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A Review on The Selection Of Granular Fertilizer Distribution Methods For Malaysia's Paddy Field In Large Scale

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Abstract

High efficiency distribution applicators such as boom sprayer (air blower concept), Kuhn Axis fertilizer spreaders (rotating disc concept) and pendulum spreader (magnetic concept) responded to the call to distribute the granular fertilizer to Malaysia's paddy field in large scale. Each of these distribution applicators and their distribution concepts had their own characteristic which is optimize for difference purposes. Most of the journal papers only provide analysis of individual distribution applicator. Therefore in this paper, shows the review results after studying the journal papers, to select the most suitable granular fertilizer distribution methods for Malaysia's paddy field in large scale. The analyse including the compliment of these applicators toward the type of granular fertilizer used in Malaysia's paddy field, the maintenance cost of the applicators, the suitability of machine to be use in the landscape of Malaysia's paddy, the distribution's areas cover by the applicators and the accuracy of the distribution. The conclusion of this review is Kuhn Axis fertilizer spreader had found to be more suitable applicator compare to other applicator in this paper. The results of comparison can further be used to improve the design of the distribution of applicators.

Keywords: Granular fertilizer, distribution applicators, paddy field, large scale, spreaders

1. INTRODUCTION

Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) reports, state that the world demand for food over the next 50 years will be greater than over the last 500 years, placing huge pressure on global food systems. According to World Bank, Malaysia population itself had grown from 25.37 million in the year of 2004 to 29.72 million in the year of 2013. Due to the high demand of food both local and international, increasing crop yield is the main agenda of most crop growers.

Rice is the staple food both local and Asia. Based on the statistic of Food and Agriculture Organization of the United Nations 2004, in Malaysia there are 6700 km^2 of paddy rice sown area. Paddy field is typically found on Peninsular Malaysia. The most scenic paddy fields are located in northern Malaysia, in Kedah, Perlis and Penang; almost covering these states. Paddy fields also can be found on Malaysia's eastern coast region, mainly in Kelantan and Terengganu, and also in Selangor, especially in the districts of Kuala Selangor and Sabak Bernam. These places had difference composition of soil that requires difference nutrition to grow paddy plant.

One of the measures to grow the paddy plant is through reviewing existing planting practices such as fertilizing, type and amount of fertilizer. Due to the advance of technology, fertilizer distribution applicators had been developing to increase the efficiency of distributing the fertilizers into the field. Which mean the distribution applicators will directly effects the yielding rate of the paddy, because it control the amount of the fertilizer that the paddy field will received to give nutrition to the crops. There are the many research institute in Malaysia that carrying the research to increase the grow of paddy such as Ministry of Agriculture, National Padi and Rice Authority, Malaysian Agricultural Research and Development Institute (MARDI), Research Station, Agriculture

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Institute, Department of Agriculture, Agricultural Development and Universiti Pertanian Malaysia. MARDI is one the main agriculture institute that has being carrying out a research to improve the distribution of applicator.

Currently, available fertilizer boom spreaders have found to have certain limitation to be used with domestically-produced granular fertilizers because of the different environment user. Therefore, it is open for more possibility such as design a new type of distribution applicators by studying the available concept in the market. So this paper contributes the review on the selection of granular distribution methods for Malaysia's paddy field in the large scales. There are basically three types of commonly used granular applicators with three types of concept of distribution such as boom sprayer (air blower concept), Kuhn Axis fertilizer spreaders (rotating disc concept), and pendulum spreader (magnetically concept). The distribution concepts often started with small model and are not effective for large paddy field. Due to the continues study and development of research, the same concept used but is modified into a bigger scale with the addition of tractor, that can carry the fertilizers around the paddy field within a short period of time and also by enlarging the sizes of equipment to enable to contain more fertilizer.

1.1 Granular fertilizer distribution applicator

According to table 1, Malaysia Agribusiness directory 2013-2014 stated that the imports fertilizer distribution applicator is lowest compare to the other machinery. Which mean, the popularity of using granular fertilizer distribution applicator in Malaysia's paddy field is low which is not proportional to the developing of agriculture in Malaysia. Many farmers still using traditional way to distribute the fertilizer into the fields. Table 1, also show that the imports of fertilizer distributor had been decreasing from 439 units in the year of 2011 until 378 units in the year of 2012 compare to 1045 units in the year of 2009. Therefore, the need of studying the popularity of fertilizer distributor in large scales in other nation, and the need to gain understanding of the structure and the application of the fertilizer distributor is needed in order to find up the reason that causes the low ranking users in Malaysia.

