

A new concept of Variable Rate Technology fertilizer applicator for oil palm

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Abstract

A new concept of Variable Rate Technology (VRT) fertilizer applicator for the oil palm was developed. Design calculations of the VRT fertilizer applicator components which include rotary valve, turbo blower, screw conveyor and fertilizer bin was carried out. A 3D model of the VRT fertilizer applicator was developed with Solid Works software. The VRT fertilizer applicator will be mounted on a 43.9 kW 4WD tractor specially designed for oil palm plantation terrain. The machine has a bin capacity of 1.20 tons, two 2.13 kg/s rotary valves, two 3.27 kW turbo blowers and an 11.70 kg/s screw conveyor. Each of these components will run on hydraulic motors that are powered by the auxiliary hydraulic power outlet on the 4WD tractor. It has the capability to increase yield and profit in the oil palm plantation. It is also anticipated to go a long way in ameliorating the environmental hazards associated with excessive fertilizer application on the oil palm plantation.

Keywords: Precision Farming, Variable Rate Technology, Fertilizer, Oil Palm, Applicator

Introduction

Oil palm produces the highest amount of oil among the perennial oil yielding crops. It is the most profitable vegetable oil business in Malaysia with RM 65.2 billion export earning in 2008 (Cugati et al., 2006). Its high productivity has resulted in expansion to diverse soil and terrain. In order to sustain the high productivity of the oil palm, the nutrient shortfall of the soil has to be augmented with addition of fertilizer. Fertilizer application is one of the most important operations in oil palm production. It constitutes a major factor for productivity and the highest operational cost in well managed plantations. However, in Malaysia, price of fertilizer has been described to be unpredictable in nature. It was asserted that some farmers were reluctant or unable to pay twice or thrice the amount that fertilizer was bought in early 2007 (Cugati et al., 2006). The soaring price of fertilizer has tempted some of the oil palm planters to withdraw fertilizer usage as a measure for breaking even. Likewise, potential wastage and haphazard timing of fertilizer application are now given due attention and redress.

Mature oil palm trees are known to have feeding roots. These roots spread around the oil palm in the soil to cover about the same area as the tree canopy. Pruned fronds from the oil palm are left in alternate rows in between the oil palm trees so as to promote microbial activity, soil moisture conservation and fertilizer efficiency. Therefore, broadcasting of fertilizer on the piles of fronds along the alternate rows ensures increase in fertilizer absorption since more roots are able to absorb it (Goh et al., 2009). Unfortunately, most of the oil palm plantations in Malaysia still prefer to use manual method of fertilizer application or seldom use the constant rate mechanical fertilizer broadcaster. Probably due to the fact that the commercially available constant rate mechanical fertilizer broadcaster is not appropriate for spot placement fertilizer application that is used in oil palm plantation. Also, it tends to consume more or waste fertilizer during operation. Both the constant rate mechanical fertilizer broadcasters and the manual method of fertilizer application are inefficient and at uniform rate which may not match with the actual nutrient variability and the needs of individual oil palm across the oil palm plantation. This method of fertilizing the whole plantation with a single fertilizer rate obviously leads to over fertilize certain regions and under fertilizing others. Apart from the waste in resources of over fertilizing, the excess fertilizer that gets leached

into nearby water bodies constitute environmental hazard. Furthermore, excessive fertilizer application causes Land Degradation and Pollution through leaching and Volatilisation (Jahiset al., 2002; Kim et al., 2006; Miller et al., 2003; Norton et al., 2005). Recently, a new technology known as Variable Rate Technology (VRT) emerged. The VRT concept offers solution to this problem by treating with actual fertilizer rates for site-specific oil palm needs. It is economical because it has the potential to reduce cost of production while increasing yields. It is environmental-friendly and sustainable due to the fact that the hazards of soil degradation as a result of excessive fertilizer application is eliminated (Reza et al., 2009; Tarmizi, 2001).

