MODELLING AND SIMULATION OF NUTRIENT DISPERSION FROM COATED FERTILIZER GRANULES

By

SHAFIQ BIN MOHAMMAD NOR

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Assoc. Prof. Dr. Radzuan bin Razali
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
SEPTEMBER 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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SHAFIQ BIN MOHAMMAD NOR

ABSTRACT

The usage of Controlled-Release Fertilizer (CRF) is essential in plants and crops to fulfil the need and requirement for the huge population in this modern world. Therefore modelling and simulation of nutrient release from coated fertilizer has become the best method in way to study the behaviour of some parameters toward water saturation in and nutrient release from the coated-fertilizer granule. This project is the further development of modelling and computer simulation by Basu [1] which include some of the factors affecting the water saturation time and nutrient release time from a coated-fertilizer. The effect of granule radius, the diffusivity of water and nutrient, the temperature of surrounding, the contact areas and the characteristic of the coating are studied and the simulation was developed in this project. The studies and understanding of this project is very important and useful especially to determine the correct parameter in the manufacturing process of the coated-fertilizer granule and also will be useful for the farmers/users in the selection of the best fertilizers for their crops.

ACKNOWLEDGEMENT

بسم الله الرحمن الرحيم

First of all, I would like to express my greatest praises to Allah, God Almighty for all His blessing and guidance throughout my life, especially during this period for me to complete my Final Year Project I and II. For without Him, I am a mere nothing without any significance. Next, I would like to show my appreciation to Universiti Teknologi PETRONAS (UTP) for giving me the chance to do my Final Year Project as it have given me valuable amount of experience.

My sincerest thank to my supervisor, Assoc. Prof. Dr Radzuan Razali for giving me the chance and trust to do this project under his supervision. His tutelage and guidance that he has given me will always be a memory that I hold strong and cherish. Finally, I would express my sincerest apologies if in any time that I have done anything that is not to his liking.

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CHAPTER 1: INTRODUCTION

1.1. Background of Study

According to The Columbia Electronic Encyclopedia, dispersion in chemistry was defined as mixture in which fine particles of one substance are scattered throughout another substance. In the context of fertilizer, it can be defined as fine particle substance (nutrients) from the fertilizer granule scattered throughout the soil it get contacted. The dispersion of nutrient is occurs at the contact point of the granule with the soil.

In this modern world, fertilizers are one of the important elements in producing good crop yields, and there are some countries keep increasing the usage of fertilizer to increase the crops in term of food production to fulfil the demand [2]. However, there are several things need to be consider in the use of fertilizer in crops, which including the saturation and release time of nutrient in a coated fertilizer granule.

In this project, the author will study about what are the effects of the size of the granule, the diffusion coefficient, and the climate change, on the saturation and release time of nutrient in a coated fertilizer granule focussing on the applications in Malaysia's climates. Several assumption need to be done in order to simplify the study which include; the shape of the granule, the contact point of the granule with soil, the condition of Malaysia which include the temperature of surrounding and the condition of the soil, the thickness of the coating layer in granule and the composition of the granule itself.

The study is basically will be done by developing the mathematical models and simulation of the saturation and release time of nutrient in the fertilizer granules by the effect of the granule size, the evaporation loss, and the climate change. Mathematical models and simulation was put as the outcome of this project because from models and simulation, this enable people to execute some important task which include; to forecast the behaviour and fully optimized the system.

Farmers (the user) can predict what will be happen if certain conditions happen during a particular time using the mathematical models and simulation. From the prediction, the farmer can plan the action to be taken to fully utilize everything (if the prediction is good) and to plan any action to be taken if the bad prediction was found.

1.2. Problem statement

Base on the NationMaster.com website and summarize in the figure 1 below, there are 136 countries around the globe that apply the usage of fertilizers. Among that 136 countries, Ireland was at the first place in term of the uses of fertilizer with the record of 594.5 kilogram per hectare (kg/ha) in a year. Malaysia on the other hand was at the 18th place with the usage of 187.8 (kg/ha) in a year. When we talk about fertilizer which mainly and usually in small size and light weight, 187.8 (kg/ha) in a year is not present that Malaysian use only small amount of fertilizers in the plantation, and this figure is not a good sign if the fertilizers used is not the nutrient-controlled fertilizers. It is a nature in the world that in everything we do we cannot expect to get the 100% efficiency. Which same in the application of the fertilizer, not all nutrients release by the granule will be absorb by the plant, but there will be some portion of it released being absorbed by the soil which we called it as excessive nutrient.

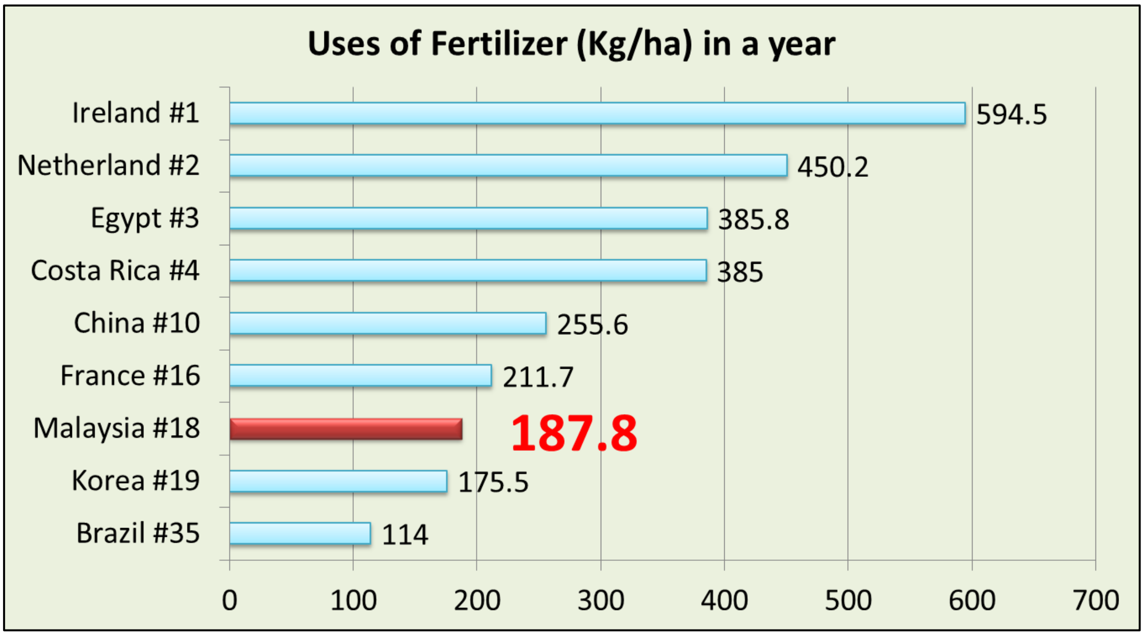


Figure 1 Statistics of uses of Fertilizer

Excessive nutrient for instance the Nitrogen (N) in the form of nitrate can get into the groundwater and increase the concentration of nitrate in the groundwater above the standard from the national drinking water. Huge amount of nitrate in drinking water can affect the health of elderly people and infant if being consumed. Animal on the other hand do not have exclusion to be affected by the nitrate as they also drink water that the source is the groundwater.

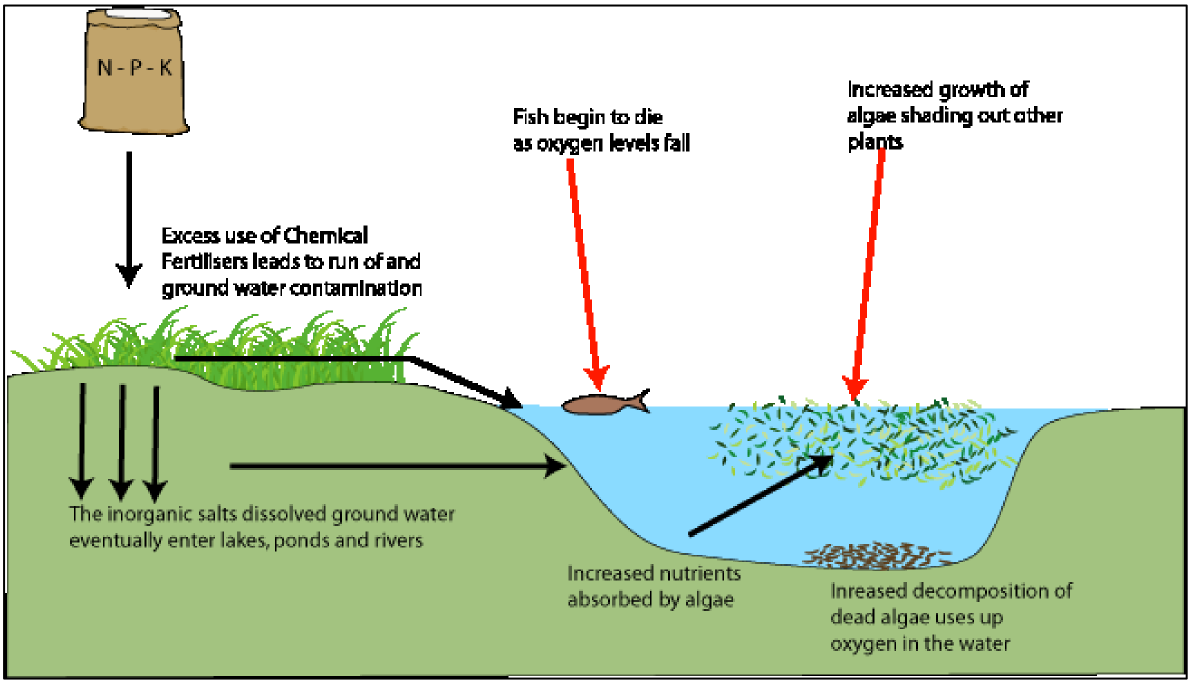


Figure 2 Eutrophication

Figure 2 shows the phenomenon known as Eutrophication that causes the water turn to green; this is the consequence due to the excessive usage of fertilizer in plantation. Excess nutrient (heavy element such as Nitrogen (N) & Phosphorus (P)) released from the fertilizer were precipitated on the ground and some were absorb into the ground, which eventually will enter the water (lakes, ponds and rivers) by moving water from rain or storm. Increasing amount of heavy elements in the water will affect the population of algae in tremendous growth because the algae absorbing the excess nutrient in the water. The increasing population of algae will shade the other plants in the river which lead to the decrease of plant population and eventually will reduce the amount of oxygen produced by the respective plants which also give the same effect from the increasing decomposition process of the dead algae that consume more oxygen in the water. Other living organism in the water will suffer the lack amount of dissolve oxygen in the water and end up with death and reduce the population of the respective organism. Now we can see that from the un-controlled use of fertilizer will ultimately affect the population of two main characters with important role in the ecosystem. Figure 3 is the other example of Eutrophication.

Figure 3 Example of Eutrophication

Basically the main objective for farmers use common fertilizer in plantation is to gain the maximum yield of crops by applying huge amount of that fertilizer to the ground which totally not the correct way to perform it. If let say they use the Nutrient-Controlled release fertilizers, by applying huge amount of the fertilizers also not the correct way of doing it. So the problem is not the type of fertilizers used; either it is common or the Nutrient-Controlled one. But the problem is the method that the farmer needs to know in way to get the highest efficiency in the usage of fertilizers.

In current modern world, there are several studied being done for development in the usage of fertilizer. There are mathematical models used to simulate the nutrient release from granule, and there are developments of control system to be applied for efficient usage of fertilizer, but apart from all the current achievement, there is no model to determine and simulate the saturation and release time of nutrient from the coated fertilizer granule.

Determining saturation and release time using a specific model is essential not only to simulate the pattern of the nutrient dispersion, but also to enable users to forecast the behaviour and fully optimized the system. This is important because forecasting is one of useful input for user to plan the next action plan in term of to fully utilize the usage of fertilizer in way to get the good quality and quantity of crops yield. From the study of the nutrient dispersion from fertilizer, indirectly the efficiency will be improved.

In term of modelling and computer simulation for determining the saturation and release time of nutrient, most of the simulations available are executed in MATLAB or any other simulation software without give the users the privilege to retrieve the data automatically and further analyse the data. Therefore the same simulation needs to develop which have link with Microsoft Excel® as this software give capability to the users to further analyse the data of the simulation.

1.3. Objectives

The aim of the project is to

1) To develop a mathematical model and computer simulation using MATLAB linked with Microsoft Excel®.
2) To determine and study the water saturation and nutrient dispersion process in a coated-fertilizer granule using mathematical modelling and computer simulation.

CHAPTER 2: LITERATURE REVIEW

2.1. The usage of fertilizer in plantation

The usage of fertilizer for a better crop has become the main option by all farmers and whoever related to agriculture. The dependent of natural nutrient from the soil is not enough to feed the huge population of consumer in this modern world.

2.2. Bad effect using the fertilizers

Not all nutrient disperse from the fertilizer will be absorb by the plant; some of it will be leached out in the soil or drained into the river by rain water. Thus excessive dispersion of nutrient from the granule will not only lead to wastage of nutrient, but also give impact to health and environment [3, 4]. Due to excessive amount of nutrient dispersed out, the pollution will keep increasing and the agriculture effectiveness will be reduced. The pollution not only gives bad effect to agriculture, but also bad effect to the river, this is because, excessive nutrient which not being absorb by the plants will directly flow into the river by rain. This phenomenon was called as nonpoint source of pollution [2]. According to Zhao Yong [2], compared to point source pollution (water was directly expose to the harmful substances), the nonpoint source of pollution was harder to control in term of the spread. Excessive nutrient in nature will also lead to Eutrophication as was discussed in problem statement section in chapter one of this report.

