttle no. 3 and restrictor no. 6
MK-DFN TFPI	Motorised knapsack	Double-fan	Full throttle and pressure for insecticide
MK-ASCN TFPI	Motorised knapsack	Adjustable solid-cone	Full throttle and pressure for insecticide
MK-DWAN TFPI	Motorised knapsack	Driftless wide-angle	Full throttle and pressure for insecticide
MK-DCN TFPI	Motorised knapsack	Double hollow-cone	Full throttle and pressure for insecticide
MK-3NRC TFPI	Motorised knapsack	Ringed triple hollow-cone	Full throttle and pressure for insecticide
MK-5NB TFPI	Motorised knapsack	Five-nozzle boom	Full throttle and pressure for insecticide

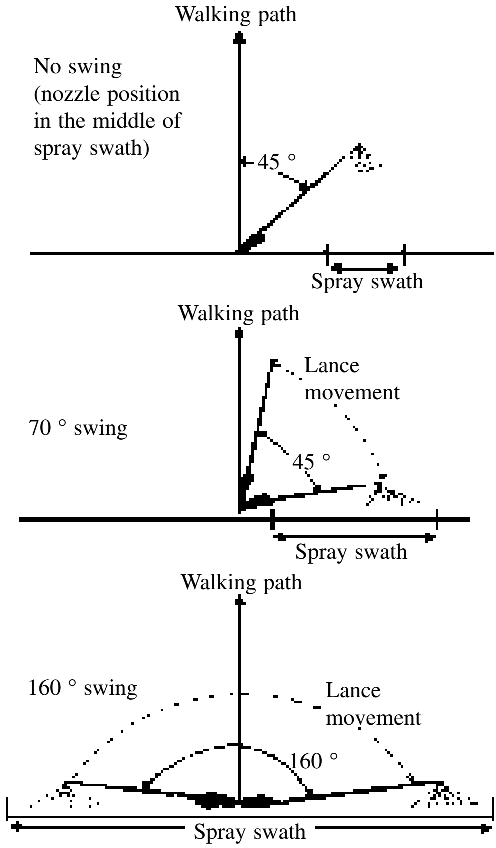

Figure 1. Three spraying techniques used in the experiments

The water-sensitive papers were collected and ranked according to a ranking scheme of 1–4 (1 = 0–20 droplets/cm^2, 2 = 21–60 droplets/cm^2, 3 = 61–300 droplets/ cm^2 and 4 = >300 droplets/cm^2) after application. Each spray operator was also tagged with water-sensitive papers on the forehead, chest, right biceps, both hands, waist and right thigh for body contamination with the spray droplets. The water-sensitive papers were collected after completing 3 min of spraying and ranked according to the scheme of 1–4. To determine the work rate, the time taken (inclusive of actual spraying time, refilling time and ferrying time) by each spray operator to complete spraying each treatment plot was recorded.

The second, third and fourth experiments dealt specifically with the spray parameters for mistblowers. There seems to be a lot of variations among farmers in adopting some of these parameters such as spray swath, walking speed and spray volume as observed in the rice fields. In the second experiment, effective spray swath for mistblower was determined at 45 DAT using water-sensitive papers. The papers were tagged on the stem surface of outer tillers at distances of 5, 10, 15, 20, and 25 m from the walking path at the beginning of the plot. The treatments consisted of seven different nozzles. Four different spray operators replicated each treatment.

The third experiment determined the effective walking speed for mistblower at 45 DAT. Three speeds were evaluated using the misblower fitted with a wide-angle spray nozzle. The coverage of spray droplets on the stem surface of outer tillers and work rate were used to determine the spray effectiveness. Each hill at 5, 10, 15, 20 and 25 m from the walking path was tagged with water-sensitive papers and each point was replicated with 10 hills per treatment.