A mechanical fertilizer spreader was developed for young oil palm (Wahid et al., 2005). It was suitable for circle application of fertilizer for the oil palm and operated at a field capacity of 6 ha/day. However, it did not have VRT capability. Also, the hopper capacity was just 200 kg which could lower its field efficiency due to time taken for refilling.

It was pointed out that the commercially available variable rate fertilizer spreaders are for field crops and vegetable production. In order to use them for tree crops like citrus, these variable rate fertilizer spreaders were modified by placing baffle plates in front of the spinner disc so as to deflect the fertilizer particles under the tree in a banded pattern (Norton et al., 2005). From the foregoing, it is obvious that there is no appropriate VRT fertilizer applicator for the oil palm yet. Especially, for the spot placement fertilizer application used in the oil palm plantation. Therefore, the objective of this research is to design a Variable Rate Technology (VRT) fertilizer applicator for the oil palm plantation.

Materials and Methods

Design Considerations

Some Preliminary Investigation about fertilizer application on the Oil palm plantation in Malaysia was made before commencing the design of the VRT fertilizer applicator. Types of fertilizer used are: Ammonium Sulphate, Christmas Island Rock Phosphate, N P K (Nitrogen-Phosphorus-Pottasium) and Pottasium Chloride. The amount applied range between 0.5 kg to 2 kg per oil palm tree. There could be 110 – 160 palm trees in one hectare. The triangular spacing of oil palm trees could be between 8 m to 10 m. The inter row spacing of oil palm is in the range of 7.5 m to 8.7 m. Table 1 shows the specifications of current fertilizer spreaders used in the oil palm plantation and the specifications of the proposed VRT fertilizer applicator.

Table 1. Specifications of the current spreader and proposed VRT fertilizer applicator

	Current fertilizer Spreader	Proposed VRT fertilizer Applicator
Fertilizer applied per hectare (kg/ha)	70 - 280	70 - 280
Capacity of fertilizer bin (kg)	500 - 800	1200
Hectares covered per day (Coastal area) (ha/day)	30 - 50	40 - 60
Hectares covered per day (Inland area) (ha/day)	70 - 100	96 - 120
Working hours per day (hr)	8 - 10	8 - 10
Height of chute of fertilizer filling silo	1.93	1.93
Number of times of refilling the fertilizer spreader per day	10 - 35	6 - 28
Speed of operation of fertilizer spreader (km/hr)	5	5

Essentially, a VRT fertilizer applicator consist of a Geographic Information System (GIS) fertilizer prescription map, Global Positioning System (GPS) device, a volume or mass flow sensor for the fertilizer rate controller, an actuator valves and a microcontrollers or embedded computer program. Fertilizers Prescription maps which indicates fertilizer requirement are generated from yield maps, soil maps, crop nutrient levels, aerial images or maps of soil electrical conductivity. The GPS position coordinates is indicated by the GPS device. Upon a user command, the microcontrollers or embedded computer program reads the GPS coordinates, calculates the correct application rate through a formula or algorithm with reference to the prescription map, translates the correct rate into actual fertilizer output through the actuators or valves (Wittry and Mallarino, 2004). A schematic of the VRT fertilizer applicator system is shown in figure 1.