2.3. Catering the problem from the fertilizer

Many country starts to focus their target in the application of Variable Rate Fertilizer Technology and the usage of Controlled-Release Fertilizer (CRF) to obtain the optimum amount of nutrient and to cater the problem of pollution cause by the excess nutrient dispersed from the granule to the soil [5]. By studying the saturation and release time of granules and the uses of Controlled-Release Fertilizer we can not only meet the required crop yields, but we also can reduce the potential of environmental pollution such as Eutrophication [6].

2.4. Usage of the coated fertilizer

Controlled Release Fertilizer (CRF) and coated fertilizer was made by applying a coating to the nutrient (active component in fertilizer) with a layer of other substances to act as the barrier separating the nutrient and the soil to control the dispersion process. The function of the coating is to control the time taken for the granule releasing the nutrient from its core. Time taken for water saturating the granule and the nutrient being release from the granule is a very important element need to be considered in the application of CRF because we can determine the optimal uptake of nutrient by the crops [1]. Optimum dispersion and consumption of nutrient by plants is essential in way to get a better and high quality of crops. Different crops have different amount of nutrient uptake like for instance being summarize in the table below [7]:

Table 1 Nutrient uptake for different crops

Crops	Nutrient uptake (Pounds/acre)
Spring Wheat	76 – 93
Winter Wheat	61 – 74
Barley	100 – 122
Oats	96 – 117
Rye	83 – 101
Corn	138 – 168

From table 1, corn is the highest in the rank that took about 138 – 168 Pound of nutrient (Nitrogen, N) per acre and winter wheat is the lowest in the rank that took about 61 – 74 Pound of nutrient (Nitrogen, N) per acre. The dispersion rate is basically depending on the material used as the coating of the granule, the contact point of granule with the soil, the size of the granule itself, and the surrounding environment (in term of temperature, humidity and weather) [1, 3].

2.5. Modelling for controlled release fertilizer

In the previous study [1, 6, 8], the main important criteria needed to develop a model for nutrient dispersion is the characteristic of the granule itself which including the size of granule, the thickness and material use of the coating layer, the condition of surrounding including humidity, weather and temperature, and the contact point of granule with soil.

CHAPTER 3: METHODOLOGY

The main outcome of this project is to produce the modelling and simulation of the saturation of water in fertilizer granule and the release time of the nutrient from the coated fertilizer granule. The model and simulation is the improvement of the modelling developed by Basu in [1, 6]. One of the improvements is the modelling will be executed using the MATLAB software linked with Microsoft Office Excel®, this is to enable the users to use the data and result effectively. The methodology of the project can be classified according to the following:

3.1. Study on the Fertilizers

3.1.1. Characteristics of the fertilizers

There are many factors affecting the process of water saturation into the granule and nutrient release from the granule, such as

3.1.1.1 The size and shape of the granule

The size of granule will definitely affect the time taken of water to completely saturating the granule and the time taken for nutrient being completely released from the granule. The shape on the other hand will affect the contact point of the granule with the soil; larger contact area will increase the rate of water saturated and the rate of nutrient released from the granule and vice versa. The parameter to be use in the simulation is the radius instead of diameter because it is more convenient in term of the computation. The radius was assigned to a parameter a.

3.1.1.2 The characteristic of the coating

Different material have different characteristic. For instance, the zinc-coated granule will release the nutrient from granule slower than the one with A. *indica* (neem)-coated urea granule [3]. Different materials have different way on how it reacts with water and this will determine the both time taken for water saturating the granule and time taken for granule releasing the nutrients. Parameter q was assigned to be the factor of coating that will affect the time taken for nutrient dispersion from the coated fertilizer and it is called as the nutrient release rate. Nutrient release rate can be different from one granule to other granule because of the width and/or the chemical nature of the coating material. For the time being, there is still no journal that briefly compares the effect of different coating to the nutrient dispersion time of fertilizer. Therefore, the values assigned for the release rate being used by Basu [1] was taken to describe the different type of coating material in the fertilizer.

3.1.1.3 The environment

The environment factors including the temperature and humidity of the surrounding. Usually high surrounding temperature will lower the humidity of surrounding and vice versa. The surrounding temperature will affect the ground temperature that contains water and this may affect the rate of water saturation in the granule. The rate of water saturation also will be affect by the evaporation factor during the saturation process due to natural phenomenon. Therefore, there will be 2 factors affecting the time taken for dispersion process; the surrounding temperature & the evaporation loss factor that will be discuss more in the saturation section in section 3.2 in this chapter.

3.1.1.4 The condition of soil

For instance, the condition of soil is basically the presence of water in the soil. High water level in the soil will increase the time taken for water saturated the granule and vice versa for low water level in the soil. In the development of the model, we assume plenty amount of water available in the soil to saturate the granule. Let the water diffusion coefficient be D_w, this coefficient will control the saturation time of water in the granule in such a way the saturation time will increase as the D_w decreasing.

3.2. Mathematical formulation

Figure 4(a) illustrates a spherical granule in contact with soil surface on one point. It is assumed that the granule was perfectly sphere in shape to ensure the maximum benefit from it. The granule with the centre point P with radius a and the line cross over the centre from the contact point O will be considered as the *z-axis* of the Cartesian plane, the longitudinal and transverse direction considered as *x-axis* and *y-axis* respectively. In this situation, the contact point O was considered as the origin, thus the value of the point is $x = 0,\ y = 0$ *and* $z = -a$. The movement of water seep into the granule is in the direction of z as shown in the figure 5(a). In term of water diffusion due to gravity and rain, it is assume to be no significant effect on the saturation as there is still no research being done regarding the subject.

Figure 5 shows the granule with surface area contact. The sector AOB of the granule is the part that in contact with the wet area of the soil and it is assumed to be circular. ON was defined as (a/c) where a is the granule radius and c is the contact parameter that determines the area in contact with the soil, the greater the c value, the smaller the area contacted with the soil. Several value of c can be used in this modelling, $c = 1$ will be the minimum value of c to be consider as it shows that all area in the lower part of the sphere get contacted with the ground [6], and $c = 120$ was proven by Basu [1] to be a point contact of granule with the ground, the illustration of contact parameter was shown in figure 4 below.

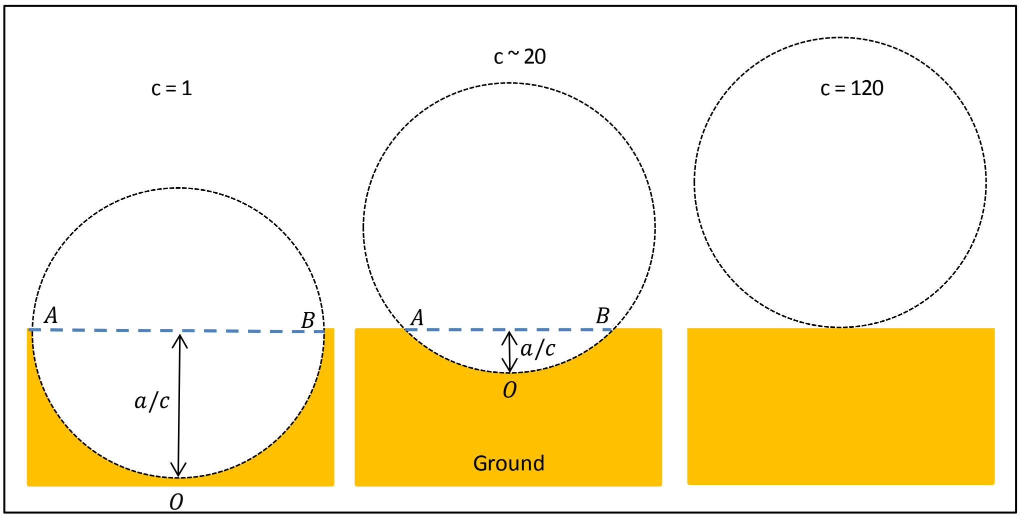


Figure 4 Granule with different contact parameter, c

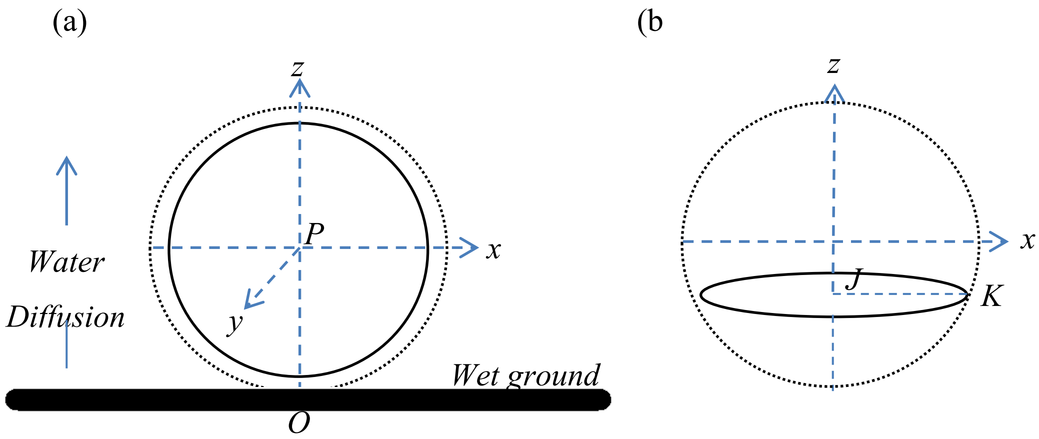


Figure 5 (a) Spherical Granule in contact with soil on one point and
(b) Horizontal circle with centre on z-axis

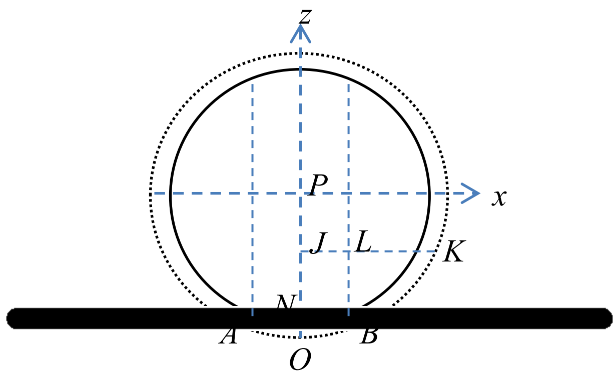
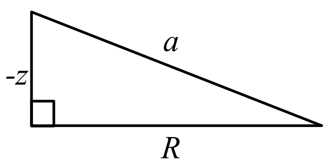


Figure 6 Spherical Granule with surface contact

3.2.1. Water saturation of the granule

From figure 6 in the case of surface area contact, water from the ground diffuse into the granule from the area of AOB, then continue to diffuse up along the z direction in cylindrical shape. As water diffusing upward along the z direction, the water will saturated in the nutrient from J to L, from this point it will be the input of water for the rest part of nutrient along L to K. Consider a circle as in figure 6 with the radius of $LK = R$ at the lower half of the granule. At this particular circle, using Pythagoras's Theorem the R can be formulated by:



$$a^2 = R^2 + (-z)^2$$

$$\therefore LK = R = \pm\sqrt{a^2 - z^2}, \qquad where - a < z < a$$

The saturation time will keep increasing as we move from the bottom of the granule ($z = -a$) to the centre (P) and it will start decreasing as approaching the top of the granule ($z = a$). The saturation time also will varies inversely proportional with the water diffusion coefficient. Therefore, the saturation time, *ts* of water in the granule can be computed using equation (1). The saturation time for all horizontal circles in the granule are found and the saturation time for the whole granule, T_s was determined by the summation of saturation time for every circle in the granule.

$$T_s = \sum t_s = \sum \beta_1 \frac{R}{D_w} \quad (1)$$

where β_1 is constant, *R* is the radius of the horizontal circle, *Dw* is the water diffusion coefficient.

The saturation of water in the granule also needs to consider the temperature changes throughout the day and night. The evaporation loss can be considered in the interval of every 1 hour for the complete day 24 hours in total. If we were to illustrate the relationship of evaporation loss factor and the time in hour, the trend will be as shown in the figure below [9]:

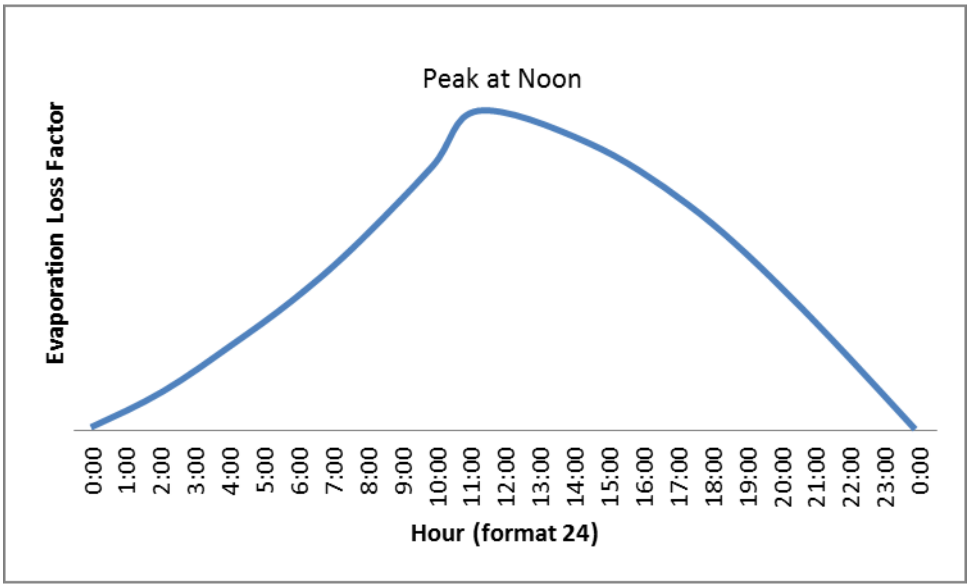


Figure 7 the trend of evaporation loss with time in Malaysia

For the time being, it is difficult to obtain an expression to illustrate the pattern as in figure 7, therefore, new pattern as in figure 8 was produced to model it. In figure 8, even though there is no abrupt change in the peak, this pattern can be consider to closely match the actual pattern as compared in figure 9.