Table 1: Status of Agricultural Machinery Imports (Malaysia Agribusiness directory, 2013-2014)

Machinery	**Year (units)**			
	2009	2010	2011	2012
Pedestrian Tractors	5093	4075	3929	2368
Tractors	5085	6121	4199	6216
Seeder and Planter	242	315	108	2826
Harrow (disc and non-disc)	1849	1270	2587	2577
Fertilizer Distributors	1045	181	439	378
Plow, soil preparation/cultivators	1289	1463	1970	1612
Mowers	3691	5874	14922	10299
Threshing machines (not combines	126	220	30	1402

1.2 Boom sprayer

The boom sprayer was developed in the 1880s in France and the United States of America and was first used in Australia in the early 1900s (Combellack, 1981). Later developments saw the pump motorised, the units drawn by tractors, larger hopper, larger booms and, in the l940s, the introduction of the fan nozzle. Based on Tucheng Hengshing Machinery Co., Ltd, there are 90.3% of buyers who contacted them received a response within 72 hours which includes responses sent in Alibaba Trade Center and Trade Manager.

Boom sprayer which commonly used with liquid fertilizer is now developing to meet the need in distributing the granular fertilizer. Boom sprayers are used for broadcast applications of pesticides and fertilizers to large areas. Boom sprayers can be precisely calibrated to apply products uniformly at a recommended rate. It come with difference model but the main structure of the applicator consisted of hoppers, metering, air blower and boom pipe with blow heads in each side. The hopper do not have compartment but the number of hopper can be manipulate. The metering control the amount of fertilizer from the hopper to the boom pipes. The model IHB-181LA and IHB-181SA consisted of only one centrifugal air blower which have two functions. One is to blow the fertilizer out of the hopper and another function is to distribute the fertilizer into the boom sprayer. The length of the boom pipes is 5 m in each side and the spreading width of 10m. Table 2, show the specification of the boom sprayer that currently use by one of the paddy field in Malaysia. It is a product from Japan with one larger than the other. Researcher is trying to improve the current design by adding another extra blower because the current design is only design for singular density of fertilizers. Whereby, fertilizers used in Malaysia's paddy field is various in density. However, this will make the machine very bulky and still gave limited support to the distribution of various density of fertilizer.

Table 2: Technical specification of Boom sprayer (Operation manual, 2014)

Specification	**Model**	
	lHB-181LA	lHB-191SA
Spreading width (m)	15	10
Capacity (l)	180	180
Spreading (kg/min)	0,4-16	0,4-16
Spreading capacity (kg/10ares)	1-60	1-60

1.3 Kuhn Axis fertilizer spreaders

Rotating disc is a very common use of concept to distribution fertilizer and pesticide. There are applicator with single disc and dual-purpose disc. Single disc applicator is simplest tin design and only be used in small scales. Whereby, dual-purpose disc applicator concept can be use in large scales which used in Kuhn Axis fertilizer spreaders. It consists of a hopper, orifices, discs and variable speed electric motor. These applicators employ the use of two discs rotating in an opposite direction driven by electric motors. Fertilizers inside the hopper fall freely by gravity through the orifices and drop directly on the rotating discs (impeller) subsequently are applied to the field. It also consists of metering that control the amount and the speed of the fall of the fertilizer from the hopper to the rotating disc.

This concept of distribution assumed to be the mainstream trend, but Kuhn has introduced a new model it has dubbed a precision broadcast fertilizer spreader. The Kuhn AXIS 50.1 H-EMC is hydraulically driven, with enough force to sprinkle an accurate, uniform swath of granular fertilizer up to 50m. The electronic mass control takes a reading once every second, allowing the distribution disc on each side to adjust independently for fertilizer density, slope, prescription map instructions and GPS location signals.

