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Energy Use Efficacy of Different Sprayers on Crop Pest Management

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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. Author SRS managed the analyses of the study. Authors KAK and XKJ managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Pesticide application plays a major role in environmental hazards associated with over application and off-target movement of toxic pesticides from inefficient spray application. The introduction of electrically charged sprays for agricultural application can provide greater control of droplet transport with impending reduction of wastage. The study aims to compare the efficacy of electrostatic sprayer on pest control in comparison with mist blower (air assisted sprayer) and air compression sprayer (hydraulic sprayer). Six pests were viz. pumpkin beetle, cowpea aphid, cucurbit fruit fly, brinjal mealy bug, caterpillar and chilli mite 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 of sprayers, Pre and Post pest count and the reoccurrence of pest infestation after spray. The energy use 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

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sprayers. In the chemical usage by electrostatic sprayer was reduced by 65 per cent and that of knapsack mist blower was 35 per cent with 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 contributed a significant increase in energy use efficiency of electrostatic sprayer, when it considered globally.

Keywords: Energy use efficiency; electrostatic sprayer; pest threshold.

1. INTRODUCTION

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 [1,2,3]. The demand for plant protection machinery in India is increasing every year. In the country, the powered knapsack mist blower [4,5] and knapsack air compression sprayers are most popular and versatile pesticide application equipment because of it's simplicity, ease of operation and inexpensiveness [6,7]. But still these sprayers have to overcome the problems of low target deposition, distribution and penetration in to the plant canopies, which will lead over application of chemicals.

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 [8,9,10]. It has an increased application efficiency of about 80 per cent with 60 per cent less spray chemical ingredients [11,12,13,14]. 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 surface [15,13,16]. It has significant potential on application of agricultural liquid formulations since charged particles can perform uniform spray coverage with considerably less quantity [17,18].

The quantification of energy use efficiency [12,15] of electrostatic sprayer over the knapsack powered mist blower and air compression sprayers in application of agricultural pesticides to control different pests shows extreme characters in movement and habitat is need of the hour [19,20,21,22,14,23].

Hence this study was undertaken to evaluate the energy usage during the production and application of required pesticides for the control of selected pests by using the selected sprayers (powered knapsack mist blower, knapsack air compression sprayer and electrostatic sprayer).

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.

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.

1. Based on integumental character
   a. Hard bodied – Pumkin beetle (*Aulacophora faveicollis*)
   b. Soft bodied – Pea aphid (*Aphis craccivora*)
2. Based on movement
   a. Flying type – Cucurbit fruit fly (*Bactrocera cucurbitae*)
   b. Sedentary – Brinjal mealy bug (*Centrocccus insolitus*)
3. Based on ecological niche
   a. Abaxial – Caterpillar (*Leucinodes orbonalis)*
   b. Adaxial – Chilli mite (*Polyphagotarsonemus latus*)

Three insecticides commonly recommended for vegetable pest management were selected for the experiment. They were carbaril (50 WP), Malathion (50 EC) and dimethoate (30 EC). The experiment layout was done with the statistical frame work of CRD.

To evaluate the sprayer for each category pest, their respective host plants were raised. The plants were kept for natural infestation of the test insect. Wherein 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.

Pest thresholds provide 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 [24,7,25].

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 application during the control of each pests [26,12,15,21,3].

a. Deposition efficiency of sprayer

The pesticide deposition efficiency on target of the sprayers was quantified by assessing the deposition efficiency and number of application during the control of each pests. The spray deposition was estimated in terms of deposition per unit leaf area sprayed, by leaf wash method [27,28].

b. 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. 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 [29].

a. 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 for the production of unit quantity of the product chemical also [26,30,22]. 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} $year^{-1}$.

b. 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 [26,30,22]. 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} $year^{-1}$.

c. 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, mechanical energy and fuel energy used (calorific value of fuel) for all the applications during the crop season [31,29,32]. The total application energy was then expressed in man hour ha^{-1} $year^{-1}$ for the further calculation of corresponding greenhouse gas emission. The total application energy was then quantified by equating a man hour to 1.96 MJ of energy.