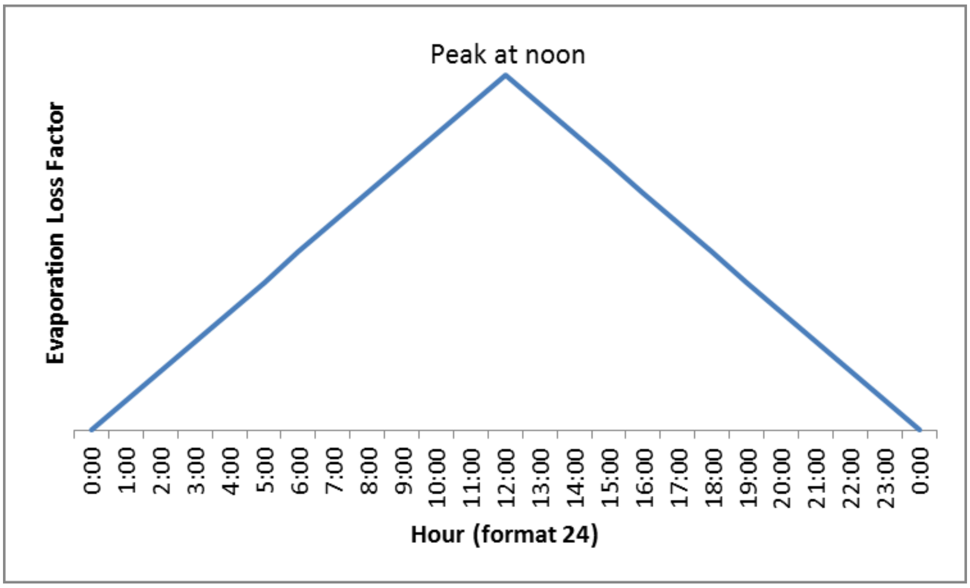


Figure 8 Produced Evaporation Loss pattern

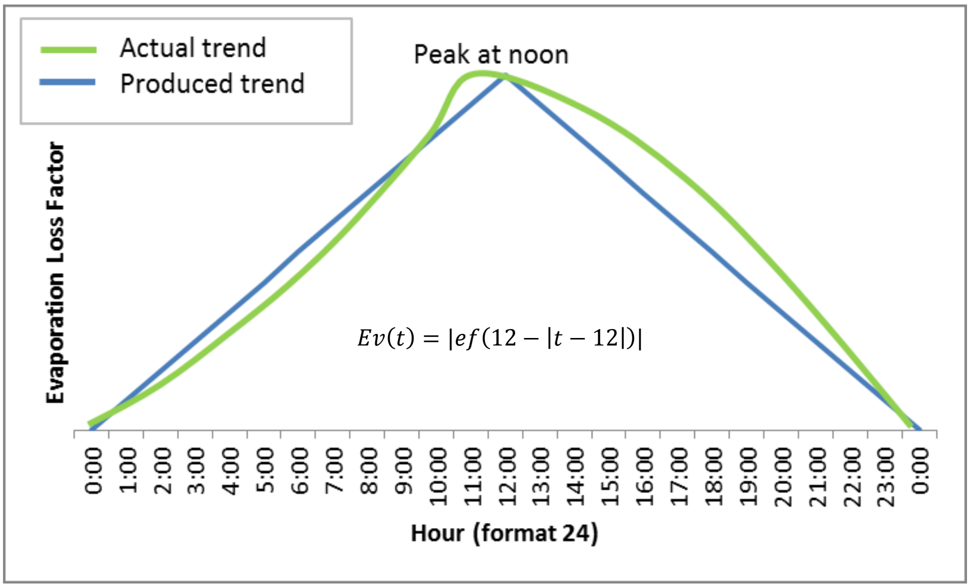


Figure 9 Comparison of actual and produced pattern

From the pattern, the mathematical expression of the loss factor was determined as:

$$Ev(t) = |ef(12 - |t - 12|)|$$

Where ef is the evaporation factor and $t = T_s = 1, 2, 3 \ldots\ldots 24$. The time used in the expression must be round off as it was assumed that the factor was the same throughout one hour. The time taken in hour, t for water saturating the granule was use to find the correspond value of the loss factor $Ev(t)$. This factor will be used to modify the value of the T_s using the following relation:

$$New\ saturation\ time, T'_s = \gamma T_s$$

$$where, \gamma = 1 + \left(\frac{ef}{1 - Ev(t)}\right)$$

The evaporation factor is 0.006 as was used by Basu [1]. The evaporation loss factor was increases and decreases at a uniform rate as shown in the figure 10.

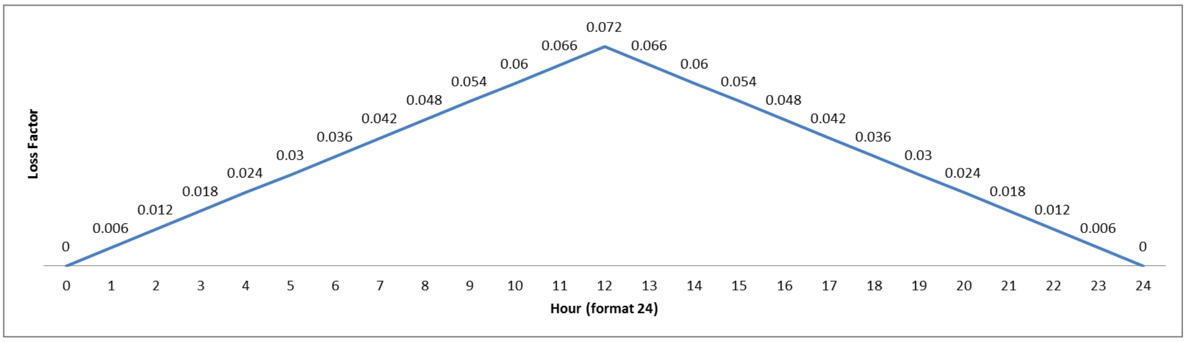


Figure 10 the loss factor for evaporation factor = 0.006

3.2.2. Nutrient Release from Granule

Nutrient from granule will start to be released as the granule completely saturated with the water. Figure shows the flow of the dispersion process [1].

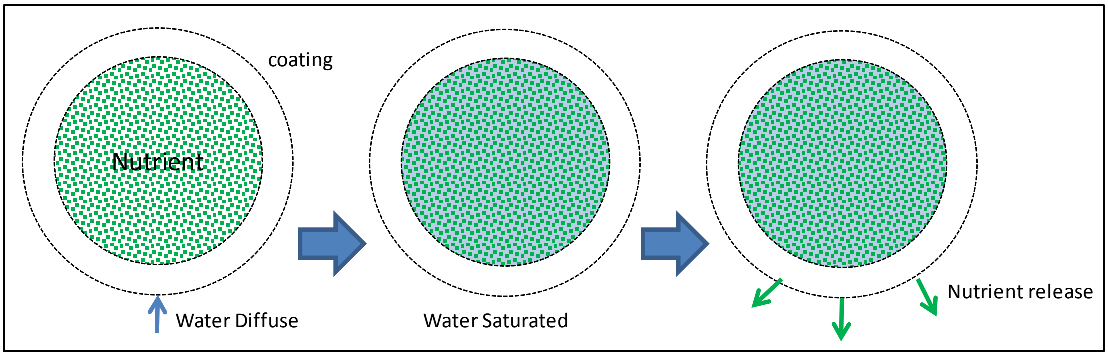


Figure 11 Dispersion process

The nutrient release process will only occur at the point of contact of the granule with soil which is the effect due to the coating of the granule. This is where the nutrient-controlled release was applied; the amount of nutrient released by each granule will be determined by the material used and the thickness of the coating of the granule. For instance, the zinc-coated granule will release the nutrient from granule slower than the one with A. *indica* (neem)-coated urea granule [1]. Another assumption was made which the diameter of the granule keeps decreasing and the shape of it remain sphere during the releasing of nutrient from the granule. The nutrient will keep released from the granule until the ratio of final diameter to initial diameter become significantly small as shown in figure 12. This is due to the movement of the nutrient is radially symmetrical, start from the most outer circumference toward the sphere-like point (which incredibly smaller than the initial diameter). The final limiting radius, d was taken as 0.2mm which is very small and the left out nutrient in the circle are negligible for the release time and at this stage, the coating material will get mixed with the soil and because of that, it is essential to choose the right material for coating to be serve as pesticide in the soil.

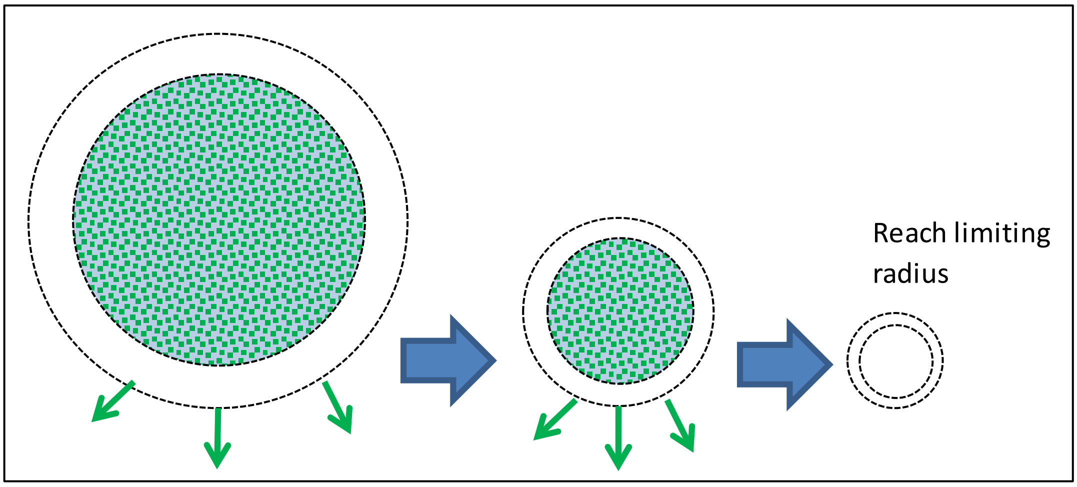


Figure 12 the movement of the nutrient

The time taken for nutrient dispersion is depending on the radius of the granule (the radius will reduce uniformly until reach the limiting radius). The release time also varies inversely proportional with the nutrient diffusion coefficient and the release rate of the granule. Therefore the total nutrient release time, *Tr* from the granule can be compute using equation (2) as the summation of nutrient release time for all sphere radius, aa, and D_{nn} is the modified nutrient diffusion coefficient, *Dn* due to the temperature of surrounding. The nutrient diffusion coefficient D_n can be affected by the temperature in such a way that the increase in temperature will increase the nutrient diffusion coefficient [1, 10]. Therefore temperature, *T* will modify the value of nutrient diffusion coefficient. The dependence of nutrient diffusion coefficient to the temperature is more toward linear-quadratic form [6, 11] in such a way that $D_{nn} = D_n(1 + T^{0.66})$ Where T is the temperature in ºC, and D_n was taken as $D_n = 0.1 + D_w$, which is relatively higher than the water diffusion coefficient.

$$T_r = \sum t_r = \sum \beta_2 \frac{aa}{qD_{nn}} \qquad (2)$$

where β_2 is a constant, aa is the sphere radius, q is the release rate.

3.3. Computer Simulation

Figure 13 and 14 is the flow chart for the computer simulation. Figure 13 shows the steps needed in way to find the saturation time of water in the granule. Figure 14 on the other hand illustrate the steps needed to find the release time of nutrient from the granule.

