EFFICACY OF ELECTROSTATIC SPRAYER ON CROP PEST MANAGEMENT AND PESTICIDE USE

by

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THESIS

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DECLARATION

I, Aneesha, V. (2011 – 20 – 119) hereby declare that this thesis entitled **"Efficacy of electrostatic sprayer on crop pest management and pesticide use"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

a.i	- Active Ingredient
CMR	- Charge Mass Ratio
EC	- Emulsifiable Concentrate
EI	- Environmental Impact
EIQ	- Environmental Impact Quotient
EPWS	- Electrostatically Assisted Particulate Wet Scrubber
ESP	- Electrostatic Precipitation
ESS	- Electrostatic Sprayer
GHG	- Greenhouse Gas
GWP	- Global Warming Potential
LCD	- Liquid Crystal Display
MJ	- Mega Joule
Nm	- Nano meter
PLC	- Programmable Logic Controller
POP	- Package of Practices
PPM	- Parts Per Million
TPP	- Tomato – Potato psyllid
ULV	- Ultra Low Volume
VMD	- Volume Median Diameter
WP	- Wettable Powder
WSP	- Water Sensitive Paper

Introduction

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. The major contributor to this phenomenon is carbon dioxide (CO_2). It nourishes plants and is good for soil, but too much of it in the atmosphere results ill effects to the planet as a whole.

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 which are rich in carbon dioxide or nitrogen oxide. Apart from application, the production industries of these chemicals contribute much higher rate of greenhouse gas emission. The quantification of greenhouse gas (CO_2) corresponds to the production and application of agricultural chemicals is being done by equating the quantum of energy involved in these activities. Energy generation and utilization in whole crop production chain is not carbon neutral over, since GHG emission occurs during the entire production stage. 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.

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. The demand for plant protection machinery in India is increasing every year. In the country, the powered knapsack mist blower and knapsack air compression sprayers are most popular and versatile pesticide application equipment because of it's simplicity, ease of operation and inexpensiveness. But still these sprayers have to overcome the problems of low target

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deposition, distribution and penetration in to the plant canopies, which will lead over application of chemicals results in 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. It has an increased application efficiency of about 80 per cent with 60 per cent less spray chemical ingredients (Lane and Law, 1982). 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. It has significant potential on application of agricultural liquid formulations since charged particles can perform uniform spray coverage with considerably less quantity.

The quantification of energy use efficiency 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, since the energy use efficiency is the direct indicator of greenhouse gas emission in this aspect.

Hence this study entitled "efficacy of electrostatic sprayer on crop pest management and pesticide use" 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).

The objectives of the study are

1. To study the efficacy of electrostatic sprayer on crop pest control in comparison with mist blower.
2. To analyze the percentage deposition of chemicals on target by the sprayers.
3. To estimate the greenhouse gas emission from the used pesticide during crop pest management.

Review of Literature

2. REVIEW OF LITERATURE

Agricultural pesticide manufacturing industry and its field application contributes a significant amount to total global greenhouse gas emission. The equipment used for the application can play a major role in reducing the quantity of chemicals both in application and production which in turn reduces the greenhouse gas emission. In this chapter a brief review of research carried out in energy consumption, energy use efficiencies of sprayers in terms of production and application of agricultural pesticides have been presented.

2.1. SPRAYERS : SELECTION AND EVALUATION.

Carlton and Bouse (1980) designed, developed and evaluated an electrostatic spray charging spinning nozzle for aircraft. The rotational speed of the spinner and hence the droplet size was altered by regulating motor voltage. Spray charging efficiency increased with increase in spinner speed and Charge Mass Ratio (CMR) about 2×10^{-2} C. kg^{-1}. The experiments showed that electrostatically charged spray deposition may exceed that of uncharged spray counterpart by 800 per cent.

Walker *et al.* (1989) conducted field testing of pesticide spray atomizers of different kinds for weed control in soybean cultivation. The soybeans were placed at four rows with 102 cm width and 18.3 m length. The study took about 6 years. The spray atomizers taken in to the study were rotary unit. The air atomizing electrostatic sprayers were compared with the conventional spray nozzle. The results showed that the non conventional atomizers did not perform significantly as compared with the conventional hydraulic sprayers based on broad leaf weed control over foliar-applied chemicals.

Blewett *et al.* (1992) studied about the foliar and non target deposition from conventional and reduced volume pesticide application in greenhouses. The study involves the comparison of conventional and air-assisted, reduced volume, electrostatic pesticide application techniques. The reduced volume electrostatic application resulted in an approximately 3.7 fold increase in foliar deposition. The electrostatic application showed a greater deposition on the target foliage of 59 % compared to the conventional application of 16 per cent. The conventional application system resulted in non-target area deposition on the bench top area between and underneath the potted plants. The result showed that the electrostatic application performed greater deposition.

Kabashima *et al.* (1995) depicted that the electrostatic sprayers improve pesticide efficacy in greenhouses. They evaluated the benefits of electrostatic sprayers than the conventional types by conducting tests in controlling green peach and melon aphids. This new technology is superior in pest control than the conventional types while using 40 times less water in an equivalent area. It also provided about 3.7 times more foliar deposition and the particles which are electrostatically sprayed are difficult to remove mechanically. So it ensures the worker health and safety than the conventional full volume wet sprays.

Piche *et al.* (2000) evaluated the reduced drift from air-assisted spraying. The study focused to compare the amount of drift produced using two sprayers-a hydraulic air assisted boom sprayer and a conventional hydraulic boom sprayer. The comparison is limited to the near-drift measured 10m away from the spray swath. The results showed that the air-assistance using high air volume coupled with the use of coarser spray decreases drift compared to the conventional type sprayer. The drift amount reduced by a factor of 9.9.

Law and cooper (2001) developed the air assisted electrostatic sprays for post harvest control of fruit and vegetable spoilage microorganisms. An oscillating array of air-assisted electrostatic induction droplet-charging nozzles has been developed in to a dielectric chamber to each atomize and charge 1 to 2 mL s^{-1} flows to conductive liquid to typically 5 to 10 Mc kg^{-1} charge to mass using 500 to 1200 V dc., 15 to

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20 kg fruits and vegetables were treated with 15 to 20 mL of finely atomized charged spray in 2 seconds. Electrostatic applications of fungicidal sprays on banana provided greater control of costa Rican crown-rot fungal complex than the conventional hydraulic sprays. The deposition efficacy of these sprayers was 27 fold higher than by the dip method. Thus, the electrostatic sprayers have both the environmental and economic benefits of post harvest protection.

Lander (2004) conducted study on reducing drift from vineyard sprayers. It describes the comparative field research trials between directed deposition sprayers and air blast sprayers in vineyards. He observed that directed deposition sprayers are better in deposition and reduce drift, only when a good target canopy exists.

Derksen *et al.* (2007) conducted a study on the field evaluation of application variables and plant density for bell pepper pest management. Fluorescent dyes and food colouring were used to compare the foliar spray coverage and spray retention in the middle and bottom of bell pepper canopies. Different delivery systems were evaluated with travel speeds of 6.4 and 12.9 km hr^{-1}. The electrostatic sprayer produced the greatest differences in deposits between the middle and bottom of the canopy. The air assist sprayer treatment found to be higher in dried droplet or blob density on the underside leaf surfaces and in the lower portion of the canopy than either of the conventional sprayer treatments.

Gossen *et al.* (2008) conducted study on improving spray retention to enhance the efficacy of foliar-applied disease and pest management products in field and row crops. The study depicts the parameters that affect retention and performance of pest and disease management products on field and horticultural crops, with special consideration of plants tissues with a vertical orientation, as the pesticide coverage of these tissues is low. The spray application parameters such as nozzle orientation and droplet size influenced the efficacy of foliar-applied disease management products and pesticides.

Celen *et al.* (2009) conducted study on the effect of air assistance on deposition distribution on spraying by tunnel-type electrostatic sprayer. The study focused on increasing the success of the spray application by tunnel-type electrostatic sprayer. Tests were conducted under two operating pressures namely 2 and 3 bar with 6 kmh^{-1} operating speed in Semillon vineyards. Tartarzine was used as spray liquid. The results showed that the increased spray deposit on the plant, caused to decrease the amount of residues on the ground. Similarly, decreased the amount of spray deposit exposed drift.

Latheef *et al.* (2009) studied about the aerial electrostatic-charged sprays for deposition and efficacy against sweet potato whitefly (*Bemisia tabaci Genn*). Biotype B was taken as the factors determining the efficacy of electrostatic charged sprays. For comparison uncharged and conventional sprays. Results showed that the potential exists for obtaining increased efficacy against whiteflies using an electrostatic spray charging system.

Zhou *et al.* (2009) implemented the design and experiments of aerial electrostatic spraying system assembled in helicopter. It's aim to prevent and cure pests in agriculture and forestry. It can make the target coverage rate increase 12 droplets cm^{-1}. Electrostatic spray can make 36 m spray breadth with the charging voltage of 10 kV and it reduces the droplet drift for 38 per cent. It showed that combining aerial spray technique with electrostatic spray technique, ensures convenient operation, high efficiency, high productivity with no harmful effects. So the electrostatic spray in helicopter is uniform and fine droplets with better droplet adhesion and spread, higher deposit efficiency, lower application rate, lower environmental contamination, less application expenses and longer residual action than conventional aerial sprays.

Yu Ru *et al.* (2011) demonstrated the design and experiments on droplet charging device for high range electrostatic sprayer. The electrostatic spray could improve the coverage uniformity, deposition efficiency, enhance the speed of droplet setting, reduce the drift loss and reduce the pesticide application rate. Electrostatic spray can make the front target coverage rate as 21 droplets cm^{-2}. It can increase the spray breadth for 0.84 m with a 20 kV voltage, with the maximum charge to mass ratio of 2.35 mC kg^{-1}. These sprayers could perform with uniform and fine droplets with better droplet adhesion and speed, higher deposit efficiency, lower application rate, less application expenses, lesser environmental pollution, longer residual action than the conventional sprayers.

Jia *et al.* (2012) conducted study on enhancing efficiency of chemical spraying with electrostatic spraying. During the study an automatic controlling system developed with PLC (Programmable Logic Controller) as the control core of the system and LCD was employed for human computer interaction interface. Accurate quantification, automatic controlling and humanized operations were done by the sprayers. They observed that the effective distance is 5-6 m and wind speed up to 12.5 m s^{-1} in the export. It effectively enhanced the spray span ULV helped to avoid the low deposition rate. As the machine integrated both the automatic as well as manual control, it can be used in various environment with high efficiency, longtime efficacy and less pesticide.

Roten *et al.* (2013) evaluated the spray deposition in potatoes using various spray delivery systems. They were a conventional boom, a canopy submerged drop sprayer combination, a pnueumatic electrostatic spraying system, and an air assisted rotary atomizer and a high volume air assist boom. It was conducted against the tomato-potato psyllid (TPP) caused a huge economic loss. The potatoes were sprayed when it reached 0.75 m tall. The study involves a complex, double nested design where the height and leaf side were nested within the treatment. Deposition was measured qualitatively by using k cards and quantitatively through physical washing. In conclusion the deposition from these different treatments were varied less than expected, however they gave higher coverage to underside of the potato leaves than the conventional boom.

Martin and Carlton (2012) studied the effect of airspeed and orifice size on the spray droplet spectra from an aerial electrostatic nozzle for rotary-wing applications. Brazilian electrostatic nozzles were used and they were tested at airspeeds of 80 to 177 km h^{-1}, with nozzle orifice diameters of 1.04 to 1.32 mm. The results showed that for all nozzle orifices tested, they produced smaller spray droplets when airspeed increased from 97 to 117 km h^{-1}. Also, CMR of the resulting spray increased with the increase in the airspeed and reductions in nozzle orifice.

Esehaghbeygi *et al.* (2012) conducted study on the comparison of electrostatic and spinning – discs spray nozzles on wheat weeds control. The efficacy of the electrostatic sprayers and spinning discs were assessed in irrigated wheat by the application of 2, 4-D to control the weeds. Wheat grain yield, weed shoot biomass and wheat residual were taken as the parameters to evaluate the sprayer nozzle performance. While comparing both the sprayers, it is clear the electrostatic sprayers shows greater efficacy than the spinning disc sprayers had more droplet uniformity, decreased water use and cheaper to operate, it did not improve herbicide efficacy.

Mamury *et al.* (2014) developed the computation model of electrostatic spraying in Agriculture industry. Electrostatic spray technology attained a wide acceptance in improved plant coverage with high efficacy. The role of electrostatic forces on target coverage with spray fluid has been investigated by an induction charging nozzle. Five metal targets flat, conical, cylindrical, ellipsoid and spherical were examined. To measure the current and charge mass ratio, faraday cage was used at 7 levels of air pressures. The results showed that the conical target showed maximum current and charge mass ratio, followed by flat, cylindrical, ellipsoid and spherical targets respectively. The direct relationship has been observed between the water flow rate and current and charge mass ratio.

Gen *et al.* (2014) demonstrated the simultaneous deposition of submicron aerosols on to both surfaces of a plate substrate by electrostatic forces. Submicrometer sized particles were used to find out the both side deposition. Center and edge regions of the substrate were found to be more in deposition. Compared to the diffusion effect, the electrostatic effect is predominated in both regions. The charged particles are deflected by the deposition velocity difference between the center and the edge and it's mutual repulsion, on the facing surface, and thereafter drift around the near side.

Kusdianto *et al.* (2014) experimented the area selective deposition of charged particles derived from colloidal aerosol droplets on a surface with different hydrophilic levels. The effect of the hydrophilicity of a chemically treated metallic substrate has been studied in the deposition of charged aerosols derived from the suspension of nanoparticles. The areas having different hydrophilic levels of a single subsrate was treated and measured using a surface potential meter, showed a higher negative potential. The higher negative charges produced by the chemical treatment enhanced the adhesion force between the phosphate and charged aerosols due to an increase in the surface energy. The attractive forces between the negative charge on the hydrophilic surface and the positive charge on the particles significantly played a role in the deposition due to the electrostatic forces among them.

Manoj *et al.* (2015) studied the new trend in agricultural pesticides spraying with an electrostatic nozzle. It can achieve more complete coverage of difficult targets than uncharged spraying. It will minimize the wastage, over dose and off target spray drift. The peculiarity of these types of sprayers is it's 'wrap round effect', with increased uniformity provided backside deposition of 4 to 5 fold efficiency. The average droplet size of the spray is 40 μm. The maximum charge to mass ratio was achieved at an applied voltage of 2.5 kV with an applied air pressure of 4 bars. As it reduced the off target spray drift, it reduce the possibility of environmental pollution.

