Current Journal of Applied Science and Technology

39(29): 20-29, 2020; Article no.CJAST.60927
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Carbon Footprint of Electrostatic Sprayer in Comparison with Air Compression Sprayer and Mistblower

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Authors' contributions

This work was carried out in collaboration among all authors. Authors VA and DD designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors SRS and OPRR managed the analyses of the study. Author DSK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i2930953
Editor(s):
(1) Ogunlade, Clement Adesoji, Adeleke University, Nigeria.
Reviewers:
(1) Sk. Shezan Arefin, RMIT University, Australia.
(2) Made Ariana, Institute Teknologi Sepuluh Nopember, Indonesia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/60927

Original Research Article

Received 10 July 2020
Accepted 16 September 2020
Published 25 September 2020

ABSTRACT

This study aimed at finding out the efficacy of electrostatic sprayer on pest control in comparison with mist blower and air compression sprayer. Six pests were selected based on specific characteristics viz. integumental, movement and ecological niche. Energy use efficiency in production and application of pesticides used by different sprayers for the control of selected pests were quantified based on application efficiency, pre and post pest count and reoccurrence of pest infestation after spray. The greenhouse gas emission for the total energy usage for the corresponding quantity of pesticide were computed for all the selected sprayers. The energy use

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efficiency of electrostatic sprayer was found to be 1.5 times more than that of mist blower and 2 times more than that of air compression sprayers. The chemical usage by electrostatic sprayer was reduced by 65%, and that of knapsack mist blower was 35% with air compression sprayers. The corresponding greenhouse gas emission was only 20% for electrostatic sprayer and 65% for powered mist blower than that of air compression sprayers. The post pest count was almost nil in all the categories of pest while applying with electrostatic sprayer and the reoccurrence of the pest to the threshold level was minimum. This contributes a significant reduction in emission of CO_2 when considered globally, and ultimately contribute to mitigation of global warming.

Keywords: Carbon footprint; air compression sprayer; mistblower; electrostatic sprayer; pest threshold; energy use efficiency.

1. INTRODUCTION

A sustained increase in average global temperature, great enough to cause changes in the global climate, due to natural or human activities is referred as global warming and climate change [1,2,3]. The major contributor to this phenomenon is carbon dioxide (CO_2) [4,5] which nourishes plants and its good for soil, but too much of it in the atmosphere results ill effects to the planet as a whole [6,7].

Agriculture accounts for roughly 14 per cent of the total global greenhouse gas emission, including fertilizer and pesticide applications, since most of the agricultural chemicals are rich in carbon dioxide or nitrogen oxide [8,9]. Apart from application, the production industries of these chemicals contribute much higher rate of greenhouse gas emission [10,11]. The quantification of greenhouse gas (CO_2) which corresponds to the production and application of agricultural chemicals is being done by equating the quantum of energy involved in these activities [1,12]. Energy generation and utilization in whole crop production chain is not carbon neutral over, since GHG emission occurs during the entire production stage [13,14,15]. Agricultural management practices, especially production of fertilizer, pesticides, farming machinery or fuel combustion from machinery used, have a considerable effect on the amount of GHG emissions from energy crop production [16, 17, 18].

Pesticide application is an integral part of modern farming to protect the crops against various pests and disease attack. Plant protection chemicals are vital for profitability, low food prices and for maintaining adequate food supply. Without them, crop losses could be as high as 50 percent for field crops and up to 100 per cent for fruit crops and greenhouse ornamentals [19,20,21]. The demand for plant protection machinery in India is increasing every year. In the country, the powered knapsack mist blower [22,23] and knapsack air compression sprayers are the most popular and versatile pesticide application equipment because of their simplicity, ease of operation and inexpensiveness [24,25]. But still these sprayers have to overcome the problems of low target deposition, distribution and penetration into the plant canopies, which will lead over-application of chemicals that result to higher greenhouse gas emission.