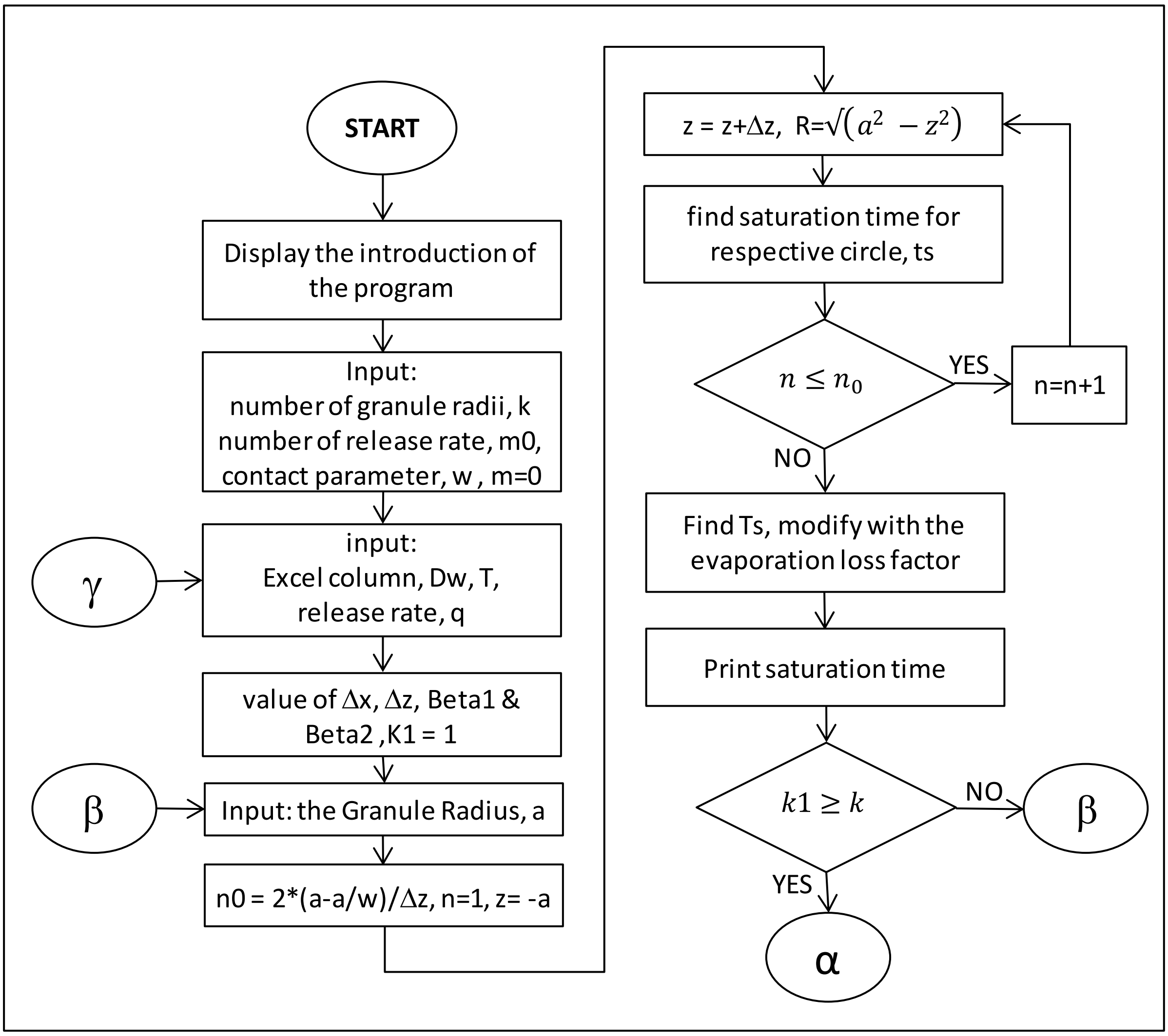


Figure 13 Flow Chart of simulation for saturation time

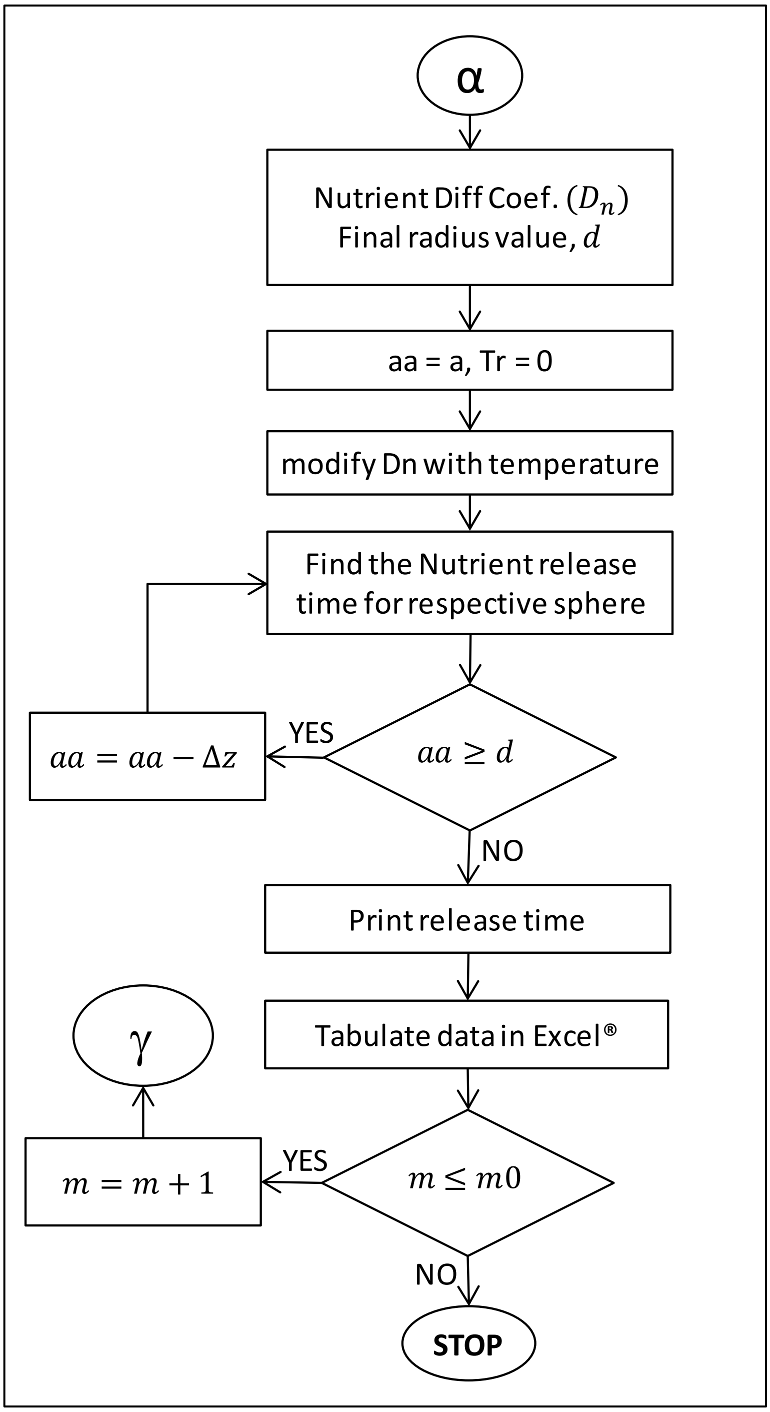


Figure 14 Flow Chart of simulation for Nutrient release time

3.3.1. MATLAB coding

There are four element in the development of the MATLAB coding; the interfacing, computation of saturation time, computation of the nutrient release time and the linkage of MATLAB with Microsoft Excel® There are several commands being used in the development of the soft-code such as, 'input' command, the 'loop' command and 'display' command. These 3 types of command was the main command used in the soft-code. The 'input' command is to get the input from the user of the application such as the important parameter in the process of computing the saturation and nutrient release time of the granule. The main important of the loop command is to make sure the application will always run computing the result base on the input data until was 'tell' to be stop or if the user 'exit' the application. The display command was used to display the result of the computation in order for user to retrieve the important data. Special command also being used to export the result into a spread sheet in Microsoft Office Excel®, this is to enable the user to view the line chart and to make further analysis of the result in the document. The special command used to export the result into spread sheet is as follow:

```
xlswrite('filename.xls',value,sheet,range));
```

3.4. Gantt Chart and Key Milestone

Refer to Appendix A for the Gantt Chart and the key milestone.

CHAPTER 4: RESULT AND DISCUSSION

Figure 15 below shows the screenshot of the FertilizerModelling™ in MATLAB. The users need to insert the desired input data such as the Number of Radii (k), the Number of Release Rate (m0), the identity column of the Excel® file, this input will determine the cell for the program to store the result of any computation made. Figure 16 - 21 below show the overview of the execution of the program.

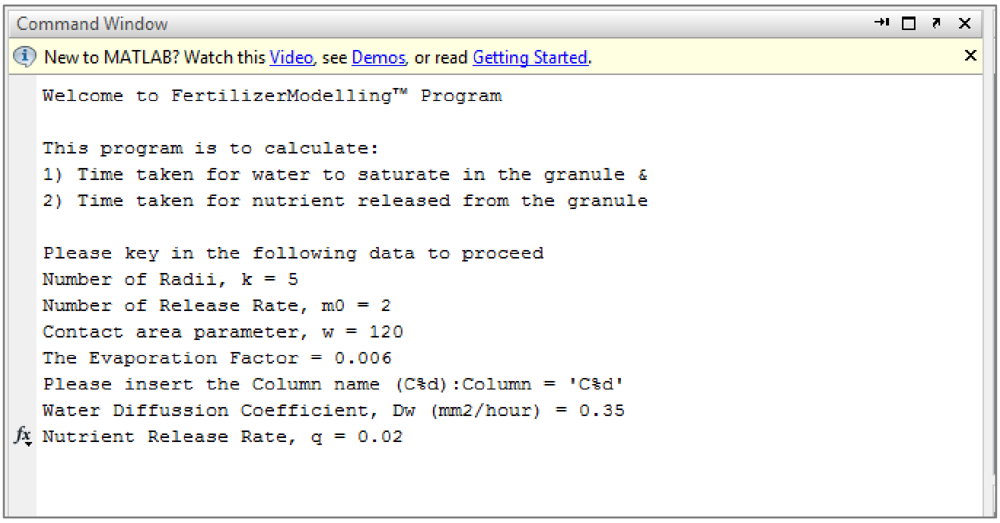


Figure 15 the starting of the FertilizerModelling™ program

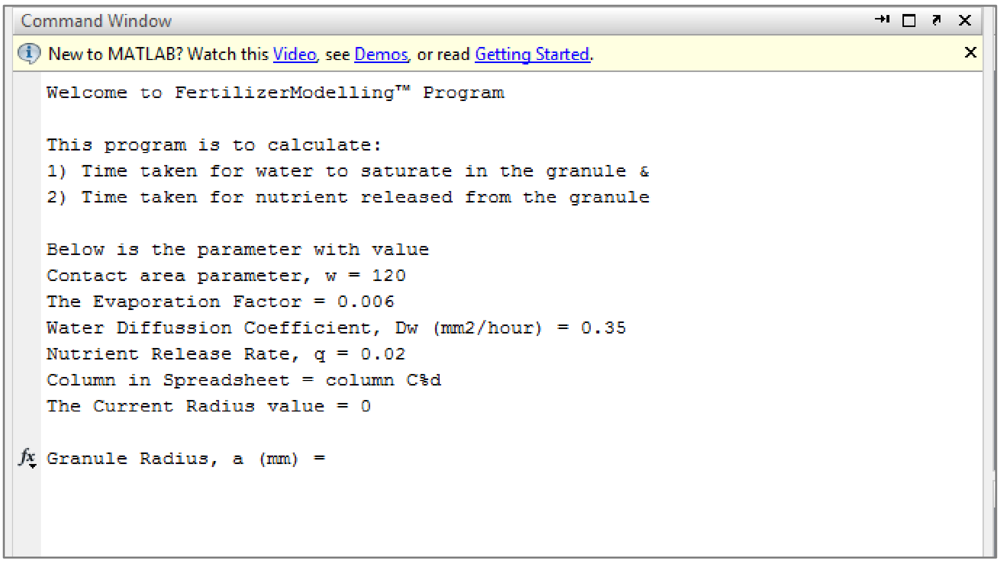
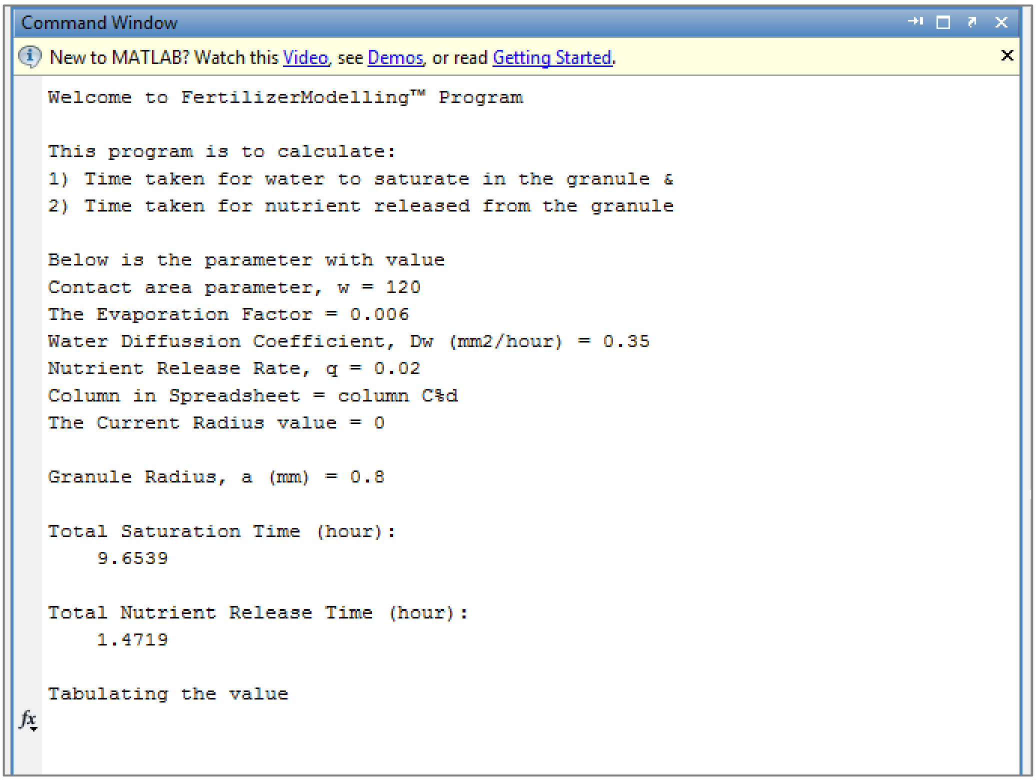
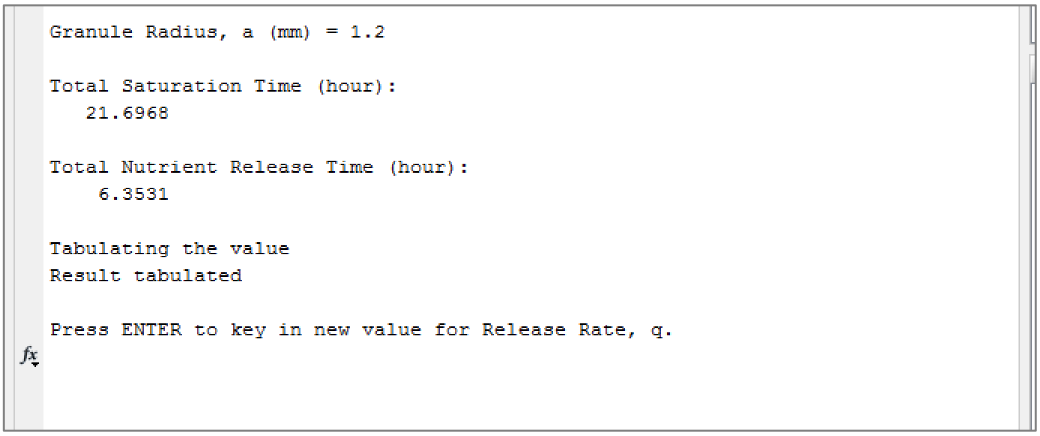