2.2. ENERGY CONSUMPTION FOR PLANT PROTECTION CHEMICAL APPLICATION

Stout (1990) estimated that energy (MJ kg^{-1} a.i.) required for production of herbicides was 203 for 2, 4-D, 238 for atrazine, 374 for trifluralin, 396 for alachlor and 414 for paraquat. Herbicides (phenoxies) were first introduced in 1945. Subsequently, triazins, thiocarbametes and bipyridyls were introduced in the estimates of emission range from 1.7 to 12.6 kg CE kg^{-1} a.i. for herbicides (with a mean value of 6.3F2.7 kg CE kg^{-1} a.i.), from 1.2 to 8.1 kg CE kg^{-1} a.i. for insecticides (5.1F3.0 kg CE kg^{-1} a.i.) and from 1.2 to 8.0 kg CE kg^{-1} a.i. for fungicides (3.9 to 2.2 kg CE kg^{-1} a.i.).

Walter and Mark (1996) studied about the comparative efficacy of electrostatic and conventional technologies. The research was developed to determine improved control or spray coverage on sugar beets. To determine weed control at varying herbicide application rates trials were completed on sugar beets. For the spray drop measurement, the water sensitive paper (WSP) were used, by placing it under the plant canopy, WSP changed the colour from yellow to blue when a drop of water contacts it. Results showed that the sugar beets with larger canopies, a significant increase in deposits were found in the upper canopy due to the ESP system. A number of trials in the mature crops showed reduced deposits band.

Gallivan *et al.* (2001) analysed the changes in pesticide use and the risk was calculated by multiplying the quantity of pesticide used by the Environmental Impact Quotient (EIQ). Pesticide risk was measured by the Environmental Impact (EI) increased 32.5 per cent from 1973 to 1983 then reduced 39.5 per cent to 151.4×10^6 in 1998. Small reductions in pesticide use on corn and soybean may allow a 50 per

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cent reduction in pesticide use, but greater reductions in risk can be achieved by reducing the use of "high risk" pesticides on fruit and vegetables.

West and Marland (2002) estimated 4.4, 4.6 and 4.8 kg CE kg^{-1} a.i. for production, packaging and transport of herbicides, insecticides and fungicides. Additional energy (0.4 kg CE kg^{-1} a.i.) is required for formulations.

David (2009) studied the energy inputs in food crop production in developing and developed nations. He evaluated the detailed energy input and output of corn, wheat, rice, soy, potato, cassava, tomato, citrus and apple in the U.S and the developing countries. The degradation and depletion of natural resources due to population explosion is the major crisis humanity is facing today. With the exponentially increasing population, arithmetically increasing food production results in food deficit. The developed countries consume about 70 % of total fossil fuels while the developing countries are only 30 %. To sustain a healthy human population and maintain a vital ecological integrity of the earth, is essential improve the economic and environmental policies and political stability.

Prueksakorn *et al.* (2010) examined the energy analysis of Jatropha plantation systems for biodiesel production of Thailand. Two different plantation system of a 20 years perennial system mainly focused on the biodiesel as the energy output, with a net energy balance of 4720GJ per hectare and a net energy ratio of 6,while the annual plantation system has 9860GJ ha^{-1} of net energy balance and 7.5 as the net energy ratio. The maximum energy consumption of the annual system helped to improve the energy profile of the systems by better farm management.

Ibrahim (2011) examined the energy use for vegetable production with a view to assess the likelihood of the production system contributing to climate change. Sampling was done among the fadama farmers who cultivate tomato and onion. The data collected from the farmers were analysed using descriptive statistics. The results showed that the tomato production was the most energy intensive among the two vegetables, Also it showed a very low energy use efficiency and energy productivity.

Mamadi *et al*. (2013) demonstrated the electrostatic hand pressure knapsack spray system with enhanced performance for small scale farms. In order to meet the increased deposition efficiency and reducing the drift of pesticides with low cost affordable to small scale farmers, this electrostatic hand pressure knapsack spray system is suitable caused no economic burden to the farmers. The applied pressure is the decisive part of optimum position of electrode and electrical conductivity of liquid. Even a 1 mm electrode position difference caused the system to change full efficient to zero efficient. "Wraparound effect" phenomena were utilized and it enhanced the uniformity and backside deposition. This special spray system is simple, free of pollution, economical, easy to control and prevented from pesticide wastage.

Singh *et al.* (2013) evaluated the current status of electrostatic spraying technology for efficient crop protection. The study mainly focused to demonstrate a global review about the present status and potential of this technology for efficient crop protection. The electrostatic sprayers enhance the deposition efficiency and coverage uniformity, accelerates the droplet settling speed and decreases the drift loss and reduces the pesticide application rate. With compared to the non-electrostatic spraying technologies it's average pest mortality was reported to be 94.5 per cent, while the other is 76.7 per cent. It reduced spray volume from 250 lit ha^{-1} to 1 lit ha^{-1}. Due to it's greater advantages, this technology is an encouraging one but still it is in infancy stage due to it's high initial cost, lesser mobility having high tech electrical system for spray charging.

2.3. GREENHOUSE GAS EMISSION DURING PLANT PROTECTION CHEMICAL APPLICATION

Giles and Blewett (1991) examined the effects of conventional and reduced – volume, charged-spray application techniques on dislodgeable foliar residue of captain of strawberries. The initial deposition and the decay time of captain dislodgeable foliar residue was found to be increased by the use of a reduced volume techniques use smaller, more concentrated droplets and the addition of spray charging has been shown to alter the spatial distribution of foliar spray deposit.

Palumbo and Coates (1996) conducted study on the air-assisted electrostatic application of pyrethroid and endosulfan mixtures for sweet potato whitefly control and spray deposition in cauliflower. Pyrethroid and endosulfan mixtures applied at full and reduced rates with three application methods (air-assisted electrostatic, air-assisted hydraulic and standard hydraulic sprayers) were evaluated in field studies in 1992 and 1993 for control of sweet potato whitefly, *Bemisia tabaci-strain B*. The air-assisted sprayers helped to control sweet potato whitefly with a 50 per cent reduction in insecticide usage.

Richard and Fleming (2004) studied the influence of global climate change on insect outbreak in forests of Canada. The climatic parameter studied was temperature. With the increase in temperature the outbreak of forest insect became high and they have a longer lifespan. The indirect effect of climate change on insects include changes in the abiotic environment, changes in species interaction and changes in the regimes of natural selection. One of the consequence observed was increase in the carbon : nitrogen ratios of plants. That caused adequate dietary nitrogen, slower larval development and increased mortality are the net effects for insects. The climate warming may allow certain insects (mountain pine beetle) to extend their ranges in to extensive regions of vulnerable host species.

Law and Scherm (2005) conducted study on the electrostatic application of a plant disease biocontrol agent for prevention of fungal infection the stigmatic surfaces of blueberry flowers. The study aimed to investigate the beneficial usage of electrostatic attraction to increase the deposition of Bacillus subtitles on to typically 0.7mm diameter blueberry stigmas using charged sprays and conventional applied hydraulic atomized sprays. Also it focused to find the electrical characteristics of floral components promoting adequate charge transfer during the electrostatic spray event. The results showed that compared to the conventional hydraulic sprays, the electrostatic sprayers significantly increased the deposition efficiency 4.5 fold than the other.

Ashfaq *et al.* (2006) studied about the efficacy of electrodyn spray system with different flow rates and application techniques against insect pests of cotton. The study was conducted in cotton against sucking insects. Carbofuran was sprayed. ED insecticides showed no significant difference, but it proved significantly better against bollworm infestation on flowers. Both EC and ED formulation in insect pest control and enhancing yield.

Fand *et al.* (2012) studied about the impact of climate change on the crop pest management. With the climate change induced challenges the emergence of the harmful insect pest of the crops also increased. Loss of biodiversity is the major challenge faced due to climate change. Being a tropical country, India is more challenged with the impacts of looming climate change. The elevated CO_2 levels, increased temperature levels and depleted soil moisture can impact the population dynamics of the insect pests. Rural farmers are the people who are most vulnerable to these changes as their livelihood is mainly based on the climate sensitive sector. So, it is the time to take careful attention for planning and devising adaptation and mitigation strategies for future pest management programmes.

Khaliq *et al.* (2014) studied how the global climatic variations are disturbing the insect ecosystems. The human interruption is the major cause of the global changes, which are responsible for wide range of natural and human-made environmental variations. Any deviation from the normal environmental conditions caused effects in insects. Insects showed various responses in different ways against the high or low thermal threshold or humidity variations and varied wavelength of light. They showed changes particularly in their ovulation, rate of fecundity, development, survival, multiplication and various immune and genetic responses.

Materials and Methods

3. MATERIALS AND METHODS

The methodology adopted for quantifying the energy use efficiency of electrostatic sprayers in comparison with powered knapsack mist blower and knapsack air compression sprayer is detailed in this chapter. The assessment of greenhouse gas emission corresponding to the energy use during application and production of pesticides is also detailed here.

3.1 LOCATION OF THE STUDY

The study was conducted at the Department of Agricultural Engineering, College of Agriculture, Vellayani, Kerala Agricultural University. The field data were collected from the farmers of Kalliyoor Grama Panchayath, vegetable growing belt of Thiruvananthapuram district. Performance assessment of different sprayers was done at the laboratories of Department of Agricultural Engineering and Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani.

3.2 SELECTION OF SPRAYERS

The powered knapsack mist blower and knapsack air compression sprayers were selected since they are the most popular and versatile pesticide application equipment used by the farmers of the country due to it's simplicity, ease of operation and inexpensiveness. Electrostatic sprayer also selected since it is a newer technology in the field of agriculture and effective in controlling the pest with impending reduction of over application of chemicals. These three sprayers were evaluated for its pesticide application efficacy in controlling different pests based on its movement and habitat. The mist blower used was OLEOMAC AM 162 model and the electrostatic sprayer used was ESS MBP 4.0 Mountain Man Sprayer, imported from USA.

3.3 SELECTION OF PESTS

Evaluation of different sprayers mentioned in section 3.2 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*)

3.4 SELECTION OF INSECTICIDE AND THEIR DOSAGE

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 insecticide dosage used was that recommended in Package of Practice, KAU recommendations.

3.5 EXPERIMENTAL LAYOUT

The experimental layout was laid out in CRD with 18 treatments and 3 replications.

The treatment combinations are

T_1 – Electrostatic sprayer + Hard bodied pest

T_2 – Electrostatic sprayer + Soft bodied pest

T_3 – Electrostatic sprayer + Flying insect

T_4 – Electrostatic sprayer + Sedentary insect

T_5 – Electrostatic sprayer + Abaxial pest

T_6 – Electrostatic sprayer + Adaxial pest

T_7 – Mist blower + Hard bodied pest

T_8 – Mist blower + Soft bodied pest

T_9 – Mist blower + Flying pest

T_{10} – Mist blower + Sedentary pest

T_{11} – Mist blower + Abaxial pest

T_{12} – Mist blower + Adaxial pest

T_{13} – Air compression sprayer + Hard bodied pest

T_{14} – Air compression sprayer + Soft bodied pest

T_{15} – Air compression sprayer + Flying pest

T_{16} – Air compression sprayer + Sedentary pest

T_{17} – Air compression sprayer + Abaxial pest

T_{18} – Air compression sprayer + Adaxial pest

3.5.1 *Pot culture*

To evaluate the sprayer for each category pest, their respective host plants were raised in grow bags filled with 1:1:1 potting mixture. For each sprayer 15 plants were maintained. 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.

3.5.2 *Spraying*

The sprayer types mentioned in section 3.2 were evaluated for the efficacy, using the insecticides mentioned in section 3.4 under pot culture detailed in section 3.5.1. Spraying was carried out under controlled conditions. After spraying at the pest levels fixed in section 3.5.1, 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 was recorded in each case.

3.6 ENERGY USE EFFICIENCY OF SPRAYER – PARAMETERS

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 (David 2009). Then the corresponding greenhouse gas (CO_2) emission for the energy consumption during application of corresponding quantity of pesticide to control selected crop pest were computed for all the selected sprayers (Green 1987 and Audsley *et.al.* 2009).

3.6.1 *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, as explained below.

a. Leaf wash method

In leaf wash method, leaf samples were randomly collected from the different parts of the plant surface and treated. Dye residues were washed from the top side and under sides of the leaves separately. Dry solutions thus collected were evaluated for transmittance with a spectrophotometer and compared with the calibration from known washed deposits to determine dye deposition on each samples (Carlton, 1995).

1.5 g of fluorescent tracer (DAY GLO type GT-15-N Fluorescent Blaze Orange dye) was dissolved in 1000 ml of water, making concentration of tracer liquid 1500 ppm (Durairaj, 1994). This concentration of tracer residue on the target was analogous to pesticide active ingredient of an actual spray solution. This facilitated a direct correlation of relative deposition efficiencies of the electrostatic versus conventional spraying techniques. After spray, the spray fluid deposited on water sensitive paper or leaf surface were retrieved and the dye was extracted by washing with known quantity of double distilled water.

The recovered tracer concentration was analyzed for optical density (absorbance) with Spectrophotometer. Spectrophotometer was pre calibrated with double distilled water representing zero absorbance reading. further calibration was carried out in the visible region of the electromagnetic spectrum of wave length (λ) 555 nm, which is same as that of fluorescent tracer material and commercial agricultural chemicals. Solutions of known standard concentrations (ppm) of the tracer were prepared and measured for their optical density on the spectrophotometer. The concentration of the tracer of the sample was directly measured by the spectrophotometer in terms of ppm.

3.6.2 *Number of application*

The number of sprayings required for a crop season to manage the pests selected in section 3.3 was estimated for each of the sprayers.

3.6.3 Estimation of man hours

Based on the concept that air compression sprayer take 13 hr, powered knapsack mist blower take 8 hr and electrostatic sprayer take 8 hr for covering 1 ha crop area, the number of applications calculated as per section 3.6.2, the labour requirement needed in man hours was calculated.

Total labour requirement (man hours ha^{-1} $year^{-1}$) = time taken for covering one hectare (hr) × Number of applications for each sprayer.

3.7 ESTIMATION OF ENERGY USE EFFICIENCY

The production energy of each pesticide was computed based on the method suggested by Green, 1987 and Audsley, *et al.* 2009. 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.