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 methods; viz. with and without considering the reoccurrence of pest to the threshold level.

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

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 Energy Use Efficiency in Managing of Hard Bodied Pest: Pumpkin Beetle

The energy expenditure during the control of pumpkin beetle in cucumber was observed (Fig. 1) to the maximum for knapsack air compression sprayer both in laboratory condition (9405.76 MJ kg^{-1} ha^{-1} $year^{-1}$) and in farmers field (14228.64 MJ kg^{-1} ha^{-1} $year^{-1}$) followed by knapsack mist blower (6308.16 MJ kg^{-1} ha^{-1} $year^{-1}$ and 9415.2 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively) and the minimum expenditure was for the electrostatic sprayer (3248.16 MJ kg^{-1} ha^{-1} $year^{-1}$ and 4778.16 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). But the reoccurrence of pest population to the threshold level was almost nil in the case of electrostatic sprayer, hence the number of application was reduced considerably (1624.08 MJ kg^{-1} ha^{-1} $year^{-1}$ and 2436.12 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). While using electrostatic sprayers for the control of pumpkin beetle in cucumber, the number of applications was reduced (due to the almost nil chance of reoccurrence of pumpkin beetle to the threshold level) and also quantity of pesticide used was lesser (deposition efficiency was more than 2 times higher) than that of other two sprayers, hence the reduction in energy use. But in farmer's field condition, the number of application was higher than that of laboratory condition since they were not waiting till the occurrence of pest.

3.2 Energy Use Efficiency in Managing of Soft Bodied Pest: Cowpea Aphid

During the control of aphid in cowpea the energy expenditure was observed (Fig. 2) to the maximum in the case of knapsack air compression sprayer both in laboratory condition (3608.4 MJ kg^{-1} ha^{-1} $year^{-1}$) and in farmers field (7216.8 MJ kg^{-1} ha^{-1} $year^{-1}$) followed by knapsack mist blower (2393.84 MJ kg^{-1} ha^{-1} $year^{-1}$ and 4734.76 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively) and the minimum expenditure was for the electrostatic sprayer (1249.84 MJ kg^{-1} ha^{-1} $year^{-1}$ and 2393.84 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). The number of application was reduced considerably, due to the zero chance of reoccurrence of the pest. (624.92 MJ kg^{-1} ha^{-1} $year^{-1}$ and 1196.92 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). The number of applications was reduced by using electrostatic sprayers for the control of aphid in cowpea (due to the almost nil chance of reoccurrence of aphid to the threshold level) and also quantity of pesticide used was lesser (deposition efficiency was more than 2 times higher) than that of other two sprayers, hence the reduction in energy use.

3.3 Energy Use Efficiency in Managing of Flying Pest: Cucurbit Fruit Fly

The energy expenditure during the control of fruit fly in bitter gourd was observed (Fig. 3) to the maximum for knapsack air compression sprayer both in laboratory condition (3161.92 MJ kg^{-1} ha^{-1} $year^{-1}$) and in farmers field (6323.84 MJ kg^{-1} ha^{-1} $year^{-1}$) followed by knapsack mist blower

(2112.92 MJ kg^{-1} ha^{-1} $year^{-1}$ and 4179.18 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively) and the minimum expenditure was for the electrostatic sprayer (1087.82 MJ kg^{-1} ha^{-1} $year^{-1}$ and 2962.9 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). The reoccurrence of pest population was less than the threshold population in the case of electrostatic sprayer, hence the number of application was reduced considerably (543.91 MJ kg^{-1} ha^{-1} $year^{-1}$ and 1481.46 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). While using electrostatic sprayers for the control of fruit fly in bitter gourd, the number of applications was reduced (due to the almost nil chance of reoccurrence of fruit fly to the threshold level) and also quantity of pesticide used was lesser (deposition efficiency was more than 2 times higher) than that of other two sprayers, hence the reduction in energy use.

