Paper No :

MSAE2018-ARWM015

Sustainability Practices for Pesticide Spraying for Wet Paddy Cultivations in Malaysia

M. Mairghany[1], A. Yahya[1]. N.M. Adam, A.H.M. Su[2] and S. Elsoragaby[1]

[1] Dept. of Biological and Agricultural Engineering
Faculty of Engineering, University Putra Malaysia
43400 UPM Serdang,
Selangor, Malaysia

[2]Dept. of Agricultural Technology
Faculty of Agriculture, University Putra Malaysia
43400 UPM Serdang,
Selangor, Malaysia

azmiy@upm.edu.my

ABSTRACT

This study evaluates on the adaptation of sustainable agriculture practices in integrated pest management in DOA's Rice Check Guidelines among the rice farmers at the Rice Scheme in Sungai Burung, Tanjung Karang, Selangor. The two common machines that were used in pesticides sprayings were the knapsack power mist duster and the handheld power sprayer machine. The calibrated spray flow rate for mist duster was 0.101 l/s while for the power sprayer was 0.071l/s. Field pesticide sprayings with the mist duster were conducted at a walking speed of 3.27 km/hr while for the power sprayer was at 2.71 km/hr. 69.8% of the farmers followed the specified amount of pesticides in the Rice Check while 21.1% of them used less than the specified amount and the remaining 9.5% sprayed over dosage. 57.38% of the farmers applied pesticides according to the specified scheduling dates while 40.98% farmers apply pesticides at presence of pest and 16.39% applied pesticide only when the crops were found to be pest and disease infested. 98% of the sprayer workers read the product label instructions when preparing the sprayer solution and 76.8% of the sprayer workers were not wearing the safety protections during the spraying operations.

KEYWORDS

Pesticide spraying, Rice check, Wet paddy cultivation, Sustainable agricultural practices.

Paper presented at the 2018 MSAE Conference, Serdang, Selangor D. E., Malaysia. 7 & 8 February 2018

INTRODUCTION

Rice is the most important staple food worldwide with the world's largest populations of farmers and o consumers worldwide (Savary, Horgan, Willocquet, & Heong, 2012) Pests have been associated with crops since times immemorial. But under changing environment their number has increased, and the minor pests now become the major one causing greater damage to the crop. Insect pests are responsible for considerable yield loss of various crops in tropical Asian countries. About 128 species of insects have been reported to ravage the rice field. Out of this only 15 to 20 insects are regarded as economically obnoxious species (Chakraborty, 2012). Estimates of the scale of these losses vary by context and scope (Pretty & Bharucha, 2015). Pest management is critical to achieve rice production in a sustainable manner (Savary et al., 2012). Farmers utilize crop protection products like fungicides, herbicides, insecticides, etc in order to increase crop yield.

The reduction of current yield losses caused by pests, pathogens and weeds are major challenges to agricultural production ((Oerke & Dehne, 2004) In order to secure the high level of food and crop productivity which is necessary to meet the increasing human demand, the protection for crop from pests should be realized (Popp, 2011). Food security is only the first step towards greater economic independence for farmers (FAO, 2009 and Popp, Peto, & Nagy, 2013). Among crops, the total global potential loss due to pests is about 40% for rice (OERKE, 2007).

The beneficial outcome from use of pesticides provides evidence that pesticides will continue to be a vital tool in the diverse range of technologies that can maintain and improve living standards for the people of the world. Some alternative methods may be more costly than conventional chemical-intensive agricultural practices, but often these comparisons fail to account for the high environmental and social costs of pesticide use. The externality problems associated with the human and environmental health effects of pesticides need to be addressed as well (National Research Council 2000) (Popp et al., 2013). An average of 35 % of potential crop yield is lost to pre-harvest pests worldwide (Oerke & Dehne, 2004). Weeds affect crop productivity especially due to the competition for inorganic (Boote, Jones, Mishoe, & Berger, 1983). Crop protection has been developed for the prevention and control of crop losses due to pests in the field. The correct use of pesticides can deliver significant socio-economic and environmental benefits in the form of safe, healthy, affordable food; contribute to secure farm incomes and enable sustainable farm management by improving the efficiency with which we use natural resources such as soil, water and overall land use (Popp et al., 2013).

Rice Check contents each farming practice and process requires farmers to pay close attention to their fields. There is specifically an important checklist for the use of pesticides as it concerns chemical input in the field. The most widely used pesticides among paddy growers in Malaysia are Category II and III which are moderately and slightly hazardous respectively (Boote et al., 1983).

This paper concentrates on farmer practices for pesticide spraying comparing to Rice Check content, the effect of pests on crop production in the field and the effect of control measures applied by farmers in order to minimize losses and increasing productivity.

METHODOLOGY

Description of study area

The area of paddy fields Sungai Burung is located in the district of Tanjung Karang in the State of Selangor (Latitude: 3°29'0.47 N "Longitude: 101°9'0.56"). This area is hot and humid zone of Malaysia with average temperature ranges from 27 to 34 °C throughout the year, relative humidity ranges from 60 to 87 % and average annual rainfall of about 2670 mm. The areas have been selected on account of it being the third largest area of paddy field in Peninsular Malaysia. It is also known as `the rice bowl of Selangor'.