3.7.1 *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 (Audsley, *et al.* 2009). It includes the energy from naphtha, gas and coke used for the production of unit quantity of the product chemical also. 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} $year^{-1}$.

3.7.2 *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 (Audsley, *et al.* 2009). It includes the energy from fuel, oil, electricity and steam used for the production of unit quantity of the product chemical also. 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} $year^{-1}$.

3.7.3 *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, mechanical energy and fuel energy used (calorific value of fuel) for all the applications during the crop season (Omid, *et al.* 2010). 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.

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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} $year^{-1}$.

3.8 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 (Green, 1987; Audsley, *et al.,* 2009 and Omid, *et al.,* 2010). The emission was calculated for each pest by considering its reoccurrence. Therefore case II (with electrostatic sprayer) was also considered.

Results

4. RESULTS

The results of the work entitled "Efficacy of electrostatic sprayer on crop pest management and pesticide use" conducted during January 2016 to September 2016 at College of Agriculture, Vellayani is presented in this chapter.

4.1 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.

4.1.1 *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 1. The mist blower used for the study was OLEOMAC AM 162 model and the electrostatic sprayer used was ESS MBP 4.0 Mountain Man Sprayer, imported from USA.

Table 1. 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

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.

4.2 EFFECT OF DIFFERENT SPRAYERS ON APPLICATION OF PESTICIDES

The number of sprayings required for a crop season to manage the pests selected in the study was estimated for each of the sprayers. The number of applications and man hour required for spraying 1 ha crop area were recorded for each sprayer and presented as follows.

4.2.1 *Pumpkin beetle*

Data recorded under laboratory condition as well as field conditions are presented in Table 2. The chemical used was Carbaryl with Dosage, a.i. 1000 g ha^{-1} both under laboratory condition and field conditions.

Table 2. Standardization of parameters for evaluation of sprayers for the management of beetle

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
Number of application	12	12	12	6
Application of a.i., kg ha^{-1} $year^{-1}$	60	40	20	10
Man hour used, h ha^{-1}	156	96	96	48
B. Under field conditions				
Number of application	18	15	12	-
Application of a.i., kg ha^{-1} $year^{-1}$	90	60	30	-
Man hour used, h ha^{-1}	234	120	96	-

The number of applications was 12 for all the three sprayers when the spraying was done as per the KAU – POP recommendations (Spray 15 days interval) under laboratory condition. But while observing the reoccurrence of pests, the number of application was reduced to 6 in case of electrostatic sprayer and recorded as case 2. The active ingredient requirement was 60 kg ha^{-1} $year^{-1}$ with the use of 156 man hours in case of air compression sprayers. The corresponding readings were 40 kg ha^{-1} $year^{-1}$ and 96 h ha^{-1} for mist blower and that of electrostatic sprayer was 20 kg ha^{-1} $year^{-1}$ with the use of 96 man hours. In electrostatic sprayer - case 2 the recorded values were 10 kg ha^{-1} $year^{-1}$ and 48 h ha^{-1} respectively.

Under field condition, the number of applications was 18 for with the expense of 90 kg ha^{-1} $year^{-1}$ active ingredient using 234 man hours ha^{-1}. For powered knapsack mist blower, the data reported were 15 applications with the expense of 60 kg ha^{-1} $year^{-1}$ active ingredient using 120 man hours ha^{-1} and for electrostatic sprayer the readings were 12 applications with the expense of 30 kg ha^{-1} $year^{-1}$ active ingredient using 234 man hours ha^{-1} respectively.

4.2.2 *Cowpea aphid*

Data recorded under laboratory condition as well as field conditions are presented in Table 3. The chemical used was Malathion with Dosage, a.i. 500 g ha^{-1} both under laboratory condition and field conditions.

Table 3. Standardization of parameters for evaluation of sprayers for the management of aphid

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
Number of application	6	6	6	3
Application of a.i., kg ha^{-1} $year^{-1}$	15	10	5	2.5
Man hour used, h ha^{-1}	90	54	54	27
B. Under field conditions				
Number of application	12	9	6	-
Application of a.i., kg ha^{-1} $year^{-1}$	30	20	10	-
Man hour used, h ha^{-1}	180	81	54	-

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Under laboratory condition the number of applications was 6 for all the three sprayers when the spraying was done as per the KAU – POP recommendations (Spray 15 days interval). But while observing the reoccurrence of pests, the number of application was reduced to 3 in case of electrostatic sprayer and recorded as case 2. In case of air compression sprayers quantity of active ingredient required was 15 kg ha^{-1} $year^{-1}$ with the use of 90 man hours. The corresponding readings were 10 kg ha^{-1} $year^{-1}$ and 54 h ha^{-1} for mist blower and that of electrostatic sprayer was 5 kg ha^{-1} $year^{-1}$ with the use of 54 man hours. The recorded values were 2.5 kg ha^{-1} $year^{-1}$ and 27 h ha^{-1} respectively in case 2 of electrostatic sprayer.

The number of applications was 12 for with the expense of 30 kg ha^{-1} $year^{-1}$ active ingredient using 180 man hours ha^{-1} under field condition. For powered knapsack mist blower, the data reported were 9 applications with the expense of 20 kg ha^{-1} $year^{-1}$ active ingredient using 81 man hours ha^{-1} and for electrostatic sprayer the readings were 6 applications with the expense of 10 kg ha^{-1} $year^{-1}$ active ingredient using 54 man hours ha^{-1} respectively.

4.2.3 *Curcurbit fruit fly*

Data recorded under laboratory condition and field conditions are presented in Table 4. The chemical used was Carbaryl with Dosage, a.i. 1000 g ha^{-1} both under laboratory condition and field conditions.

The number of applications was 4 for all the three sprayers when the spraying was done as per the KAU – POP recommendations (Spray 15 days interval) under laboratory condition. But while observing the reoccurrence of pests, the number of application was reduced to 2 and recorded as case 2 in the case of electrostatic sprayer. In case of air compression sprayers quantity of active ingredient required was noted as 20 kg ha^{-1} $year^{-1}$ with the use of 52 man hours. The corresponding readings were 13.40 kg ha^{-1} $year^{-1}$ and 32 h ha^{-1} for mist blower and that of electrostatic sprayer was 6.70 kg ha^{-1} $year^{-1}$ with the use of 32 man hours. In case 2 electrostatic sprayer values recorded were 3.35 kg ha^{-1} $year^{-1}$ and 16 h ha^{-1} respectively.

Table 4. Standardization of parameters for evaluation of sprayers for the management of fruit fly

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
Number of application	4	4	4	2
Application of a.i., kg ha^{-1} $year^{-1}$	20	13.40	6.70	3.35
Man hour used, h ha^{-1}	52	32	32	16
B. Under field conditions				
Number of application	8	6	4	-
Application of a.i., kg ha^{-1} $year^{-1}$	40	26.7	13.4	-
Man hour used, h ha^{-1}	104	48	32	-

The number of applications was 8 for with the expense of 40 kg ha^{-1} $year^{-1}$ active ingredient using 104 man hours ha^{-1} under field condition. The data reported were 6 applications with the expense of 26.7 kg ha^{-1} $year^{-1}$ active ingredient using 48 man hours ha^{-1} for powered knapsack mist blower, and for electrostatic sprayer the readings were 4 applications with the expense of 13.4 kg ha^{-1} $year^{-1}$ active ingredient using 32 man hours ha^{-1} respectively.

4.2.4 *Brinjal mealy bug*

Data recorded under laboratory condition as well as field conditions are presented in Table 5. The chemical used was Carbaryl with Dosage, a.i. 1000 g ha^{-1} both under laboratory condition and field conditions.

Table 5. Standardization of parameters for evaluation of sprayers for the management of mealy bug

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
Number of application	16	16	16	12
Application of a.i., kg ha^{-1} $year^{-1}$	80	54	27	20.25
Man hour used, h ha^{-1}	320	160	160	120
B. Under field conditions				
Number of application	24	24	16	-
Application of a.i., kg ha^{-1} $year^{-1}$	12	80	40	-
Man hour used, h ha^{-1}	480	240	160	-

Under laboratory condition, the number of applications was 16 for all the three sprayers when the spraying was done as per the KAU – POP recommendations (Spray 15 days interval). But while observing the reoccurrence of pests, the number of application was reduced to 12 in case of electrostatic sprayer and recorded as case 2. Quantity of active ingredient required was 80 kg ha^{-1} $year^{-1}$ with the use of 320 man hours in case of air compression sprayers. The corresponding readings were 54 kg ha^{-1} $year^{-1}$ and 160 h ha^{-1} for mist blower and that of electrostatic sprayer was 27 kg ha^{-1} $year^{-1}$ with the use of 160 man hours. In electrostatic sprayer - case 2 the recorded values were 20.25 kg ha^{-1} $year^{-1}$ and 120 h ha^{-1} respectively.

Under field condition, the number of applications was 24 for with the expense of 12 kg ha^{-1} $year^{-1}$ active ingredient using 480 man hours ha^{-1}. For powered knapsack mist blower, the data reported were 24 applications with the expense of 80 kg ha^{-1} year^{-1} active ingredient using 240 man hours ha^{-1} and the readings were 16 applications with the expense of 40 kg ha^{-1} year^{-1} active ingredient using 160 man hours ha^{-1} for electrostatic sprayer respectively.

4.2.5 *Caterpillar*

Data recorded under laboratory condition as well as field conditions are presented in Table 6. The chemical used was Carbaryl with Dosage, a.i. 1000 g ha^{-1} both under laboratory condition and field conditions.

Table 6. Standardization of parameters for evaluation of sprayers for the management of caterpillar

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
Number of application	6	6	6	4
Application of a.i., kg ha^{-1} year^{-1}	30	20	10	7.5
Man hour used, h ha^{-1}	78	48	48	32
B. Under field conditions				
Number of application	9	6	6	-
Application of a.i., kg ha^{-1} year^{-1}	45	30	15	-
Man hour used, h ha^{-1}	117	48	48	-

The number of applications was 6 for all the three sprayers when the spraying was done as per the KAU – POP recommendations (Spray 15 days interval) under laboratory condition. But while observing the reoccurrence of pests, the number of application was reduced to 4 while using electrostatic sprayer and recorded as case 2. Quantity of active ingredient required was 30 kg

ha^{-1} $year^{-1}$ with the use of 78 man hours in case of air compression sprayers. The corresponding readings were 20 kg ha^{-1} $year^{-1}$ and 48 h ha^{-1} for mist blower and that of electrostatic sprayer was 10 kg ha^{-1} $year^{-1}$ with the use of 48 man hours. In electrostatic sprayer - case 2 the recorded values were 7.5 kg ha^{-1} $year^{-1}$ and 32 h ha^{-1} respectively.

Under field condition, the number of applications was 9 for with the expense of 45 kg ha^{-1} $year^{-1}$ active ingredient using 117 man hours ha^{-1}. The data reported were 6 applications with the expense of 30 kg ha^{-1} $year^{-1}$ active ingredient using 48 man hours ha^{-1} for powered knapsack mist blower and for electrostatic sprayer the readings were 6 applications with the expense of 15 kg ha^{-1} $year^{-1}$ active ingredient using 48 man hours ha^{-1} respectively.

4.2.6 *Chilli mite*

Data recorded under laboratory condition as well as field conditions are presented in Table 7. The chemical used was Dimethoate with Dosage, a.i. 500 g ha^{-1} both under laboratory condition and field conditions.

Under laboratory condition, the number of applications was 9 for both air compression sprayer and mist blower while it was 6 for electrostatic sprayer when the spraying was done as per the KAU – POP recommendations (Spray 15 days interval). But while observing the reoccurrence of pests, the number of application was reduced to 3 in case of electrostatic sprayer and was recorded as case 2. In case of air compression sprayers quantity of active ingredient required was 22.50 kg ha^{-1} $year^{-1}$ with the use of 180 man hours. The corresponding readings were 15 kg ha^{-1} $year^{-1}$ and 135 h ha^{-1} for mist blower and that of electrostatic sprayer was 7.5 kg ha^{-1} $year^{-1}$ with the use of 90 man hours. In electrostatic sprayer - case 2 the recorded values were 5.63 kg ha^{-1} $year^{-1}$ and 45 h ha^{-1} respectively.

Table 7. Standardization of parameters for evaluation of sprayers for the management of chilli mite

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
Number of application	9	9	6	3
Application of a.i., kg ha^{-1} $year^{-1}$	22.50	15	7.5	5.63
Man hour used, h ha^{-1}	180	135	90	45
B. Under field conditions				
Number of application	12	9	6	-
Application of a.i., kg ha^{-1} $year^{-1}$	30	20	10	-
Man hour used, h ha^{-1}	240	135	90	-

Under field condition, the number of applications was 12 for with the expense of 30 kg ha^{-1} $year^{-1}$ active ingredient using 240 man hours ha^{-1}. For powered knapsack mist blower, the data reported were 9 applications with the expense of 20 kg ha^{-1} $year^{-1}$ active ingredient using 135 man hours ha^{-1} and for electrostatic sprayer the readings were 6 applications with the expense of 10 kg ha^{-1} $year^{-1}$ active ingredient using 90 man hours ha^{-1} respectively.

4.3 ENERGY USE EFFICIENCY OF DIFFERENT SPRAYERS IN THE MANAGEMENT OF DIFFERENT PESTS

The total energy use efficiency of the three selected sprayers were calculated as the sum of application energy, process energy and inherent energy and expressed in MJ ha^{-1} $year^{-1}$ for the control of selected pests with the application of respective chemical. The results are presented below.

4.3.1 *Pumpkin beetle*

The energy use efficiency of knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer in management of pumpkin beetle was computed and presented in Table 8.

Table 8. Energy use efficiency of sprayers for management of beetle

Sprayer type	Energy use, MJ kg^{-1} ha^{-1} year^{-1}			
	Inherent	**Process**	**Application**	**Total**
A. Under laboratory conditions				
Air compression sprayer	5100	4080	305.76	9405.76
Powered mist blower	3400	2720	188.16	6308.16
Electrostatic sprayer, case 1	1700	1360	188.16	3248.16
Electrostatic sprayer, case 2	850	680	94.08	1624.08
B. Under field conditions				
Air compression sprayer	7650	6120	458.64	14228.64
Powered mist blower	5100	4080	235.2	9415.2
Electrostatic sprayer	2550	2040	188.16	4778.16

Under laboratory condition, the maximum energy use was recorded for knapsack air compression sprayer with 9405.76 MJ kg^{-1} ha^{-1} year^{-1} followed by powered mist blower with 6308.16 MJ kg^{-1} ha^{-1} year^{-1}. The minimum energy expenditure was reported for electrostatic sprayer with 3248.16 MJ kg^{-1} ha^{-1} year^{-1} in case 1 and 1624.08 MJ kg^{-1} ha^{-1} year^{-1} in case 2.