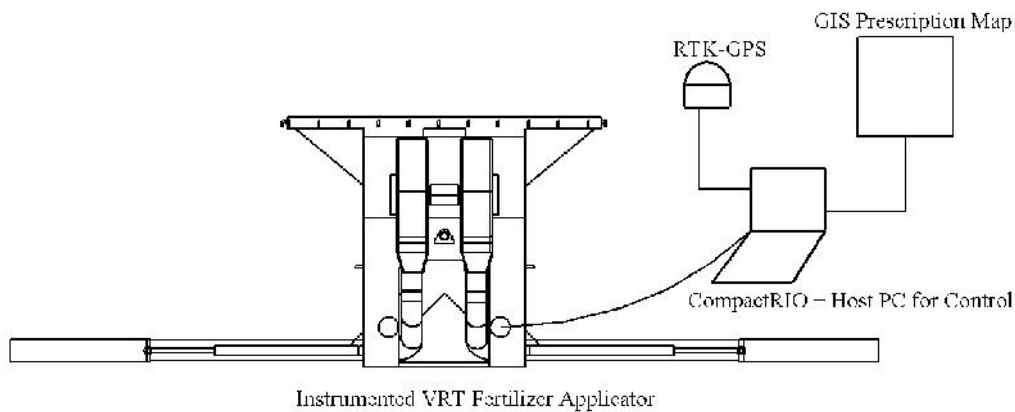


Figure 1. Schematic of the VRT fertilizer applicator system

Conceptual Engineering drawing of the VRT fertilizer Applicator

Using all the values obtained in the design calculations of the various components of the VRT fertilizer applicator, an engineering drawing has been drawn. A 3D model of the VRT fertilizer applicator was also developed in Solid Works software. The conceptual design drawing of the VRT fertilizer applicator is shown in figure 2.

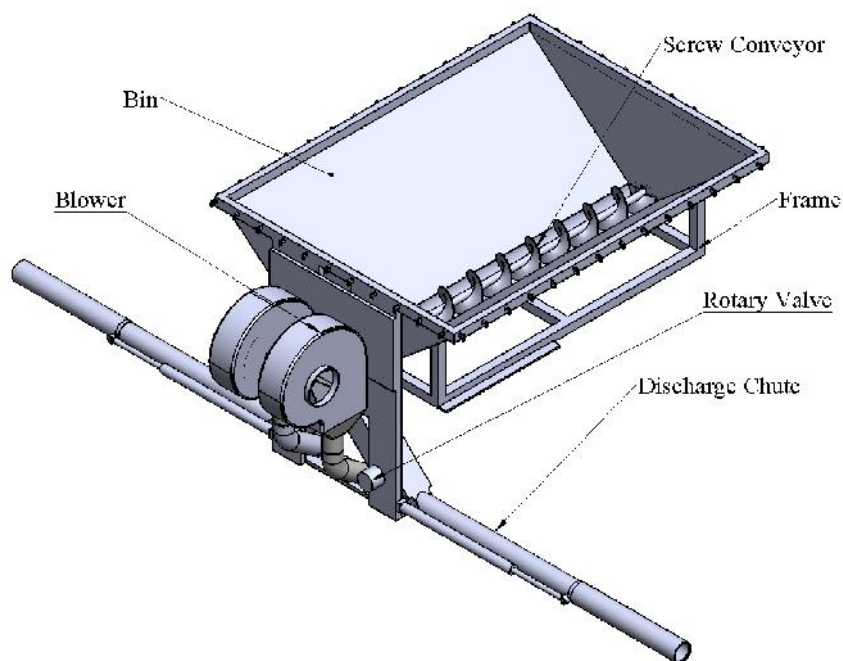


Figure 2. Conceptual design drawing of the VRT fertilizer Applicator

Description of the components of the VRT fertilizer applicator

RTK-GPS receiver

The VRT fertilizer applicator will be equipped with an RTK-GPS receiver (Trimble 5800 GPS receiver with Real Time Kinematics corrections). The RTK-GPS receiver will provide plane coordinates of the location of the VRT fertilizer applicator.

Variable Rate Controller

Variable rate controller is a host PC (Panasonic toughbook CF-19) and compactRIO(NI cRIO 9004). The compactRIO is a low cost, high performance system that functions as a rugged industrial signal conditioner as well as data acquisition and control hardware system, thereby saving time and money. It is powered by reconfigurable Field Programmable Gate Array (FPGA) technology for ultra high performance. It runs on

National Instruments LabVIEW graphical programming software. It incorporates a real time processor, reconfigurable FPGA and hot-swappable industrial input/output module with built-in signal conditioning for direct connection to sensors and actuators. The LabVIEW graphical programming language running on the host PC and compactRIO real-time embedded controller will be used to control and synchronize the actions of the variable rate fertilizer applicator.