Data collection:

The study was conducted during the main season from June to November of 2017 involving 13 farms. Data collected directly from all pesticide operations from the beginning and till the end of the season. Data collected included farm: farm ID, application number, number of rows, length of rows, distance between every two rows, pesticide: types of (insecticide, herbicide, fungicide and etc.) and the amount of pesticide used (ml liter or g), amount of water used to mix the pesticide (liter), time of applications, machine: type of machine used (power sprayer or HARRY knapsack mist duster), operator: name, nationality, experience, age, protection procedures and speed. This paper evaluates pesticide productivity in rice production in direct seeded (DS) and transplanted plant (TP).

In the study, farm two machines were used for pesticides application. The two spray machines were calibrated at the beginning of the season, after equipment has underwent for the necessary repair and maintenance. Calibration included forward speed, swath width, and liquid flow rate.

RESULTS AND DISCUSSIONS

Pesticide Use

From the field study, a total of fourteen different pesticides were identified as the most commonly used by the rice farmers in Sungai Burung Tanjong Karang to control the infestation of various pests. Table 1. characterizes the fourteen pesticides according to formulation, group and class. The use of these pesticides was recommended by the DOA Rice Check. Due to major pests, farmers usually applied several types of pesticide during the rice that includes all types of insecticides, herbicides, fungicides and rodenticides. It was found that pesticides from insecticide group followed by fungicide group are the most common pesticide utilized by the farmers, with formulation or commercial names of MACTRON, KARATE, ZIMEC, ALIKA ZC, AMISTAR TOP, PREVATHON, PLENUM 50WG, and SUMIBASSA 40% EC.

Table 1: Common pesticides used by rice farmers in Sungai Burung

Pesticide Formulation	Pesticide Group	Pesticide Class
SOFIT N 2	HERBICIDE	III
SATUNIL EC	HERBICIDE	III
MACTRON	INSECTICIDE	II
ZIMEC	FUNGICIDE	IV
KARATE	INSECTICIDE	II
(BLB)	FUNGICIDE	-
ALIKA ZC	INSECTICIDE	II
AMISTAR TOP	FUNGICIDE	III
PREVATHON	INSECTICIDE	III
PLENUM 50WG	INSECTICIDE	IV
FUJI ONE 40 EC	FUNGICIDE	III
SUMIBASSA EC	INSECTICIDE	II
AMISTAR	FUNGICIDE	IV
AMOLIN 29.2 EC	FUNGICIDE	III

Note: WHO classification of chemical classes: Ia = extremely hazardous, Ib = highly hazardous, II = moderately hazardous, III = slightly hazardous, U = unlikely to present acute hazard in normal use. bEPA United Stated of chemical class: I = danger, II = warning, III = caution, IV = none required.

Each pesticide formulation has different active ingredient and chemical class depending on its group. From Table 1, it can be seen that most of the pesticides were classed under Class II, III, IV and IV. Four of pesticides contains active ingredients classified as 'moderately hazardous', and six contain active ingredients classified by the WHO as 'Slightly hazardous'. None of these products contains active ingredients classified as 'highly hazardous'. According to the classification of the US EPA one product is classified as "warning", three are classified as "caution" and four are classified as non-required. All pesticides used by farmer are registered and recommended in rice check.

Effect of pesticide using in transplanting (TP)

A total of six farms in the study area adopted transplanting method for planting. All farms were given the same amount of pesticide in very closed times, the farmers followed the schedule perfectly and there were no big differences in terms of pesticide application. Thus, there were no significant differences on rice yields among the farm plots.

Effect of pesticide using in direct seeding (DS)

A total of seven farms in the study area adopted direct seeding method for planting. The involved farms used different doses of pesticide. Depend on pesticide applications, the farms as in Table 2 were classified as follows; A1 using pesticides for 5 times using herbicides, insecticides fungicides and cutting weedy rice one time (Farm 2, 10 & 12); A2 uses pesticides for 5 times using herbicides, insecticides fungicides and without cutting weedy rice (farm 7); A3 using pesticides for 4 times using herbicides, insecticides fungicides and without cutting weedy rice and A4 using pesticides for 4 times using insecticides fungicides with not using herbicide and cutting weedy rice one time.

Group A1 has highest amount of mean yield at 31.39% of the total average yield (6.808 ton/ha), while group A3 has the lowest amount at 18.61% of the total average yield (4.036 ton/ha). Group A2 and group A4 have amount of mean yield of 25.63% (5.559 ton/ha) and 24.37% of the total average yield (5.286 ton/ha), respectively. Group A1 showed 68.68% greater mean yield than the group A3 (6.808 ton/ha and 4.036 ton/ha).

Table 2: Pesticide applications and yield at direct seeding farms.

