BULLETIN OF THE POLISH ACADEMY OF SCIENCES
TECHNICAL SCIENCES, Vol. 59, No. 3, 2011
DOI: 10.2478/v10175-011-0037-7

Development of variable rate sprayer for oil palm plantation

W.I.W. ISHAK[1]*, R.M. HUDZARI[2], and M.M.N RIDZUAN[1]

[1] Department of Biological and Agriculture Engineering, Faculty of Engineering, UPM, 43400, Serdang, Selangor, Malaysia
[2] Department of Agriculture Science, Faculty of Agriculture and Biotechnology, UniSZA, 21300, Kuala Terengganu, Terengganu, Malaysia

Abstract. This project describes the design and development of a camera vision with color detection for the variable rate technology (VRT) automated sprayer. In this project, the smart sprayer system was already developed and mounted on the ATV. The automated sprayer system was developed by combination of the electromechanical system, PC parallel port relay board, the controller and visual basic programming software. This smart sprayer system is guided with the camera to detect the presence of weeds. Detection of weeds is based on the green color value from RGB value. The amount or percentage (%) of weeds detected determines the rate of spraying that is controlled by an electric motor and the relay board. In this project, the spray nozzles were modified to be fully open, fully closed and half open. The closing and opening of valves were controlled by the electromechanical system that receives the instruction from the camera vision. Experiments carried out shows that the nozzle is closed when the percentage of weeds detected is less than 2%. It is half open at 3% to 50% and fully open at more than 51%. The application rate of spraying can be determined from the result of the spraying operation.

Key words: smart sprayer, variable rate, camera vision, weedicide, oil palm.

1. Introduction

Weeds are a major problem in the oil palm plantation in Malaysia. While there is an adequate equipment available to control the weeds between the rows, weed control in the rows still requires a lot of manual labor. The required labor for manual weeding is costly and hardly available. Besides that, agricultural workers performing manual weeding are exposed to high risks of musculoskeletal disorders to the lower back. Hand weeding exposes workers to continued static loading to spinal soft tissues, which can lead to the initiation of a cycle of inflammatory reaction. Thus, if a mechanical spraying technology could replace this labor; this could mean an enormous stimulus for oil palm plantation.

Nowadays, the big farm and plantation area want to reduce the use of many labor in the working field especially to do routine works such as weed control, harvesting and other works. Many researches have been carried out to overcome those problems especially in uncertain environment control [1]. The application of the camera vision was introduced in detecting the oil palm fruit in an uncertain environment of the outdoor condition for the actual oil palm plantation [2].The variable rate spraying system was also contributed to control the weed growth in an oil palm plantation and then increases the crop yield [3]. Sprayers have been used in many different types of function such as for the growth of plant and to handle the weed problem. The photo sensor-based plant detection systems [4, 5] can detect all the green plants (weed and crop plants) and spray only on the plants. Sankarasubramanian and Venkatakrishnan, 1998 used Charge Couple Device (CCD) sensor for testing a waveplate in development of the interferometric polarization technique [6]. A machine-vision guided precision band sprayer for small-plant foliar spraying [7] demonstrated a target deposition efficiency of 2.6 to 3.6 times that of a conservative sprayer, and the non-target deposition was reduced by 72% to 99%. Many current commercial sprayer controllers maintain the unvarying application rate by compensating for ground speed changes, a concept that was researched more than a decade ago [8]. To use GIS or remote sensing information, a research was initiated on map-driven variable rate sprayers [9].

The flow rate and spray pattern performances of the controller used solenoid valves were the same as those of the manual control system. But the automatic controller is expected to save more herbicide since it is more precise and accurate. The Variable-rate (VR) application of manure would help to reduce energy wasting due to the environmental uncertainty [9]. Several authors have emphasized the potential of VR fertilization to improve water quality by reducing fertilization where nutrients are above levels required for optimum crop production. Furthermore, many researchers demonstrated that manure application equipment can be easily modified to apply VR manure [3].