Under filed conditions the maximum energy use was recorded for knapsack air compression sprayer with 14228.64 MJ kg^{-1} ha^{-1} year^{-1} followed by powered mist blower with 9415.2 MJ kg^{-1} ha^{-1} year^{-1} and the minimum was for electrostatic sprayer with 4778.16 MJ kg^{-1} ha^{-1} year^{-1}.

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4.3.2 *Cowpea aphid*

The energy use efficiency of knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer in management of cowpea aphid was computed and presented in Table 9.

Table 9. Energy use of sprayers for management of aphid

Sprayer type	Energy use, MJ kg^{-1} ha^{-1} $year^{-1}$			
	Inherent	**Process**	**Application**	**Total**
A. Under laboratory conditions				
Air compression sprayer	1548	1884	176.40	3608.40
Powered mist blower	1032	1256	109.84	2393.84
Electrostatic sprayer, case 1	516	628	105.84	1249.84
Electrostatic sprayer, case 2	258	314	52.92	624.92
B. Under field conditions				
Air compression sprayer	3096	3768	352.80	7216.80
Powered mist blower	2064	2512	158.76	4734.76
Electrostatic sprayer, case 1	1032	1256	105.84	2393.84

Under laboratory condition, the maximum energy use was recorded for knapsack air compression sprayer with 3608.40 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 2393.84 MJ kg^{-1} ha^{-1} $year^{-1}$.The minimum energy expenditure was reported for electrostatic sprayer with 1249.84 MJ kg^{-1} $ha^{-1}year^{-1}$ in case 1 and 624.92 MJ kg^{-1} ha^{-1} $year^{-1}$ in case 2.

Under filed conditions the maximum energy use was recorded for knapsack air compression sprayer with 7216.80 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 4734.76 MJ kg^{-1} ha^{-1} $year^{-1}$ and the minimum was for electrostatic sprayer with 2393.84 MJ kg^{-1} ha^{-1} $year^{-1}$.

4.3.3 *Curcurbit fruit fly*

The energy use efficiency of knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer in management of curcurbit fruit fly was computed and presented in Table 10.

Table 10. Energy use of sprayers for management of fruit fly

Sprayer type	Energy use, MJ kg^{-1} ha^{-1} $year^{-1}$			
	Inherent	Process	Application	Total
A. Under laboratory conditions				
Air compression sprayer	1700	1360	101.92	3161.92
Powered mist blower	1139	911.20	62.72	2112.92
Electrostatic sprayer, case 1	569.50	455.60	62.72	1087.82
Electrostatic sprayer, case 2	284.75	277.80	31.36	543.91
B. Under field conditions				
Air compression sprayer	3400	2720	203.84	6323.84
Powered mist blower	2269.50	1815.60	94.08	4179.18
Electrostatic sprayer, case 1	1989	911.20	62.72	2962.92

The maximum energy use was recorded for knapsack air compression sprayer with 3161.92 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 2112.92 MJ kg^{-1} ha^{-1} $year^{-1}$ under laboratory condition. The minimum energy expenditure was reported for electrostatic sprayer with 1087.82 MJ kg^{-1} $ha^{-1}year^{-1}$ in case 1 and 543.91 MJ kg^{-1} ha^{-1} $year^{-1}$ in case 2.

Under field conditions the maximum energy use was recorded for knapsack air compression sprayer with 6323.84 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 4179.18 MJ kg^{-1} ha^{-1} $year^{-1}$ and the minimum was for electrostatic sprayer with 2962.92 MJ kg^{-1} ha^{-1} $year^{-1}$.

4.3.4 *Brinjal mealy bug*

The energy use efficiency of knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer in management of brinjal mealy bug was computed and presented in Table 11.

Table 11. Energy use of sprayers for management of mealy bug

Sprayer type	Energy use, MJ kg^{-1} ha^{-1} $year^{-1}$			
	Inherent	Process	Application	Total
A. Under laboratory conditions				
Air compression sprayer	6800	5440	627.20	12867.20
Powered mist blower	4590	3672	313.60	8575.60
Electrostatic sprayer, case 1	2295	1836	313.60	4444.60
Electrostatic sprayer, case 2	1721.25	1377	235.20	3333.45
B. Under field conditions				
Air compression sprayer	10200	8160	940.80	19300.80
Powered mist blower	6800	5440	470.40	12710.40
Electrostatic sprayer, case 1	3400	2720	313.60	6433.60

Under laboratory condition, the maximum energy use was recorded for knapsack air compression sprayer with 12867.20 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 8575.60 MJ kg^{-1} ha^{-1} $year^{-1}$.The minimum energy expenditure was reported for electrostatic sprayer with 4444.60 MJ kg^{-1} $ha^{-1}year^{-1}$ in case 1 and 3333.45 MJ kg^{-1} ha^{-1} $year^{-1}$ in case 2.

The maximum energy use was recorded for knapsack air compression sprayer with 19300.80 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 12710.40 MJ kg^{-1} ha^{-1} $year^{-1}$ and the minimum was for electrostatic sprayer with 6433.60 MJ kg^{-1} ha^{-1} $year^{-1}$ under filed conditions.

4.3.5 ***Caterpillar***

The energy use efficiency of knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer in management of caterpillar was computed and presented in Table 12.

Table 12. Energy use of sprayers for management of caterpillar

Sprayer type	Energy use, MJ kg^{-1} ha^{-1} $year^{-1}$			
	Inherent	**Process**	**Application**	**Total**
A. Under laboratory conditions				
Air compression sprayer	2550	2040	152.88	4742.88
Powered mist blower	1700	1360	94.08	3154.08
Electrostatic sprayer, case 1	850	680	94.08	1624.08
Electrostatic sprayer, case 2	637.50	510	62.72	1210.22
B. Under field conditions				
Air compression sprayer	3825	3060	229.32	7114.32
Powered mist blower	2550	2040	93.12	4683.12
Electrostatic sprayer, case 1	1275	1020	93.12	2388.12

The maximum energy use was recorded for knapsack air compression sprayer with 4742.88 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 3154.08 MJ kg^{-1} ha^{-1} $year^{-1}$ under laboratory condition The minimum energy expenditure was reported for electrostatic sprayer with 1624.08 MJ kg^{-1} ha^{-1} $year^{-1}$ in case 1 and 1210.22 MJ kg^{-1} ha^{-1} $year^{-1}$ in case 2.

The maximum energy use was recorded for knapsack air compression sprayer with 7114.32 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 4683.12 MJ kg^{-1} ha^{-1} $year^{-1}$ and the minimum was for electrostatic sprayer with 2388.12 MJ kg^{-1} ha^{-1} $year^{-1}$ under filed conditions.

4.3.6 *Chilli mite*

The energy use efficiency of knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer in management of chilli mite was computed and presented in Table 13.

Table 13. Energy use of sprayers for management of Chilli mite

Sprayer type	Energy use, MJ kg^{-1} ha^{-1} $year^{-1}$			
	Inherent	Process	Application	Total
A. Under laboratory conditions				
Air compression sprayer	1507.5	2092.5	352.8	3952.8
Powered mist blower	1005	1395	264.6	2664.6
Electrostatic sprayer, case 1	502.5	697.5	176.4	1376.4
Electrostatic sprayer, case 2	376.8	523.1	88.2	988.2
B. Under field conditions				
Air compression sprayer	2010	2790	470.4	5270.4
Powered mist blower	1340	1860	264.6	3464.6
Electrostatic sprayer, case 1	670	930	176.4	1776.4

Under laboratory condition, the maximum energy use was recorded for knapsack air compression sprayer with 3952.8 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 2664.6 MJ kg^{-1} ha^{-1} $year^{-1}$. The minimum energy expenditure was reported for electrostatic sprayer with 1376.4 MJ kg^{-1} ha^{-1} $year^{-1}$ in case 1 and 988.2 MJ kg^{-1} ha^{-1} $year^{-1}$ in case 2.

Under filed conditions the maximum energy use was recorded for knapsack air compression sprayer with 5270.4 MJ kg^{-1} ha^{-1} $year^{-1}$ followed by powered mist blower with 3464.6 MJ kg^{-1} ha^{-1} $year^{-1}$ and the minimum was for electrostatic sprayer with 1776.4 MJ kg^{-1} ha^{-1} $year^{-1}$.

4.4 GREENHOUSE GAS EMISSION OF DIFFERENT SPRAYERS IN MANGEMENT OF DIFFERENT PESTS

The total greenhouse gas emission in Kg ha^{-1} $year^{-1}$ was computed from the total energy use of the selected sprayers in management of different pests with the application of respective chemicals. The results are presented below.

4.4.1 *Pumpkin beetle*

The greenhouse gas emission during the management of pumpkin beetle using knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer was computed and presented in Table 14.

Table 14. CO_2 emission of different sprayers – management of beetle

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
CO_2 emission, Kg ha^{-1} $year^{-1}$	649	435.26	224.12	112.06
B. Under field conditions				
CO_2 emission, Kg ha^{-1} $year^{-1}$	981.78	649.65	329.69	-

Under laboratory condition the CO_2 emission was maximum for Knapsack air compression sprayer with 649 Kg ha^{-1} $year^{-1}$ followed by Knapsack powered mist blower with 435.26 Kg ha^{-1} $year^{-1}$ and that of Electrostatic sprayer was 224.12 Kg ha^{-1} $year^{-1}$ in case 1 and 112.06 Kg ha^{-1} $year^{-1}$ in case 2.

Under field condition the CO_2 emission was maximum for Knapsack air compression sprayer with 981.78 Kg ha^{-1} $year^{-1}$ followed by Knapsack powered mist blower with 649.65 Kg ha^{-1} $year^{-1}$. The minimum emission of 329.69 Kg ha^{-1} $year^{-1}$ was recorded during the operation with Electrostatic sprayer.

4.4.2 *Cowpea aphid*

The greenhouse gas emission during the management of cowpea aphid using knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer was computed and presented in Table 15.

Table 15. CO_2 emission of different sprayers – management of aphid

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
CO_2 emission, Kg ha^{-1} $year^{-1}$	248.98	165.18	86.24	43.12
B. Under field conditions				
CO_2 emission, Kg ha^{-1} $year^{-1}$	497.96	326.70	165.18	-

The CO_2 emission was maximum for Knapsack air compression sprayer under laboratory condition with 248.98 Kg ha^{-1} $year^{-1}$ followed by Knapsack powered mist blower with 165.18 Kg ha^{-1} $year^{-1}$ and that of Electrostatic sprayer was 86.24 Kg ha^{-1} $year^{-1}$ in case 1 and 43.12 Kg ha^{-1} $year^{-1}$ in case 2.

Under field condition the CO_2 emission was maximum for Knapsack air compression sprayer with 497.96 Kg ha^{-1} $year^{-1}$ followed by Knapsack powered mist blower with 326.70 Kg ha^{-1} $year^{-1}$. The minimum emission of 165.18 Kg ha^{-1} $year^{-1}$ was recorded during the operation with Electrostatic sprayer.

4.4.3 *Curcurbit fruit fly*

The greenhouse gas emission during the management of curcurbit fruit fly using knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer was computed and presented in Table 16.

Table 16. CO_2 emission of different sprayers – management of fruit fly

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
CO_2 emission, Kg ha^{-1} year^{-1}	218.17	145.79	75.06	37.53
B. Under field conditions				
CO2 emission, Kg ha^{-1} year^{-1}	436.35	288.36	204.44	-

Under laboratory condition the CO_2 emission was maximum for Knapsack air compression sprayer with 218.17 Kg ha^{-1} year^{-1} followed by Knapsack powered mist blower with 145.79 Kg ha^{-1} year^{-1} and that of Electrostatic sprayer was 75.06 Kg ha^{-1} year^{-1} in case 1 and 37.53 Kg ha^{-1} year^{-1} in case 2.

The CO_2 emission was maximum for Knapsack air compression sprayer with 436.35 Kg ha^{-1} year^{-1} followed by Knapsack powered mist blower with 288.36 Kg ha^{-1} year^{-1} under field condition The minimum emission of 204.44 Kg ha^{-1} year^{-1} was recorded during the operation with Electrostatic sprayer.

4.4.4 *Brinjal mealy bug*

The greenhouse gas emission during the management of brinjal mealy bug using knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer was computed and presented in Table 17.

Under laboratory condition the CO_2 emission was maximum for Knapsack air compression sprayer with 887.83 Kg ha^{-1} year^{-1} followed by Knapsack powered mist blower with 591.71 Kg ha^{-1} year^{-1} and that of Electrostatic sprayer was 306.67 Kg ha^{-1} year^{-1} in case 1 and 230 Kg ha^{-1} year^{-1} in case 2.

Table 17. CO_2 emission of different sprayers – management of mealy bug

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
CO_2 emission, Kg ha^{-1} year^{-1}	887.83	591.71	306.67	230
B. Under field conditions				
CO_2 emission, Kg ha^{-1} year^{-1}	131.75	877.01	443.91	-

Under field condition the CO_2 emission was maximum for Knapsack air compression sprayer with 131.75 Kg ha^{-1} year^{-1} followed by Knapsack powered mist blower with 877.01 Kg ha^{-1} year^{-1}. The minimum emission of 443.91 Kg ha^{-1} year^{-1} was recorded during the operation with Electrostatic sprayer.

4.4.5 *Caterpillar*

The greenhouse gas emission during the management of caterpillar using knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer was computed and presented in Table 18.

Table 18. CO_2 emission of different sprayers – management of caterpillar

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
CO_2 emission, Kg ha^{-1} year^{-1}	327.25	217.63	112.06	83.50
B. Under field conditions				
CO_2 emission, Kg ha^{-1} year^{-1}	490.88	323.13	164.78	-

Under laboratory condition the CO_2 emission was maximum for Knapsack air compression sprayer with 327.25 Kg ha^{-1} year^{-1} followed by Knapsack powered mist blower with 217.63 Kg ha^{-1} year^{-1} and that of Electrostatic sprayer was 112.06 Kg ha^{-1} year^{-1} in case 1 and 83.50 Kg ha^{-1} year^{-1} in case 2.