Group	Number of Applications	Cutting weedy rice	Average Yields ton/ha	%
A1	5	1	6.808	31.39
A2	5	0	5.559	25.63
A3	4	0	4.036	18.61
A4	4	1	5.286	24.37

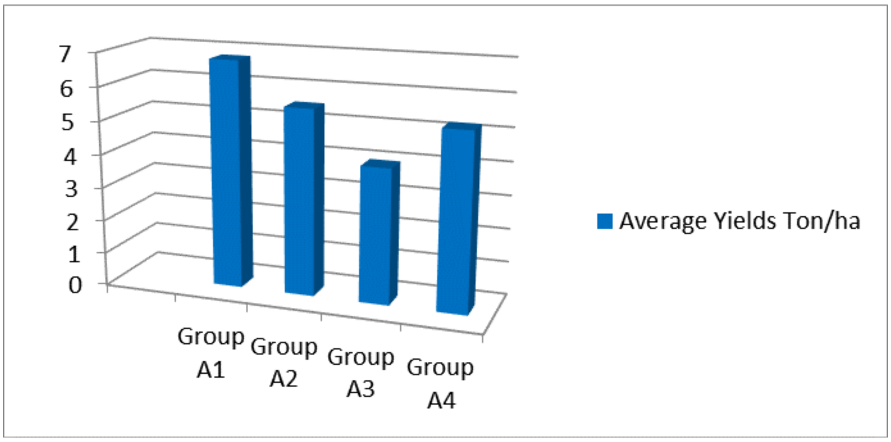

Figure 1: Pesticide applications and yield at direct seeding farms

Fungicide use:

Fungicide has different amount used on farms during the season as in Table 3. The highest consumption of the FUJI ONE 40 EC and BLB was shared with three Farms 1, 2 and 5 with 25% for both, while farms 3 and 4 did not have pesticide on them. Farms 1, 2, and 3 gained the lowest amount of Amistar Top (12.12%). They were also the highest consumer of ZIMEC similar to Farm 7 used (18.18%), whereas Farms 3, 5 and 6 have the lowest amount (9.1%). Farm 7 got the biggest amount of Amistar Top (19. 7%), while Farms 1, 2 and 5 gave the lowest amount (12.1%).

Table 3: Application of fungicide percentage at direct seeding farms

PESTICIDE	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Total (10 *l*/ha)
FUJI ONE 40 EC %	25	23	0	0	25	12.5	12.5	33.3
ZIMEC %	18.2	18.2	9.1	9.1	18.2	9.1	18.2	45.8
(BLB) %	25	25	0	0	25	12.5	12.5	6.7
AMISTAR TOP %	12.1	12.1	15.2	13.6	12.1	15.2	19.7	27.5
Yield (ton/ha) %	13.4	10.6	10	15.1	19	14.1	17.8	39.3

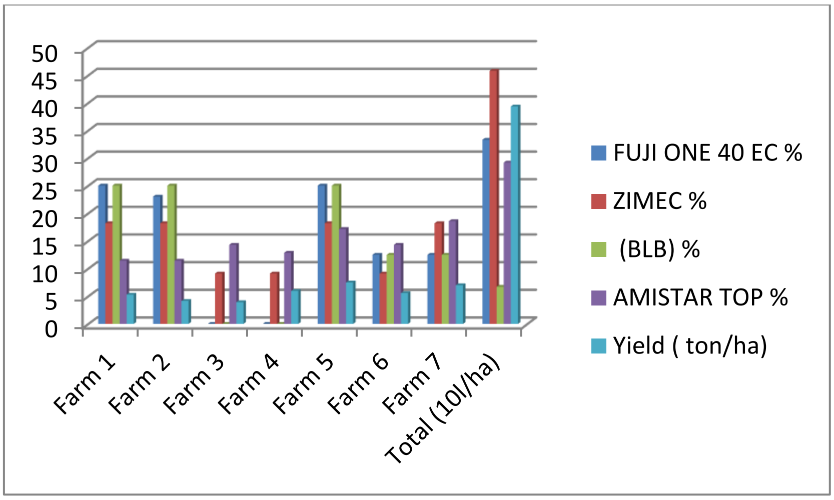

Figure 2: Application of fungicide percentage at direct seeding farms

Insecticide use:

The common insecticide used were MACHTRON, ALIKA ZC, KARATE, PREVATHON, SUMIBASSA 40% EC and PLENUM 50WG. Farm 5 has the highest amount of the three insecticides namely ALIKA ZC, PREVATHON and PLENUM 50WG at 19.8%, 25% and 23.1% respectively. Farms 1 and 2 got the highest value of KARATE at 23.9%. Farm 6 has the highest amount of MACHTRON at 23.8% and Farm 7 has the highest amount of SUMIBASSA 40% EC at 11.1%. The lowest amount of MACHTRON at 9.5% was shared by Farms 3, 4, and 5. Farm 7 which also the had the lowest value of ALIKA ZC (9,5%) and PREVATHON (7.1%). Farms 6 and 3 have the lowest amount of KARATE and SUMIBASSA 40% EC at 6.3% and 0%, respectively.