Figure 16 the program waiting for the input from user



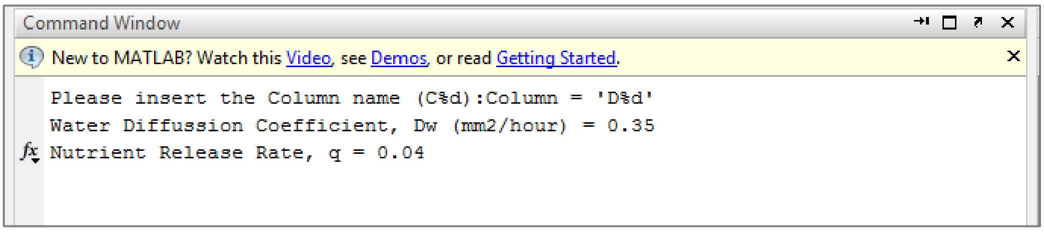
```
Command Window
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
Welcome to FertilizerModelling™ Program

This program is to calculate:
1) Time taken for water to saturate in the granule &
2) Time taken for nutrient released from the granule

Below is the parameter with value
Contact area parameter, w = 120
The Evaporation Factor = 0.006
Water Diffussion Coefficient, Dw (mm2/hour) = 0.35
Nutrient Release Rate, q = 0.02
Column in Spreadsheet = column C%d
The Current Radius value = 0

Granule Radius, a (mm) = 0.8

Total Saturation Time (hour):
    9.6539

Total Nutrient Release Time (hour):
    1.4719

Tabulating the value
fx
```

Figure 17 the program tabulating the result into Excel®



```
Granule Radius, a (mm) = 1.2

Total Saturation Time (hour):
   21.6968

Total Nutrient Release Time (hour):
    6.3531

Tabulating the value
Result tabulated

Press ENTER to key in new value for Release Rate, q.
fx
```

Figure 18 showing the program will repeat for another value of q



```
Command Window
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
Please insert the Column name (C%d):Column = 'D%d'
Water Diffussion Coefficient, Dw (mm2/hour) = 0.35
fx Nutrient Release Rate, q = 0.04
```

Figure 19 require the user to specify different column for new variable

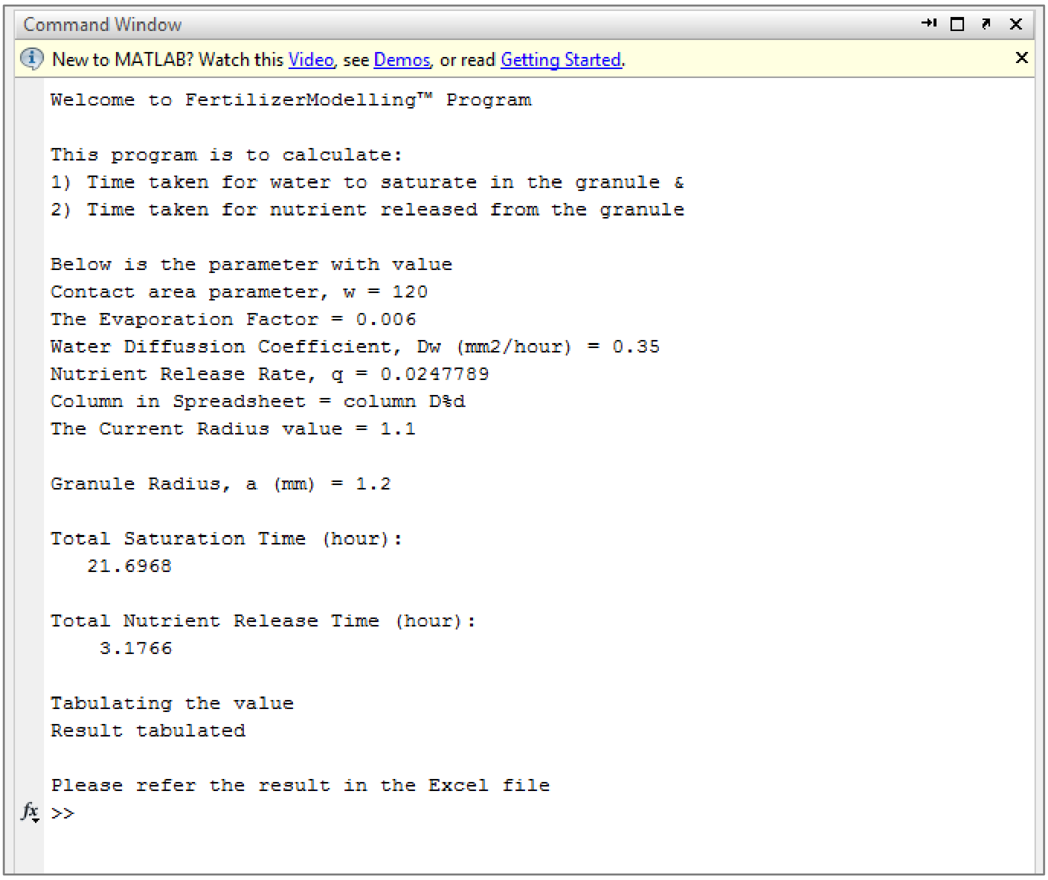


Figure 20 screenshot after finish the computation

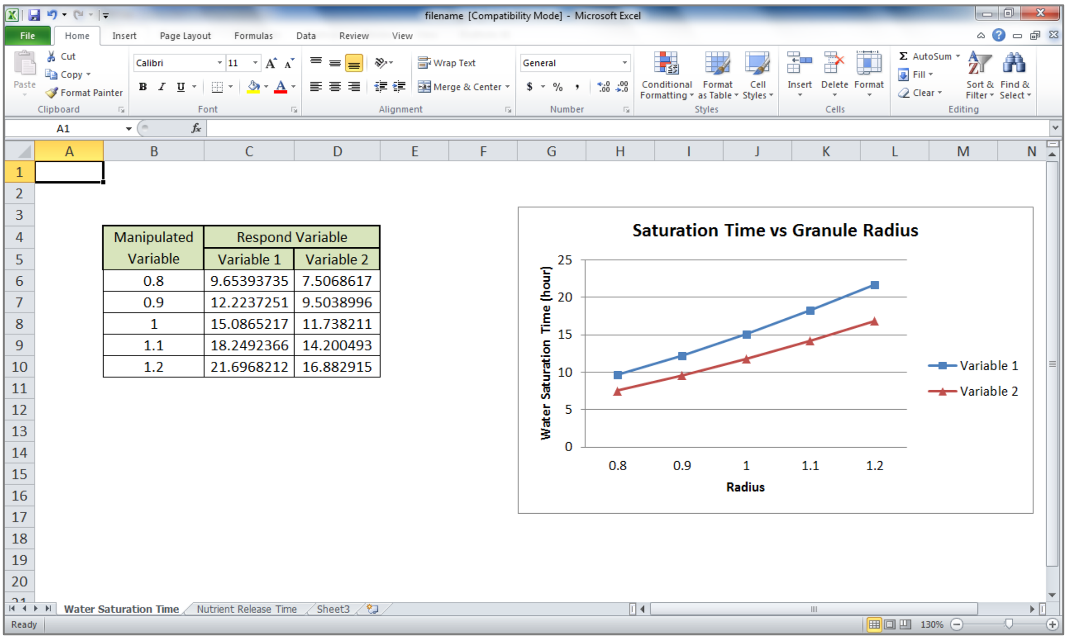


Figure 21 tabulated result in Excel® with line chart

The simulation was carried out with the value of radius, a from 0.8 – 1.2 mm as was used by Basu [1]. The simulation result from the program developed in the

MATLAB was compared to the simulation in the literature [1]. This is to ensure that the program was run as required and produce the same value as the reference.

4.1 Saturation of the granule

The effect of granule radius to the saturation time for point and surface contact of the new program and from literature [1] was simulated in the figure 22 and figure 23 respectively. The saturation time increase as the radius increase in linear trend. Granule with larger diameter may be the best choice for cold-weather condition as the ground will dries slowly.

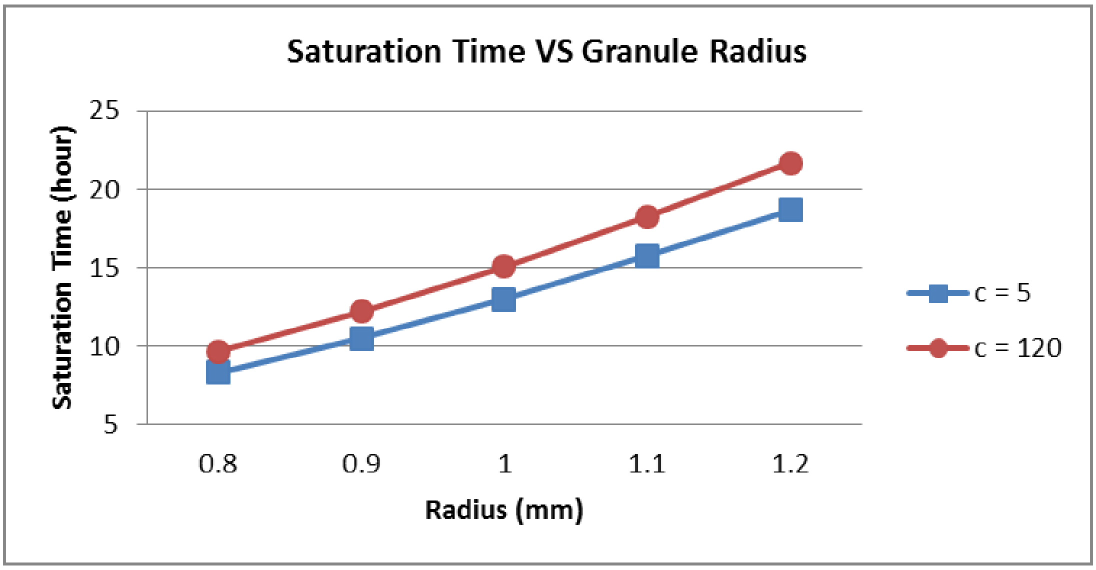


Figure 22 Ssturation time against granule radius for 2 point contacts (new program)

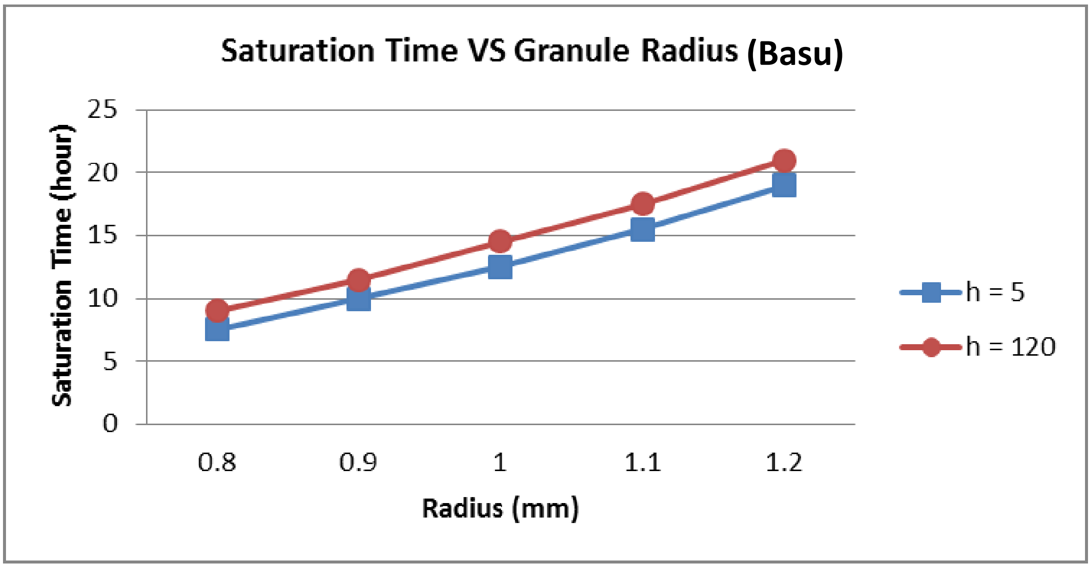


Figure 23 Ssturation time against granule radius for 2 point contacts from lit [1]

Figure 24 and 25 shows the effect of Diffusion Coefficient to the saturation time for point and surface contact of the new program and from literature [1] respectively. The computation was done with five value of diffusivity, $D_w = 0.15, 0.25, 0.35, 0.45, 0.55$. From figures below, it show that the saturation time is decreases as the water diffusion coefficient increases.