The hydraulic drive technology lets you spread urea in a uniform pattern 37m wide at 24km/h. The machine can spread up to 500kg of granular per minute in 24km/h. Kuhn has conducted 40,000 calibration and uniformity tests on virtually every granular fertilizer on the market, so it knows how each distinct product will react in the disc and what adjustments are needed for the best performance. There is 80 percent of the product fall in the main target area while the other 20 percent falls out toward the far tips of the triangle. Then when we come back, that tip of the triangle gets filled in with the remaining 80 percent. The result is close to perfect uniformity in any situation because there's no sharp edge at the extremity of the spread. Other than that, Kuhn also develops many other model. It is smaller in scales compare to Kuhn Axis 50.1 H-EMC Table 3, show certain model that develop by Kuhn.

Table 3: Technical specification of Kuhn axis spreaders (Kuhn, 2014)

Specification	**Model**		
	UKS80	UKS100	UKS120
Working width (m)	0.8	1.0	1.2
Capacity (min).(l)	165	200	240
Weigh approx. (kg)	105	120	130
Drive	Hydraulic or PTO	Hydraulic	Hydraulic

1.4 The pendulum spreader

Pendulum spreader had a magnetically damped inclinometer. It has a shaft with attached pendulum that rotates. The rotation causes an index member to rotate past one or a set of magnets or electromagnets that are connected to the load. The magnet or electromagnet may be mounted directly the load or it may be in the form of an off center ring. Another embodiment uses a spring to bias two magnets apart. A cam is attached to the shaft such that, as the pendulum and shaft rotate, a roller connected with the load or spreader bar allows the spring to push the magnets farther apart. The damped inclinometers are used to determine and provide information to respond to the initials way of a load prior to bringing the load to a stop.

One of the model is Kubota pendulum spreader. The Kubota pendulum spreader is for maximum spreading quality and ease of operation. With hopper capacities of 600, 800 and 1000 with the 600 hopper as a basic hopper and 750, 950, 1150, 1350 and 1650 litres with the 750 as a basic hopper. The advantages is SuperFlow spreading system, easy setting of the application rate, a wide range of spreading spouts, Optional PS-ED II on-board computer available. Table 2 show the technical specification available model for Kubota.

Table 4: Technical specification available model for Kubota (Kubota, 2014)

Specification	**Model**		
	VS1150	VS1350	VS1650
Hopper capacity (l)	1150	1350	1650
Hopper width (cm)	175	175	175
Filling height (cm)	116	125	141
Weight 3-point types (kg)	171	178	184
PTO speed (rpm/min)	540	540	540
Three-point linkage category	2	2	2

2. METHODOLOGY

Most of the journal papers only analysed based on individual type of distribution applicators for example the spreading width, the structure of the distribution applicators and the accuracy. The selection of the suitability of the distribution applicator is going to be based on both qualitative with the support of qualitative methods. In order to make the best selection, qualitative provide what, where, when, why and how of decision making and must has a strong basis in the field of the need of agriculture, the types of fertilizer used and the characteristic of the granular distribution applicator. Figure 1, show the level of gather and eliminate the journal paper or articles or website or operation manual that related to paddy, paddy fertilizer and distribution applicator. Categorising the data will be helpful to link all the data with data and to the direction of achieving the objectives. It involves open coding, axial coding and selective coding which help to have deeper understanding in our data.