The technology of a site-specific herbicide application system was already developed [10]. By using camera vision the presence of weeds can be detected. The nozzle sprayed bases on the intensity of the weeds. The solenoid valve controlled the sprayer only for fully open and fully close valve operations. The nozzle will always spray at full opening even at low density of weed. Thus, a more accurate system could be feasible, to monitor the exact amount of spray through the variable rate technology. For more accurate and efficient spraying, the variable rate sprayer system is needed to control the amount of chemical used, so that, the spraying will be done according to

*e-mail: wiwi@eng.upm.edu.my

the actual density of weeds. The chemical use and production costs can be reduced by using the variable rate technology.

The aim of this project is to execute efficiently the weeds by varying the optimum usage of herbicides in agricultural operations. In achieving this, the rate of spraying from the variable rate nozzle needs to be varied based on intensity of the weed green color using the camera vision system that already was developed at Universiti Putra Malaysia (UPM) for the automated spraying system. The objective is to design an affordable variable rate nozzle to control the rate of spraying; more for high intensity weeds and less spraying for the low density weeds. Besides that, it is also to improve on the site-specific herbicide application model using camera vision. The cameras which use the optic technology give some advantage in term of non destructive technique with high technology expected for the application [11].

2. Materials and methods

The purpose of this project is to design the variable rate sprayer system based on weed density using camera vision for the application of herbicides spraying. The automated sprayer system was already developed at the Faculty of Engineering, Universiti Putra Malaysia. The program to fully open the nozzle when the camera detected the green weeds was already developed. In this project, the camera vision is used to detect the amount (percentage) of the weeds on the ground. Once the camera recognizes the image and amount of the weeds, the computer will run the program to automatically open the nozzle by using DC motor. However, the rate of application was constant based on the applied pressure and the speed of operation. The rate of application ought to be based on the intensity of weed detected to increase the efficiency and reduce the wastage of chemical applications. This project will concentrate on the design of a cheap variable rate nozzle and to control the rate of spraying from it.

A good sprayer consists of number of parts assemble in a manner that permits all parts to work together and function as a unit. Figure 1 shows the front and back view of smart sprayer attached on the ATV, ATP 5000. The smart sprayer system consists of sprayer tank, pump, hose and nozzles. The tank was used to store the chemical liquid for spraying. The tank should be made of a corrosion-resistant material. Herbicides may be corrosive to certain material. A suitable material used in sprayer tanks includes stainless steel, polyethylene plastic and fiberglass. The capacity of tank must be known to add the correct amount of herbicides. Most new tanks have capacity marks on the side. The pump is the heart of a hydraulic system. The use of pump is to produce a desired operating pressure at the capacity required for the spraying job. The flow rate of the pump used for this system is 1.8 gallon per minute at 60 psi pressure.

The length and size of the galvanized pipes and hoses are one of important criteria. A hose and fitting to handle water operating pressure and quantities are selected; 1/2 inches galvanized pipes are used as the main line for a liquid flow.

Fig. 1. Front and back view of smart sprayer

Nozzles are the critical part of the sprayer. Nozzles determine the rate of spray distribution at a particular pressure and nozzle spacing. Nozzle parts consist of a ball valve, car power window motor, sprocket and chain. Selecting a nozzle that produces largest droplets while providing an adequate coverage at the intended application rate and pressure can minimize drift. The five millimeters narrow nozzle is selected for this purpose. A little modification has been made to the nozzle so it can suit the sprayer design. To boost the herbicide delivery accuracy, each spray nozzle was controlled independently.

Figure 2 shows the nozzle that was modified to suit the variable rate technology. Six nozzles were modified, with 3 nozzles on each side of the sprayer tank. Both sides have one camera to capture the image of weeds. The image captured by a camera, would send the signal of image to program analyzing. The relevant signal would trigger the relay for further action. The motor will control the opening of the nozzle after getting signal from relay at the control board as shown in Fig. 3. The control board consists of eight relays. The signals depend on the percentage of weeds that was captured by a camera. When the camera detected 3% to 50% of green weeds, the relay will send the message to respective motor to open 50% or half open. When the camera detects less than 3% of area weeds, the relay will send the message to close the valve of the nozzle, thus no spraying. When the camera detects more than 50% of the green weeds, the relay will send the message for fully opening of the valve nozzle and that it would be sprayed in a full operation.

