DISSERTATION

A STUDY OF CHRISTIANSEN'S COEFFICIENT UNIFORMITY (CU) OF WATER DISTRIBUTION IN A SPRINKLER IRRIGATION SYSTEM

By

NOOR AZREEN BINTI ABU AZRI
15465

Supervisor : AP. Dr. Khamaruzaman Wan Yusof
Internal Examiner:AP. Ahmad Mustafa B Hashim
External Examiner : Ir. Mazura Nor Bt Zulkifli

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UniversitiTeknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak DarulRidzuaN

CERTIFICATION OF APPROVAL

A Study of Christiansen's Coefficient Uniformity (CU) of Water Distribution in a Sprinkler Irrigation System

by
Noor Azreen Binti Abu Azri
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Approved by,

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(AP. Dr. Khamaruzaman Bin Wan Yusof)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
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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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NOOR AZREEN BINTI ABU AZRI

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ABSTRACT

The application of sprinkler as the irrigation is widely used to the world, but the system is detected still not too efficient since there are some problems exist regarding to the water distributions and shows the poor uniformity of the sprinkler also the value of coefficient uniformity (CU) of the water distribution not in a satisfactory level. This study is conducted to evaluate the uniformity of water distributions on the sprinkler system based on Christiansen's Coefficient of Uniformity (CU).

The "Catch Can" experiment is done by use the combination of three types of sprinkler in rotating head, three different levels of water pressure and height of the riser of the sprinkler system. The types of sprinkler rotating head used in the research are Plastic Impact Sprinkler, Rain Bird Sprinkler and Orbit Spinning Sprinkler. While the levels of water pressure used are 12, 15, and 18 Psi respectively. Then, the heights of riser tested in the experiment are 1, 0.75 and 0.5 meter (m) respectively. From the "Catch Can" experiments the CU values were evaluated to determine the coefficient uniformity of water distribution. The purpose of this experiment is to get the CU value and do the comparison by combination types of sprinkler rotating head, levels of water pressure and height riser of the sprinkler.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Background Study

1.1.1 Irrigation System

Irrigation is defined as the application of water to the field. To have the good irrigation system, the efficient application of the correct amount of the water need to be more appropriate with the right time and place [16].An efficient irrigation method is that which best suits local condition such as [16]:

I. Soil characteristic
II. Kind of crops and its age
III. Crop rotation
IV. Topographic condition
V. Available water flow
VI. Underground water condition
VII. State of soil salinity

Figure 1.0: Normal Irrigation System

There are a lot of methods of irrigation can be used to irrigate the plants or fields. The methods of irrigation can be classified as follows [16]:

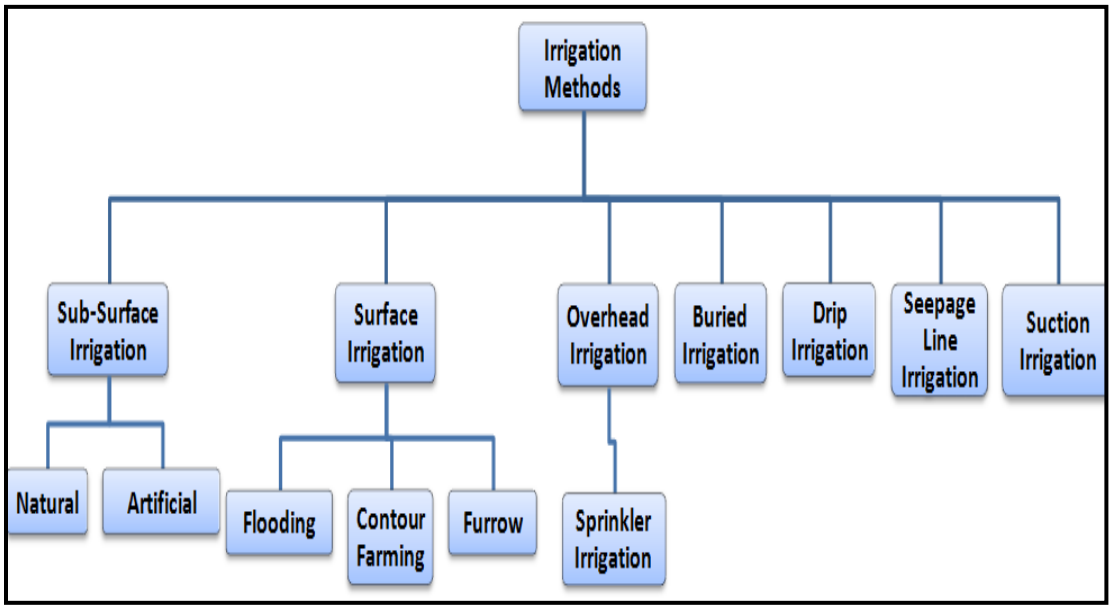

Figure 1.1: Methods of Irrigation

The primary objective of any irrigation method is to supply water to soil so that moisture will be readily available at all times for crop growth but without indiscriminately adding to the water table, as well as avoiding influence of soil sanity especially during the periods less of rainfall [16].

1.1.2 Sprinkler Irrigation System

In this study, the author will focus on the sprinkler irrigation system. The application of the sprinkler irrigation system is suitable and very widely used by people as the irrigation to the plants and landscape. It is because of sprinkler system is one of the faster way to irrigate the plants and landscape.

Sprinkler irrigation is an improvement over conventional surface irrigation. The basic objective of sprinkler irrigation is to simulate rainfall and uniformly apply a calculated amount of water at a specific rate [18].

The sprinkler system is started with water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. The spray is developed by the flow of water under pressure through the nozzle. The pressure of the water flow is usually obtained by pumping. Selection of nozzle sizes, operating flow pressure and sprinkler head spacing will determine the amount of irrigation water to the ground [15].

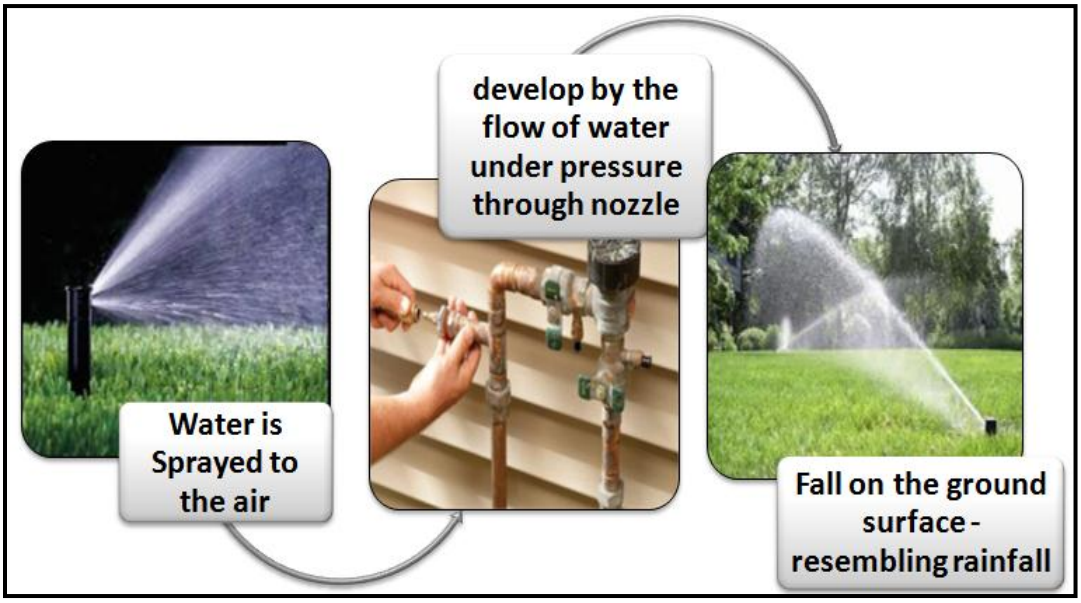

Figure 1.2: Sprinkler Irrigation System

The sprinkler irrigation is suitable for all types of soils, more particularly coarse, sandy, and gravelly soils and for almost all crops. However, it is not recommended for crops having high water such as rice, jute and plantation like coffee, and tea. It is particularly suitable for production of high yielding crops or for having continuous and quick growth of valuable crops [15].

