Field Evaluation of a Variable Rate Herbicide Applicator

Borpit Tangwongkit¹, Ratana Tangwongkit¹, V. M. Salokhe², H. P. W. Jayasuriya² and Hiroshi Nakashima*³

¹) Kasetsart University, Kamphansean Campus, Thailand
²) Asian Institute of Technology, Bangkok 12120, Thailand
³) Graduate School of Agriculture, Kyoto University, 606-8502, Japan

Abstract

A tractor mounted variable rate herbicide applicator with an 800 mm width of application was developed for spraying herbicides in a sugarcane field with a row spacing of 1,500 mm. The system components included a web camera to capture picture of field entries, a ground speed sensor, a PWM circuit to control a 12-volt DC electrical pump and application software that was programmed by Borland C++ builder for processing and controlling the system. The applicator was tested in constant application mode and the variable rate mode. It was observed that working speed, field capacity, field efficiency during constant application mode was higher than that use as a variable rate applicator. The amount of herbicide used depended on application rate, working speed and field capacity. Application rate with the constant application system was maximum e.g. 2.78 L/min or 407.07 L/ha at 0.41 ha/h field capacity and 1.13 m/s working speed. With a variable rate system, at 0.33 ha/h field capacity and 0.77 m/s working speed, the application rates were varied to 2.00, 1.90, 1.80, 1.70 and 1.60 L/min. At these application rates, herbicide use was 363.64, 345.45, 327.27, 309.09 and 290.91 L/ha, thus herbicide saving, compared to constant application system, was 10.67, 15.14, 19.6, 24.07 and 28.54% respectively. As the working speed of the variable application rate system was slower than constant application system, it affected to field capacity and field efficiency but its less use of herbicide was not only economical but good for reducing harmful effects on the environment. An economic analysis conducted showed the area required for breakeven is 81.86 ha.

Key words
variable rate applicator, machine vision, sugarcane, herbicide

Introduction

Agricultural production depends on effective and economical control of pests. Efforts to develop non-chemical control measures (Lumsden and Vaughn, 1993) and successful biological controls are well documented (U.S. Congress, 1995).

Sugarcane is one of the major cash crops in Thailand. Thai sugarcane growers are facing problems of high production costs and low yields—one of the principal causes for it is inefficient weed control. Good weed management should be practiced when weeds are young and their density is low. If weed management is implemented too late, not only sugarcane yield decreases but also the cost of weed management increases (Tingnangwattana, 2003). The most common method of weed control, as revealed during a survey of 374 sugarcane producers in the northeastern province of Buri Ram in Thailand, is manual chemical spraying by knapsack sprayer (used by 79%). It costs about US$ 52 per ha. Survey also revealed 50% excess use of herbicide quantity or spraying on the bare ground, which eventually causes high production costs and detrimental effects on the environment (Tangwongkit et al., 2004). By using the traditional application technology, the spraying is done uniformly over the entire field without considering weed density. This could lead mostly to over or under applications of herbicides (Schmoldt, 2001).

Precision agriculture relates to the production of food, feed and fiber, and offers the commitment of enhancing productivity, while decreasing production cost with optimal use of resources. It aims at minimizing the environmental impact by over-application of chemicals (National Research Council, 1997). Precision agri-
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culture technology helps sensing micro-site specific conditions, on-the-go basis, and can automatically adjust the treatment to meet the specific needs. Different stages of variability can be achieved by two approaches, viz. the map-based approach and the sensor-based approach. Sensor-based approach, which is employed in this research (Tangwongkit et al., 2006), allows less dependency on positioning devices, an additional advantage over map-based approach with higher position accuracy and real-time application (Zhang et al., 2002).

This paper presents performance evaluation of a low cost variable rate herbicide applicator (Tangwongkit et al., 2006) in a sugarcane field. The applicator was developed considering the need and economic conditions of Thai farmers.