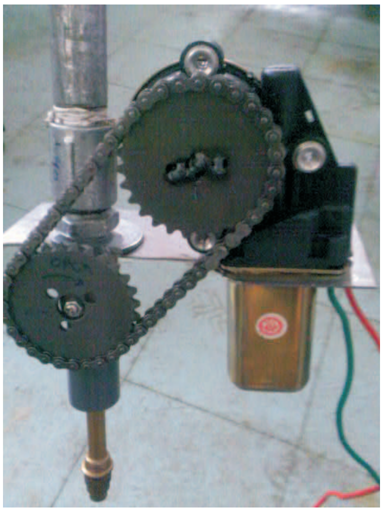

Fig. 2. Nozzle that was modified

```
If percentNozzle1 < 2 Then
lblSprayerOnOff(0).Caption = "Nozzle 1 : Off "
ElseIf percentNozzle1 > 2 And percentNozzle1 <= 50 Then
lblSprayerOnOff(0).Caption = "Nozzle 1 : Half "
ElseIf percentNozzle1 > 50 Then
lblSprayerOnOff(0).Caption = "Nozzle 1 : Full "
```

Fig. 4. Algorithm for percentage of weeds

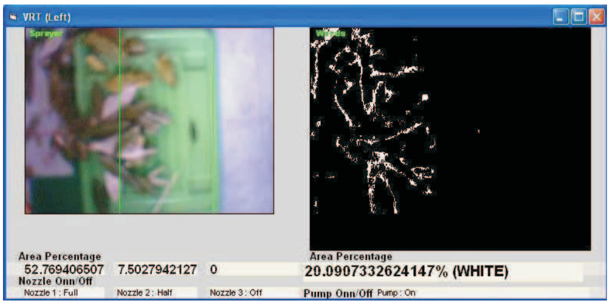

Fig. 5. The picture of the green weeds

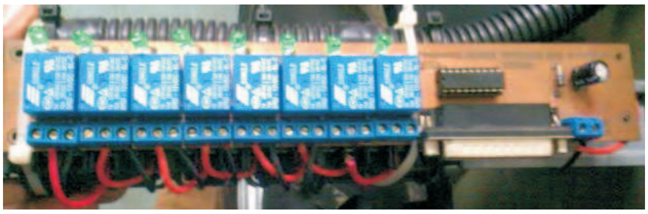

Fig. 3. Control board

VRT nozzles consist of a ball valve, DC motor, two gears, chain and nozzle as in Fig. 2. The first gear is attached to the DC motor and the second one is attached to the ball valve. The gears are connected together by a chain. A clockwise rotation will open the valve meanwhile a counter clockwise rotation will close the valve. After the signal was sent from relay to DC motor, the motor will rotate the first gear. Then, the rotation caused the chain to move, eventually rotate, the second gear. The opening and closing of the valve will depend on the signal that was sent by a relay. If the second gear rotated 45°, the ball valve is only half open. If the second gear rotated 90°, then the ball valve is fully open. For example, if the signal received by a relay with the indicated percentage of weeds, 27%, it means the percentage of weeds within range 3–50% which means that the half opening operation would be activated. So, the first gear will only rotate 45° and cause that the ball valve is open in half operation.

3. Results and discussion

The original program which had been developed by Ishak and Khairuddin [10] was modified as follows, Fig. 4. Figure 5 shows the picture of the green weeds captured by the camera that was attached to the smart spraying system. The width of spraying area was divided into three sections, one section per nozzle. The first section for the first nozzle shows 52.8% of weeds. The second section for the second nozzle shows 7.5% of weeds followed by 0% for third section.

The percentage of the weed green color per area covered varies with the opening of nozzles as shown in Table 1.

Table 1
Percentage of green color per area width according to rate of spraying

Opening of the nozzle	Fully close	Half open	Fully open
Green level (%)	0–2	3–50	51–100

If the percentage of the green (per area) was between 0–2%, the nozzle is closed. If the percentage of the green (per area) was between 3–50%, the nozzle will be half open and if the percentage of the green (per area) was between 51–100%, the nozzle will be fully open. The rate of spraying will increase when the percentage of green color covered is high.

The obtained result shows that the automated sprayer will work successfully when the green color of weed is detected. The nozzles will be triggered when the target which is weed in green color is detected within the area covered by the camera vision.