There are many types of sprinkler system and it has own its classification [15]:

1. Classification Based on Spraying Pattern
   i. <u>Rotary head or revolving system</u>

      In this system nozzles are mounted on riser pipes at uniform intervals along the lateral pipe which may be laid on the ground or installed on posts above the crops.

   ii. <u>Perforated sprinkler system</u>

      It is a simple, low-cost sprinkler. In this system water is carried through the main pipeline and let out through lateral pipelines which have small perforation of 5 mm or smaller diameter.

2. Classification Based on Sprinkler Head

   i. Fixed head type

      Various type of fixed head sprinkler is used for irrigation of turf, and ornamental gardens. Parallel pipes with fixed nozzles are installed apart, supported on rows of posts. Water is controlled by pressure passing through the pipes discharges perpendicularly from the pipelines.

   ii. Rotary head type

      Most of agriculture uses this type. Rotary heads move in circular manner and water is thrown by spray head to a considerable distance.

There are also some advantages of using sprinkler system as irrigation method. Such as [16]:

i. Saves water, and irrigates more land
ii. Less of water loss
iii. Effective way for water management
iv. Saving in fertilizer
v. Land leveling not necessary to irrigate the hilly crops
vi. Drainage problems eliminated
vii. Crops are protected from frost damaged
viii. Faster way of irrigation

1.1.3 Christiansen's Coefficient Uniformity (CU)

Moshrefi (2010) has found the performance of a sprinkler irrigation system is always evaluated from the uniformity coefficient that collected in some of measuring devices [1][7]. The one of most frequently referenced measures to determine the coefficient uniformity of an irrigation sprinkler system is by using Christiansen's Coefficient of Uniformity (CU)[1][2][7].

Christiansen's Coefficient of Uniformity (CU) is defined as relationship between the average depth of measured water in total container used and overall depth of measured water [2][7]. There are two measuring methods that frequently used to determine CU value which are rain gauge and "catch can"methods [8].

The accuracy of irrigation depth measurement of several catch cans was also studied by Marek and Howell [6]. Both of the methods have the same concept but different equipments for the experimental work.

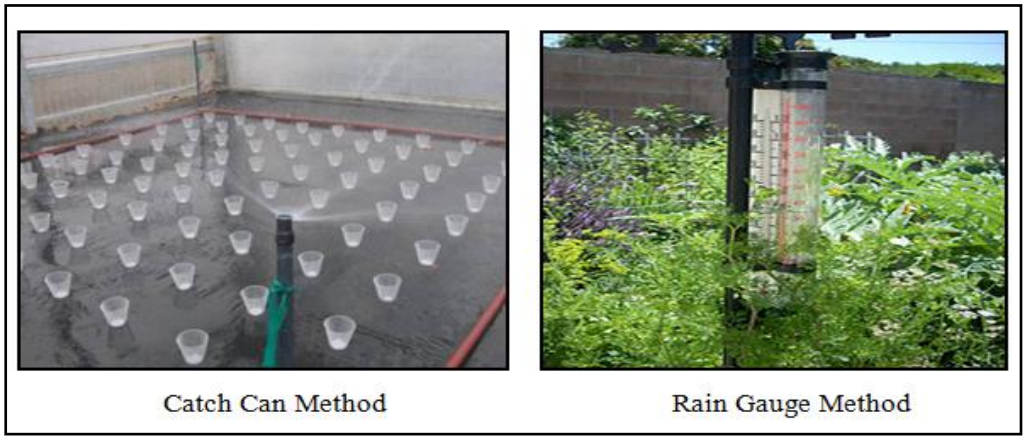

Figure 1.3:"Catch Can" and Rain Gauge Method

The importance of CU in the irrigation of sprinkler system is it will determine the performance of the sprinkler irrigation system. To get the satisfactory level of CU need a high uniformity of the sprinkler irrigation [3][4][7].