Electrostatic spraying technology is a newer technology in the field of agriculture and effective in controlling the pest with impending reduction of over-application of chemicals [26,27,28]. It has an increased application efficiency of about 80 per cent with 60 per cent less spray chemical ingredients [29,30,31,32,33]. It works based on the principle of electrostatics, like charges repel and opposite charges attract (Coulomb’s law). As the chemical mix leaves the nozzle, it is exposed to a negative charge and is then attracted to the positively charged leaf surfaces [34,35]. It has significant potential on application of agricultural liquid formulations since charged particles can perform uniform spray coverage with considerably less quantity [36,30].

The energy use efficiency is the direct indicator of greenhouse gas emission [37,38]. The quantification of energy use efficiency [39,40,31,34] of electrostatic sprayer in comparison with the knapsack powered mist blower and air compression sprayers in application of agricultural pesticides is need of the hour [41,42,14,43,44].

Hence, this study was undertaken with the objective of estimating the carbon footprint of electrostatic sprayer on crop pest control in comparison with air compression sprayer and mist blower at Kerala Agricultural University.

2. MATERIALS AND METHODS

The powered knapsack mist blower (OLEOMAC AM 162), knapsack air compression sprayer and electrostatic sprayer (ESS MBP 4.0 Mountain Man Sprayer) were selected for the study.

Technical specifications of OLEOMAC make AM 162 model knapsack mistblower was.

Table 1. Technical specifications

Power	4.5 HP, 3.3 kW
Displacement	61.3 cm^3
Max. air flow	20.0 m^3 min^{-1}
Air speed	70 to 90 m s^{-1}
Liquid delivery rate	0.67 – 5.00 L min^{-1}
Liquid tank capacity	16.0 L
Weight	11.5 Kg

Technical specifications of ESS MBP 4.0 Mountain Man Sprayer model Electrostatic sprayer was:

Overall dimensions (H×W×L): 1.1 m × 0.6 m × 1.8 m

Air-compressor prime mover: 5 kW Briggs & Stratton gasoline engine

No. of nozzles: 01 (one)
Flow rate: 9.5 L hr^{-1}
Droplet size: 40 microns
Spray range: 6 m

Evaluation of selected sprayers was carried out in different categories of pests, selected based on their integumental character, type of movement and ecological niche as grouped below.

Based on integumental character

a. Hard bodied – Pumpkin beetle (*Raphidopalpa foveicollis*)
b. Soft bodied – Pea aphid (*Aphis craccivora*)

Based on movement

a. Flying type – Cucurbit fruit fly (*Bactrocera cucurbitae*)
b. Sedentary – Brinjal mealy bug (*Coccidohystrix insolita*)

Based on ecological niche

a. Abaxial – Caterpillar (*Leucinodes orbonalis)*
b. Adaxial – Chilli mite (*Polyphagotarsonemus latus*)

The experimental layout was done with the statistical framework of Completely Randomized Design.

To evaluate the sprayer for each category of pest, their respective host plants were raised. The plants were kept for natural infestation of the test insect and in cases where natural infestation did not occur, the pests were released artificially. The treatments were carried out when 30 per cent of the leaves per plants were infested in the case of sucking pests. For other pests, the treatments were initiated when a maximum of 5 caterpillar or beetle or flies were located.

Economic pest threshold provides a quantitative basis upon which crop managers can decide whether arthropod pest populations are below, at, or exceeding a level that warrants the expense of activities to reduce the pest's density. These interventions may be cultural, biological, or chemical control practices that reduce the pest population below the economic threshold [45,25,46].

2.1 Spraying

Spraying was carried out under controlled conditions. After spraying one set of plants were kept aside to note the reoccurrence of pests after first spraying. The other set were observed under natural conditions for re-infestation upon 30 per cent occurrence (sucking pests) and minimum number (caterpillar, beetles, flies), spraying was repeated as before. From the set of plants observed for reoccurrence, those attaining the prefixed levels were considered for second spraying. Spraying was repeated whenever the prefixed level of pest was noted. Pre and post counts at 48 h were recorded in each case.