Table 4: Insecticide applications and yield at direct seeding farms

Pesticide	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Total (10l/ha)
MACHTRON %	19	19	9.5	9.5	9.5	23.8	9.5	17.5
ALIKA ZC %	18.3	18.3	11.4	11.4	19.8	11.4	9.5	21.9
KARATE %	23.9	23.9	11.1	13.7	17.1	6.8	3.4	48.8
PREVATHON %	14.3	14.3	10.7	14.3	25	14.3	7.1	46.7
SUMIBASSA 40% EC %	22.2	22.2	0	11.1	22.2	11.1	11.1	18.8
PLENUM 50WG %	19.7	19.7	8.1	5.8	23.1	13.9	9.8	28.8
AMISTAR								
Yield (ton/ha)	5.286	4.152	3.92	5.956	7.483	5.559	6.985	39.3

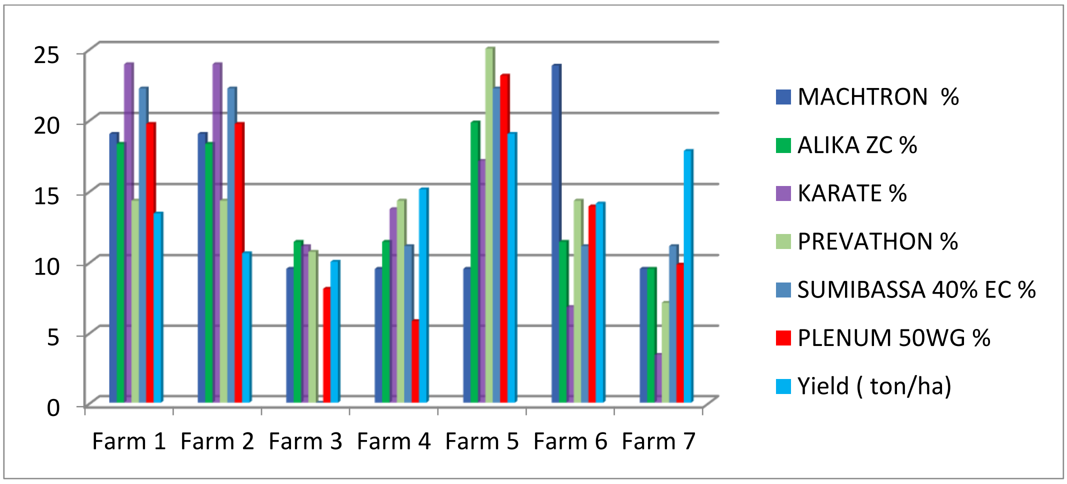

Figure 3: Application of insecticide percentage at direct seeding farms

ISBN 978-967-16145

Herbicide use:

Farms 2, 3, 4 and 7 had the same amount of SATUNIL EC at 26.1%, while Farms 5 and 6 has amount of the chemical at 13.0% and 8.7%, respectively. Farms 5 and 6 have the same amount SOFIT N at 50% and Farm 1 has no herbicide sprayed on it.

Table 5: Application of herbicide percentage on direct seeding farm

PESTICIDE	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Total (10l/ha)
SOFIT N 2 %	0	0	0	0	50	50	0	33.3
SATUNIL EC %	0	26.1	26.1	26.1	13	8.7	26.1	95.8
Yield (ton/ha)	4.62	4.14	3.86	5.87	7.48	5.14	6.82	39.3

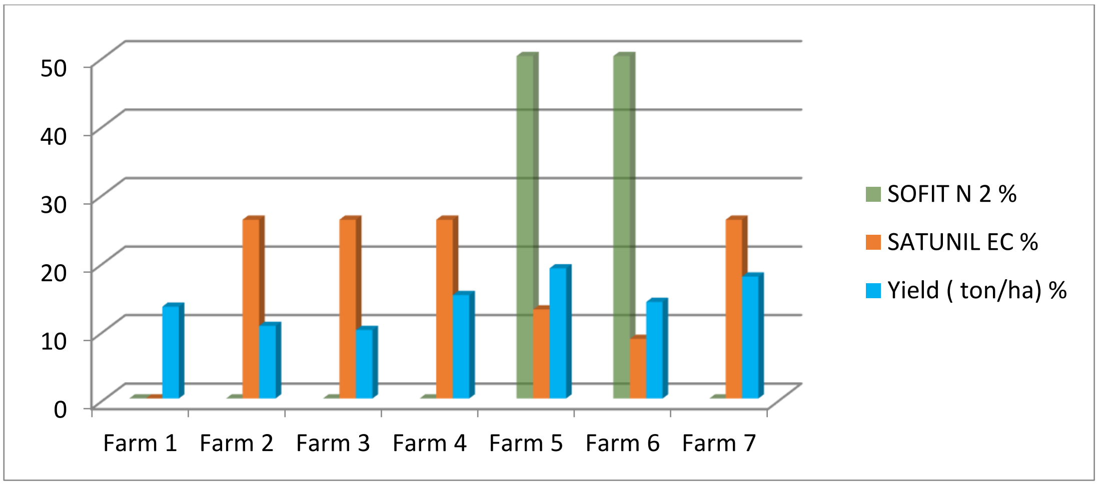

Figure 4: Application of herbicide percentage at direct seeding farms

Weed Control management:

Commonly, weed controls used are mechanically hand weeding and chemical herbicides weeding in the study area; mechanically hand weeding is used for weedy rice probably by hoe and hand pulling.

The analysis results on rice yields in Table 2 shows that the highest mean rice yield was achieved by control A (Herbicide SOFT N and SATUNIL + manual weeding for weedy rice), while control E (Herbicide SATUNIL) had the lowest mean rice yield. Control D and E shows that the hand weeding only is more effective than using herbicide only, the same result was obtained by Antralina et al. (2015).