The fourth experiment determined the effect of spray volume on the coverage of spray droplets on rice plants, and its effectiveness in reducing the brown planthopper (BPH) and green leafhopper (GLH) populations at 45 DAT. Using mistblower fitted with a wide-angle nozzle, four spray volumes were obtained as treatments by regulating the restrictor to number 1, 2, 3 and 4. The same amount of BPMC insecticide (at 500 mL/ha) was used in each treatment per plot; only the amount of water varied according to treatment. The coverage of spray droplets on the upper leaf surface and stems of outer tillers was assessed by tagging 10 hills per treatment with water-sensitive papers at 5 m from the spray walking path. BPH and GLH on 20 hills per plot in each treatment were counted a day before spraying (DBS), and 1 and 14 days after spraying (DAS). Each treatment consisted of four replicates.

Results

Results of the first experiment showed that the mean walking speed of the four spray operators was 26 m/min when operating the lever-operated and motorised knapsack sprayers, and 30 m/min when operating the mistblower *(Table 2).* The highest application volume of 284 L/ha was achieved by the motorised knapsack sprayer fitted with a 5-nozzle boom (operated at full throttle and pressure for insecticide spraying,

Table 2. Mean flow rate, swath, walking speed and application volumes using 14 sprayer-nozzle combinations on rice crop (45 and 90 days after transplanting) via 160 ° swing spraying technique

Sprayer-nozzle combination	Flow rate (L/min)	Swath (m)	Walking speed (m/min)	Application volume (L/ha)
LOK-SCN	0.85	4	23.31	98.50de
LOK-VLVN	0.27	4	24.84	30.13f
LOK-SOAN	0.36	4	26.36	37.25f
LOK QOAN	1.57	4	27.96	153.75c
MM-SN T3R1	4.50	7	29.40	232.00b
MM-SN T3R3	5.84	7	31.55	283.00a
MM-ULVN T3R3	0.001	7	27.61	0.06g
MM-ULVN T3R6	0.015	7	30.43	0.80g
MK-DFN TFPI	1.88	9	24.23	90.38e
MK-ASCN TFPI	2.45	9	25.33	112.50d
MK-DWAN TFPI	3.15	9	25.50	143.38c
MK-DCN TFPI	1.80	9	25.64	83.00e
MK-3NRC TFPI	1.94	9	25.08	93.75de
MK-5NB TFPI	6.75	9	28.41	283.88a

Mean values with different letters are significantly different ($p < 0.05$) according to DMRT and at a walking speed of 28.41 m/min) and the mistblower fitted with a standard nozzle (operated at throttle speed number 3, restrictor number 3 and a walking speed of 31.55 m/min). The lowest possible application volume of 0.06 L/ha was achieved with the mistblower fitted with an ultra-low volume nozzle (operated at throttle speed number 3, restrictor number 3 and a walking speed of 27.61 m/min).

The highest work rate of 6.96 ha/man-day with 100% spraying efficiency (percentage of time spent on actual spraying over the total time spent on conducting the spraying job inclusive of ferrying and refilling time) was achieved when using the mistblower fitted with an ultra-low volume nozzle operated at throttle speed number 3, restrictor number 3 and a walking speed of 27.61 m/min *(Table 3).* Using the same machine but fitted with a standard nozzle operated at throttle speed number 3, restrictor number 3 and a walking speed of 31.55 m/min produced the lowest work rate of 2 ha/man-day with 26% spraying efficiency. The decrease in work rate and spraying efficiency was caused by a significant increase in refilling and ferrying times due to the high nozzle flow rate and small tank capacity (12 L). However, in terms of spray droplet coverage on plant surfaces and penetration into the plant canopy, the motorised knapsack sprayer fitted with a 5-nozzle boom was the best with mean ranking of 2.97 (300 droplets/ cm^2) on the upper leaf surfaces, 2.63 on the stems of outer tillers and 2.16 on the stems of inner tillers *(Table 4).* The mistblower fitted with an ultra-low volume nozzle operated at throttle speed number 3, restrictor number 3 and a walking speed of 27.61 m/min gave the highest work rate but poor spray coverage and penetration of 0.55 (less than 20 droplets/cm^2) on the upper leaf surface, 0.42 on the stems of outer tillers and 0.21 on the stems of inner tillers.