The satisfactory level of CU is 80 % to be the minimum acceptable performance in the sprinkler irrigation system, while the low CU values often indicate an incorrect combination of nozzle number and size, operating pressure, and head spacing [5].The coefficient of uniformity (CU) for the irrigation sprinkler system can be calculated based on the catch can or rain gauge test by use the given formula [2]:

$$C_u = 100\left[1 - \frac{\sum |a|}{m \cdot n}\right] \quad (\%)$$

Figure 1.4: Formula of Christiansen's Coefficient Uniformity (CU).

Where;

CU is Christiansen's Coefficient of Uniformity and it is determined as percentages. For "***a***" is the sum of the deviations of each observation from "***m***", the mean value of such observations and *"**n**"* is the number of observations All deviations from the mean are positive numbers[1].

1.2 Problem Statements

The application of sprinkler as the irrigation is widely used to the world, but the system is detected still not too efficient since there are some problems exist regarding to the water distributions and shows the poor uniformity of the sprinkler also the value of coefficient uniformity (CU) of the water distribution not in a satisfactory level. As a result, some parts of the area will over-irrigate and under irrigate.

Figure 1.5: Over Irrigation Problem

Figure 1.6: Non-Uniformity of Water Distribution from a Sprinkler System

One of the problems caused the non uniformity of water distribution is the unsuitable combination of type of sprinkler rotating head, water pressure, and height riser of the sprinkler. The non-uniformity of water distribution will determine the Coefficient of Uniformity (CU) value for the irrigation of a sprinkler system. Since the acceptance level of CU is 80%, further improvements should be done on the sprinkler system to obtain the good water distribution of a sprinkler system.

The "Catch Can" experiment will be used by changes the level water pressure, nozzle diameter and riser height. The purpose of this experiment is to choose the suitable nozzles diameter, water pressure and height of the sprinkler riser that will be used in future.

1.3 Objectives of the Study

The objective of this study is to evaluate the uniformity of water distributions on the sprinkler system based on Christiansen's Coefficient of Uniformity (CU).

1.4 Scope of Study

This study will be focused on the sprinkler system that used for plant irrigation. Beside that to full fill the objectives of this study which is to evaluate the uniformity of water by using Christiansen's Coefficient of Uniformity (CU).

The "Catch Can" experiment were done by uses different type of sprinkler rotating head, different levels of water pressure and height of the riser of the sprinkler system.

From the "Catch Can" experiments the CU value were evaluated to determine the Coefficient Uniformity % (CU) of water distribution. The purpose of this experiment is to see the comparison value of CU while using the combination of parameters of the experiment.

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

There are various studies that have been done to determine the efficiency of sprinkler irrigation system through experiment methods by different researchers. Topak et.al [20], has investigated that the performance of a sprinkler irrigation system always evaluated based on water distribution collected in an array of measuring device such as “Catch Can”.

2.1 Effects Combination of Water Pressure and Height of Riser to the Uniformity of Water Distribution

Pressure (kPa)	6.1 Height (m)		7.0 Height (m)		7.8 Height (m)	
	1.0	1.5	1.0	1.5	1.0	1.5
100	—	90.0	87.1	92.2	92.5	89.3
150	92.2	90.3	92.3	91.1	92.6	91.2
200	92.3	91.8	92.4	92.1	91.4[a]	92.0[a]
100	—	93.6	86.8	93.7	93.5	91.7
150	93.7	90.4	94.1	91.5	94.2	91.1
200	93.9	91.3	94.1	90.9	91.6[a]	92.1[a]

Figure 2.0: Result of Coefficient Uniformity (CU) [7]

Figure 2.0 shows that the result of Coefficient Uniformity (CU) that was studied by Sorell et. al, by conducted the "Catch Can" experiment by using three different diameter of nozzle, two different height of riser for sprinkler, and three different level of water pressure to obtain the CU value. From the CU value obtained which is above 85 %, it shows that the coefficient of uniformity for the water distribution for the sprinkler system is in good level [7].