Table 6. Effects of difference weed control methods on rice yields

Control	Weed Control Methods	Average yield (ton/ha)
A	Herbicide SOFT N(2l) +SATUNIL (1) + manual weeding for weedy rice	7483
B	Herbicide SATUNIL + manual weeding for weedy rice	6.4705
C	Herbicide SOFT N +SATUNIL	5.559
D	Manual weeding for weedy rice only	5.286
E	Herbicide SATUNIL.	4.036

Effect of Pesticide on Yield:

The result showed that using appropriate amount of pesticide in proper timing had increased rice yield, Table 3 with Figure 2 and Table 4 with Figure 3 shows that using appropriate amount of fungicide and insecticide leaded to achieved high yield in Farm 5 (7.48 ton/ha) which are 90. 9%, 80.7% and 61.9%

greater than Farms 3, 2 and 1, respectively. Farm 3 produced the lowest yield although was being given slightly more fertilizers than Farm 5 with 23.71 kg N/ha, 21.00 kg P2O5/ha and 13.55 kg K2O /ha for two times and 29.6 kg N/ha, 5.1 Kg P2O5/ha and 42.3 Kg K2O /ha while Farm 5was being given 23.3 kg N/ha, 20.7 kg P2O5/ha and 13.3 kg K2O /ha also for two times and 20 kg N/ha, 20 kg P2O5/ha, 41.7 kg K2O /ha). Farm 3 was given 2% more amount of Nitrogen than Farm 5 with 39.0 kg N/ha and 38.3 kg/ha N. Farm 2 was given 31.7 kg N/ha, 28.1 kg P2O5/ha and 18.1kg K2O /ha twice and 43.3 kg N/ha, 7.6 kg P2O5/ha and 63.6 kg K2O /ha while Farm 1 was given 40.1kg N/ha, 35.5 kg P2O5/ha and 22.9 kg K2O /ha, 26.7 kg N/ha, 23.7 kg P2O5/ha and15.3 kg K2O /ha and 32.4kg N/ha, 5.7kg P2O5/ha, 47.7kg K2O /ha. Farms 2 and 1 got 35.7% and 14.5% more amount of Nitrogen than Farm 5 which was 52.0 kg N/ha and 43.9 kg N/ha, respectively.

Controlling weed management mechanically or chemically or using both, reduced yield losses and increase the productivity and indicated in Table 6. and Figure 5.

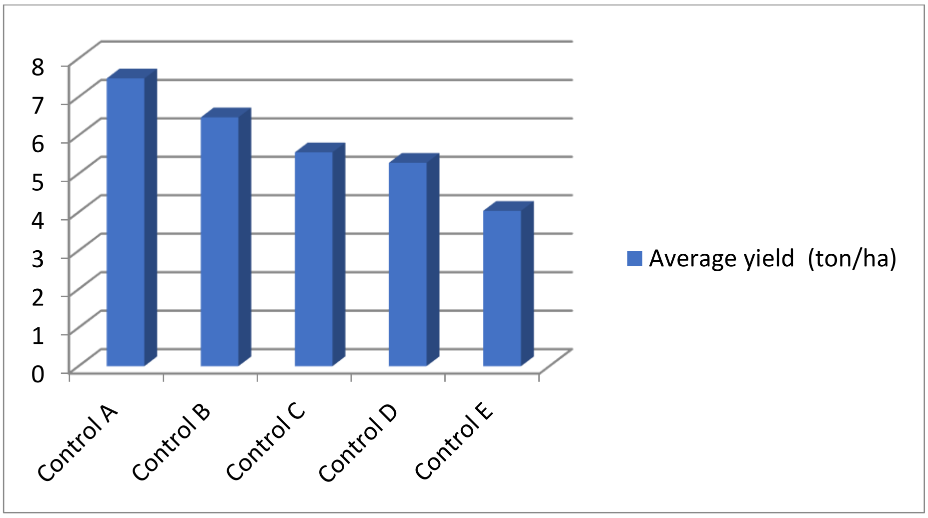

Figure 5: Effect of difference weed control methods on rice yields

Table 7: Pesticides usage by farmers against the recommended amount in DS

LOT ID	Number of application	In the range	Over Dosage	Less Dosage
Farm 1	20	12	3	5
Farm 2	19	11	6	3
Farm 3	19	12	2	5
Farm 4	13	8	1	5
Farm 5	22	16	1	5
Farm 6	15	12	1	2
Farm 7	12	9	1	2

Use of Recommended Quantity

More than 69.8% of the farmers used the recommended quantity of pesticides in their crops (Tables 7 and 8) and (Figures 5 and 6). On the other hand, 30.6% of them either uses more or less than the required quantity. Most of pesticides used are insecticide and fungicide. Insecticide used specially for brown plant hopper and green leafhopper and fungicide for disease such as sheath blight and Leaf blast. Most of the time, severity of pest and insects such as brown plant hoper and green plant hoper forced farmers to use over dose pesticides. In addition to that, some farmer missed the use pesticide in appropriate time which led to the spreading of weeds but then they were forced to fight the weeds in order to keep the crops.