Use of the motorised knapsack sprayer fitted with a 5-nozzle boom caused the worst spray droplet contamination on spray operators *(Table 5).* The overall mean ranking of 2.7 was considered as heavy contamination (300 droplets/cm^2 of body surface after 3 min of spraying). The mistblower fitted with an ultra-low volume nozzle caused the least contamination of body surface. However, it was not necessarily in terms of quantity of pesticide because it sprayed undiluted pesticide, which was 1 000 times stronger than the diluted spray liquid of other sprayer-nozzle

Table 3. Mean work rate and spraying efficiency using 14 sprayer-nozzle combinations on rice crop (45 and 90 days after transplanting) via 160 ° swing spraying technique

Sprayer-nozzle combination	Refilling & ferrying time (min/ha)	Actual spraying time (min/ha)	Work rate (ha/man-day)	Spraying efficiency (%)
LOK-SCN	33.00f	15.88a	2.64fg	78.20d
LOK-VLVN	6.00g	1.75ab	3.44e	95.58b
LOK-SOAN	10.50ij	103.38bc	3.46e	91.00c
LOK-QOAN	56.25d	98.13c	2.59fg	63.84h
MM-SN T3RI	109.50b	51.63de	2.38fg	32.12k
MM-SN T3R3	137.25a	48.50de	2.08g	26.16l
MM-ULVN T3R3	0.00k	56.88d	6.96a	100.00a
MM-ULVN T3R6	16.50hi	53.13de	5.70ab	75.33e
MK-DFN TFP1	24.50g	48.13de	5.29bc	66.77fg
MK-ASCN TFPI	33.25f	46.00de	4.82cd	58.56I
MK-DWAN TEPI	43.75e	45.63de	4.24d	51.24j
MK-DCN TEPI	22.75gh	46.13de	5.64b	67.59f
MK-3NRC TEPI	26.25fg	48.50de	5.37b	65.52g
MK-5NB TEPI	92.75c	42.13e	2.89ef	31.38k

Mean values with different letters are significantly different (p <0.05) according to DMRT

Table 4. Mean ranking of spray droplet coverage on rice plants (45 and 90 days after transplanting) achieved by 14 sprayer-nozzle combinations via 160 ° swing spraying technique

Sprayer-nozzle combination	Ranking* of coverage		
	Upper leaf surface	Stems of outer tillers	Stems of inner tillers
LOK-SCN	2.13	1.69	1.63
LOK-VLVN	2.01	1.50	0.88
LOK-SOAN	1.94	1.63	1.19
LOK-QOAN	2.57	1.88	1.32
MM-SN T3RI	2.71	2.25	1.80
MM-SN T3R3	2.92	2.33	1.79
MM-ULVN T3R3	0.55	0.42	0.21
MM-ULVN T3R6	1.00	0.67	0.55
MK-DFN TFP1	2.16	1.63	1.19
MK-ASCN TFPI	2.56	2.01	1.47
MK-DWAN TEPI	2.69	1.78	1.29
MK-DCN TEPI	2.53	1.86	1.60
MK-3NRC TEPI	2.78	2.25	1.76
MK-5NB TEPI	2.97	2.63	2.16

*Based on a ranking system of 1–4: 0.0–1.0 = poor coverage (<20 droplets/cm^2), 1.1–2.0 = moderate coverage (21–60 droplets/cm^2), 2.1–3.0 = good coverage (61–300 droplets/cm^2), 3.1–4.0 = excessive coverage (blotched)

Table 5. Contamination of spray operator's body after 3 min of spraying via 160 ° swing spraying technique and 14 sprayer-nozzle combinations on rice crop (45 and 90 days after transplanting) based on water-sensitive paper tags