3.4 Energy Use Efficiency in Managing of Sedentary Pest: Brinjal Mealy Bug

During the control of mealy bug in brinjal the energy expenditure was observed (Fig. 4) to the maximum for knapsack air compression sprayer both in laboratory condition (12867.2 MJ kg^{-1} ha^{-1} $year^{-1}$) and in farmers field (19300.8 MJ kg^{-1} ha^{-1} $year^{-1}$) followed by knapsack mist blower (8575.6 MJ kg^{-1} ha^{-1} $year^{-1}$ and 12710.4 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). The minimum energy expenditure

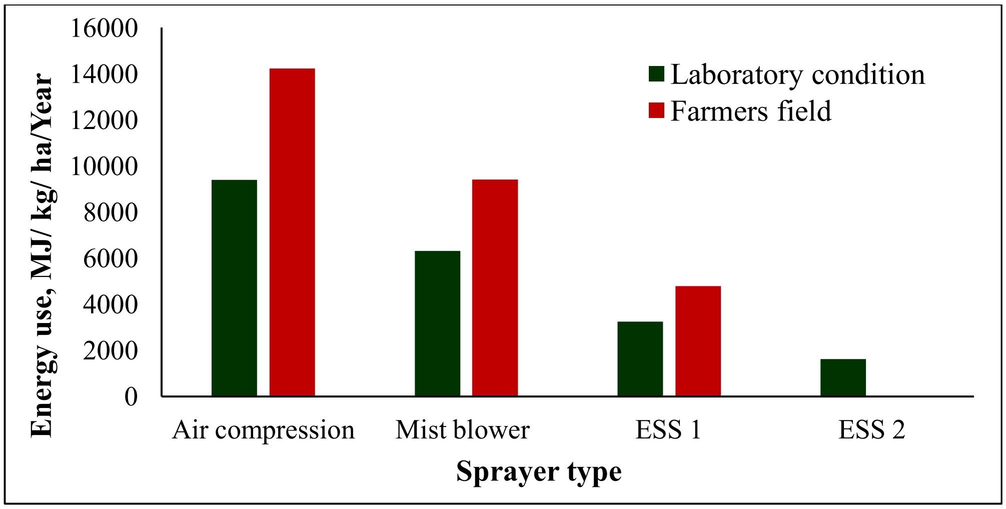

Fig. 1. Energy usage of sprayers for the management of pumpkin beetle

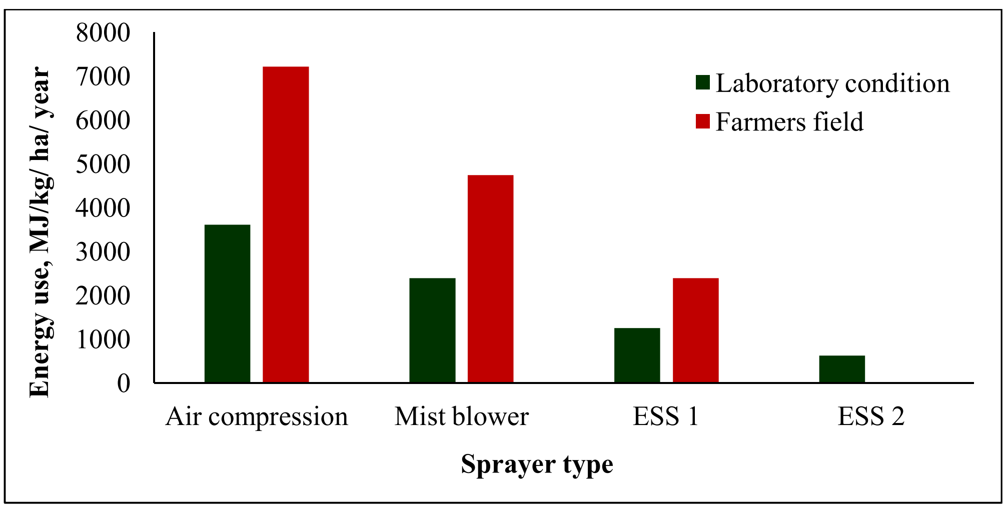

Fig. 2. Energy usage of sprayers for the management of cowpea aphid

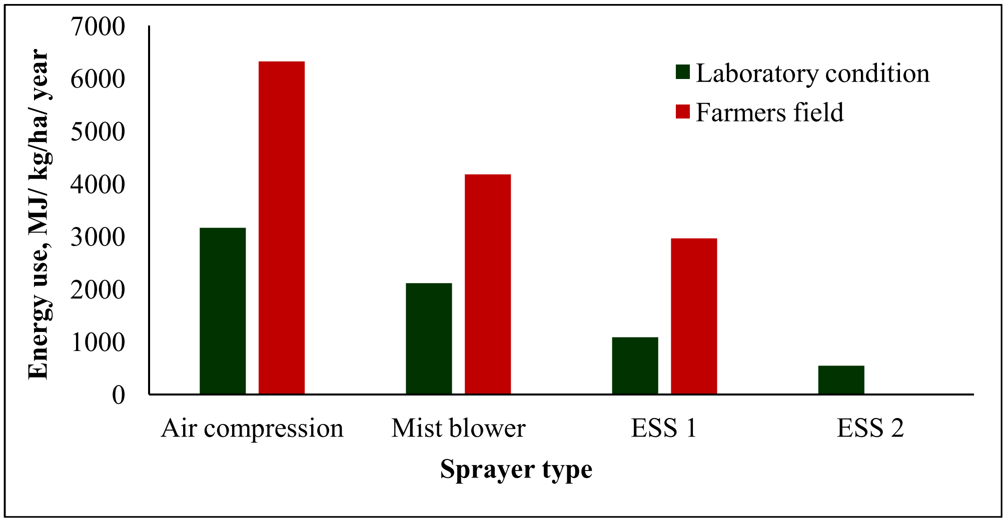

Fig. 3. Energy usage of sprayers for the management of cucurbit fruit fly