Fertilizer bin

The VRT fertilizer applicator will have a fertilizer bin that will be made of stainless steel because of its strength and resistance to corrosion. It has a trapezoidal cross section. In order to achieve easy flow of fertilizer, the sides of the bin are inclined at 40° which is greater than the angle of repose of fertilizer granules. In addition, a stainless steel rotating screw conveyor will be included to ensure that the fertilizer is flowing freely from the hopper especially from the end that is away from discharge opening.

Rotary valve

A stainless steel rotary valve which rotates according to the required application rate of the fertilizer will be used as a metering device. It is powered by a hydraulic motor (Samhydraulik BGM 13 SP1) with an electro hydraulic valve. The blades of the valve are made of plastic and are spring loaded so as to provide airlock in the rotary valve. The rotational speed of the rotary valve is controlled by the compactRIO real-time embedded controller. The rotational speed is directly proportional to the quantity of fertilizer that will be metered through the rotary valve.

Centrifugal turbo blower

The chambers into which the fertilizer drops will be equipped with two air tubes. Two centrifugal turbo blowers (Model ATT – 038 -015) that are powered by a hydraulic motor (Samhydraulik H1C 12M) via a right angle gear box (SITI bevel Gear unit R19F 3C) will supply air to these two air tubes simultaneously. The jet of air coming from the air tubes will help to throw the fertilizer granules through their individual discharge chute to the point of application.

Discharge chute

This is an extensible stainless steel tube through which the fertilizer granules are blown to the point of application. It is equipped with a linear actuator (hydraulic cylinder) for adjusting its length. This flexibility in length will allow the VRT fertilizer applicator to accommodate varying distance of throw required in the oil palm plantation.

The whole unit of the VRT fertilizer applicator will be mounted on a prime mover specially designed for oil palm plantation terrain. Figure 3 depicts the drawing of the VRT fertilizer Applicator when it mounted on the 4WD prime mover.

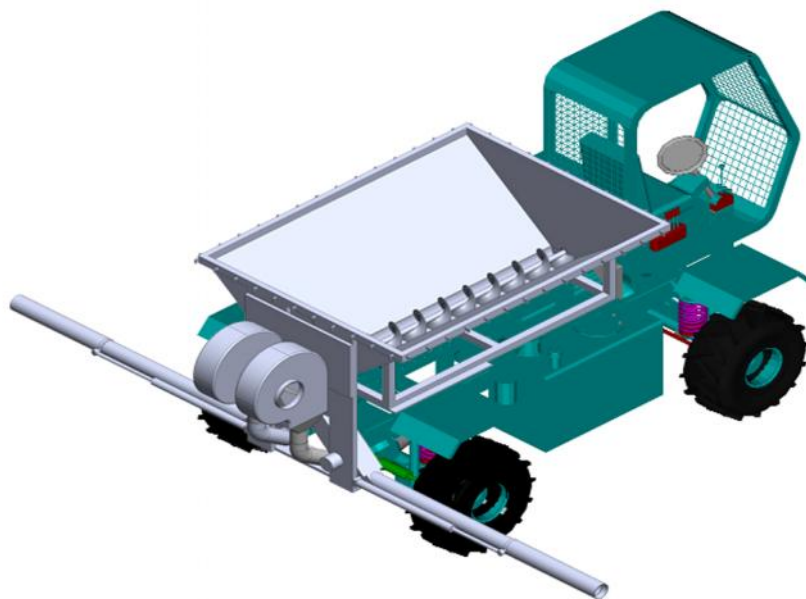


Figure 3. Drawing of the VRT fertilizer Applicator mounted on the 4WD prime mover

Operation of the Variable Rate Technology fertilizer applicator

The VRT fertilizer applicator is operated by one operator. On board the VRT fertilizer applicator is a host PC and a dedicated 2 KVA generating set (Honda EU 20i). Prior to the fertilizer application, a prescription map should have been prepared. This map contains the plane coordinates and the respective fertilizer dosage required for each point on the oil palm plantation. The prescription map data is stored in the hard disc memory of the host PC.