Sprayer-nozzle combination	Ranking* of contamination on operator's body							
	Forehead	Chest	Right biceps	Right hand	Left hand	Waist	Right thigh	Whole body
LOK-SCN	1.0	1.3	1.1	2.5	1.6	1.4	2.8	1.7
LOK-VLVN	0.5	0.5	1.1	2.1	1.3	1.1	2.3	1.3
LOK-SOAN	0.5	1.0	1.0	2.3	1.3	1.4	2.6	1.4
LOK-QOAN	1.0	1.3	1.3	2.9	2.1	1.8	3.4	2.0
MM-SN T3RI	1.1	1.8	2.0	3.1	2.3	2.6	3.8	2.4
MM-SN T3R3	1.8	2.0	2.5	3.3	2.3	3.3	3.9	2.7
MM-ULVN T3R3	0.5	0.5	0.8	1.5	0.6	1.3	1.6	1.0
MM-ULVN T3R6	1.3	1.3	1.0	2.0	1.5	1.8	2.3	1.6
MK-DFN TFP1	2.3	1.9	2.3	3.1	2.5	2.3	3.5	2.5
MK-ASCN TFPI	1.3	1.5	1.6	2.8	1.9	2.9	3.4	2.2
MK-DWAN TEPI	1.3	1.4	1.6	2.8	2.3	2.3	3.4	2.1
MK-DCN TEPI	1.8	1.6	1.6	2.6	2.0	3.1	3.3	2.3
MK-3NRC TEPI	1.8	1.8	1.8	3.0	2.0	2.4	3.3	2.3
MK-5NB TEPI	2.0	2.0	2.3	3.3	2.4	3.4	3.8	2.7

*Based on a ranking system of 1–4: 0.0–1.0 = negligible (<20 droplets/cm^2), 1.1–2.0 = considerable (21–60 droplets/cm^2), 2.1–3.0 = heavy (61–300 droplets/cm^2), 3.1–4.0 = excessive (blotched)

Table 6. Spraying performances of three spraying techniques using three sprayer-nozzle combinations on rice crop (45 and 90 days after transplanting)

Spraying technique	Work rate (ha/man-day)	Ranking of spray droplet coverage[a]			Ranking of whole body contamination[b] (3 min)
		Upper leaf surface	Stems of outer tillers	Stems of inner tillers	
160 ° swing	2.90a	2.56	2.13	1.61	2.08
70 ° swing	1.84b (37)	2.94	2.47	1.84	1.40 (33)
No swing	1.43c (51)	3.28	3.03	2.49	0.79 (62)

Mean values with different letters are significantly different (p <0.05) according to DMRT
Values in parentheses are percentage reductions
[a]Based on a ranking system of 1–4: 0.0–1.0 = poor coverage (<20 droplets/cm^2), 1.1–2.0 = moderate coverage (21–60 droplets/cm^2), 2.1–3.0 = good coverage (61–300 droplets/cm^2), 3.0–4.0 = excessive coverage (blotched)
[b]Based on a ranking system of 1–4: 0.0–1.0 = negligible (0–20 droplets/cm^2), 1.1–2.0 = considerable (21–60 droplets/ cm^2), 2.1–3.0 = heavy (61–300 droplets/ cm^2), 3.1–4.0 = excessive (blotched)

combinations. Amongst the various parts of operator's body, the right thigh and the right hand (holding the lance) were most contaminated regardless of sprayer-nozzle combination used.

As shown in *Table 6,* holding the lance steadily at 45 ° angle to the walking path produced better coverage and penetration, and reduced the amount of spray contamination on the spray operator by about 60%. Swinging the lance left and right, especially at 160 °, reduced spray efficiency and increased contamination although it increased the work rate by about 50%. The spray parameters at 45 and 90 DAT rice crop were compared *(Table 7).* The mean walking speed was significantly faster at 90 DAT due to the absence of standing water in the rice field. This resulted in a significantly smaller mean application volume and consequently a higher work rate. However, spraying at 45 DAT gave better spray coverage and less body contamination.