2.2 Energy Use Efficiency of Sprayers

Energy use efficiency in application of pesticides used by different sprayers for the management of selected pests were quantified by considering the application efficiency of sprayers and the number of applications during the control of each pests [47,31,34,21].

2.2.1 Deposition efficiency of sprayer

The pesticide deposition efficiency on target of the sprayers was quantified by assessing the deposition efficiency and number of applications during the control of each pests. The spray deposition was estimated in terms of deposition per unit leaf area sprayed, by leaf wash method [48,49].

2.2.2 Estimation of man hours

Based on the concept that air compression sprayer take 13 h, powered knapsack mist blower take 8 hr and electrostatic sprayer take 8 h for covering 1 ha crop area, the number of applications calculated, the labour requirement needed in man hours was calculated.

$$Total\ labour\ requirement\ (man\ hour\ ha^{-1}\ year^{-1}) = Time\ taken\ for\ covering\ one\ hectare\ (h) \times Number\ of\ applications \quad (1)$$

2.3 Estimation of Energy Use Efficiency

The amount of energy required in the manufacturing process of pesticide, include energy for heating, creating pressure and cooling, the energy needed to create and transmit that energy to the manufacturing process, powder and granules formulation, packaging and transport, hence the energy requirements for the production of different pesticides vary. The total energy involved in the production system of all the agricultural chemicals can be categorized under two energy systems, *viz.* inherent energy, and process energy. The total energy for the production process of the chemical is the sum of the total inherent energy and the total process energy [39, 40, 50].

2.3.1 Inherent energy

Inherent energy is the primary energy resource used in the production of the chemical but retained in the chemical structure of the pesticide. It includes the energy from naphtha, gas and coke used to produce unit quantity of the product chemical also [47, 51, 43]. The inherent energy was calculated for the corresponding quantity of chemical requirement observed for each pest management with all the three sprayers separately and represented in unified unit of MJ Kg^{-1} ha^{-1} $year^{-1}$.

2.3.2 Process energy

The process energy is the energy required in the manufacturing process to produce the chemicals such as heating, creating pressure and cooling, plus the energy needed to create and transmit that energy to the manufacturing process. It includes the energy from fuel, oil, electricity and steam used for the production of unit quantity of the product chemical also [47, 51, 43]. The process energy was calculated for the corresponding quantity of chemical requirement observed for each pest management with all the three sprayers separately and represented in unified unit of MJ Kg-1 ha-1 year-1.

2.3.3 Application energy

The application energy of agricultural chemicals for the control of selected pests by using the selected three sprayers were estimated from the labour energy required and fuel energy used (calorific value of fuel) for all the applications during the crop season. The total labour energy was then quantified in man hour ha^{-1} $year^{-1}$ and converted to MJ ha^{-1} $year^{-1}$ (1 man hour = 1.96 MJ) [38, 52, 50, 14, 32]. The fuel energy was also expressed in MJ ha^{-1} $year^{-1}$ for the further calculation of corresponding greenhouse gas emission. Electrostatic sprayer and mistblower had prime movers as petrol engines and air compression sprayer was manually operated. The total application energy (Labour energy + Fuel energy) was then quantified [47,38, 52, 50, 53].

Finally the total energy utilized during the application of respective chemical for the control of selected pests with the three selected sprayers were calculated as the sum of application energy, process energy and inherent energy and expressed in MJ ha^{-1} $year^{-1}$.

The electrostatic sprayer was evaluated in two different experimental conditions; viz. with and without considering the reoccurrence of pest to the economic threshold level [35, 7].

Experiment named as ESS 1: Application energy of electrostatic sprayer was estimated in laboratory without considering the reoccurrence of pest to the economic threshold level.