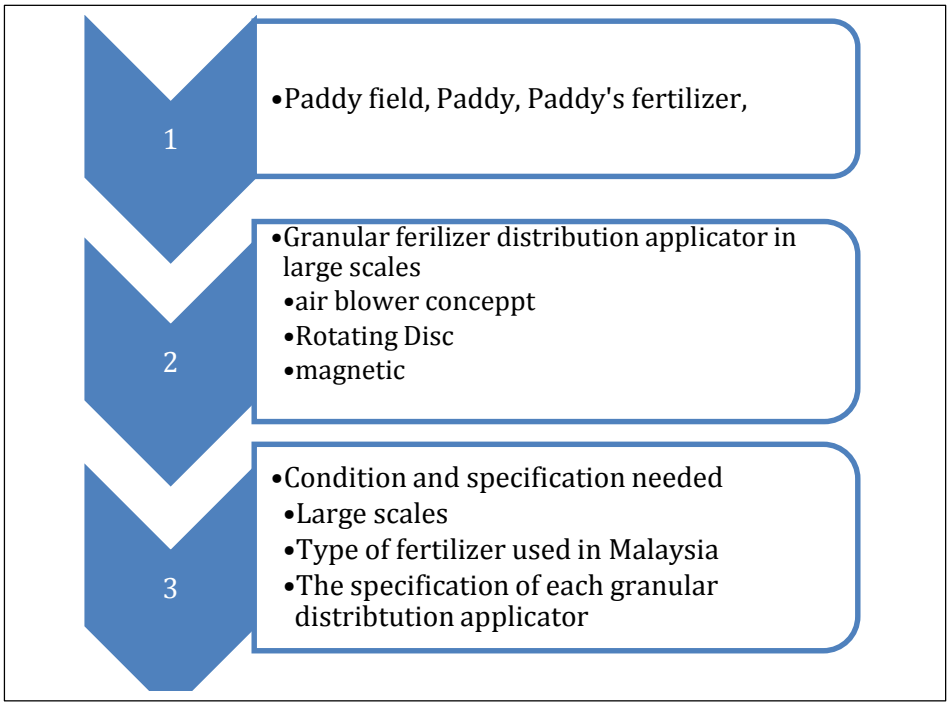


Figure 1: The process of gather and eliminate journal

The conclusion is make after comparing all the quantitative analytical of the specification the granular distribution applicators and analyse the external factors influence the suitability of the applicators. Quantitative analyzation cannot stand alone in this investigation to achieve the objectives. The reason is it had a lot of external factors that causes the suitability of the distribution applicators to decrease. The way of measuring the accuracy of distribution by each journal papers regarding the distribution applicators is very difference due to various concepts. Therefore, qualitative investigation is very important in this paper. The purposes of this study are to help to improve the design of distribution applicator or in developing the new design of distribution applicator. The introduction of this paper is open coding. 2.1 until 2.2 is the axial coding. Results and discussion base on selective coding. Only after that the data is process into conclusion.

2.1 The use of fertilizers

The fertilizer used is NPK fertilizer which is in granular form is a chemical component use in growing paddy by regular agronomic practice. It comes with separate forms, sizes and densities. However, due to the soil in Malaysia is very various. Therefore, difference formulae of ratio of each type of fertilizer vary according to places and its soil. N is more in promoting leaf grow, P contributes to root, flower and fruit development and K contributes to stem and root growth. However, the negative impact of this type of fertilizer is when excessive usage will causes residue toxicity and environment pollution because about 40–70% of nitrogen, 80–90% of phosphorus, and 50–70% of potassium of the applied normal fertilizers is lost to the environment and cannot be absorbed by plants (Corradini, E., de Moura, M. R., & Mattoso, L. H. C., 2010). The fertilizers will dilute into sticky liquid due to the chemical reaction of mixing them together. According to table 3, the fertilizer amount is recommended according to the area.

Table 5: Recommended fertilizer application rate per unit area according to area and soil (Kim, Y. J., Kim, H. J., Ryu, K. H., & Rhee, J. Y.,2008).

Location of paddy field	**Type of paddy field**	**Amount (ingredient, kg ha-1)**		
		N	P	K
Plain field below 250m above sea level	Normal	110	45	57
Plain field below 250m above sea level	Sandy	130	51	71
Field from 250 to 400m above sea level		110	64	78
Field over 400m above sea level		110	77	93
Reclaimed field from the sea	Salty	200	51	57