Results of the second experiment showed that mistblower fitted with either a standard nozzle or a wide-angle diffuser nozzle achieved the widest effective swath of up to 10 m of horizontal throw *(Table 8).* In the third experiment, the most effective walking speed for operating the mistblower based on the criteria of very good spray coverage and work rate was 36 m/min, i.e. 2.16 kph *(Table 9).* In the fourth experiment, use of the mistblower at a spray volume of 143 L/ha resulted in significantly better coverage of spray droplets on the top parts of rice plants, and correspondingly resulted in better reduction of the GLH population than the lowest application volume of 27 L/ha *(Table 10).* On the other hand, there was no significant difference in spray coverage on the lower part of rice plants. Hence, the four application volumes tested did not significantly reduce the BPH populations.

Discussion

In rice farming, farmers normally apply 128 L (eight tanks of 16 L each) of insecticide solution per hectare via the lever-operated knapsack sprayer fitted with the standard (1/16") hollow-cone nozzle. This application volume, a standard practice by the rice farmers in Tanjong Karang, is 30% more than what has been achieved with the same sprayer and nozzle in the first experiment *(Table 2).* The farmers' slower walking speed or use of old nozzle with an enlarged orifice probably caused this difference. The slower walking speed generally adopted by the rice farmers is likely due to their hearsay belief that they

Table 7. Spray parameters at 45 and 90 days after transplanting rice crop via three spraying techniques (160 °, 70 ° and no swing) using three sprayer-nozzle combinations (Crossmark VLVN, MD300 SN T3R1 and MS055s 5NB TFPI)

Days after transplanting	Walking speed (m/min)	Application volume (L/ha)	Work rate (ha/man-day)	Ranking of spray droplet coverage[a]			Ranking of whole body contamination[b]
				Upper leaf surface	Stems of outer tillers	Stems of inner tillers	
45	29.70b	303.92a	1.66b	3.27a	2.74a	2.14a	1.21a
90	41.23a	214.94b	2.46a	2.74a	2.45a	2.00a	1.66a

Mean values with different letters are significantly different ($p < 0.05$) according to DMRT

[a]Based on a ranking system of 1–4: 0.0–1.0 = poor coverage (<20 droplets/cm^2), 1.1–2.0 = moderate coverage (21–60 droplets/cm^2), 2.1–3.0 = good coverage (61–300 droplets/ cm^2), 3.1–4.0 = excessive coverage (blotched)

[b]Based on a ranking system of 1–4: 0.0–1.0 = negligible (<20 droplets/ cm^2), 1.1–2.0 = considerable (21–60 droplets/cm^2), 2.1–3.0 = heavy (61–300 droplets/cm^2), 3.1–4.0 = excessive (blotched)

need to wet the plants for more effective spray which we know is not true. The possible cause of nozzle with enlarged orifice could be attributed to abrasion, wear and tear. Sometimes farmers who are doing contract spraying for other farmers purposely enlarged the orifice to achieve a higher flow rate. In doing so, they finish the job faster at the expense of getting good spray coverage.

The work rate is another highly variable parameter depending on the purpose of spraying, existing field conditions, equipment and spray technique used. If a farmer sprays his own field to maximise control of an intended insect pest, he tends to be thorough in spraying coverage. He reduces his walking speed thus putting in a higher application volume and consequently lowering his work rate. On the other hand, if his purpose of spraying is to maximise his wage per day, then he will increase his walking speed and reduce the swath overlaps thus increasing the work rate. The wet and muddy field with 5–8 cm of standing water at 45 DAT has decreased walking speed by 28%, increased application volume by 41% and decreased work rate by 48% *(Table 7)* compared with the less muddy and no standing water situation at 90 DAT. The work rate is also reduced by as much as 51% *(Table 6)* when no-swing spraying technique is adopted compared with the 160 ° swing technique. This is the main reason why the great majority of our farmers persist in swinging their lance when spraying rice crop without realising that by doing so they will get poor to moderate spray coverage.