In addition, the suitable combination water pressure and riser height will produce a good distribution of water in a sprinkler irrigation system [18]. According to Shearer (1969) [17], by improving the application uniformity of a sprinkler system can reduce the water supply to irrigate a given area. Plus, the operating cost will lower by the saving water.

2.2 Effect Height of Riser and Water Pressure to Water Distribution

The height of riser also is the main factor to produce a good uniformity of water distribution.

Height of Riser (m)	Water Pressure (kPa)	Coefficient Uniformity (CU) (%)
0.3	104	83
0.6	104	85
0.75	104	88

Table 2.1: Comparison CU Value based on Height of Riser [11]

Based on table 2.1 as above, the CU values were obtained by using different height of riser, same water pressure and wider sprinkler nozzle. This study was conducted by Keller and Bliesner (1990) by using "Catch Can" experiment too. It shows that, the height riser of height 0.75 m got the high value of CU, which is 88 %, and the level of CU is in good condition [11].

Sprinkler discharge (m^3/minute)	Riser Height (m)
Less than 0.037	0.15
0.037-0.094	0.23
0.094-0.189	0.30
0.189-0.454	0.46
More than 0.454	0.91

Table 2.2: Height of Riser and the Sprinkler Discharge from Natural Resource Conservation Service (NRCS), 1983 [14]

Besides that, Natural Resources Conservation Service (NRCS) has set up the guideline of the height of riser of sprinkler irrigation system and the sprinkler discharge per minute as table 2.2 above. According to NRCS (1983) also, riser pipes used on lateral lines shall be high enough to prevent interference with the distribution pattern when the tallest crop is irrigated. Plus, height of riser shall not be less than as the shown table above.

Plus, Susanawatiet. al [19] was performed a test by using "Catch Can" experiment by using different level pressure and height of riser, which the level pressure were 138, 172, 207 kPa respectively and the height of riser were 50, 100, and 150 cm respectively. The CU result shows 96% by using 172 kPa of water pressure and 50 cm height of riser.

Mis. J (2008), was conducted a "Catch Can" experiment by using three different heights of riser which is 30 cm, 60 cm and 75 cm at 104 kPa of water pressure, and the result of CU were showed as 83%, 85% and 88% respectively [13].

2.3 Comparison CU value Based on Nozzle Diameter and Type of Sprinkler

Nozzle Diameter (mm)	Type of Sprinkler	Coefficient Uniformity (CU) (%)
5.6	Fixed	80
6.9	Rotating	90

Table 2.3: Comparison CU Value for Fix and Rotating Sprinkler [12]

Table 2.3 as above shows that the "Catch Can" experiment was conducted by Moshrefiet. al (2010) [12] by using fix and rotating sprinkler. It is to determine the uniformity of the system under low pressure which was 103 kPa and used two different type of nozzle diameter. The CU value was showed 90 % for rotating sprinkler and 80 % for fixed sprinkler. Rotating sprinkler was obtained good level of CU compared to the fix sprinkler which was obtained average level of CU.

2.4 Christiansen's Coefficient of Uniformity Value Basic Interpretation

Cu Value Range (%)	Level Of Uniformity
< 65	Inadequate
65-75	Stable
75-85	Average
> 85	Good

Table 2.4: Level of Coefficient Uniformity (CU)[7][9]

Table 2.4 shows the level of Coefficient Uniformity (CU) of the water distribution in the sprinkler irrigation system. For the CU value less than 65% indicates that the level of uniformity is inadequate, while for the CU value more that 85% indicates that the uniformity is good [7][9].