Experiment named as ESS 2: The electrostatic sprayer was evaluated for application energy in the laboratory by considering the reoccurrence of pest to the threshold level after the first spray. The experiment ESS 2 could not be done in farmers' field, since they were not willing to spare the crop till the pest population reaches the threshold level.

2.4 Estimation of Greenhouse Gas Emission

The total greenhouse gas emission was estimated from the total energy use efficiency of the three selected sprayers in control of selected pests by applying corresponding pesticide. The greenhouse gas (CO_2) corresponding to one MJ of total energy was quantified as 0.069 kg CO_2 emission [47, 37, 38, 32, 18]. The emission was calculated for each pest by considering its reoccurrence. Therefore case II (with electrostatic sprayer) was also considered.

3. RESULTS AND DISCUSSION

The comparison between the three sprayers in energy use efficiency was done by considering the deposition efficiency of sprayers and the reoccurrence of pests to the threshold level.

3.1 Deposition Efficiency of Sprayers

The deposition efficiency of all the three sprayers were evaluated by leaf wash method using fluorescent tracer (DAY GLO type GT-15-N Fluorescent Blaze Orange dye) and the results are presented in Table 2.

The average value of knapsack air compression sprayer (20%) and knapsack powered mist blower (30%) were considered during the study. But in the case of electrostatic sprayer, the minimum value of deposition efficiency was considered.

3.2 Comparative Energy Use Efficiency of Electrostatic Sprayer in Crop Pest Management

The energy use efficiency was observed to be the maximum for the electrostatic sprayer both in laboratory condition (Fig. 1) and in farmers field (Fig. 2) in comparison with air compression sprayer and mistblower.

The energy use efficiency was observed to be the maximum under Case 2 experimental condition for all the pest. Pumpkin beetle – 82.73%, Aphid – 82.68%, Fruit fly – 83.02%, Mealy bug – 74.09%, Caterpillar – 74.48%, Chilli mite - 75.00% in comparison with air compression sprayer. The maximum energy saving reported for the electrostatic sprayer Case – 2 was due to the reduction in number of application resulted from the higher deposition efficiency and almost nil occurrence of pest to the pre-set level after the application of pesticide with electrostatic sprayer.

Table 2. Deposition efficiency of sprayers

Sprayer	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer
Deposition efficiency %	15 to 25	25 to 35	60 to 70

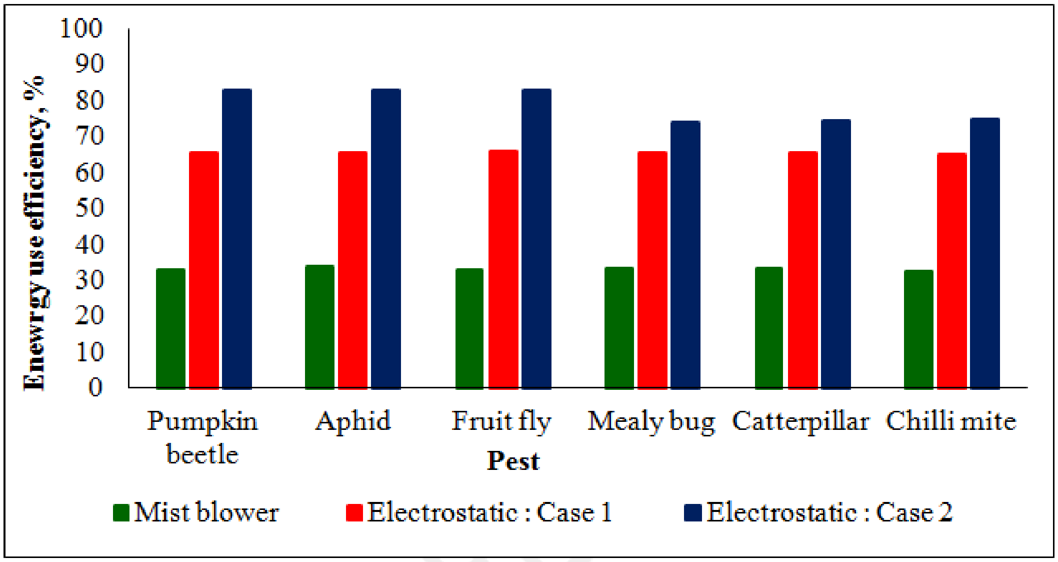

Fig. 1. Effect of type of sprayer on energy use efficiency in management of pests under laboratory condition