The coverage of spray droplets on target plant surfaces is a very important factor besides a host of other factors (e.g. chemical toxicity, application technique and timing) in determining the biological efficacy of pesticide application. Very good spray coverage means the sprayed surface received close to the maximum number of droplets before the droplets begin to coalesce and cause a run-off. When run-off

Table 8. Effective spray swath for two types of motorised mistblower for rice crop (45 days after sowing) spraying via 70 ° swing spraying technique based on a minimum spray droplet coverage of 20/cm^2

Mistblower+	Nozzle	No. of spray droplets/cm^2 for 5 swath				
		5 m	10 m	15 m	20 m	25 m
Solo 423	Standard nozzle	134.6b	65.6a	19.9a	3.2a	3.2a
Solo 423	Wide-angle diffuser nozzle	244.9a	47.9a	11.6a	0.0a	0.0a
Solo 423	Copper gauze screen 45 ° deflector nozzle	42.7c	2.8b	0.0b	0.0a	0.0a
Solo 423	Plastic screen 45 ° deflector nozzle	41.4c	0.6b	0.0b	0.0a	0.0a
Solo 423	Double plastic screen 45 ° deflector nozzle	160.7b	8.0b	0.0b	0.0a	0.0a
MD300D	Extended standard nozzle	197.7ab	10.9b	0.0b	0.0a	0.0a
MD300D	Retracted standard nozzle	136.7b	6.1b	0.0b	0.0a	0.0a

Mean values with different letters are significantly different (p >0.05) according to DMRT
+Mentioned of brand names does not mean endorsement by the author or MARDI

Table 9. Effective walking speed for motorised mistblower Solo 423 with a wide-angle diffuser nozzle for rice crop (45 days after sowing) spraying via 70 ° swing technique

Walking speed (m/min)	No. of spray droplets/cm^2			Work rate (ha/man-day)
	5 m	10 m	15 m	
69 (fast)	63.0c	20.9a	5.8a	13.3
36 (normal)	158.8b	39.9a	8.6a	6.2
25 (slow)	242.2a	69.3a	24.4a	4.4

Mean values with different letters are significantly different (p >0.05) according to DMRT

Table 10. Effect of BPMC spray volume on spray droplet coverage, and control of brown planthoppers and green leafhoppers on rice crop (45 days after sowing) using a mistblower fitted with a wide-angle diffuser nozzle via 70 ° swing spraying technique

Spray volume (L/ha)	Ranking of spray coverage[a]		No. of BPH per m^2 quadrat			No. of GLH per m^2 quadrat		
	ULS	SOT	1 DBS	1 DAS	14 DAS	1 DBS	1 DAS	14 DAS
27	4.1b	3.5a	17.6a	2.6b	0.7b	7.2b	0.9b	0.0b
43	4.5ab	3.9a	21.1a	2.1b	0.7b	14.5a	0.7bc	0.0b
111	6.1ab	4.9a	5.6a	2.3b	0.6b	9.4ab	0.4c	0.0b
143	6.4a	5.2a	11.8a	1.9b	0.5b	8.7ab	0.4c	0.1b
Untreated	–	–	17.7a	13.0a	2.3a	6.5b	1.9a	1.1a