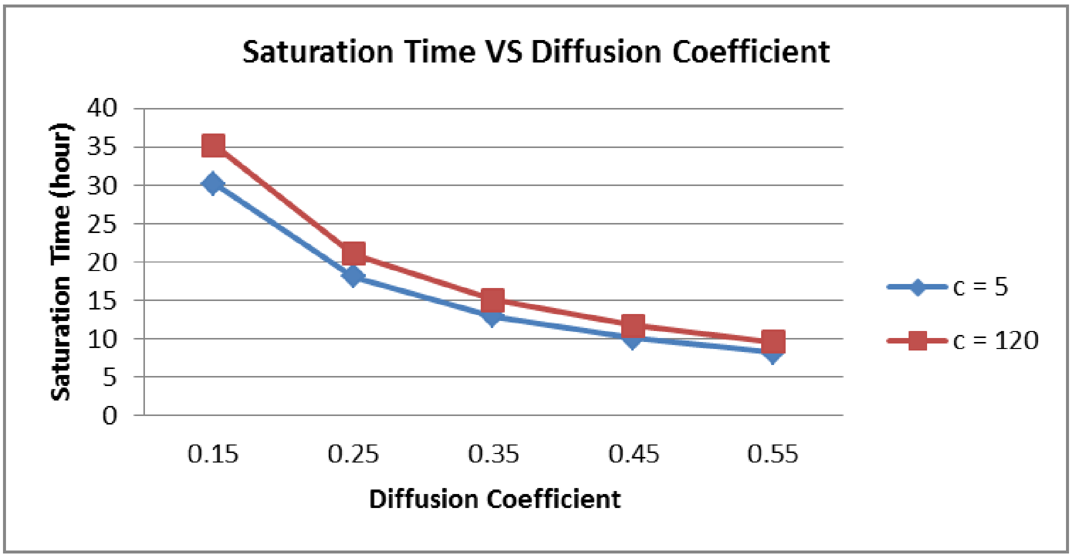


Figure 24 Ssturation time against diffusion coefficient for 2 point contacts (new program)

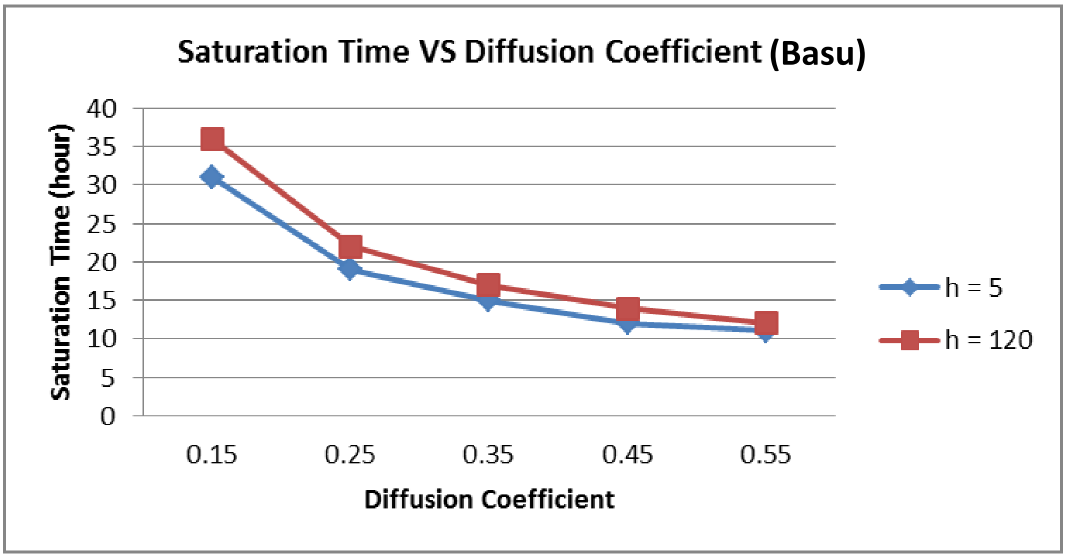


Figure 25 Ssturation time against diffusion coefficient for 2 point contacts from Lit [1]

Figure 26 and 27 shows the effect of Evaporation Factor to the saturation time for the point contact of the new program and from literature [1] respectively. From the figures, the water saturation time is increases in linear way with the increment of the evaporation factor. In the application of fertilizer, the evaporation factor must be considered depending on the month the fertilizers being applied.

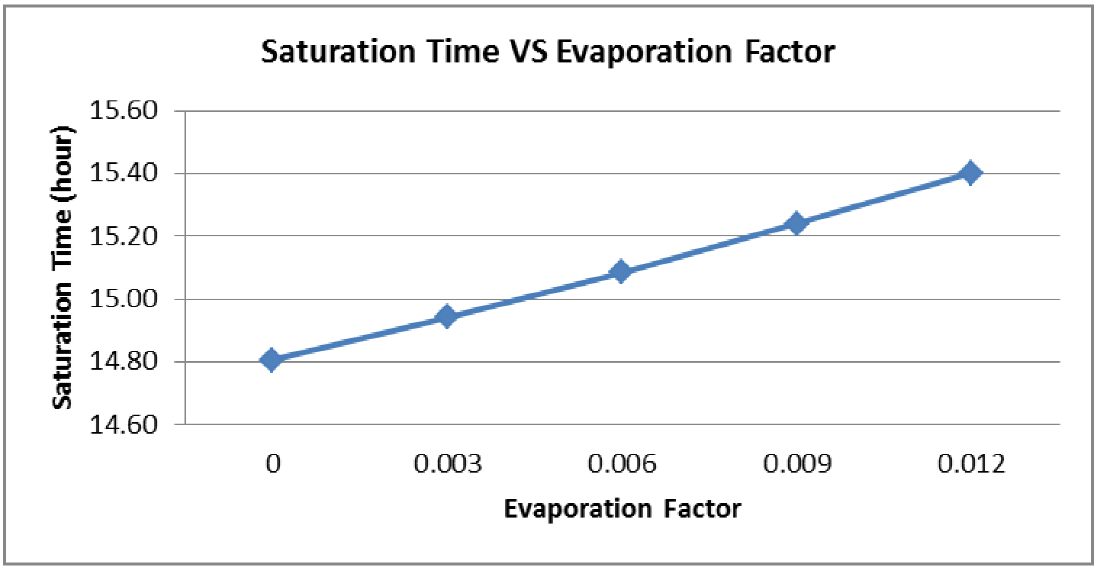


Figure 26 saturation time vs evaporation factor (new program)

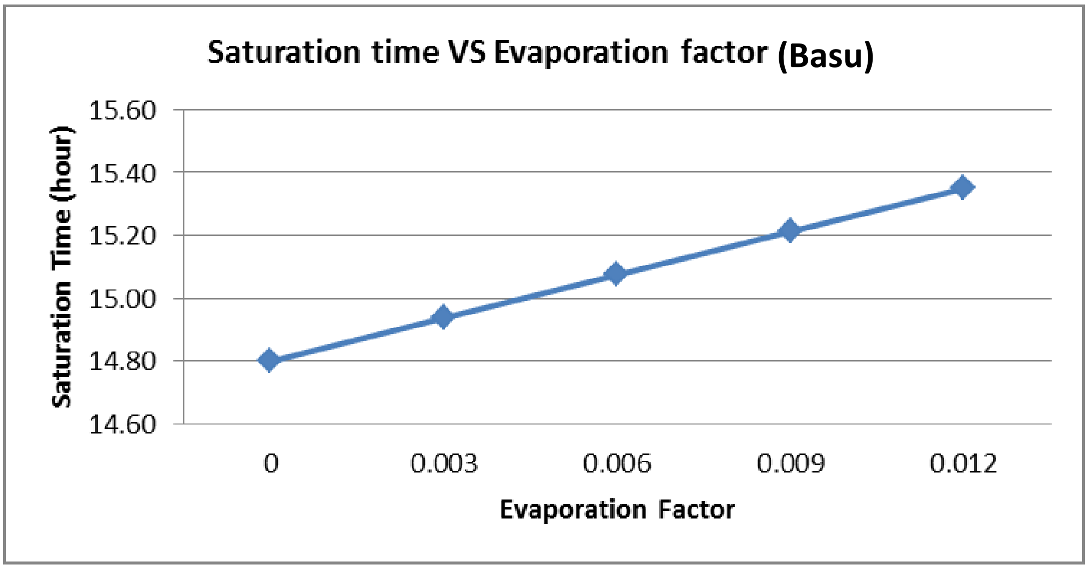


Figure 27 saturation time vs evaporation factor in lit [1]

4.2 Nutrient release from granule

Figure 28 and 29 shows the effect of granule radius to the nutrient release time for the point contact of the new program and from literature [1] respectively. From figures below, the nutrient release time increase for larger granule diameter. Apart from that, as the release rate (q) increases, the nutrient release time reduce. The release rate will be helpful in the choice of the characteristic of the coating in term of the width and/or the material used.

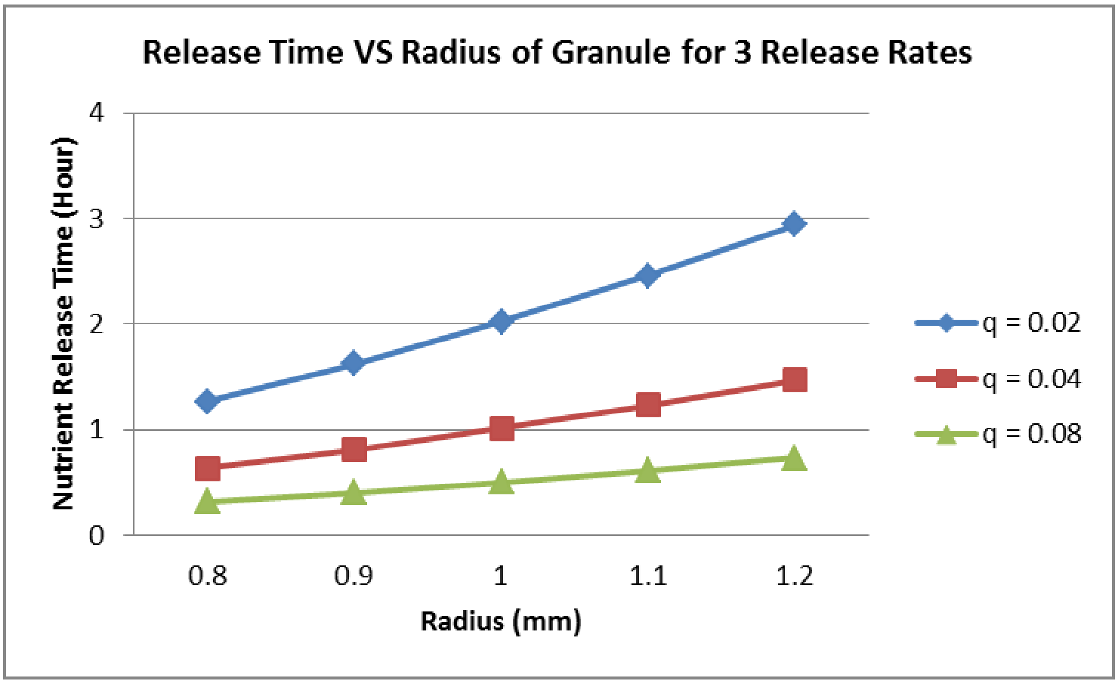


Figure 28 Nutrient release time vs granule radius (new program) for 3 release rates

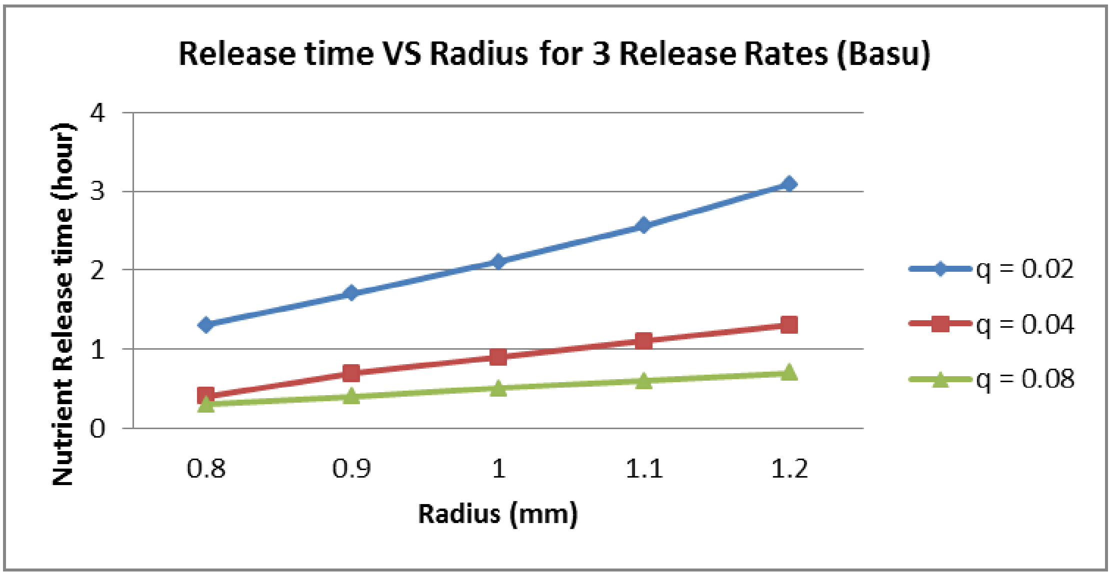


Figure 29 Nutrient release time vs granule radius (lit [1]) for 3 release rates

Figure 30 and 31 shows the effect of granule radius to the nutrient release time of the new program and from literature [1] respectively for 3 contacts. The nutrient release time reduce in tremendous way as the surface area contact becomes larger.