2.2 The structure of the distribution applicators

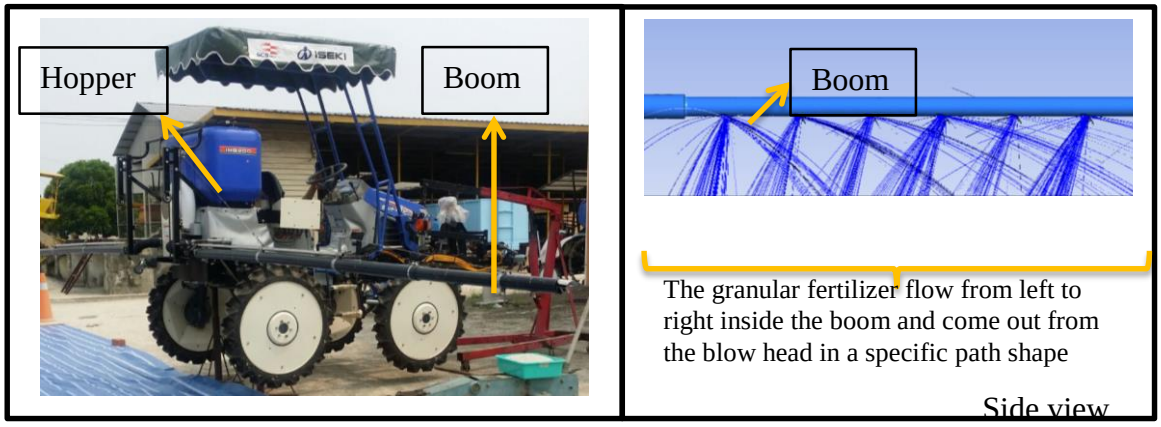
The table and the figures below show the structure of the 3-distribution applicator. By comparing the difference of the structures and function of the distribution applicator can help to understand the advantageous and the disadvantageous of the each applicator. Each applicator has 1 hopper and 1 metering. Every metering function to control the amount of fertilizer drop from hopper to the parts of distributing.

Figure 2(a), shows the design of the boom sprayer. The boom sprayer consists of left and right boom. The right side of the boom, the granular fertilizer will go through the boom from the left to the right and then flow from the blow heads. Every blow heads consist of a reflector that channels the granular fertilizer out of the boom. When the granular fertilizer come out from the blow head it will not drop vertically into the ground but it will reflected as show in the figure. It is using pneumatic because it uses blower to blow the fertilizer out of the boom. Fig. 2(b), shows the design of the pendulum spreader. The pendulum spreader only have one spreader bar that rotated left and right dropping the fertilizer out of the spreader bar. It is moving in a very fast motion. The motion is control by the magnetically damped inclinometer. Figure 2(c), shows the design of the Kuhn Axis fertilizer spreaders. It functions by rotating disc. The spreading is semi- circle path.

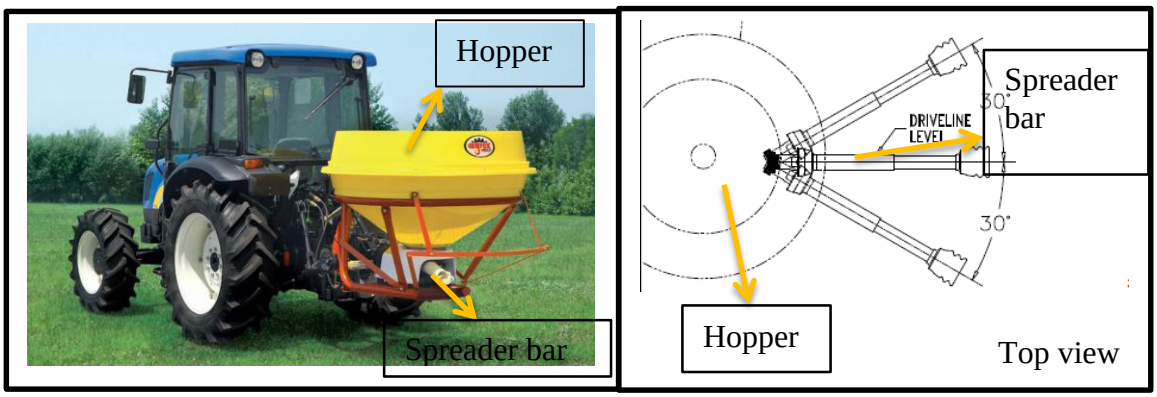
Table 6: The structure of the distribution applicators.