The CO_2 emission was maximum for Knapsack air compression sprayer with 490.88 Kg ha^{-1} year^{-1} followed by Knapsack powered mist blower with 323.13 Kg ha^{-1} year^{-1} under field condition. The minimum emission of 164.78 Kg ha^{-1} year^{-1} was recorded during the operation with Electrostatic sprayer.

4.4.6 *Chilli mite*

The greenhouse gas emission during the management of chilli mite using knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer was computed and presented in Table 19.

Table 19. CO_2 emission of different sprayers – management of chilli mite

Parameters	Knapsack air compression sprayer	Knapsack powered mist blower	Electrostatic sprayer – Case 1	Electrostatic sprayer – Case 2
A. Under laboratory conditions				
CO_2 emission, Kg ha^{-1} year^{-1}	272.74	183.85	94.97	68.18
B. Under field conditions				
CO_2 emission, Kg ha^{-1} year^{-1}	363.65	239.05	122.57	-

Under laboratory condition the CO_2 emission was maximum for Knapsack air compression sprayer with 272.74 Kg ha^{-1} year^{-1} followed by Knapsack powered mist blower with 183.85 Kg ha^{-1} year^{-1} and that of Electrostatic sprayer was 94.97 Kg ha^{-1} year^{-1} in case 1 and 68.18 Kg ha^{-1} year^{-1} in case 2.

Under field condition the CO_2 emission was maximum for Knapsack air compression sprayer with 363.65 Kg ha^{-1} year^{-1} followed by Knapsack powered mist blower with 239.05 Kg ha^{-1} year^{-1}. The minimum emission of 122.57 Kg ha^{-1} year^{-1} was recorded during the operation with Electrostatic sprayer.

Discussion

5. DISCUSSION

Among greenhouse gases, CO_2 is one of the most significant contributors to global warming as well as climate change. Pesticide production and application is one of the major contributors of greenhouse gas emission from agricultural sector. This study hypothesized assessment of CO_2 emission from various pesticide production system and field application while using three different sprayers for the control of pests. In this chapter the observations and results obtained from field and laboratory were analyzed and discussed.

5.1 EFFECT OF DIFFERENT SPRAYERS ON ENERGY USE EFFICIENCY

The energy use efficiency of three different 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 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.

5.1.1 *Integumental characters : Hard bodied pest : Management of 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 and recommended level. They applied the pesticide in anticipation of pest ie., they were not waiting till the occurrence of pest. Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition.

5.1.2 *Integumental characters : Soft bodied pest : Management of 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 reoccurance 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. But in farmers field condition, the number of application was higher than that of laboratory condition and recommended level.

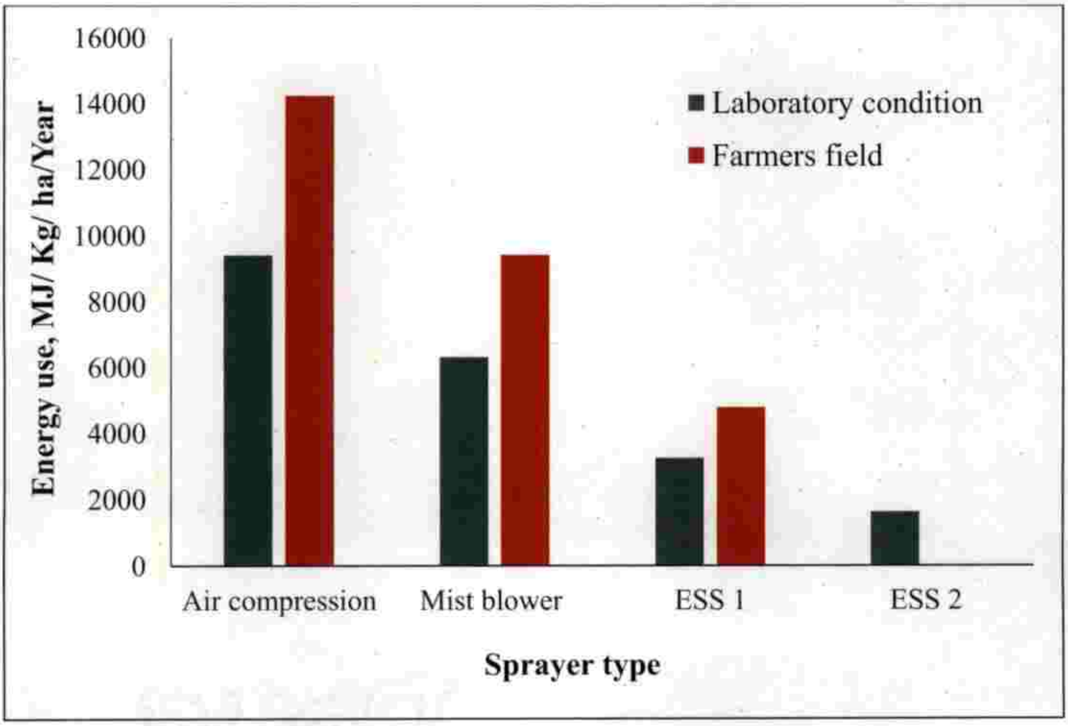

Fig. 1. Energy usage of sprayers for the management of pumpkin beetle

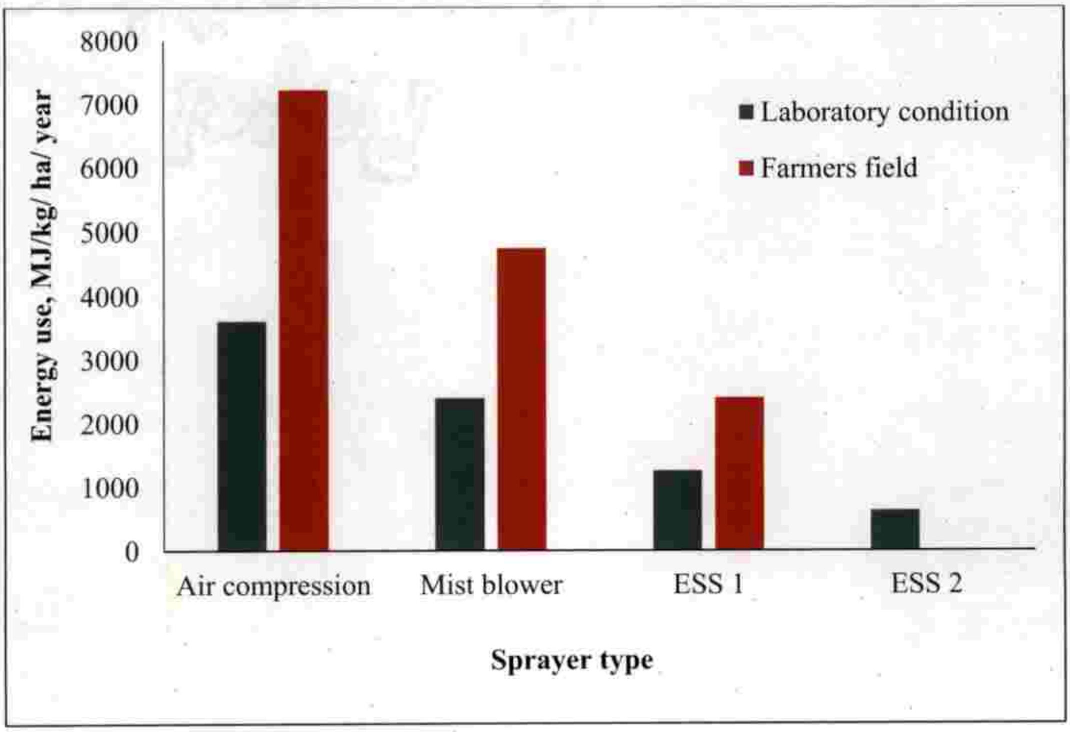

Fig. 2. Energy usage of sprayers for the management of cowpea aphid

Farmers were not waiting till the occurrence of pest, they applied the pesticide in anticipation of pest . Hence the number of application enhanced, the amount of chemical used was higher and finally the energy usage was also higher than that of other condition.

5.1.3 *Movement : Flying pest : Management of 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 pest population to the threshold level was almost nil 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. In farmers field condition, the number of application was higher than that of laboratory condition and recommended level. They applied the pesticide in anticipation of pest ie., they were not waiting till the occurrence of pest. Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition.

5.1.4 *Movement : Sedentary pest : Management of 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).

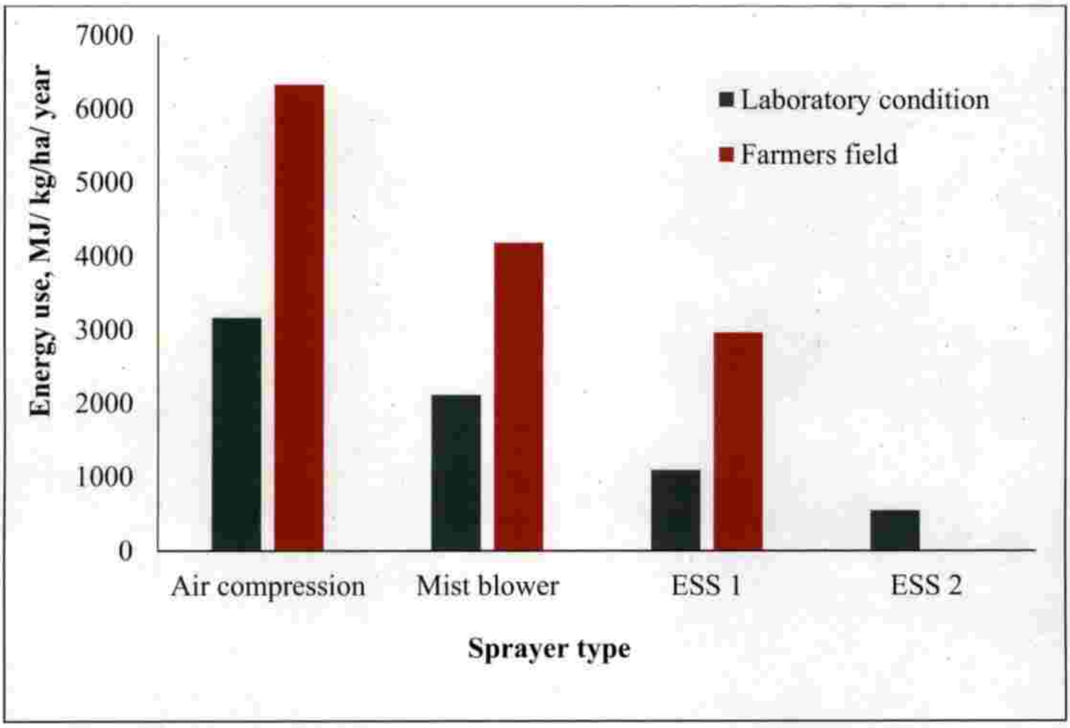

Fig. 3. Energy usage of sprayers for the management of cucurbit fruit fly

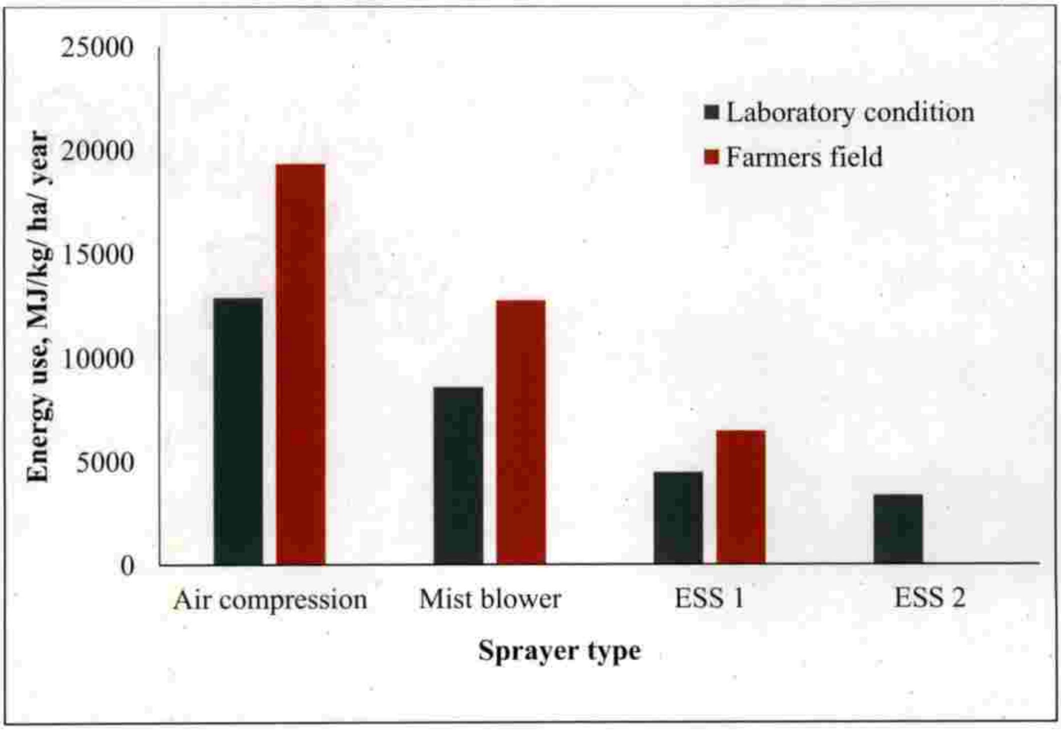

Fig. 4. Energy usage of sprayers for the management of brinjal mealy bug

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The minimum energy expenditure 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 (deposition efficiency was doubled) than that of other two sprayers, hence the reduction in energy use. In farmers field condition, the number of application was higher than that of laboratory condition and recommended level. they were not waiting till the occurrence of pest they applied the pesticide in anticipation of pest Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition.

5.1.5 ***Ecological niche : Abaxial : Management of 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.

In farmers field condition, the number of application was higher than that of laboratory condition and recommended level. They applied the pesticide in anticipation of pest ie., they were not waiting till the occurrence of pest. Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition.

5.1.6 ***Ecological niche : Adaxial : Management of 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). 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. In farmers field condition, the number of application was higher than that of laboratory condition and recommended level. They applied the pesticide in anticipation of pest ie., they were not waiting till the occurrence of pest. Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition.