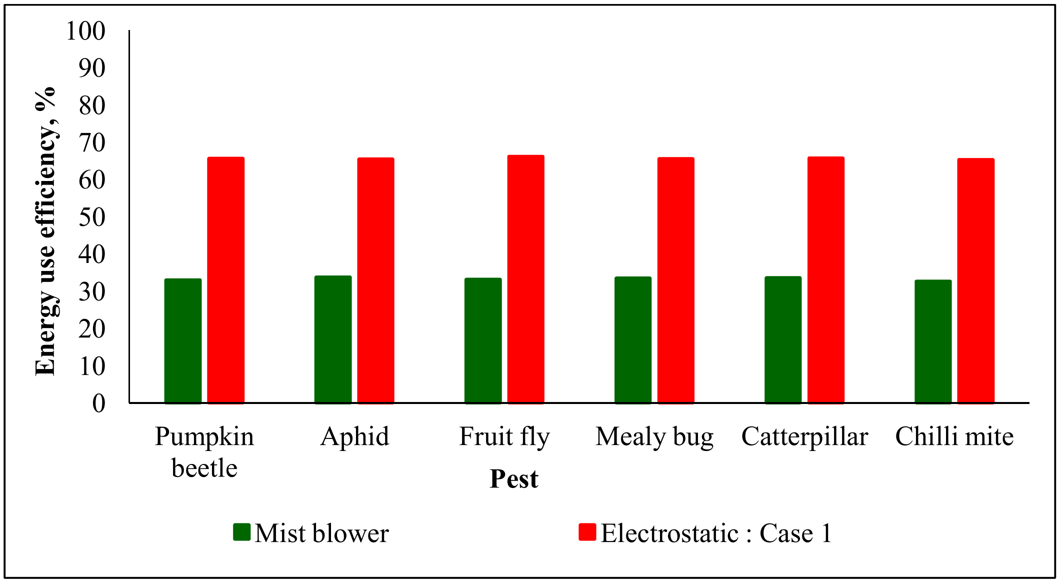

Fig. 2. Effect of type of sprayer on energy use efficiency in management of pests under field condition

Under laboratory condition Case 1, the energy use efficiency of electrostatic sprayer was for Pumpkin beetle – 66.41%, Aphid – 66.82%, Fruit fly – 53.14%, Mealy bug – 66.66%, Caterpillar – 66.43% and Chilli mite - 66.29% in comparison with air compression sprayer. In this case, the higher value of energy saving could be explained by the higher deposition efficiency, which in turn the low quantity of chemical requirement and ultimately the reduction in energy use during the production and application of chemical.

The energy use efficiency of the mist blower under laboratory condition was for Pumpkin beetle – 32.93%, Aphid – 33.65%, Fruit fly – 33.08%, Mealy bug – 33.35%, Caterpillar – 33.49% and Chilli mite – 32.58% in comparison with air compression sprayer. These values clearly indicates the wastage of chemicals which leads to the environmental contamination when compared with electrostatic sprayer.

The energy use efficiency under field condition Case 1, the of electrostatic sprayer was at an average of 65% in managing all categories of pests in comparison with air compression sprayer. It could be explained by the higher deposition efficiency.

In comparison with mist blower the electrostatic sprayer shown higher value of energy use efficiency (Case – 2: 40% higher and Case – 1: 30% higher). It could be explained by the higher rate of deposition efficiency and almost nil occurrence of pest to the threshold level after the application of pesticide with electrostatic sprayer in comparison with mist blower. But the energy use efficiency was about 35% higher than that of air compression sprayer, which was the clear indication of higher application efficiency of mist blower than the air compression sprayer.