Parts	**Boom sprayer**	**Kuhn Axis fertilizer spreaders**	**Pendulum spreader**
Hopper	1	1	1
Concepts	Air blower	Rotary (disc)	magnetically damped inclinometer
Part of distribution	Boom	Disc	Spreader bar
Metering	1	1	1

a



b



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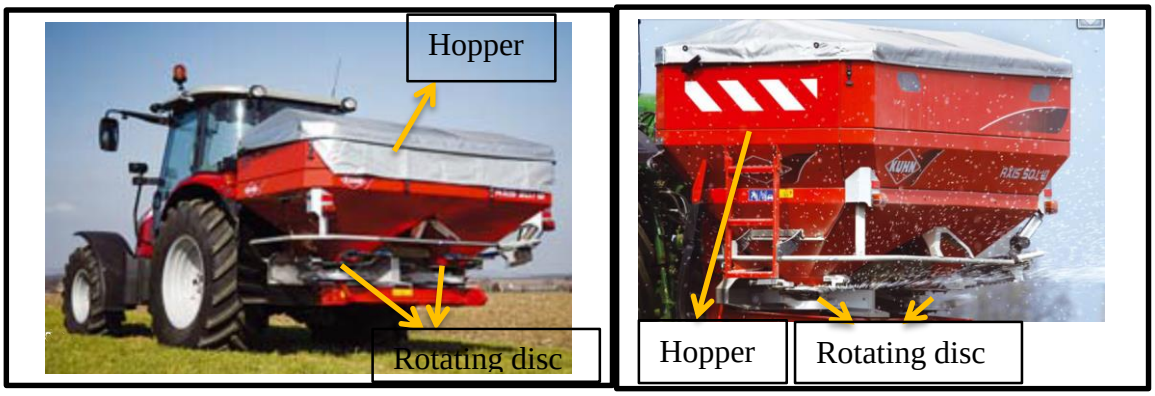


Figure 2: (a) Boom Sprayer; (b) pendulum spreader; (c) Kuhn Axis fertilizer spreaders.

3. RESULTS AND DISCUSSION

Base on Table 1, show the decreasing of import of the distribution applicator compare to the rest of the machines. Comparing local with international, other countries already widely improving and designing granular distribution applicator. The market is actually very wide according to the description of each type of granular applicator. These phenomena can be because the application is not widely promote to the local farmer.

According to table 2, table 3 and table 4, all the applicators had a large hopper to contain the fertilizer and a wide spreading width. It had tractors to move around the field in a short time based on figure 2. Even though the hopper of the pendulum seem to be much larger than the other two, but each concept of distribution had a lot of model, which come with difference sizes of hopper. In other word, the size of the hopper can be manipulated according to the needs.

Further selection, is the accuracy of distribution the applicator and it depends on both external factors and internal factors. For internal factors, the accuracy of the three applicators is high according to all the journals paper and operation manual description but it will varies according to the places and the effect by the external factors. However, external factor is hard to predict. For example all the three applicators will be affected by wind factor, the gravity force and the condition of landscape. So, when carrying out this review, all the three applicators are based on the condition Malaysia's paddy fields.

The compliment of the applicator toward the fertilizer is one of the important factors to be considered to achieve the objective of this paper. When the fertilizer N, fertilizer P and fertilizer K mix together they will have chemical reaction. Among the three applicators, the applicators that affect the most by the chemical reaction of NPK fertilizer is boom sprayer. The fertilizer dissolves in the boom sprayer not just affecting the hopper but also in the boom. When it reached a certain period of time, the other fertilizers will stuck in the boom and it is hard to clean up. The boom might need to be discharge in order to clean up. It take time because need to wash it and dry it. The maintenance cost becomes very high due to time consume and might need to replace with new parts if the situation get serious. The fertilizers will also stuck in the boom because the blower not enough power to support the three types of fertilizer in the boom. Due to difference density of each fertilizer, it is impossible to produce even distribution by using one blower. The fig. 2 show the pictures taken by a scales down model of boom sprayer that show that the particles of differences density stuck in the pipe by using a blower.