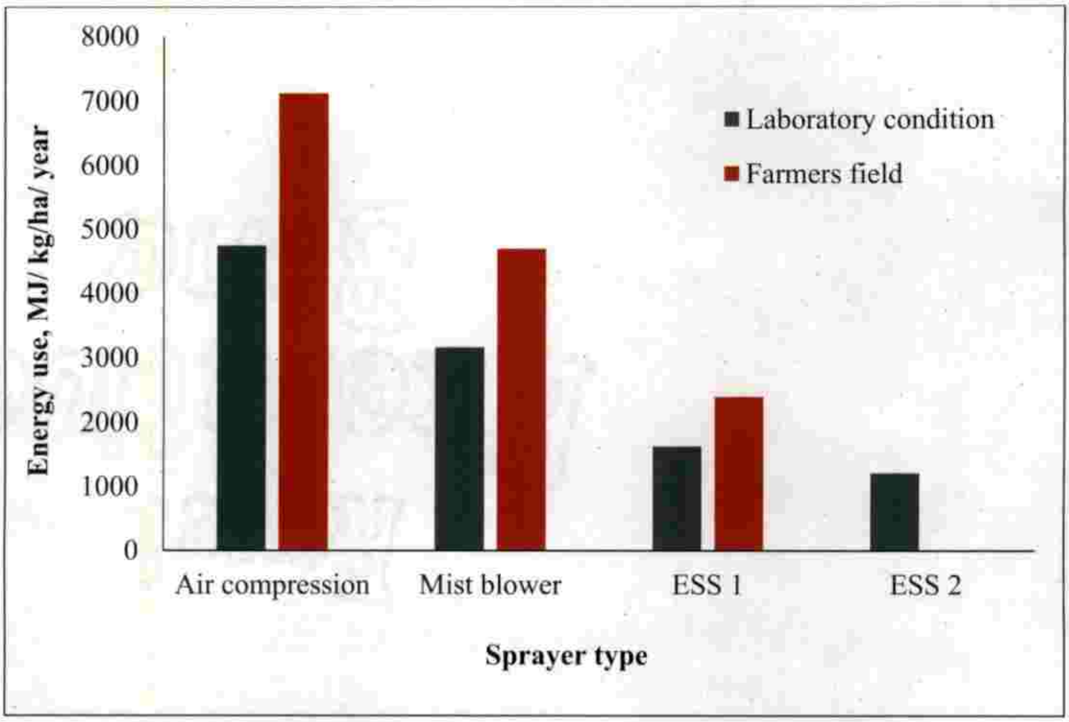

Fig. 5. Energy usage of sprayers for the management of caterpillar

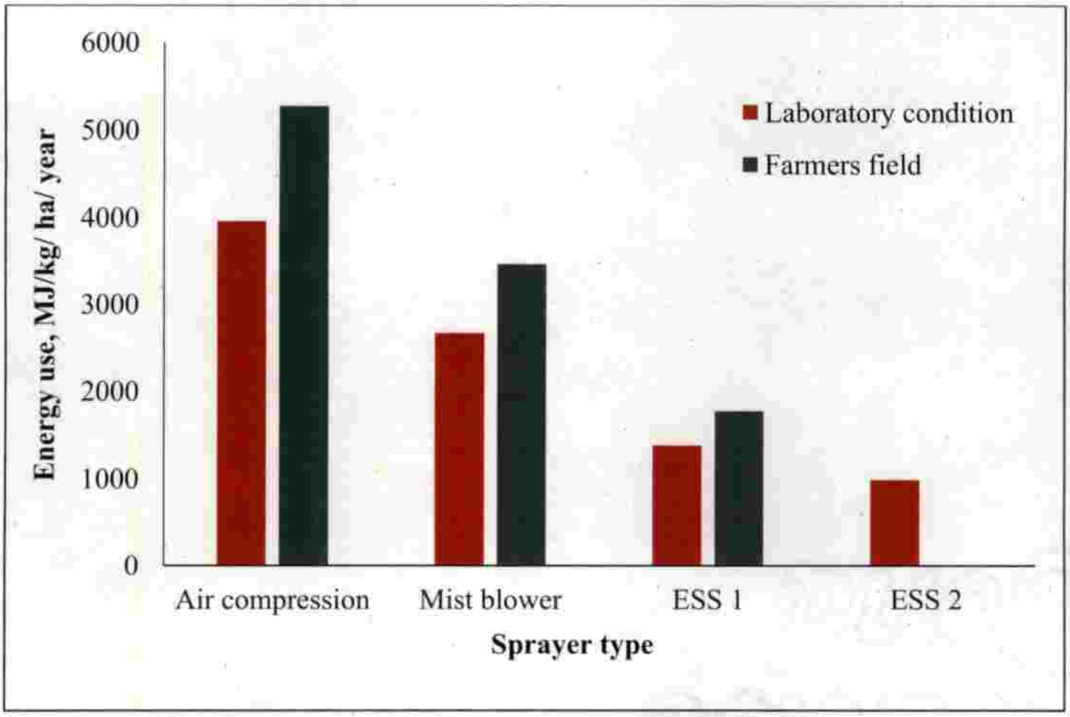

Fig. 6. Energy usage of sprayers for the management of chilli mite

5.2 EFFECT OF DIFFERENT SPRAYERS ON GREENHOUSE GAS EMISSION DURING MANAGEMENT OF THE SELECTED PESTS

The quantity of greenhouse gas (CO_2) was calculated from the total energy use efficiency of the three selected sprayers (knapsack air compression sprayer, knapsack mist blower and electrostatic sprayer) for the control of selected pests by applying corresponding pesticide. It was evaluated both in laboratory conditions and farmers field condition for the control of 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 total emission during the production and application was calculated.

5.2.1 *Greenhouse gas emission : Hard bodied pest : Management of pumpkin beetle*

The quantity of CO_2 released during the control of pumpkin beetle in cucumber was observed (Fig. 7) to the maximum for knapsack air compression sprayer both in laboratory condition (649 Kg ha^{-1} year^{-1}) and in farmers field (981.78 Kg ha^{-1} year^{-1}) followed by knapsack mist blower (435.26 Kg ha^{-1} year^{-1} and 649.65 Kg ha^{-1} year^{-1} respectively) and the minimum emission for the electrostatic sprayer (224.12 Kg ha^{-1} year^{-1} and 329.69 Kg ha^{-1} year^{-1} respectively). But 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 (112.06 Kg ha^{-1} year^{-1} and 168.09 Kg 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. Correspondingly with the energy use the quantity of CO_2 can also be reduced. But in farmers field condition, the number of application was higher than that of

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laboratory condition and recommended level. They applied the pesticide in anticipation of pest ie., they were not waiting till the occurrence of pest. Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition. Correspondingly with the amount of chemical used and the energy usage the quantity of CO_2 emission also be increased.

5.2.2 *Greenhouse gas emission: Soft bodied pest: Management of cowpea aphid*

During the control of aphid in cowpea the quantity of CO_2 released was observed (Fig. 8) to the maximum for knapsack air compression sprayer both in laboratory condition (248.98 Kg ha^{-1} $year^{-1}$) and in farmers field (497.96 Kg ha^{-1} $year^{-1}$) followed by knapsack mist blower (165.18 Kg ha^{-1} $year^{-1}$ and 326.70 Kg ha^{-1} $year^{-1}$ respectively) and the minimum emission for the electrostatic sprayer (86.24 Kg ha^{-1} $year^{-1}$ and 165.18 Kg ha^{-1} $year^{-1}$ respectively). But the reoccurrence pest population to the threshold level was almost zero in the case of electrostatic sprayer, hence the number of application was reduced considerably (43.12 Kg ha^{-1} $year^{-1}$ and 82.59 Kg ha^{-1} $year^{-1}$ respectively). While using electrostatic sprayers for the control of aphid in cowpea, the number of applications was reduced (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. Correspondingly, with the energy use the quantity of CO_2 can also be reduced. But, the number of application was higher than that of laboratory condition and recommended level in farmer's field condition. They applied the pesticide in anticipation of pest i.e. they were not waiting till the occurrence of pest. Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition. Correspondingly with the amount of chemical used and the energy usage the quantity of CO_2 emission also be enhanced.

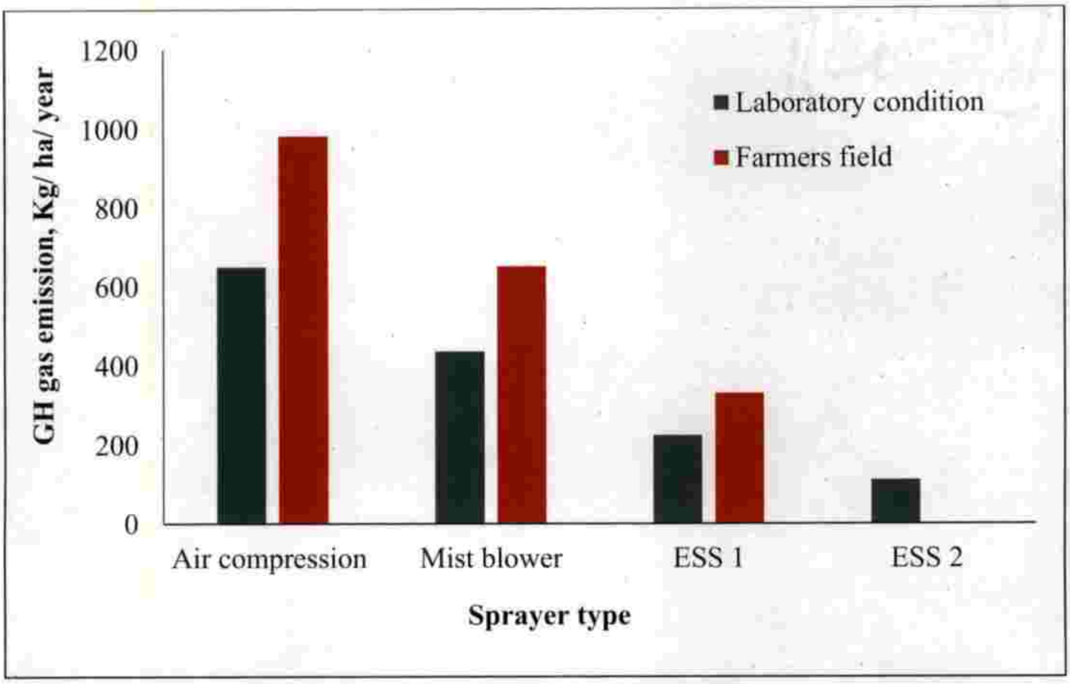

Fig. 7. Greenhouse gas emission for management of hard bodied pest : pumpkin beetle

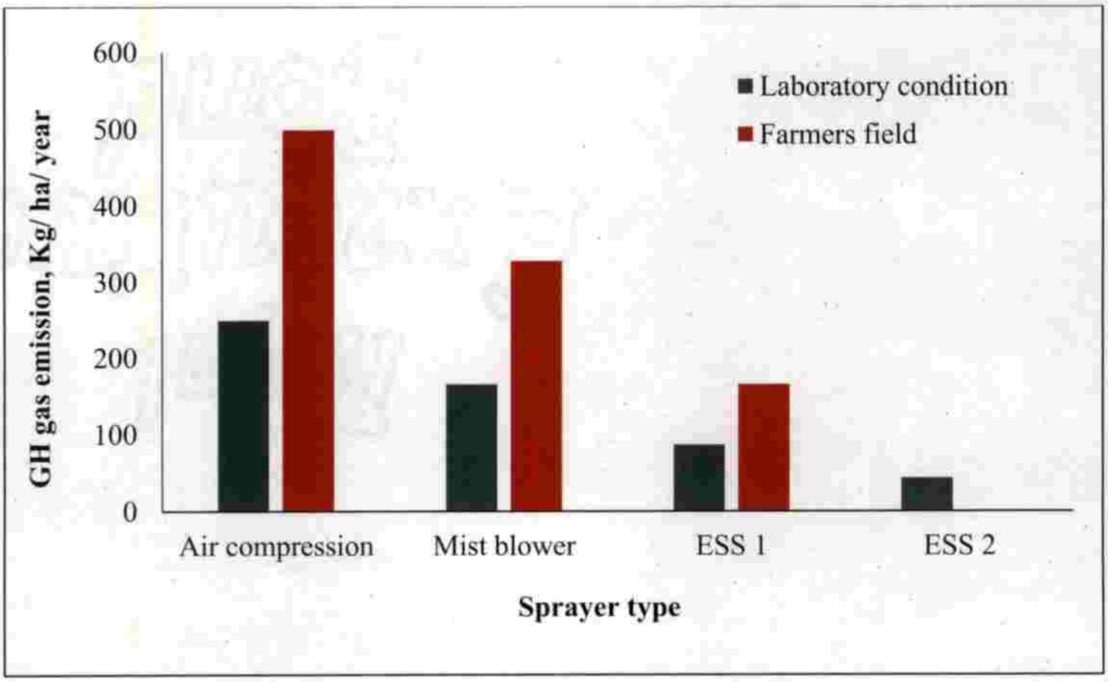

Fig. 8. Greenhouse gas emission for the management of soft bodied pest : cowpea aphid

5.2.3 *Greenhouse gas emission: Management of flying pest : Cucurbit fruit fly*

The quantity of CO_2 released during the control of fruit fly in bitter gourd was observed (Fig. 9) to the maximum for knapsack air compression sprayer both in laboratory condition (218.17 Kg ha^{-1} $year^{-1}$) and in farmers field (436.35 Kg ha^{-1} $year^{-1}$) followed by knapsack mist blower (145.79 Kg ha^{-1} $year^{-1}$ and 288.36 Kg ha^{-1} $year^{-1}$ respectively) and the minimum emission for the electrostatic sprayer (75.06 Kg ha^{-1} $year^{-1}$ and 204.44 Kg ha^{-1} $year^{-1}$ respectively). But 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 (37.53 Kg ha^{-1} $year^{-1}$ and 102.22 Kg 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. Correspondingly, with the energy use the quantity of CO_2 can also be reduced. But in farmer's field condition, the number of application was higher than that of laboratory condition and recommended level. They applied the pesticide in anticipation of pest i.e. they were not waiting till the occurrence of pest. Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition. Correspondingly with the amount of chemical used and the energy usage the quantity of CO_2 emission also be increased.