Material and Methodology

In Thailand, sugarcane is grown in rows with a commonly used spacing of 1,500 mm. Traditional herbicide application in sugarcane field is constant application over the entire field between sugarcane rows by using knapsack sprayer or wide boom sprayers mounted on a large or small 4-wheel tractor. A variable rate herbicide applicator was developed and fixed on this applicator. Field tests of herbicide applicator in both—constant application mode (the same application rate) and as a variable rate application system were conducted. Field capacity, field efficiency, fuel consumption and herbicide saving were calculated.

Variable rate herbicide applicator system

Tangwongkit et al. (2006) developed a variable rate herbicide applicator for sugarcane field—using the software based machine vision system, the pictures captured were processed and the quantified greenness level due to weeds was used to actuate the controllers of a sprayer pump system. The pulse width modulation (PWM) drive motor speed control was correlated with the proportion of greenness to vary the application rate by adjusting the duty level of PWM motor. The software developed could be reprogrammed and the threshold levels can be adjusted according to the user preference. In laboratory studies, at five operation-speeds tested, the prototype could spray on green targets satisfactorily. The inaccuracy of green color output from image processing was about 0.31% at SD±0.25; the application rate accuracy was about 91.7%.

Major components of the application system

The major components of the system were image acquisition and processing system. Picture frames captured by the web camera and images were sent to the image acquisition system through USB port and then processed by Borland C++ builder program. After diagnosis of all pixels, the overall Green Pixel threshold level was assessed based on the calibration. This processed information then activated the mechatronic system. The output signal (an 8-bit signal) passed through parallel port was acquired and processed for the percentage of greenness. These signals were used to control the speed of the 12 V DC electric motor of the pump to apply desired level of application rate. A proximity sensor was used to measure the ground speed. The application software combined the speed changes and compensated the position and rate inaccuracies in the system. Changing percentage level of green color and PWM duty cycle (%) can maneuver the threshold e.g.

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5%</td>
<td>no weed no spray</td>
</tr>
<tr>
<td>5.1–20%</td>
<td>minimum amount of weed low application rate</td>
</tr>
<tr>
<td>20.1–40%</td>
<td>medium amount of weed medium application rate</td>
</tr>
<tr>
<td>40.1–100%</td>
<td>high amount of weed high application rate</td>
</tr>
</tbody>
</table>

More details of the developed system are given in Tangwongkit et al. (2006).

Specification of the herbicide applicator prototype mounted on a small tractor

The developed applicator, having two small support wheels, was designed to mount with a 3-point hitch of a small 4-wheel tractor (21 kW; John Deere series 1000). This applicator attached with a plastic tank of 100 liters herbicide storage capacity. A 12-V DC electrical pump was used with a frame for spray nozzle to adjust nozzle height and nozzle spacing. Table 1 gives the details of the applicator and some system components. The picture of the applicator and its mounting on the tractor are shown in Figs. 1 and 2. A schematic of the variable rate applicator is shown in Fig. 3.

Field test

For sake of comparison, the same applicator was tested in a field, in both constant application mode and as a variable applicator (Fig. 4). In both tests, the same field was used. This assured having almost similar weed conditions during the testing. The sugarcane crop was four months old.

Each test was replicated five times. The sugarcane row spacing
was 1,500 mm. In each test, the distance traveled was 20 m. Overall area covered under each test was 150 m$^2$. The total time of operation including turning time was measured.

The quantity of weed distribution calculated by the system was about 70%. There was bright sunshine and no wind was blowing during the testing. The average temperature was 29°C and the RH was about 80%. Field performance and application rate were calculated as below.