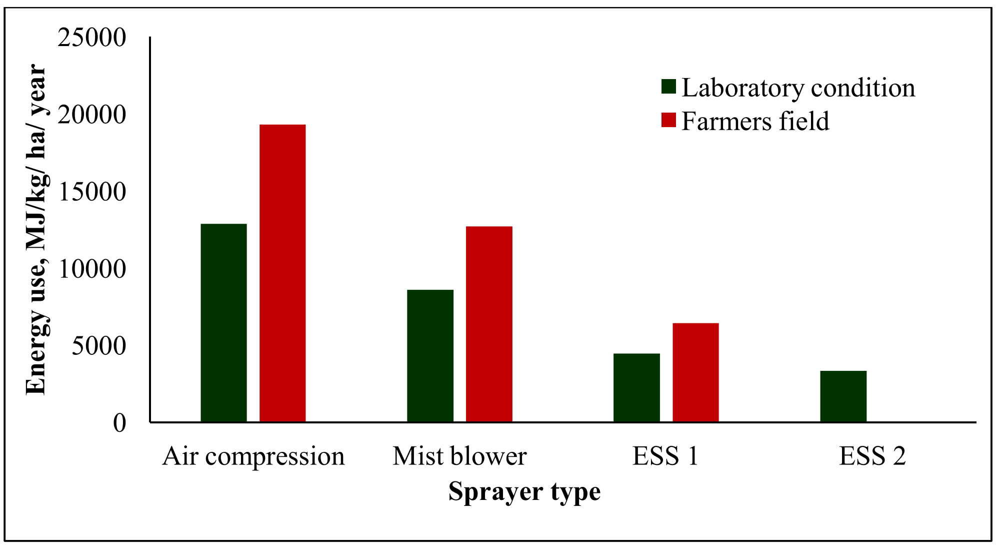

Fig. 4. Energy usage of sprayers for the management of brinjal mealy bug

was for the electrostatic sprayer (4444.6 MJ kg^{-1} ha^{-1} $year^{-1}$ and 6433.6 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). The reoccurrence pest population to the threshold level was almost nil in case of electrostatic sprayer, hence the number of application was reduced considerably (3333.45 MJ kg^{-1} ha^{-1} $year^{-1}$ and 4825.20 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). The number of applications was reduced while using electrostatic sprayers for the control of mealy bug in brinjal (due to the low chance of reoccurrence of mealy bug to the threshold level) and also quantity of pesticide used was lesser than that of other two sprayers, hence the reduction in energy use.