5.2.4 *Greenhouse gas emission: Management of sedentary pest : Brinjal mealy bug*

During the control of mealy bug in brinjal the quantity of CO_2 released was observed (Fig. 10) to the maximum for knapsack air compression sprayer both in laboratory condition (887.83 Kg ha^{-1} $year^{-1}$) and in farmers field (1331.75 Kg ha^{-1} $year^{-1}$) followed by knapsack mist blower (591.71 Kg ha^{-1} $year^{-1}$ and 877.01 Kg ha^{-1} $year^{-1}$ respectively) and the minimum emission for the electrostatic sprayer

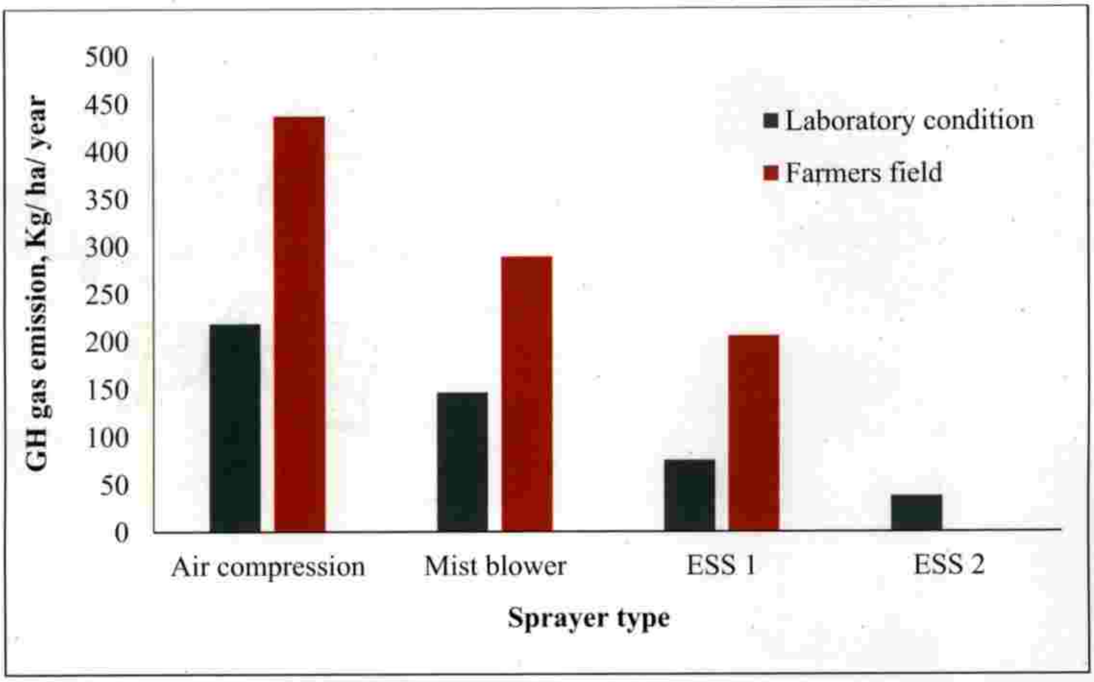

Fig. 9. Greenhouse gas emission for the management of flying pest : cucurbit fruit fly

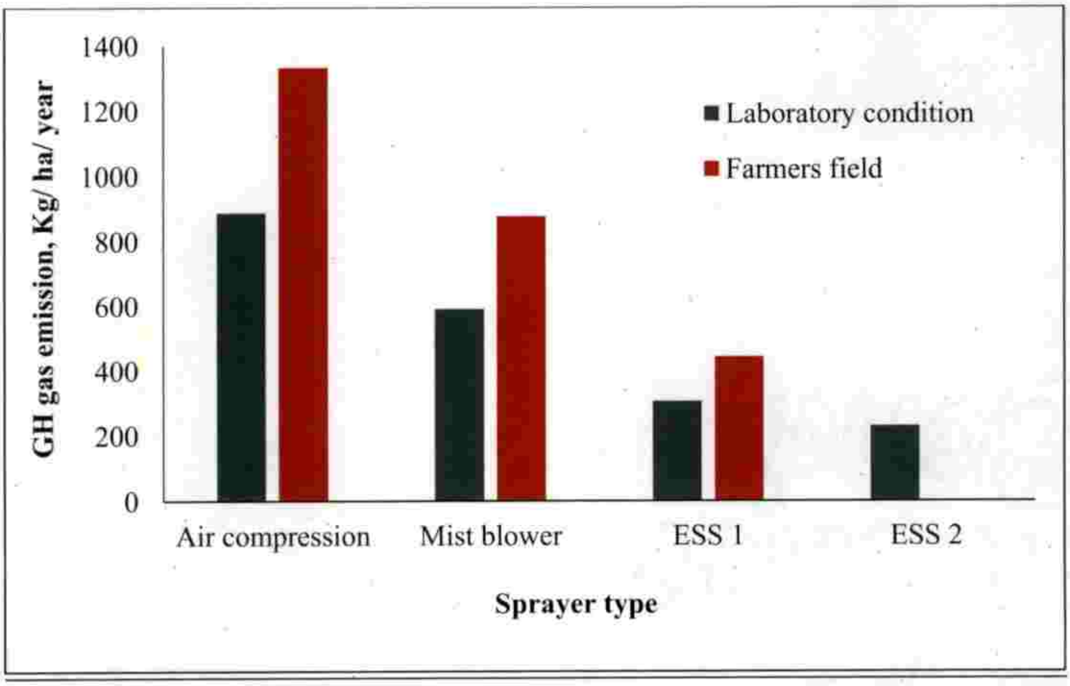

Fig. 10. Greenhouse gas emission for the management of sedentary pest : brinjal mealy bug

(306.67 Kg ha^{-1} year^{-1} and 443.91 Kg ha^{-1} year^{-1} respectively). But 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 (230 Kg ha^{-1} year^{-1} and 332.93 Kg ha^{-1} year^{-1} respectively). While using electrostatic sprayers for the control of mealy bug in brinjal, 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. Correspondingly, with the energy use the quantity of CO_2 can also be reduced. But in farmer's field condition, the number of application was higher than that of laboratory condition and recommended level. They applied the pesticide in anticipation of pest i.e. they were not waiting till the occurrence of pest. Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition. Correspondingly with the amount of chemical used and the energy usage the quantity of CO_2 emission also be increased.

5.2.5 *Greenhouse gas emission: Management of abaxial pest : Caterpillar*

The quantity of CO_2 released during the control of caterpillar in brinjal was observed (Fig. 11) to the maximum for knapsack air compression sprayer both in laboratory condition (327.25 Kg ha^{-1} year^{-1}) and in farmers field (490.88 Kg ha^{-1} year^{-1}) followed by knapsack mist blower (217.63 Kg ha^{-1} year^{-1} and 323.13 Kg ha^{-1} year^{-1} respectively) and the minimum emission for the electrostatic sprayer (112.06 Kg ha^{-1} year^{-1} and 164.78 Kg ha^{-1} year^{-1} respectively). But 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 (83.50 Kg ha^{-1} year^{-1} and 123.09 Kg 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 fruit fly to the threshold level) and also quantity of pesticide used was lesser (deposition

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efficiency was more than 2 times higher) than that of other two sprayers, hence the reduction in energy use. Correspondingly, with the energy use the quantity of CO_2 can also be reduced. But in farmer's field condition, the number of application was higher than that of laboratory condition and recommended level. They applied the pesticide in anticipation of pest i.e. they were not waiting till the occurrence of pest. Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition. Correspondingly with the amount of chemical used and the energy usage the quantity of CO_2 emission also be increased.

5.2.6 *Greenhouse gas emission: Management of adaxial pest : Chilli mite*

The quantity of CO_2 released during the control of chilli mite in chilli was observed (Fig. 12) to the maximum for knapsack air compression sprayer both in laboratory condition (272.74 Kg ha^{-1} $year^{-1}$) and in farmers field (363.65 Kg ha^{-1} $year^{-1}$) followed by knapsack mist blower (183.85 Kg ha^{-1} $year^{-1}$ and 239.05 Kg ha^{-1} $year^{-1}$ respectively) and the minimum emission for the electrostatic sprayer (94.97 Kg ha^{-1} $year^{-1}$ and 122.57 Kg ha^{-1} $year^{-1}$ respectively). But 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 (68.18 Kg ha^{-1} $year^{-1}$ and 88.88 Kg 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 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. Correspondingly, with the energy use the quantity of CO_2 can also be reduced. But in farmer's field condition, the number of application was higher than that of laboratory condition and recommended level. They applied the pesticide in anticipation of pest i.e. they were not waiting till the occurrence of pest.

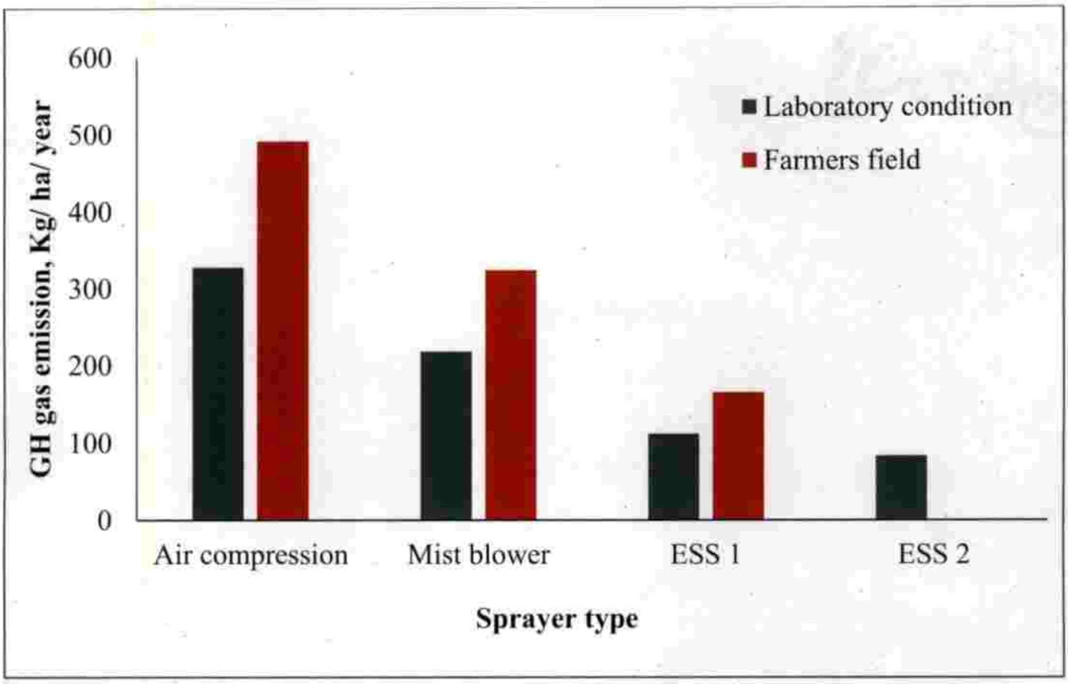

Fig. 11 . Greenhouse gas emission for the management of abaxial pest : caterpillar

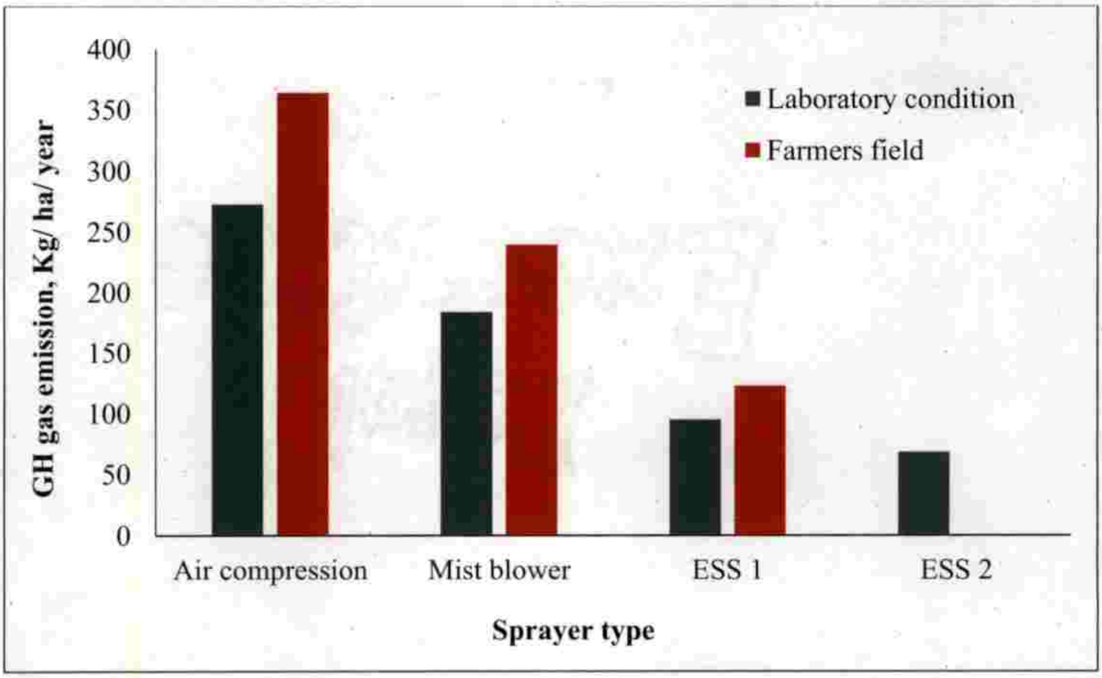

Fig. 12 . Greenhouse gas emission for the management of adaxial pest : chilli mite

Hence the number of application increased, the amount of chemical used was higher and finally the energy usage was also higher than that of laboratory condition. Correspondingly with the amount of chemical used and the energy usage the quantity of CO_2 emission also be increased.

5.3 EFFECT OF SPRAYER ON ENERGY USE EFFICIENCY DURING MANAGEMENT OF DIFFERENT PESTS

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 energy use efficiency of mist blower and electrostatic sprayer (case 1 and case 2) was assessed by considering the deposition efficiency of sprayers and the reoccurrence of pests to the threshold level under laboratory condition (Fig. 13) and in farmers field (Fig. 14).