At the start of the operation on each block, the fertilizer discharge chutes are set to the right length according to the distance of throw required for the each block. The bin is filled with the type of fertilizer to be applied. The generating set is switched on. Then, the valves of the hydraulic motors of the centrifugal blowers are actuated to put them on. There is a toggle switch placed inside the discharge duct of the fertilizer bin. The toggle switch only switches on the valve of the hydraulic motor of the screw conveyor when the discharge duct is not filled up to a preset level. The fertilizer bin is also equipped with a web cam that displays the condition inside the bin on the host PC at the operator's cabin.

The control of each of the rotary valve comes from the host PC at the operator's cabin. This control is done in LabVIEW program running on the host PC and compactRIO. The LabVIEW program reads the GPS reading from the RTK-GPS compares it with the prescription map coordinates. When there is a match, it sends control to the rotary valve via the compactRIO. The speed of the rotary valve is set according to the required discharge rate and dosage for each point on the oil palm plantation. Once the operator clicks the run command on the LabVIEW program, the program take over the control of the VRT fertilizer application. The operator only needs to concentrate on driving the 4WD prime mover and once in a while observe the display of the fertilizer bin condition.

As the fertilizer exits the rotary valve and enters the air duct of the centrifugal blower, it is thrown by the blast of air from the blower to the top of the pile of cut oil palm fronds on either side of the machine path in the plantation.

This operation continues until the fertilizer bin is almost empty and the operator pauses the LabVIEW program to go and refill the fertilizer bin at the nearby fertilizer silo on the oil palm plantation. When he is ready to continue again, he clicks the run command on the LabVIEW program again and the operation goes on. The flow chart of operation of the VRT fertilizer applicator is shown in Figure 4.

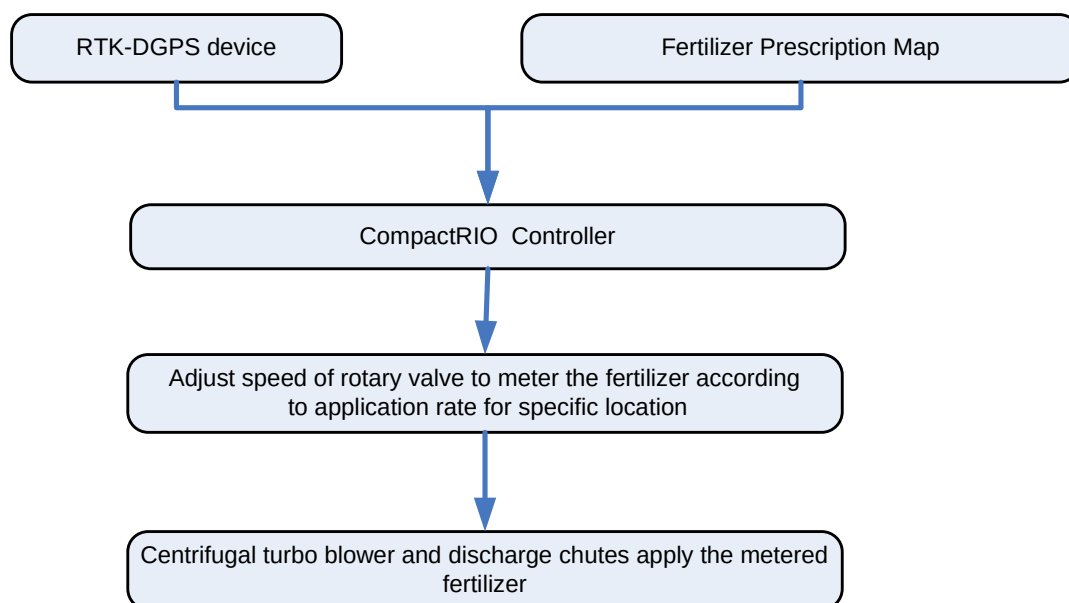


Figure 4. Flow Chart of the operation of the VRT fertilizer applicator

Design Calculations for the Components of the VRT Fertilizer Applicator System

All the components of the VRT fertilizer applicator were properly designed. Due considerations were paid to the type, characteristics and method of fertilizer application in the oil palm plantation. Table 2 shows the summary of values obtained from the design calculations.