3.5 Energy Use Efficiency in Managing of Abaxial: Caterpillar

The energy expenditure during the control of caterpillar in brinjal was observed (Fig. 5) to the maximum for knapsack air compression sprayer both in laboratory condition (4742.88 MJ kg^{-1} ha^{-1} $year^{-1}$) and in farmers field (7114.32 MJ kg^{-1} ha^{-1} $year^{-1}$) followed by knapsack mist blower (3154.08 MJ kg^{-1} ha^{-1} $year^{-1}$ and 4683.12 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively) and the minimum expenditure was for the electrostatic sprayer (1624.08 MJ kg^{-1} ha^{-1} $year^{-1}$ and 2388.12 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). The reoccurrence pest population to the threshold level was low in the case of electrostatic sprayer, hence the number of application was reduced considerably (1210.22 MJ kg^{-1} ha^{-1} $year^{-1}$ and 1783.97 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). While using electrostatic sprayers for the control of caterpillar in brinjal, the number of applications was reduced (due to the almost nil chance of reoccurrence of caterpillar to the threshold level) and also quantity of pesticide used was lesser (deposition efficiency was more than 2 times higher) than that of other two sprayers, hence the reduction in energy use.

3.6 Energy Use Efficiency in Managing of Adaxial: Chilli Mite

For the control of chilli mite in chilli the energy expenditure was observed (Fig. 6) to the maximum for knapsack air compression sprayer both in laboratory condition (3952.8 MJ kg^{-1} ha^{-1} $year^{-1}$) and in farmers field (5270.4 MJ kg^{-1} ha^{-1} $year^{-1}$) followed by knapsack mist blower (2664.6 MJ kg^{-1} ha^{-1} $year^{-1}$ and 3464.6 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively) and the minimum expenditure was for the electrostatic sprayer (1376.4 MJ kg^{-1} ha^{-1} $year^{-1}$ and 1776.4 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively).