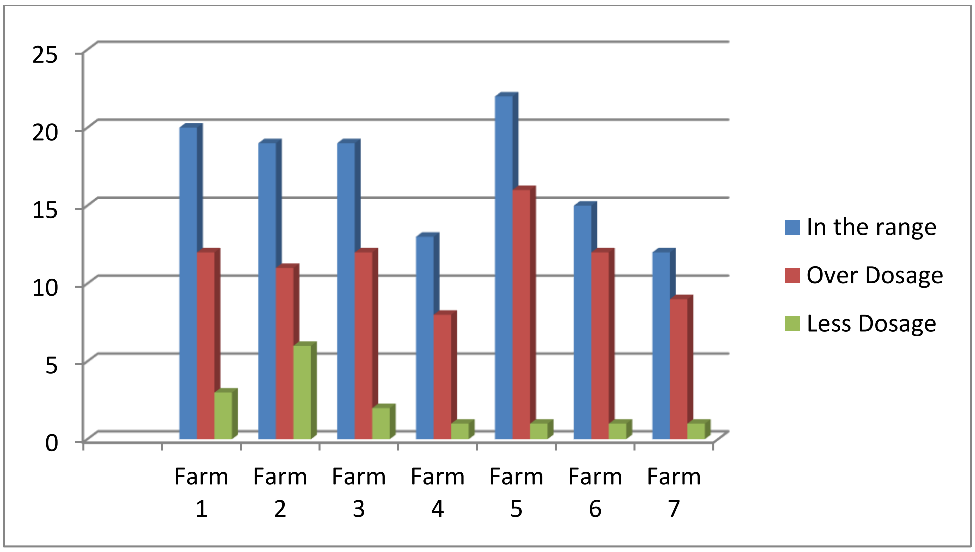

Figure 6: Pesticides usage by farmers against the recommended amount in DS

Table 8: Pesticide was used by farmers due to the recommended amount in TP

LOT ID	Number of use	Range		Over Dose		Less Dose	
Farm 1	20	12		3		5	
Farm 2	23	18		1		5	
Farm 3	25	18		3		5	
Farm 4	24	15		1		4	
Farm 5	23	16		1		6	
Farm 6	22	17		2		3	
Total	272	189	69.8%	26	9.5%	57	21.1%

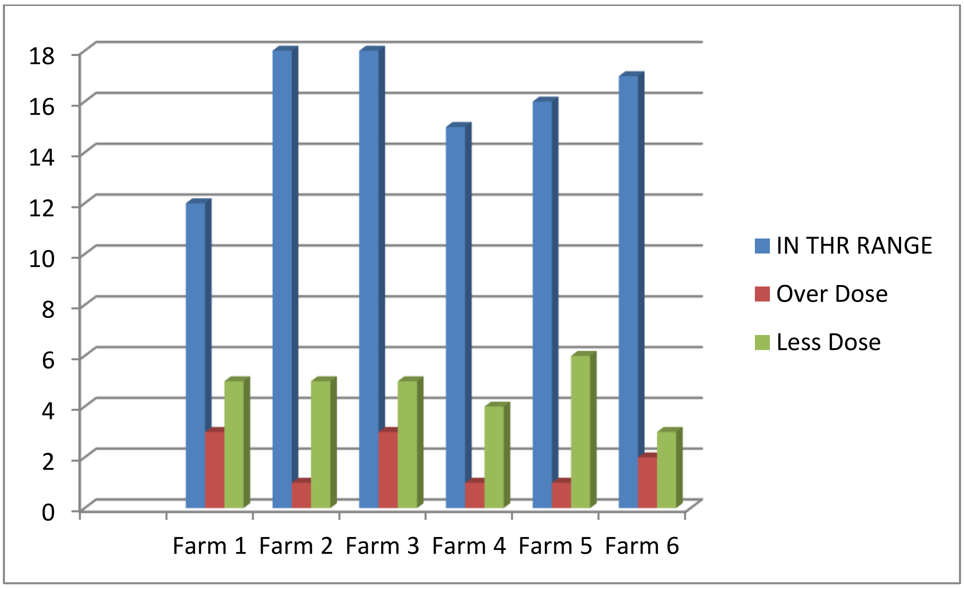

Figure 7: Pesticides usage by farmers against recommended amount in TP

Timing of insecticide applications

The critical time for pesticide applications included when the presence of pests, perceived intensity of infestation and transplanting, and date and fertilizer application dates (Table 8). 16.39% of farmer sprays when pest infestation is heavy while 40.98% of them spray whenever pests are present, irrespective of pest density. Other criteria such as date of transplanting and date of fertilization were reminiscent of the recommended calendared spray schedules or complete protection treatments. Most of the farms (57.38%) got pesticides on it after applying fertilizers. Although farmers applied pesticides on most farms at prefixed time, they also applied pesticides on majority of farms during initial attack.

Table 9: Pesticide applications and farm yields

Factor	Number of Applications	% of total
Date of transplanting	35	57.38
Presence of pest	25	40.98
Perceived intensity of infestation	11	16.39
Misused	5	8.2

Using pesticides correctly

Farmers usually used pesticides only when needed and economically important need but when they detected that the application of pesticides would not return with profit because damage was too severe, they would neglect using pesticides and as this could clearly in seen in Farms 8 and 4.