The energy use efficiency was maximum for the electrostatic sprayer both in laboratory condition (Case 2 : Pumpkin beetle – 82.73 %, Aphid – 82.68 %, Fruit fly – 83.02 %, Mealy bug – 74.09 %, Caterpillar – 74.48 %, chilli mite 75.00 % and Case 1 : 65.46 %, 65.36 %, 66.04 %, 65.45 %, 65.57 %, 65.17 % respectively) and farmers field (Case 2 : 82.87 %, 83.41 %, 76.57 %, 75 %, 74.92 %, 75.55 % and Case 1 : 66.41 %, 66.82 %, 53.14 %, 66.66 %, 66.43 %, 66.29 % respectively) in comparison with air compression sprayer. But the corresponding values for the mist blower were under laboratory condition : 32.93 %, 33.65 %, 33.08 %, 33.35 %, 33.49 %, 32.58 % respectively and in farmers field 33.82 %, 34.40 %, 33.9 %, 34.14 %, 34.17 % and 34.26 % respectively. 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

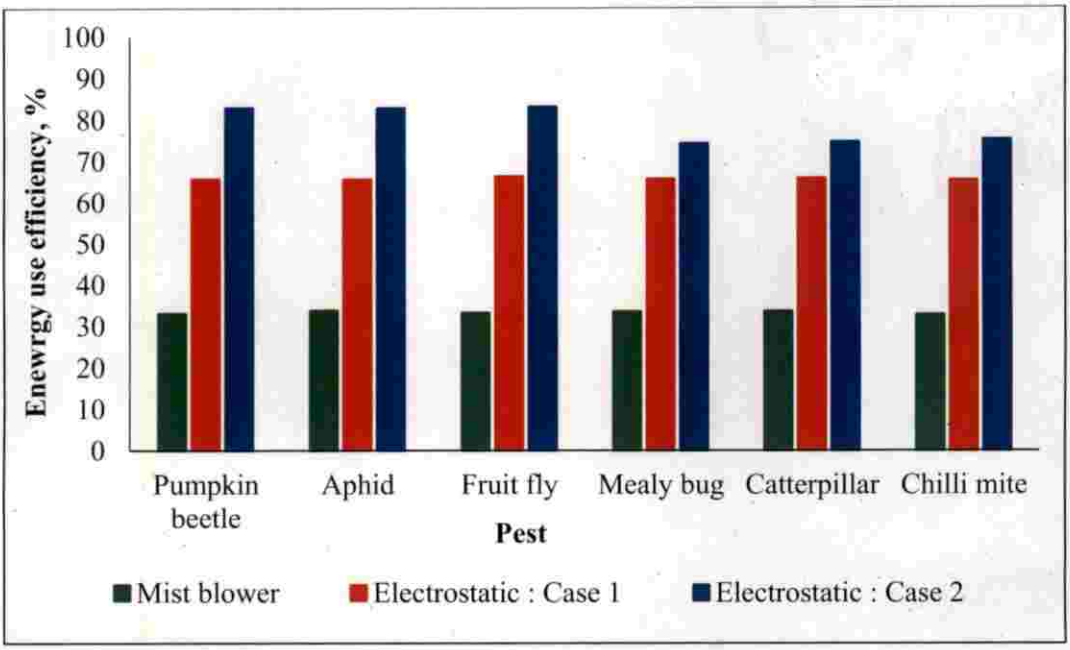

Fig. 13. Effect of type of sprayer on energy use efficiency in management of pests under laboratory condition

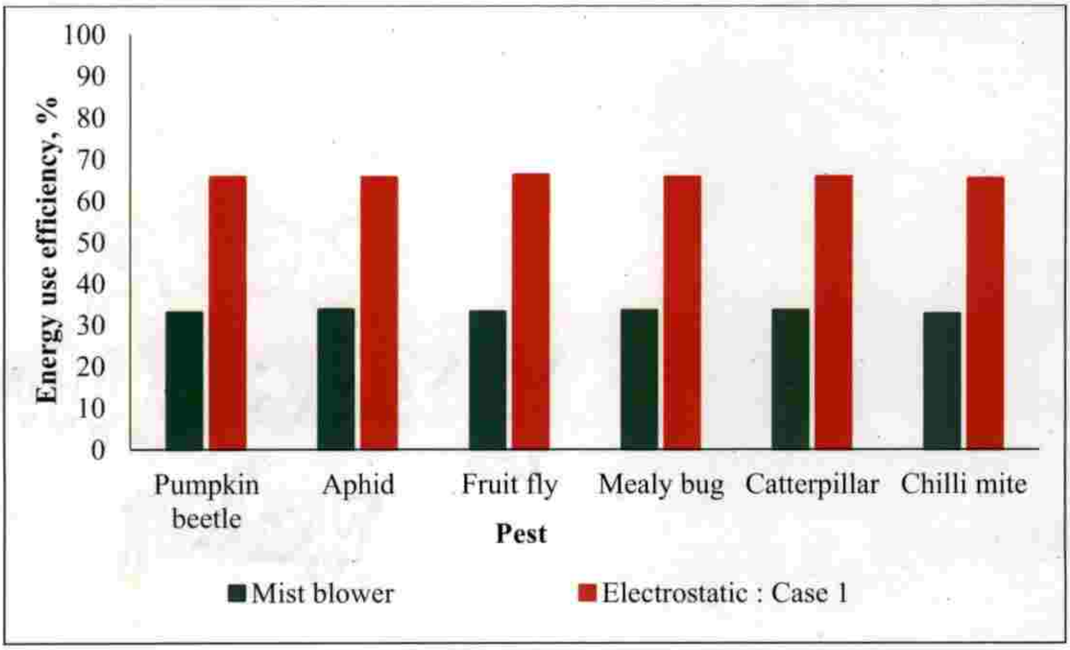

Fig. 14. Effect of type of sprayer on energy use efficiency in management of pests under field condition

after the application of pesticide with electrostatic sprayer. In Case -1 also, the higher value of energy saving (about 65 %) 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.

In comparison with mist blower the electrostatic sprayer shown higher value of energy use efficiency (Case – 1 : 40 % higher and Case – 2 : 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.

5.4 EFFECT OF SPRAYER ON GREENHOUSE GAS EMISSION FOR THE MANAGEMENT OF DIFFERENT PESTS

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. 15) and in farmers field was assessed (Fig. 16).

The greenhouse gas emission was minimum for the electrostatic sprayer both in laboratory condition (Case 2 : Pumpkin beetle – 17.27 %, Aphid – 17.32 %, Fruit fly – 17.21 %, Mealy bug – 25.91 %, Caterpillar – 25.51 %, chilli mite – 24.99 % and Case 1 : 34.53 %, 34.64 %, 34.41 %, 34.54 %, 34.24 %, 34.82 % respectively) and farmer's field (Case 2 : 17.12 %, 16.58 %, 27.55 %, 24.99 %, 25.07 %, 24.44 % and Case 1 : 33.58 %, 33.17 %, 46.85 %, 33.33 %, 33.56 %, 33.70 % respectively) in comparison with air compression sprayer. But the corresponding values for the mist blower were under laboratory condition : 67.07 %, 66.34 %, 66.82 %, 66.85 %, 66.50 %, 67.41 % respectively and in farmers field 66.17 %, 65.60 %, 66.08 %, 65.85 %, 65.82 % and 65.73 % respectively. 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.

In comparison with mist blower the electrostatic sprayer shown lower value of CO_2 release both in laboratory condition and famers plot (Case – 1 : 45 % lower and Case – 2 : 30 % 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.

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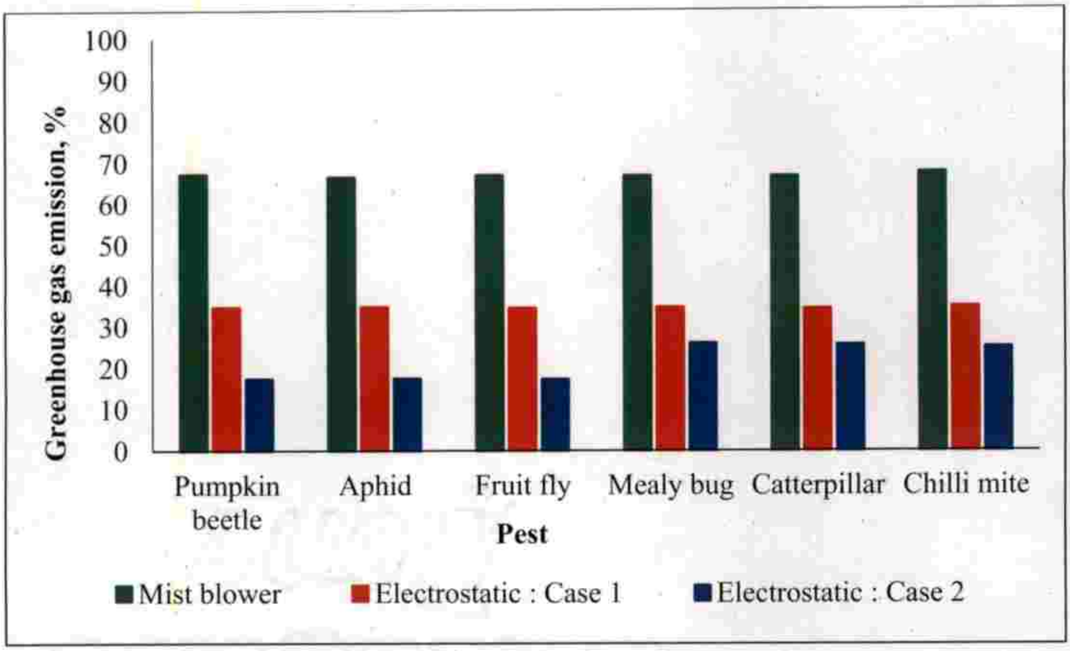

Fig. 15. Effect of type of sprayer on CO_2 release in management of pests under laboratory condition

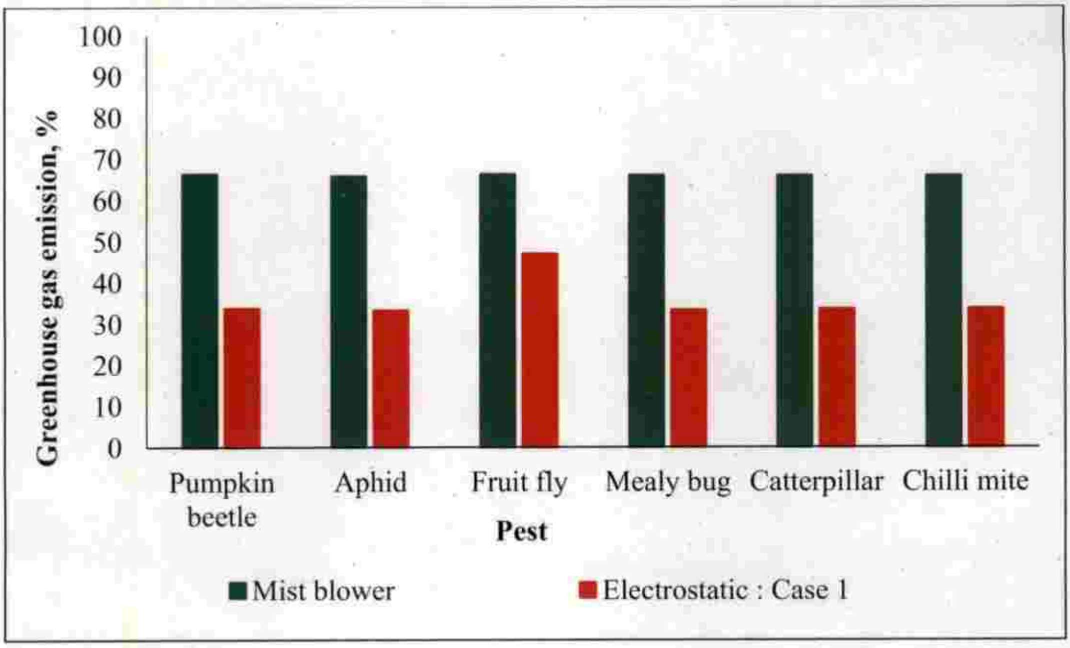

Fig. 16. Effect of type of sprayer on CO_2 release in management of pests under field condition

Summary

6. SUMMARY

Pesticide application plays a major role in the CO_2 emission and has contributed to the changes in the concentration of greenhouse gases in the atmosphere. The agricultural pesticide application lead to the carbon dioxide emission to the atmosphere. The study entitled 'Efficacy of electrostatic sprayer on crop pest management and pesticide use' was carried out at college of Agriculture, Vellayani during November 2015 to July 2016. The objectives of the study include study of the efficacy of electrostatic sprayer on pest control in comparison with mist blower, analysis of the percentage deposition of chemicals on target and estimation of the greenhouse gas emission from the used pesticides.

The study was undertaken on the selected crops viz. cucumber, cowpea, bittergourd, brinjal and chilli. Six pests such as pumpkin beetle, aphid, fruitfly, mealybug, caterpillar and chilli mite were identified. The pests were selected based on the three characteristics such as integumental characters, movement and ecological niche. Three different sprayers selected were knapsack air compression sprayers, knapsack mist blower and electrostatic sprayers.

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. The greenhouse gas (CO_2) emission were quantified by using the energy use efficiency of the selected pests. The spray deposition was estimated in terms of deposition per unit leaf area sprayed by leaf wash method. The study was conducted under the statistical frame work. And the following 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.

- The corresponding greenhouse gas (CO_2) released to the atmosphere during operation with electrostatic sprayer was 35 % lower that of mist blower and 65 % lower than 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, energy utilization, greenhouse gas emission also reduced.

- The greenhouse gas emission will be reduced to 20 % by the use of electrostatic sprayer and 65 % by the use of mist blower in comparison with air compression sprayer.

From these observations and analysis it could be concluded that the electrostatic sprayers are being highly efficient and contribute minimum CO_2 emission to the atmosphere. The knapsack air compression sprayers gives the maximum CO_2 emission and that of knapsack powered mist blower resulted as intermediate emission. This contributes a significant reduction in emission of CO_2 when it considered globally. Hence this reduction significantly affect the concentration of CO_2, the major greenhouse gas in the atmosphere, ultimately contribute in mitigation on global warming.

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Abstract

EFFICACY OF ELECTROSTATIC SPRAYER ON CROP PEST MANAGEMENT AND PESTICIDE USE

by

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ABSTRACT OF THE THESIS

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ABSTRACT

International pressure is increasing on India to adopt a more pro-active role in greenhouse gas emission. Hence it is important to develop a clear understanding of our emission inventory towards reducing greenhouse gas emissions. Pesticide application play a major role in the greenhouse gas emission. Environmental hazards associated with pesticides results from 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 find out the efficacy of electrostatic sprayer on pest control in comparison with mist blower and air compression sprayer. Six pests were viz. pumpkin beetle, cowpea aphid, curcurbit 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 greenhouse gas emission for the total energy usage for the corresponding quantity of pesticide were computed for all the selected sprayers. 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 sprayers. In 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 contribute a significant reduction in emission of CO_2 when it considered globally, ultimately contribute in mitigation of global warming.