Mean values with different letters are significantly different (p >0.05) according to DMRT
[a]Based on a ranking system of 1–10: 1 = <10 droplets/cm^2, 2 = 10–20, 3 = 21–50, 4 = 51–100, 5 = 101–200, 6 = 201–300, 7 = 301–400, 8 = 401–500, 9 = 501–600 (partially blotched) and 10 = >600 (completely blotched)
ULS = upper leaf surface, SOT = stems of outer tillers, DBS = day before spraying, DAS = days after spraying

occurred, most of the sprayed chemical will drop-off the target surface to the standing water in the paddy field and/or the soil, which is away from the target insect. This reduces the chances of chemical to be in contact with the target insect. Results of experiment 1 showed that spray coverage varies with the type of nozzle *(Table 4)* and spray technique *(Table 6)* used. Most of the sprayer-nozzle combinations tested gave good coverage only on the upper leaf surfaces but not on the stems of outer and inner tillers. The no-swing technique seems to give a better spray coverage on leaf as well as stem surfaces than the 70 ° and 160 ° swing *(Table 6).* Therefore to control both GLH and BPH, it is best to adopt the no-swing spraying technique.

Integrated pest management (IPM) of rice crop has been introduced and practised in Malaysia since 1977, and strongly advocates judicious and safe use of pesticides (Md. Jusoh et al. 1981; Heong and Md. Jusoh 1982). A successful pesticide application is one that results in a very high percentage kill of the target pest while poses minimum hazard to the spray operator. In using the lever-operated knapsack sprayer, mistblower and motorised knapsack sprayer, the operator is exposed to two kinds of hazard: direct physical harm such as wounds and bruises caused by the equipment, and direct contamination by the pesticides being applied. Results in *Table 5* and *Table 6* indicate that the extent of contamination on spray operator's body varies according to the sprayer-nozzle combination and spray technique employed. Based on these results, it is recommended that the hand holding the lance should be protected by wearing an elbow length rubber glove, while the legs and feet wear knee length rubber boots when spraying using the lever-operated knapsack sprayer. When operating mistblower and motorised knapsack sprayer, especially the mistblower fitted with a standard nozzle, motorised knapsack with a double-fan nozzle or the 5-nozzle boom, the operator should use a complete safety wears to protect his whole body.

Acknowledgements
The author is grateful to his research assistants Mr Muhamad Shah Ab. Lah, Mr Ahmad Basir and Mr Yaakub Kasin for their active involvement in field experiments; to Mr Ahmad Shokri Hj. Othman and Dr Ahmad Selamat for statistical analyses.

References

Heong, K. L. and Md. Jusoh, M. (1982). Pengawalan musuh secara integrasi. *Teknol. Pertanian, MARDI* ***3(2):*** 127–39

Heong, K. L., Md. Jusoh, M., Ho, N. K. and Anas, A. N. (1992). Sprayer usage among rice farmers in the Muda area, Malaysia. *Tropical Pest Management* ***38(3):*** 327–30

Md. Jusoh, M., Heong, K. L., Nik Mohd Nor, N. S., Chang, P. M. and Lim, G. S. (1981). Integrated pest control: rationale, needs and case study for paddy in Malaysia. Paper presented at the MARDI Senior Staff Conf., 16 June 1981, Serdang, Selangor, 35 p. Organiser: MARDI

Md. Jusoh, M., Heong, K. L. and Rahim, M. (1985). Principles and methodology of pesticide application techniques. Paper presented at the Workshop and Course on Pesticide Application Technology, 21–26 Oct. 1985, p. 9–26, Serdang, Selangor. Organiser: Univ. Pertanian Malaysia and Malaysian Plant Protection Society (MAPPS)

Lim, G. S., Hussein, M. Y., Ooi, A. C. P. and Zain, M. B. A. R. (1983). Pesticide application technology in annual crops in Malaysia. In *Pesticide application technology* (Lim, G. S. and Ramasamy, S., ed.) p. 13–41. Kuala Lumpur: Malaysian Plant Protection Society (MAPPS)

Zam, A. K. (1980). Bancian pengurusan dan kawalan serangga perosak padi di Rancangan Perairan Tanjong Karang dan Krian, Cawangan Pemeliharaan Tanaman, Jabatan Pertanian, Kuala Lumpur, 20 p. (mimeo.)

Accepted for publication on 14 August 1997