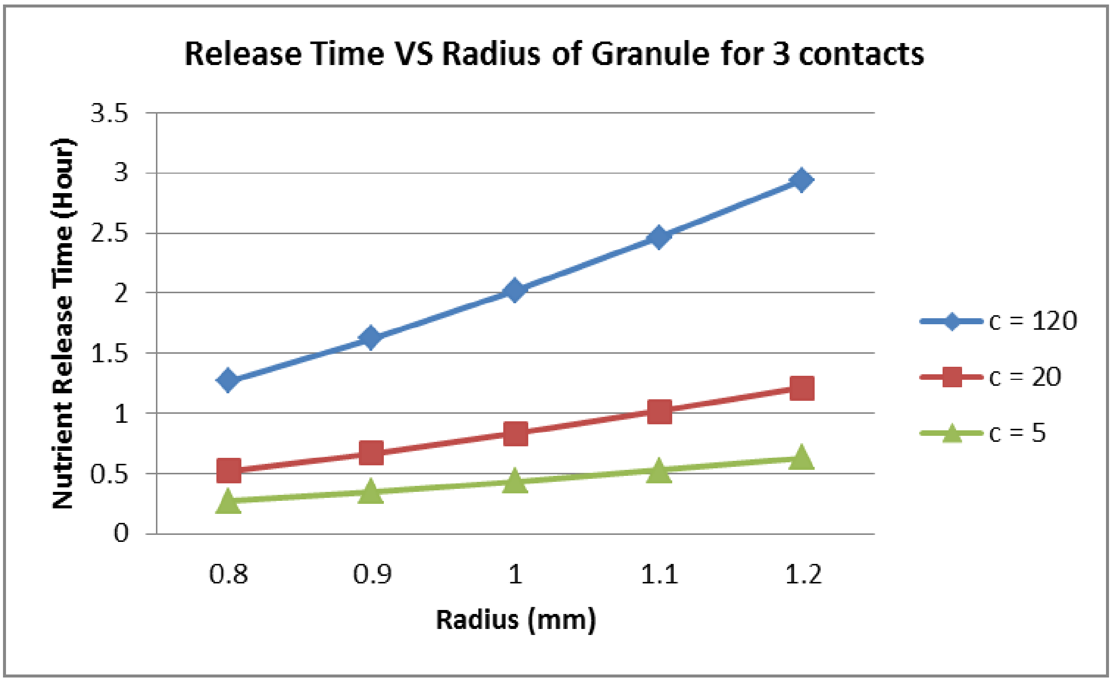


Figure 30 Nutrient release time vs granule radius (new program) for 3 contacts

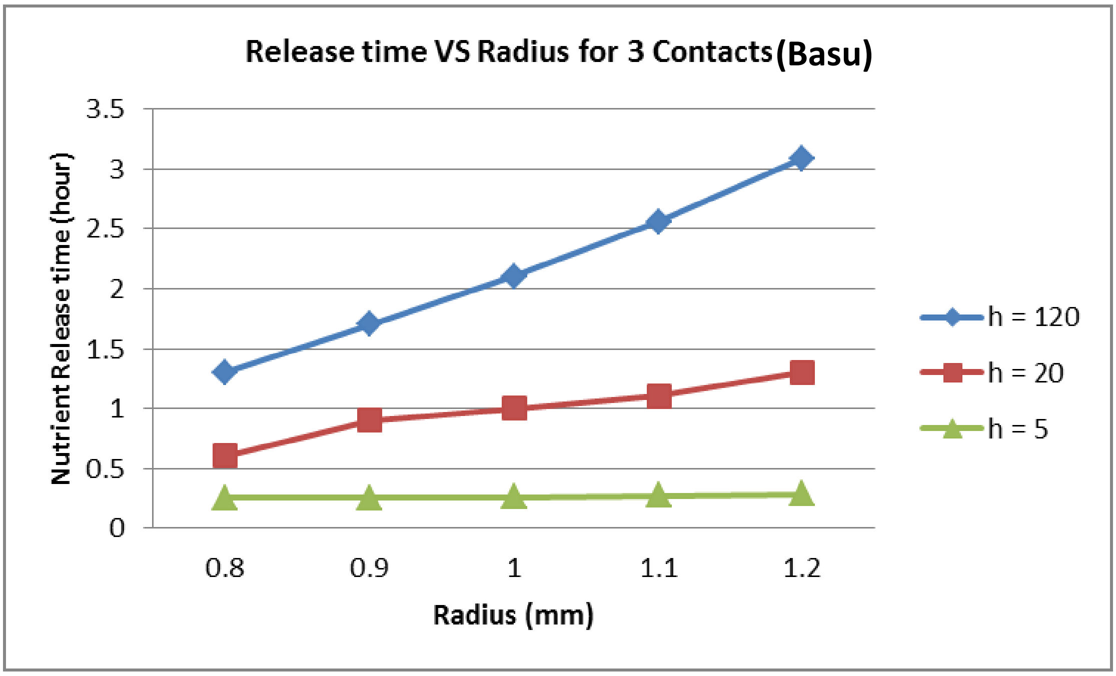


Figure 31 Nutrient release time vs granule radius (lit [1]) for 3 contacts

Figure 32, 33, 34 and 35 shows the effect of water diffusivity to the nutrient release time for three surface area contacts and three different release rates of the new program and from literature [1] respectively. Both trends show that the nutrient release time decreases faster when both of the parameter (surface area contact & release rate) increase.

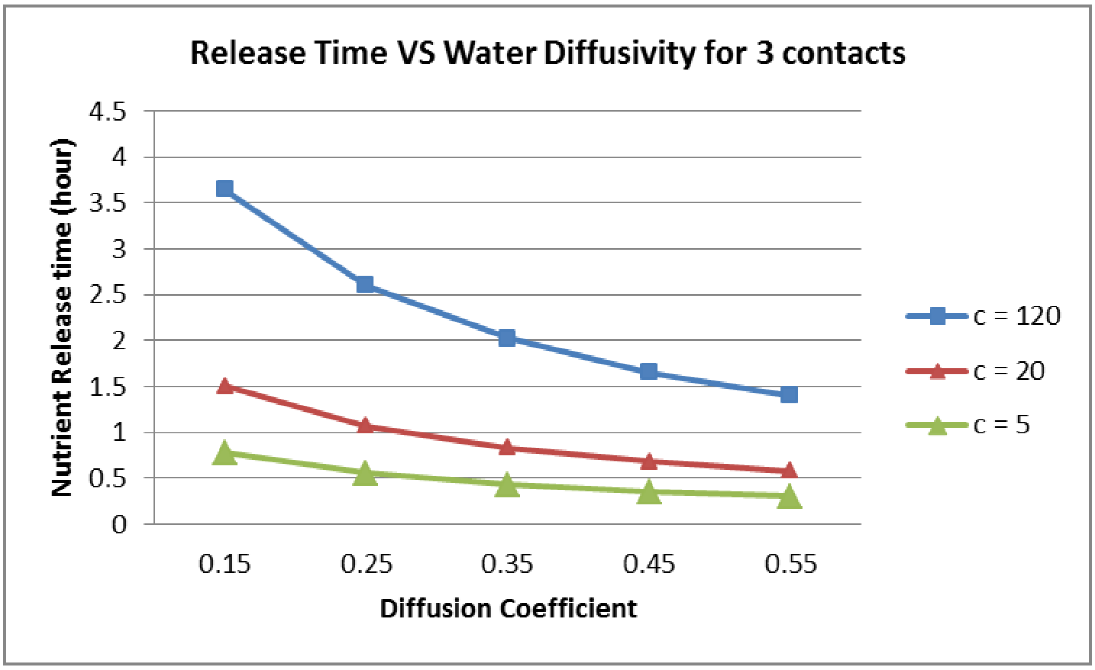


Figure 32 Nutrient release time vs diffusion coefficient (new program) for 3 contacts

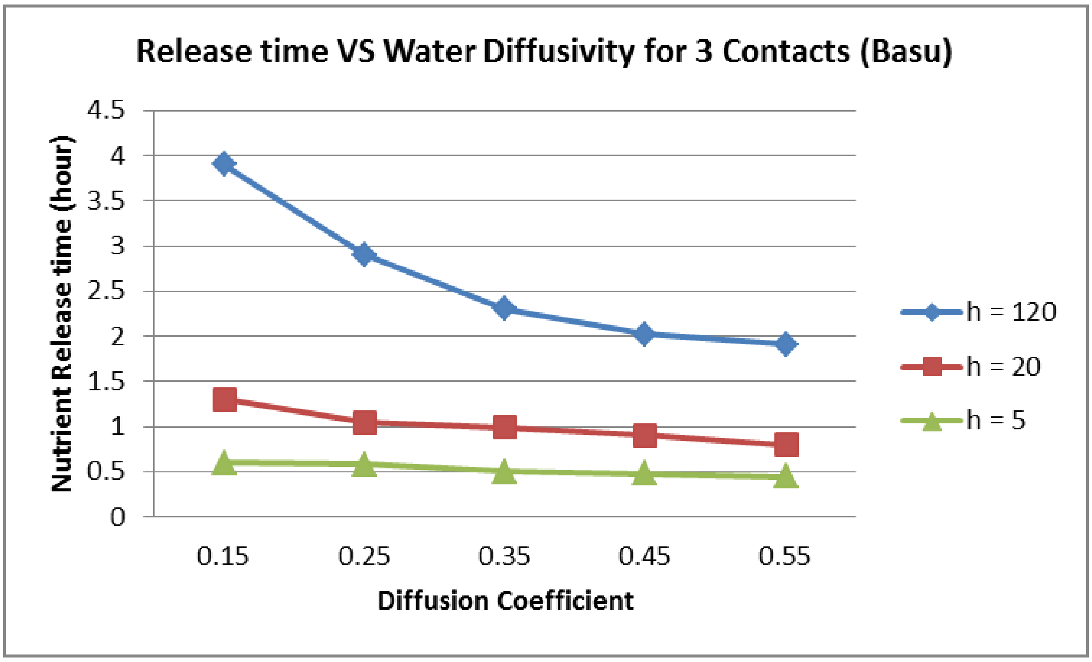


Figure 33 Nutrient release time vs diffusion coefficient (lit [1]) for 3 contacts

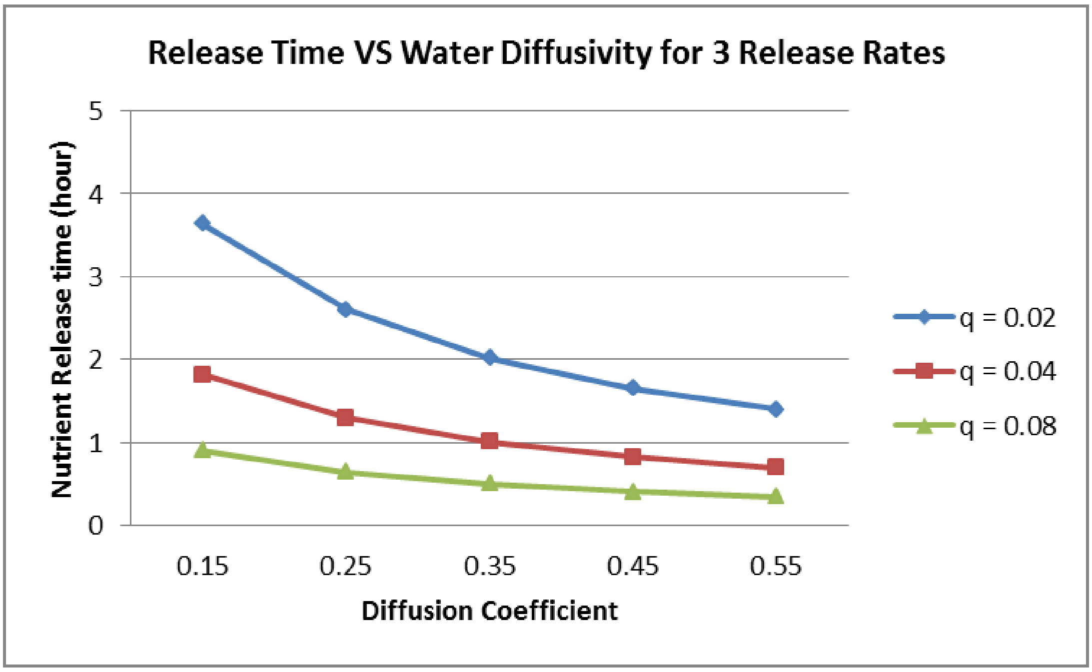


Figure 34 Nutrient release time vs diffusion coefficient (new program) for 3 release rates