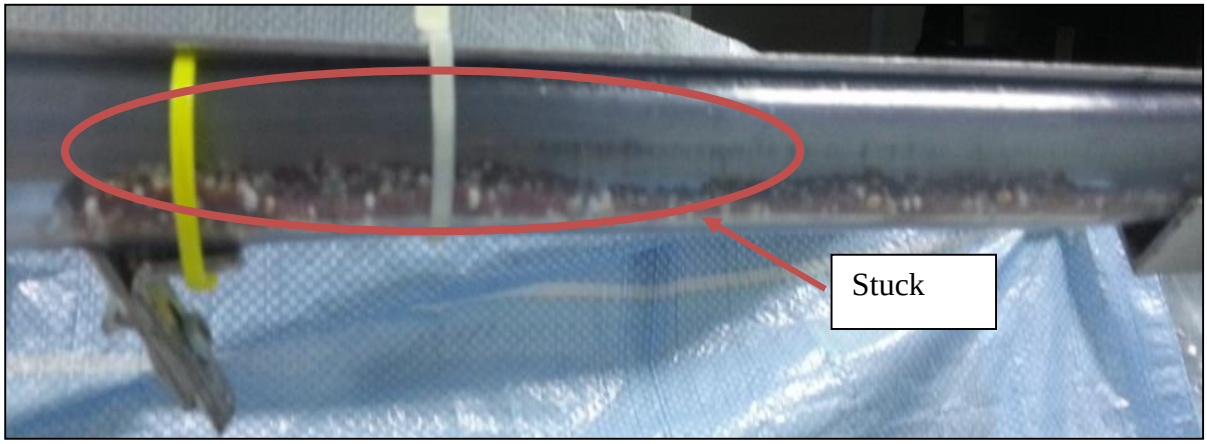
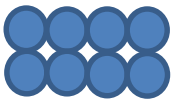


Figure 3: The stuck of particles in the pipe of a scale down model of boom sprayer. (Fatin, 2015)

As for pendulum spreader, the fertilizer will be dissolve into sticky liquid mostly in the hopper but less in the spreader bar because the spreader is rotating in a high speed whereby the fertilizer will just stay in the spreader bar in the short period of time. However, due to the fast speed motion of the spreader bar, the fertilizers will be crushed into powder before it is distribute into the field. (Pendulum Spreaders, 2015) The reason that the fertilizer must remain in granular form when it is distribute into the field is because to lengthen the time of dissolve. If the fertilizer dissolve time had been shorten, the soil will become acidic and poison to the paddy plants. (Corradini, de Moura & Mattoso, 2010).

Table 7: The comparison results of the distribution applicators.

Parameter	**Boom sprayer**	**Kuhn Axis fertilizer spreaders**	**Pendulum spreader**
Fertilizers	Dissolve into sticky liquid after sometime in the boom	Dissolve into sticky liquid after sometime in the hopper	Dissolve into sticky liquid in the hopper. The fertilizer been clash into powder form before it is distribute into the field
Maintenance cost	High because more parts to clean up	Low because less parts is involve in clean up	Moderate
Accuracy	High	High	High
Spreading shape			
Part that use to spread the fertilizer	Blower	Rotating disc	Magnetically damped inclinometer
References	(Sun and Miao, 2011) (Woodward, Connell, Zabkiewicz, Steele and Praat, 2008)	(Abubakar, Ahmad, Jamarei, Samsuddin, and Norhisam, 2011) (Sima, Nozdrovicky, Dubenova, Kristof, and Krupicka, 2013)	(Parish, n.d.) (Pendulum Spreaders.,2015)

4. CONCLUSSION

The fact is, according to the technical specification, all the 3 applicators actually had a high efficiency. Therefore granular distribution applicator should be well promoted to the locals. It is make for large scales and highly promote the grow for crops. The suitable applicator that used to distribute the NPK fertilizer into the paddy field in Malaysia is Kuhn Axis fertilizer fertilizers spreaders according to all the discussion and result above base on the analytical of this paper.

In this paper, both quantitative and qualitative investigation is needed. In engineer, most of the analyzation is interpret through graphs and tables. The objective of this paper is to compare all the three distribution applicators and eliminate the other two distribution applicators to find the suitable distribution applicators for Malaysia's paddy field in large. Therefore after study the advantages and the disadvantages of each distribution applicator, the accuracy of the distribution and the type's fertilizers, qualitative investigation help to make the final conclusion. Whereby, qualitative analyzation can cover both external, internal factors and table represent in numerical.

For further study, the comparison is ready to be tested in the experiment by fabricating the spreader parts. More result will be taken for verified the conclusion of this paper. Both quantitative and qualitative is important in engineering field. If qualitative investigation make without quantitative, it is very subjective with high possibilities of human error. Vice vasa, external factors will be neglected. The results can further use for improving the design of the spreaders applicators and for simulation validation in the actual scales.

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