Table 2. Summary of calculated specifications of the VRT fertilizer applicator components

Components	Parameters	Specifications
Rotary Valve	Discharge rate	2.13 kg/s
	Speed	100 rpm
Centrifugal turbo blower	Total pressure capacity	2.70 kPa
	Volumetric air flow rate	0.36 m ³ /s
	Speed	2466 rpm
	Power required	3.27 kW
Screw conveyor	Mass discharge rate	11.70 kg/s
	Power required	0.68 kW
Discharge chute actuator	Hydraulic power	0.57 kW
	Pressure	4.5 bar
Fertilizer bin	Angle of repose	40°
	Capacity	1.20 tons

Conclusions

A conceptual design of a VRT fertilizer applicator for oil palm was carried out. It comprises of two rotary valves, two turbo blowers, a screw conveyor and a fertilizer bin. It could be used for spot application of granular fertilizer for mature oil palm. The machine has a bin capacity of 1.20 tons, two 2.13 kg/s rotary valves, two 3.27 kW turbo blowers and an 11.70 kg/s screw conveyor. It has the potential of reducing excessive fertilizer application which leads to land degradation and pollution.

References

- Cugati, S. A., Miller, W. M., Schueller, J. K., and Schumann, A. W. 2006. Dynamic characteristics of two commercial hydraulic flow-control valves for a variable-rate granular fertilizer spreader. ASABE Paper No. 061071. St. Joseph, Mich.: ASABE.: 1 - 10.
- Goh, K.J, Ng, P. H. C. and Lee, C. T 2009. Fertilizer management and productivity of oil palm in Malaysia. Advanced Agroecological Research (AAR) Newsletter(October, 2009.): 1 - 24.
- Jahis, S., Hitam, A., Ali, Z. M. and Nor, M. M. 2002. Mechanical fertilizer spreader for young palm. Malaysian Palm Oil Board (MPOB). Information Series(MPOB TT No. 135): 1 - 4.
- Kim, Y. J., Yang, S.H and Rhee, J. Y. 2006. Development of a variable rate granule applicator and analysis of uniformity. ASABE Paper No. 061070. St. Joseph, Mich. ASABE.: 1 - 10.
- Miller, W. M., Schumann, A. and Buchanon, S. 2003. VRT citrus test plots applications of granular fertilizer. ASAE Paper No: 031127. St Joseph, Mich: ASAE: 1 - 15.
- Norton, E. R., Clark, L.J, and Borrego, 2005. Evaluation of variable rate fertilizer application in an Arizona cotton production system. Arizona Cotton Report.: 145 - 151.
- Reza, E., Arnold, S., and Masoud, S. 2009. Variable rate Technology for Florida Citrus. AE 444, Agricultural and Biological Engineering Department, University of Florida. : 1 - 5.
- Tarmizi, A. M. 2001. Nutritional requirements and efficiency of fertilizer use in Malaysian oil palm cultivation. Advances in Oil palm Research, Malaysian Palm Oil Board. 1: 411 - 440.
- Wahid M. B, Abdullahi, S. N. A, and Henson, I. E. 2005. Oil palm - Achievements and potential. Plant Production Science. 8(3): 288 -297.
- Wittry D. J. and Mallarino, A. P. 2004. Comparison of uniform and variable rate phosphorus fertilizer for corn-soybean rotation. Agronomy Journal 96: 26 - 33.