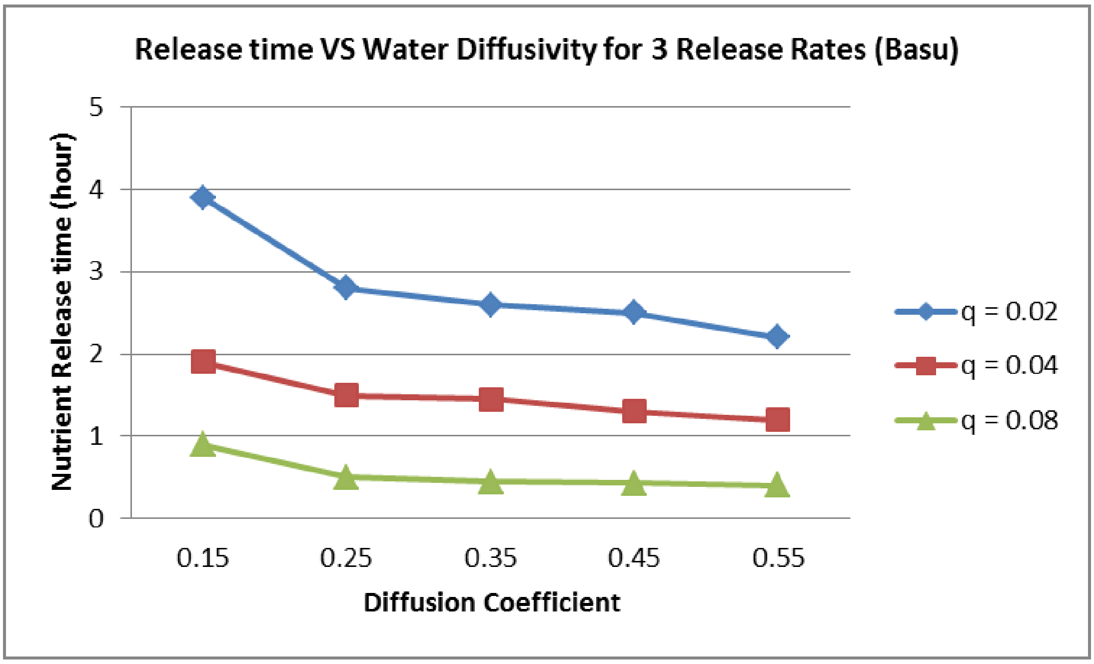


Figure 35 Nutrient release time vs diffusion coefficient (lit [1]) for 3 release rates

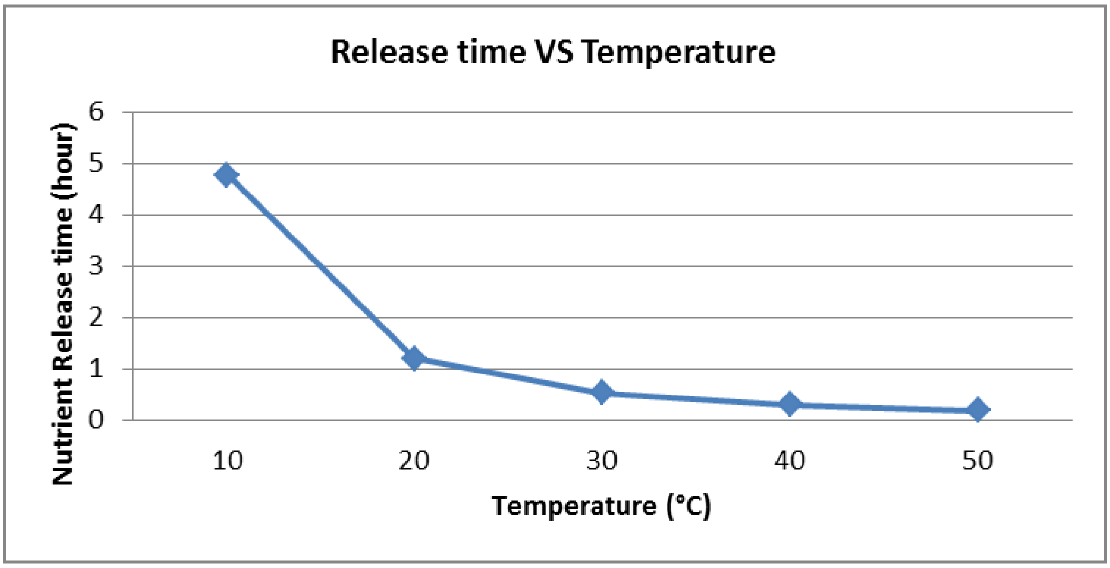


Figure 36 Nutrient release time vs temperature

Figure 36 shows the relationship between nutrient release times with the temperature. The increase in temperature will speed up the rate of nutrient release from the granule; this is because temperature is one of the catalysts factors that can speed up most of the chemical process and nutrient release is one of the processes. Therefore fertilizer in country with high temperature in climate will release nutrient faster than the one in cold-weather environment.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

Base on all the comparison of simulation made in between the new program and literature [1], all simulations are in the same trends and with close value. Thus this new program can be used to determine and simulate the time taken for water saturating the granule and also the time taken for nutrient released from the granule.

The development of this program will ease the user (farmer/person involve in agriculture) to determine which fertilizer is the best to be use in their plantation. The users can determine the best fertilizer by using some important parameter such as the granule radius, the evaporation factor and surrounding temperature, the diffusivity of water and nutrient, the release rate of the coating material and also the surface contact of the granule with the ground. Users also can further analyse the result of the simulation as all data was tabulated in the Microsoft Excel® file.

However, still this program is not the ultimate program for modelling and simulation of nutrient dispersion because there are still a room for improvement. The program can be further improved by specifying the right method of determining the release rate, q for a coating material. This can be done by assigning one type of coating as the main reference in term of the release rate. The new release rate, q of other coating material can be determine by comparing the time taken for nutrient release of the desired coating with the reference coating, and this must be done at the first line in the production process of the fertilizer in the factory which mean that, the producer must do the experiment to determine the time taken of nutrient release and the release rate to include this information together with the fertilizer produced. The other improvement that can be done in this program is by varying the shape of the fertilizer granule, by conducting experiment, maybe the best fertilizer are not in the sphere shape anymore, therefore this program must be further improved to satisfied the other shape of granule. In term of water saturation time in the granule, the effect of gravity must be further study to ensure this program can satisfied the phenomenon of gravitational force and eventually will make this program as the ultimate for modelling and simulation of nutrient dispersion of coated-fertilizer granule.

CHAPTER 6: REFERENCES

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Appendices

Appendix A: Gantt Chart

Activities / week	1	2	3	4	5	6	7	8	9	10	11	12	13	14		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of Project Title	■																												
Literature review		■	■	■	■																								
Identifying the objective and goals		■	■	■	■																								
Identifying the Mathematical formulations		■	■	■	■																								
Submission of Extended proposal						■																							
Proposal defend									■																				
Literature review / data collection										■	■	■	■	■	BREAK	■	■	■											
MATLAB revision and practice						■	■	■	■	■	■	■	■	■		■	■	■	■	■									
Coding / implementation/validation												■	■	■		■	■	■	■	■	■	■	■	■	■	■	■		
Analysis												■	■	■		■	■	■	■	■	■	■	■	■	■	■	■		
Interim report draft													■																
Interim report final draft														■															
viva																												■	■
Final report																													■

Appendix B: Some of The MATLAB Coding

```
%---------------------------- Main Coding -----------------------------
------
clc
% take time input from user
disp ('Welcome to FertilizerModelling™ Program')
fprintf ('\n')
disp ('This program is to calculate:')
disp ('1) Time taken for water to saturate in the granule &')
disp ('2) Time taken for nutrient released from the granule')
fprintf ('\n')
disp ('Please key in the following data to proceed')

% ----------------------------- input -------------------------------
------
a = 0;
k1 = 'Number of Radii, k = ';
k1 = input(k1);
m0 = 'Number of Release Rate, m0 = ';
m0 = input(m0);
m = 2;
w = 'Contact area parameter, w = ';
w = input(w);
Evafactor = 'The Evaporation Factor = ';
Evafactor = input(Evafactor);

inputQ

disp ('Please refer the result in the Excel file')


% ----------------------------- inputQ ------------------------------
------
offset = 5;
disp('Please insert the Column name (C%d):')
fprintf ('\b')
column = 'Column = ';
column = input(column);
% column = 'C%d';
k = 2;

Dw = 'Water Diffussion Coefficient, Dw (mm2/hour) = ';
Dw = input(Dw);

T = 'Temperature (°C) = ';
T = input(T);

q1 = 'Nutrient Release Rate, q = ';
q1 = input(q1);


FinalCoding
```

```
%------------------------ Final Coding ------------------------------
------
clc

disp ('Welcome to FertilizerModelling™ Program')
fprintf ('\n')
disp ('This program is to calculate:')
disp ('1) Time taken for water to saturate in the granule &')
disp ('2) Time taken for nutrient released from the granule')
fprintf ('\n')
disp ('Below is the parameter with value')
% fprintf ('Number of Radii, k = %d\n', k)
% fprintf ('Number of Release Rate, m0 = %d\n', m0)
fprintf ('Contact area parameter, w = %d\n',w)
fprintf ('The Evaporation Factor = %g\n',Evafactor)
fprintf ('Water Diffussion Coefficient, Dw (mm2/hour) = %g\n',Dw)
fprintf ('Nutrient Release Rate, q = %g\n',q)
fprintf ('Column in Spreadsheet = column %s\n',column)
fprintf ('The Current Radius value = %g\n',a)
fprintf ('\n')

%--------------------------------------------------------------------
------
offset = offset + 1;
%time = 'Time of fertilizer application = ';
%time = input(time,'s');
a = 'Granule Radius, a (mm) = ';
a = input(a);

% w = 'Contact area parameter, w = ';
% w = input(w);
% Dw = 'Water Diffussion Coefficient, Dw (mm2/hour) = ';
% Dw = input(Dw);
% Evafactor = 'The Evaporation Factor = ';
% Evafactor = input(Evafactor);
% q = 'Nutrient Release Rate, q = ';
% q = input(q);
DeltaX = 1;                             % this is fix
% distance between two successive horizontal circles
DeltaZ = 0.01;
%Delta_time = 'Delta_time = ';          % we take 0.005
%Delta_time = input(Delta_time);
Delta_time = 0.005;
Gamma1 = 3.30;                          % Fix (Length)
Gamma2 = 0.04;                          % Fix (Length)
% Radii = 'Radii, k = ';                % Granule Radii, k
% Radii = input(Radii);
% k1 = 1;                               % starting value for loop K
Ts = 0;                                 % initial value for
saturation time
n0 = 2*(a-a/w)/DeltaZ;                  % no of horizontal circle
n = 1;                                  % starting value for loop N
z = -a;

rs = sqrt(a^2 -(-a+(a/w))^2);
b = rs/a;                          % to determine the value of b
q = q1;
q = b*q1;
```

```
%-----------------------------------------------------------------------
------
% Function of simulation time and nutrient release time
Saturation                                      % Call Saturation function

Release                                         % Call Release function

disp ('Result tabulated') %just to make sure it 'return'
fprintf('\n')

while k <= k1
        k = k + 1;
        FinalCoding
end

while m <= m0
        m = m + 1;
        disp ('Press ENTER to key in new value for Release Rate, q.')
        pause
        clc
        inputQ
end


% disp ('Press ENTER to proceed with other value.')
% pause
% FinalCoding                                     % to repeat the program

%------------------- Main Code for Saturation------------------------
------

t = 0;                          % starting value for time
z = z + DeltaZ;                 % the circle are choosen from z=(-a+dz)
to z=(a-dz)
R = sqrt(a*a - z*z);            % radius of one such circle at any
point on z axis
tMax = Gamma1*R/Dw;             % time period of saturation for each
such circle
DeltaR = R/DeltaX;              % Uniform interval for horizontal
circle

Ts = Ts + tMax;                 % to accumulate the total saturation
time

% b = a*sqrt((2*w-1))/(w*DeltaR);

% Calling for Loop N Function
LoopNFinal

%---------------------------- Main Coding ---------------------------
------

while n >= n0
        T_hour = Ts/100;
        T_evafact = round(T_hour);                              % round
off the time T
        Loss_Factor = abs(Evafactor*(12-abs(T_evafact-12))); %
calculate the loss factor
        Inc_Factor = 1 + (Evafactor/(1-Loss_Factor))*3;
```

```
        Saturation_Time = T_hour*Inc_Factor;
        fprintf ('\n')                                          % New
line
        disp('Total Saturation Time (hour): ')
        disp(Saturation_Time)
        %disp(Ts/100)
        return
end
        n = n+1;
        Saturation

%------------------------ Main Coding -------------------------------
------
%Continue from Saturation time program


Dn = Dw+0.1;                            % Nutrient diffusion
coefficient
% The Final redius value, fixed to 0.2mm
d = 0.2;                                % Final redius value, fix to
0.2 mm
% m0 = 'Number of release rate, (m0) = ';
% m0 = input(m0);
%q = 'Release rate, (q) = ';            % release rate, base on
coating width
%q = input(q);
%q = 0.02;
% m = 0;                                % initial value for loopM
Tr = 0;                                 % initial value for release
time
aa = a;
%q = 2*b*q;
                              % untuk kita manually control q
NewDn = Dn*(T^(1.9955)+1);

CalcNutrient


%------------------------------- Main Coding ------------------------
------

while aa <= d
        %Tr_hour = Tr/100;
        disp('Total Nutrient Release Time (hour): ')
        disp(Tr)
        disp('Tabulating the value')


xlswrite('filename.xls',Saturation_Time,1,sprintf(column,offset));
        xlswrite('filename.xls',Tr,2,sprintf(column,offset));
        return
end
        aa = aa - DeltaZ;
        CalcNutrient
```