Sprayer calibration

Two machines were used for spraying chemicals, knapsack HARRY Mist Duster Power Broadcaster and Power Sprayer machine were tested in field to determine optimal row pacing, the average row spacing was used for modified row patterns, row spacing (width of area covered per row) and number of rows were found to be 6.6 m and 10 rows. The calibrated mist duster and power sprayer machine had a flow rate outlet of 6.05 l/s and 4.25 l/s and labor speeds of 0.84 m/s and 0.63 m/s, respectively. The distance between application rows run by labors on the farm depending on number of rows, with 8 rows, the distance was 8.571m while for 10 rows, the distance became 6.667 m. The study found the average of labor speed during applying pesticide was 0.847m/s for mist duster and 0.754 m/s for power sprayer.

Table 10: Spraying machines nozzle outlet, forward speed and effective width

Machine type	Nozzle outlet (l/s)	Ideal speed (km/hr)	Effective width (m)	Ideal number of rows	Tank capacity	Standard capacity	Losses out the field
Power Sprayer	0.071	2.27	3.75 (right) 3.75 (left	8	180 (l)	3001	No
Knapsack mist duster	0.101	3.02	3 (right) 3 (left)	10	(24 liter × 10)	280 l	Yes

Health and Security measures

The application of pesticides on crops is necessary to prevent unacceptable losses of the crop production. However, their use may pose health risks to the farmers and pesticide workers, often as a consequence of improper or careless handling. Majority of workers or 76.83% do not adopt security measure during pesticide application while 23.17% of them follow the security and health perfectly (Table 11). All labors cover their face with cloth during application.

Table 11: Pesticide recommended Personal Protective Equipment (PPE)

Applications	Standard requirement											
	APR		BTS		GLV		FCS		FFR		WBH	
	Y%	N%	Y%	N%	Y %	N%	Y%	N%	Y%	N%	Y%	N%
	0	100	23.2	76.8	23.2	76.8	100		23.2	76.8	23.2	76.8

NOTES: APR = Aprons BTS = Boots GLV = Gloves FCS = Face Shields FFR = Full Face Respirator WBH = Wide-Brimmed Hat

In addition to covering face, 76.83% of them cover their head and wear boot and gloves at the time of pesticides application. Only 23.17% reportedly use socks to cover their hands and legs and 23.17% use glasses to protect their eyes.

Figure 8: Operator covering their faces during pesticides application in study area

Figure 9: Operator wearing FFR during pesticides application in study area

Speed of applications

Speed of operators varies from one to another, some laborers has very fast sped while other has a wise speed. Tables 12 and 13 show the average speed of the labor during pesticides application. The maximum speed range was from 0.625 m/s to 1.587 m/s and the minimum speed range was from 0.276 m/s to 0.743 m/s.

Table 12: Average operator forward speed (km/hr) for Sprayer

OPERATOR	AVERAGE SPEED (km/hr)
MAASUM BILLAH	2.592
RAMLI	1.818
M.IMRAN	3.2148
M.RASUL	3.2724
AMINUL RAHMAN	2.682
MUHAYMIN	2.9808
MAGSUD	2.1528
IDEAL SPEED (km/hr)	2.27

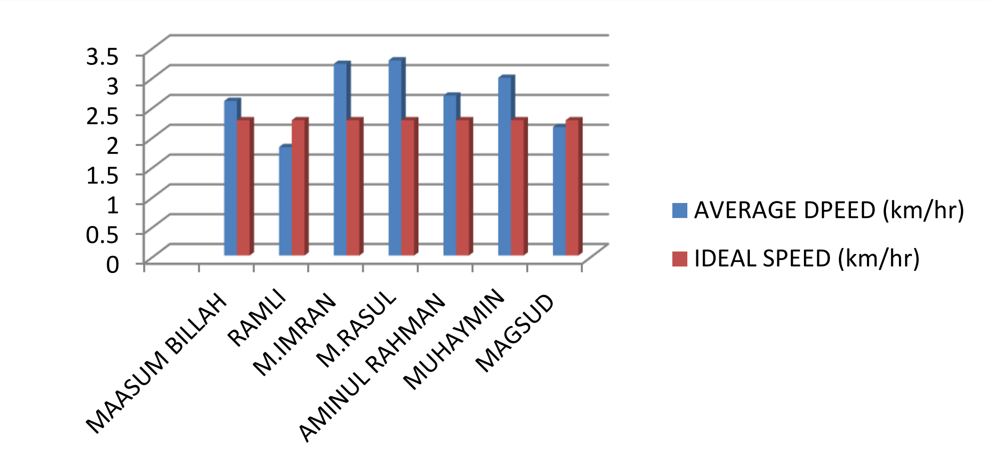

Figure 10: Average operator forward speed (km/hr) for Sprayer

Table 13: Average operator forward speed (km/hr) for Knapsack

OPERATOR	AVERAGE DPEED (km/hr)
MUHAYMIN	2.9664
M.RASUL	3.3372
SAIFUL	3.1536
AMINUL RAHMAN	2.8908
MAGSUD	2.8512
M.IMRAN	3.42
IDEAL SPEED (km/hr)	3.024