3.3 Comparative Greenhouse Gas Emission of Electrostatic Sprayer in Crop Pest Management

The greenhouse gas emission correspond to the energy usage of the selected sprayers (knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer) was evaluated both in laboratory conditions and farmers field condition for the control of different pests based on its integumental characters (hard bodied: pumpkin beetle in cucumber; soft bodied: aphid in cowpea), movement (flying: fruit fly in bitter gourd; sedentary: mealy bug in brinjal), ecological niche (abaxial: cater pillar in brinjal; adaxial: chilli mite in chilli). The comparative emission of greenhouse gas of mist blower and electrostatic sprayer (case 1 and case 2) on its energy use efficiency with the air compression sprayer under laboratory condition (Fig. 3) and in farmers field was assessed (Fig. 4).

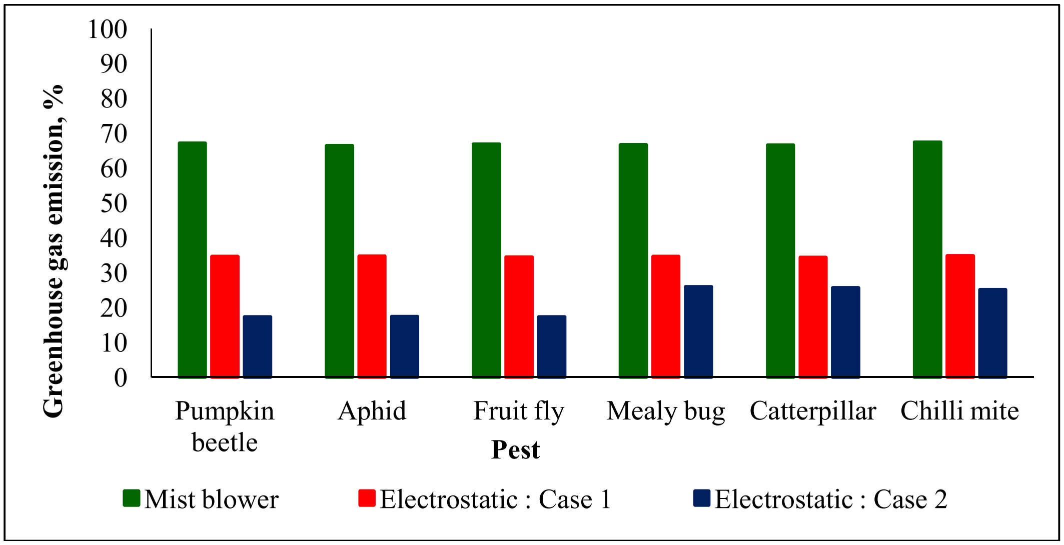

Fig. 3. Effect of type of sprayer on CO_2 release in management of pests under laboratory condition