The green color will be detected with a certain value that comes from R(red), G (green) and B (blue) color value and an appropriate brightness intensity that the green color value had been installed into the source code of the visual basic programming. The same technique is also mentioned by Glinicki and Litorowicz, (2006) which used the RGB color components to acquire color image and converted them into a binary image for the segmentation process [12]. The triggering time is instantaneous to the nozzles operation and sometimes, the triggering time is a little bit late. This is due to webcam used having a low image quality and the image processing takes time.

The relay board with an electric motor also works successfully when the system operates depending on the percentage of weeds detected in terms of the green color percentage covered by the camera vision. In this project, the nozzle will open at a full state when the camera detects the weed range between 51–100%.

The amount of herbicide used depends on the brand and specifications of the herbicides. Different types of herbicides kill different types of weeds according to the purpose of the herbicides in agricultural field.

4. Conclusions

An inexpensive variable rate nozzle has been developed. It can vary the rate of spraying based on the intensity of weeds. The rate of spraying has been varied based on the detection of the weed green color by a camera vision. The nozzle will spray at three different rates that are off, half open and fully open according to the intensity of a green color detected by the camera vision.

The color recognition program using for visual basic program determines the percentage of a green color detected. The level of green was divided into three percentage condition; minimum (0–2%), medium (3–50%) and maximum (51–100%).

Besides that, the site-specific herbicide application model has been improved from a previous model. The combination of the electric motor with the relay board controller and the color recognition program upgrades the available sprayer system to be more effective in a chemical usage. The nozzle will spray at a certain rate with a certain color percentage based on the program developed. For example, the nozzle will spray at half open for 3–50% of green color detected.

It was found out that the use of Pulse Width Modulation (PWM) will give the better result for monitoring the opening of the nozzles. The PWM nozzle is very precise and very expensive for the farmers or for agricultural operations.

Acknowledgements. The authors would like to thank Mr. Khairuddin Abdurrahman and Mr. Zakiria Ismail from KBP UPM for giving us the opportunity and support to do this work.

REFERENCES

[1] P. Apostoli and A. Kanda, “Cantorian sets, fuzzy sets, rough sets and fregean sets”, *Bull. Pol. Ac.: Tech.* 50 (3), 247–276 (2002).

[2] M.H. Razali, W.I. Wan Ismail, A.R. Ramli, and M.N. Sulaiman, “Modeling of oil palm fruit maturity for the development of an outdoor vision system”, *Int. J. Food Eng.* 4 (3), CD-ROM (2008).

[3] W.I.W. Ishak and M.S. Shazrol (2007), “Camera vision guidance for automated weed sprayer on all terrain vehicles (ATV)”. *Proc. 2^{nd} Asian Conf. on Precision Agriculture*, (ACPA07) 1, CD-ROM (2007).

[4] S.A. Shearer and P.T. Jones, “Selective application of postemergence herbicides using photoelectrics”, *Trans. ASAE* 34 (4), 1661–1666 (1991).

[5] J.E. Hanks, “Smart sprayer selects weeds for elimination”, *Agricultural Research* 44 (4), 15 (1996).

[6] K. Sankarasubramanian and P.A. Venkatakrishnan, “CCD-based polarization interferometric technique for testing waveplates”, *Optics & Laser Technology* 30 (l), 15–21 (1998).

[7] D.K. Giles, and D.C. Slaughter, “Precision band sprayer with machine-vision guidance and adjustable yaw nozzles”, *Trans. ASAE* 40 (1), 29–36 (1997).

[8] M.R. Gebhardt, C.L. Day, C.E. Goering, and L.E. Bode, *Automatic Spray Control System*, IST World, Michigan, 1974.

[9] A.D. Rockwell and P.D. Ayers, “Variable rate sprayer development and evaluation”, *Applied Engineering in Agriculture* 10 (3), 327–333 (1994).

[10] W.I.W. Ishak and A.R. Khairuddin, “Development of real-time color analysis for the on-line automated weeding operations”, *Proc. 9^{th} Int. Conf. on Precision Agriculture* 1, CD-ROM (2008).

[11] M. Bom and E. Wolf, *Principles of Optics*, 6th ed., Pergamon Press, Oxford, 1989.

[12] M.A. Glinicki and A. Litorowicz, “Crack system evaluation in concrete elements at mesoscale”, *Bull. Pol. Ac.: Tech.* 54 (4), 371–379 (2006).