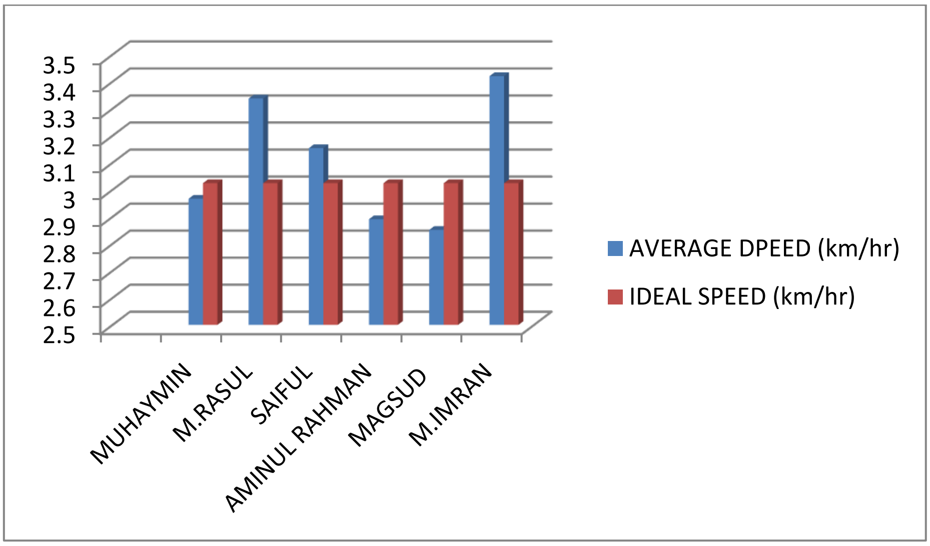

Figure 11: Average operator forward speed (km/hr) for Knapsack

CONCLUSIONS

Chemical pesticides will continue to play a role in pest management because environmental compatibility of products is increasing, and competitive alternatives are not universally available. Pesticides provide economic benefits to producers and by extension to consumers. One of the major benefits of pesticides is protection of crop quality and yield. The result showed that 69.8% of farmers practiced quite sustainable paddy farming by following Rice Check schedule for pesticide applications and 76.8% of operators do not follow the label instruction and safety precautions.

Pesticides can prevent large crop losses. The benefits of pesticide use are high-relative to risks. The side-effects of pesticides could be reduced by improving application technologies. Innovations in pesticide-delivery systems in plants promise to reduce adverse environmental impacts even further but are not expected to eliminate them. The correct use of pesticides can deliver significant socio-economic and environmental benefits.

Long-term dependence on pesticides is unsustainable. Manual weeding, although effective, is becoming difficult due to labor scarcity, cost increase and depend on weather conditions. Natural control is the conservation of natural enemies by preventing their destruction or preserving their habitats. Varietal resistance to rice pests is an effective means of controlling yield losses

REFERENCES

1. Abhilash, P. C., & Singh, N. 2009. Pesticide use and application: An Indian scenario. *Journal of Hazardous Materials*, *165*(1–3), 1–12. https://doi.org/10.1016/j.jhazmat.2008.10.061
2. Antralina, M., Istina, I. N., YuyunYuwariah, & Simarmata, T. 2015. Effect of Difference Weed Control Methods to Yield of Lowland Rice in the SOBARI. Procedia Food Science, 3, 323–329.
3. Bajwa, W. I., & Kogan, M. 2002. Compendium of IPM Definitions (CID) What is IPM and how is it defined in the Worldwide Literature? *IPPC Publication*, *998*(998), 1–14. https://doi.org/10.1002/ird.2086
4. Boote, K. J., Jones, J. W., Mishoe, J. W., & Berger, R. D. 1983. Coupling pests to crop growth simulators to predict yield reductions [Mathematical models]. Phytopathology (USA).
5. Chakraborty, K. 2012. Evaluation of integrated pest management module against paddy yellow stem borer Scirpophaga incertulas Walk. Karnataka Journal of Agricultural Sciences, 25(2), 273–275.
6. Gianessi, L. P. 2014. Importance of Pesticides for Growing Rice in South and South East Asia. CropLife Foundation, (International Pesticide Benefit Case Study 108), 30–33.
7. Malaysian Standard MS479:2012. 2012. Malaysian Standard MS 479:2012 The safe handling of agricultural pesticides - Code of recommended practice (First revision. *Chrysanthemum Standard*, 1–3.
8. Nwilene, F. E., Nacro, S., Tamò, M., Menozzi, P., Heinrichs, E. A., Hamadoun, A., & Togola, A. 2013. Managin Insect Pest of Rice in Africa. *Realizing Africa's Rice Promise*, 229–240.
9. OERKE, E.-C. (2007). Crop losses to pests. AgBioForum, 10(3), 178–183.
10. Oerke, E.-C., & Dehne, H.-W. 2004. Safeguarding production—losses in major crops and the role of crop protection. Crop Protection, 23(4), 275–285. https://doi.org/https://doi.org/10.1016/j.cropro.2003.10.001
11. Popp, J., Peto, K., & Nagy, J. 2013. Pesticide productivity and food security. A review. Agronomy for Sustainable Development, 33(1), 243–255. https://doi.org/10.1007/s13593-012-0105-x
12. Pretty, J., & Bharucha, Z. P. 2015. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. *Insects*, *6*(1), 152–182. https://doi.org/10.3390/insects6010152
13. Ragunathan, V. (2001). Integrated Pest Management Package for Rice, 1–21.
14. Savary, S., Horgan, F., Willocquet, L., & Heong, K. L. 2012. A review of principles for sustainable pest management in rice. *Crop Protection*, *32*, 54–63. https://doi.org/10.1016/j.cropro.2011.10.012