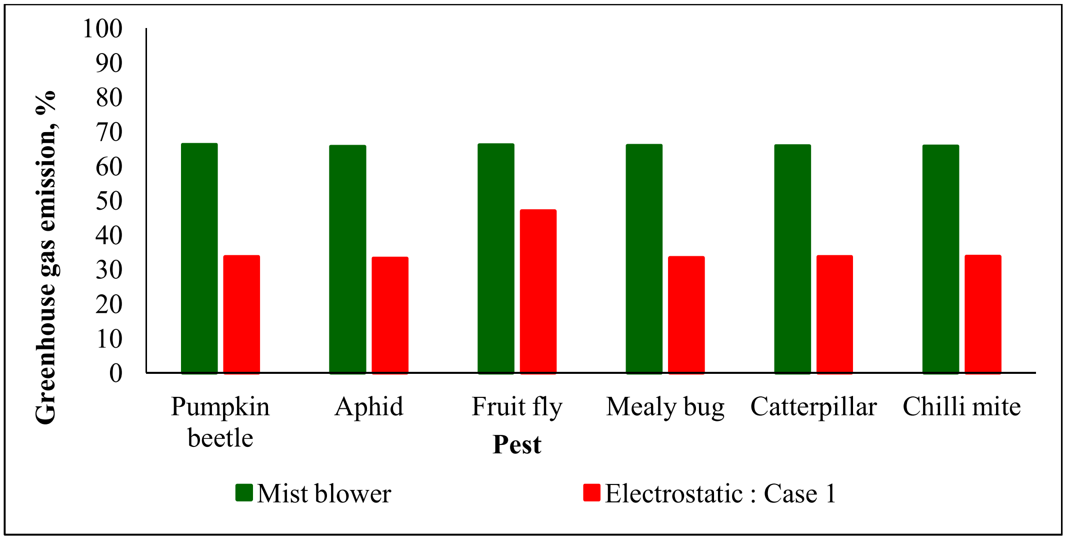

Fig. 4. Effect of type of sprayer on CO_2 release in management of pests under field condition

Table 3. Two factor ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Sprayer Type	1022113	3	340704.3	18.15942	2.96E-05	3.287382
Pests	907802.8	5	181560.6	9.677111	0.000277	2.901295
Error	281427.8	15	18761.86			

From the ANOVA, the significant differences between the sprayers in managing different crop pests are proven statistically

The greenhouse gas emission was recorded the minimum for electrostatic sprayer under laboratory experiment Case 2 for Pumpkin beetle – 17.27%, Aphid – 17.32%, Fruit fly – 17.21%, Mealy bug – 25.91%, Caterpillar – 25.51%, chilli mite – 24.99%. Under laboratory experiment Case 1, the average CO_2 emission was estimated as 34% for the management of all the selected pest's infestation.

The minimum CO_2 emission was reported both in laboratory condition and farmers field for the electrostatic sprayer Case – 2 was due to the reduction in number of application resulted from the higher deposition efficiency and almost nil occurrence of pest to the threshold level after the application of pesticide with electrostatic sprayer. In Case - 1 also, the lower value of greenhouse gas emission (only about 35% of air compression sprayer) could be explained by the higher deposition efficiency, which in turn the lesser amount of chemical requirement and ultimately the reduction in energy use during the production and application of chemical.

But in farmer's field the CO_2 emission during all the pest management experiments was at the range from 17 to 28% in comparison with air compression sprayer. But the corresponding CO_2 emission for the mist blower was at the range of 65 to 67%.

The minimum CO_2 emission was reported in farmers field for the electrostatic sprayer could be explained by the higher deposition efficiency, which in turn the lesser amount of chemical requirement and ultimately the reduction in energy use during the production and application of chemical.

In comparison with mist blower the electrostatic sprayer shown lower value of CO_2 release both in laboratory condition and famers plot (Case – 1: 30% lower and Case – 2: 45% lower). It could be explained by the higher rate of deposition efficiency and almost nil occurrence of pest to the threshold level after the application of pesticide with electrostatic sprayer in comparison with mist blower. But the energy use efficiency was only about 65% that of air compression sprayer, which was the clear indication of higher application efficiency of mist blower than the air compression sprayer.

The experiment was conducted under statistical framework of two factor analysis.

4. CONCLUSION

From the observations and analysis, it could be concluded that the electrostatic sprayers are highly efficient and contribute minimum CO_2 emission to the atmosphere. The greenhouse gas emission could be reduced by 65 per cent using electrostatic sprayer and 25 per cent by the use of mist blower in comparison with air compression sprayer. The knapsack air compression sprayers give the maximum CO_2 emission while the knapsack powered mist blower gave an intermediate emission which contributes a significant reduction in emission of CO_2 when considered globally which will otherwise mitigate global warming.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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