The field capacity was calculated by using the formula below:

$$F_c = \frac{A}{(T_p + T_l)}$$

$F_c$: Field Capacity, ha/h

The field efficiency was estimated as:

$$E_f = \frac{W_e \times V_e \times T_p}{W_t \times V_t \times (T_p + T_l)} \times 100$$

$E_f$: Field Efficiency, %
$W_e$: Effective working width, m
$W_t$: Theoretical working width, m
$V_e$: Effective working speed, km/h
$V_t$: Theoretical working speed, km/h
$T_p$: Productive time, h
$T_l$: Non-productive time, h

Fig. 1 Location of an electric pump and nozzles on the applicator for site-specific herbicide application

Fig. 2 The variable rate system mounted on a small 4-wheel tractor

Fig. 3 Schematic of the variable rate applicator (all dimensions in mm)
The application rate was calculated from volume of herbicide discharged through nozzles and collected into a container along 20 m travel of the applicator per unit time.

Assuming seven years of average life, an economic analysis was conducted for annual break-even use of the applicator.

Results and Discussion

The traditional application pattern was straight alteration pattern. Whilst the variable rate application pattern was overlapping alteration pattern (Fig. 5).

The application rate in constant application was 2.78 L/min of uniform pattern but in variable rate application it was varied by percentage of green color of weed in the field which was registered and averaged in the same condition as 2.00 L/min. The results of both constant rate application system and variable rate application system are presented in Table 2.

With camera assembly at the front of the tractor and applicator at the back the working length of the applicator was much longer. Higher speeds caused up and down movement of the front part of the setup. To avoid this, the working speed in variable application system was slower than constant rate application mode which affected the field capacity and field efficiency. However, the variable rate application required less herbicide for the same size of field spraying. Thus it could reduce the adverse effects on the environment.

During field testing, for the variable rate applicator, the camera setup and its shed extended to about 200 mm ahead of the tractor front. The field was undulated which also caused this setup swing up and down and thus this was limiting factor for the tractor travel speed. In addition at the curves the tractor has to be maneuvered carefully as there was no way the front portion of the setup can be lifted. However, the tank fitted on 3-point linkage can be lifted up at the turning.

During testing, it was found that for higher weed density cover of as much as 70%, for the variable application rate system the application rate was 2.00 L/min while for the same weed cover, in constant application mode the application rate was 2.78 L/min. Thus there was a saving of 10.67% of herbicide by using the developed site specific applicator. At 2.78 L/min the amount of herbicide use will be 407 L/ha. In good weed management, cane growers usually control weeds, and the overall cover will not be more than 50%. Under these situations the variable rate application system will need lesser amount of herbicides. There was not much difference between the field efficiency of both systems.

When the application rate of the variable rate system was reduced from 2.00 L/min to 1.9, 1.8, 1.7 and 1.6 L/min, the herbicide use was decreased to 345.45, 327.27, 309.09 and 290.91 L/
Eventually at these application rates, herbicide savings were by 10.67, 15.14, 19.6, 24.07 and 28.54% respectively.

In order to estimate the minimum area to be sprayed per year by the newly developed applicator, a break-even analysis was carried out. It was assumed that working life of the applicator will be seven years and the annual use will be 384 h. The cost of applicator was estimated to be US$ 950. Its use per ha will cost $ 4.58 while traditional spraying method will cost US$ 7.25/ha. The cost of herbicide used is not considered. Thus use of lesser herbicide than conventional method will result added economic benefits to farmers. The break-even area estimated to be 81.86 ha per year (Fig. 6).

Conclusions

By using the basic mechatronic and machine vision principles a variable rate herbicide applicator was developed to optimize the herbicide application rate corresponding to the amount of weeds. The applicator was tested in actual field under two operating conditions—constant application and variable rate system application. In the field working speed of variable rate system was lower than during constant application. The working pattern was different due to the difference in length of the system units. The field capacity of the applicator in constant mode was better than its use in variable application mode. But later mode could save the amount of herbicides sprayed. However, there was not much difference between the field efficiency in both modes. The saving in herbicide use can be of the order of 10 to 29% depending on application rate. This technology being simple and less expensive is expected to be acceptable by Thai sugarcane growers. To cover the break-even area farmers can rent the unit to other farmers. The cost of the developed system is affordable for Thai farmers.

References