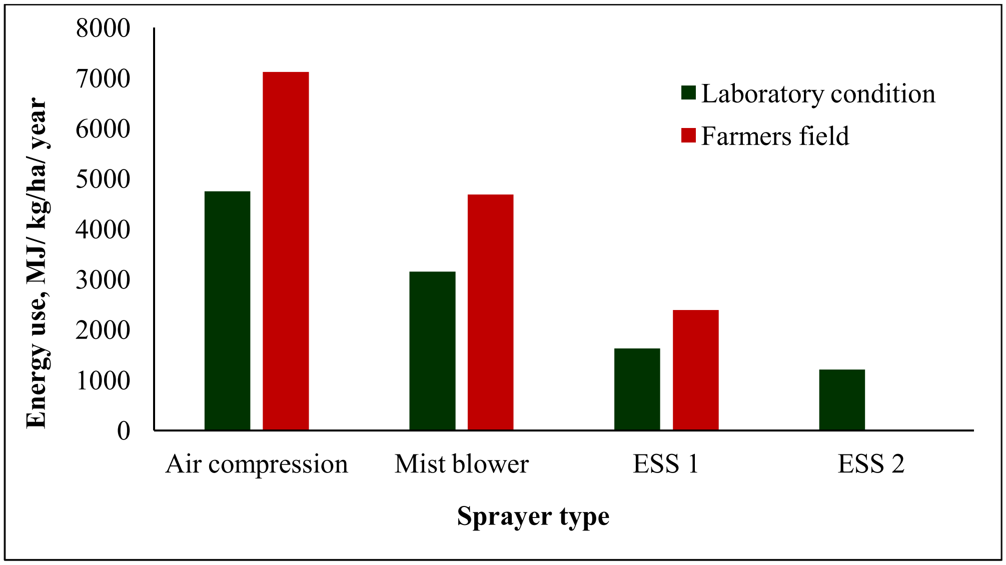

Fig. 5. Energy usage of sprayers for the management of caterpillar

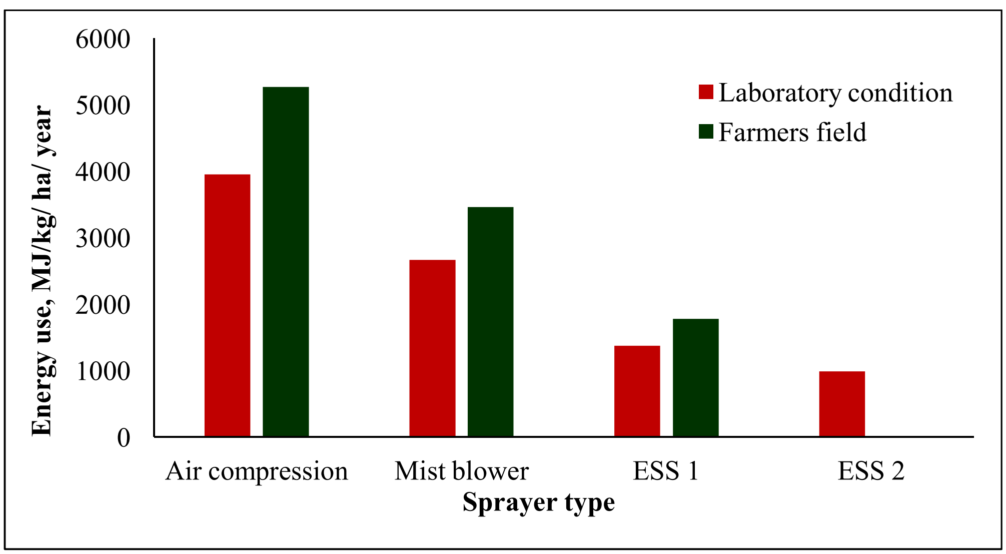

Fig. 6. Energy usage of sprayers for the management of chilli mite

Table 1. Two factor ANOVA

ANOVA						
Source of variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Sprayer type	214684140.2	3	71561380	18.16	2.96226E-05	3.29
Pests	190677439.7	5	38135488	9.68	0.000276818	2.9
Error	59109916.44	15	3940661.1			

The reoccurrence pest population to the threshold level was almost nil in the case of electrostatic sprayer, hence the number of application was reduced considerably (988.2 MJ kg^{-1} ha^{-1} $year^{-1}$ and 1288.2 MJ kg^{-1} ha^{-1} $year^{-1}$ respectively). While using electrostatic sprayers for the control of chilli mite in chilli, the number of applications was reduced (due to the almost nil chance of reoccurrence of chilli mite to the threshold level) and also quantity of pesticide used was lesser (deposition efficiency was more than 2 times higher) than that of other two sprayers, hence the reduction in energy use.

The experiment was conducted under statistical frame work of two factor analysis.

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

4. CONCLUSIONS

The energy use efficiency in the production and application of pesticides used by the selected sprayers for the management of selected pests were quantified by considering the application efficiency of sprayers, pre and post pest count and the reoccurrence of pest infestation after spray and the below mentioned findings were obtained from the study.

The energy use of ESS was found to be lesser (1.5 times) that of mist blower and 2 times that of air compression sprayers. The chemical usage by electrostatic sprayer reduced by 35% with that of knapsack mist blower and 65% with that of air compression sprayers. Since the pest count after the application of chemical with electrostatic sprayer was almost nil in all the categories of pest. Hence the reoccurrence of the pest to the threshold level was minimum. As a result the number of application during the crop season was reduced. Correspondingly the amount of chemical applied and energy utilization emission also reduced.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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