CHAPTER 3

METHODOLOGY& PROJECT ACTIVITIES

3.0 METHODOLOGY

The methodology will be done by solve the problem of sprinkler irrigation system that had been stated at the objectives of this study:

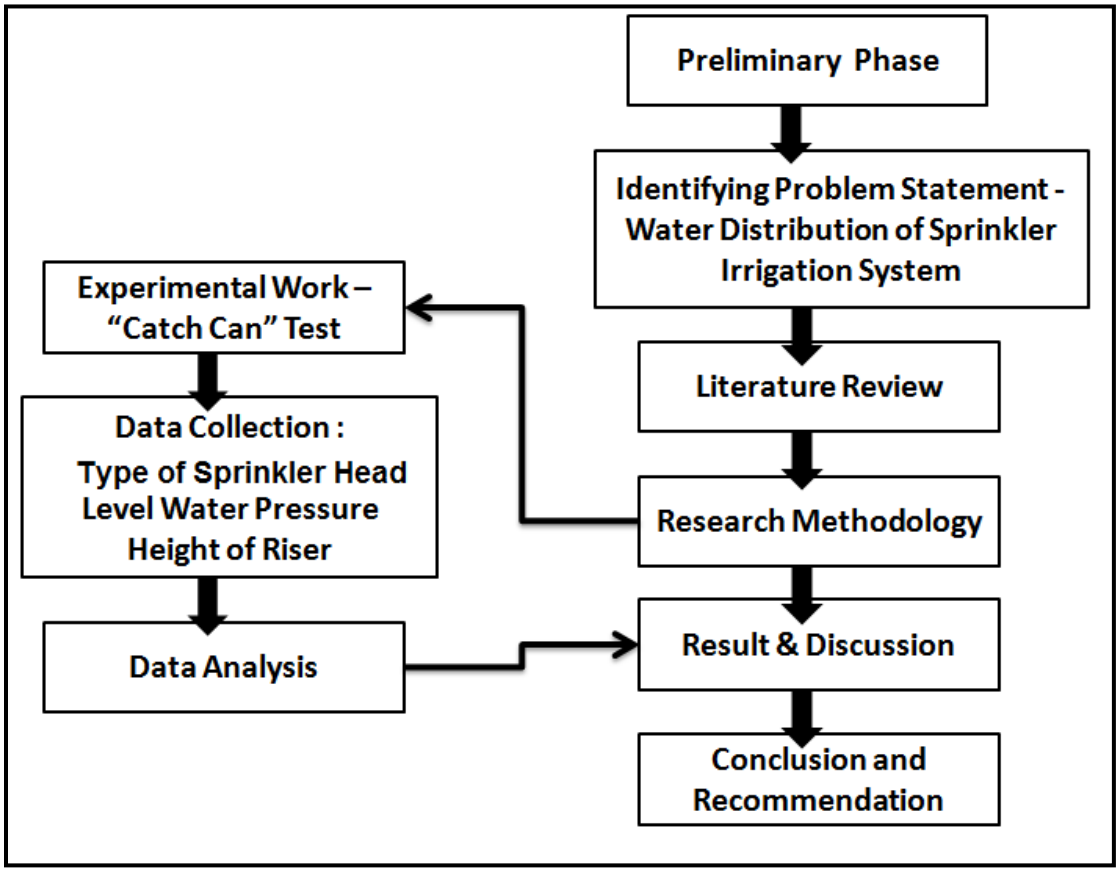

Figure 3.0: Work Sequence for "A Study of Christiansen's Coefficient Uniformity (CU) of Water Distribution in a Sprinkler Irrigation System".

Preliminary Phase

This study was started with the preliminary phase by revise some of the research and journals related to the topic, and the research and journals already be summarized to come out with the literature review problem statements, and research methodology.

Identifying Problem Statements

The problem statements were done by reviewing the journals and research. Besides that, some observations were done at UTP surrounding on sprinkler irrigation system. There are a lot of over irrigation under irrigation problems happened.

Literature Review

This stage also by reviewing and summarizing the journals and research and come out with the critical thinking of studies which is combination of suitable sprinkler head, height of riser, and level of pressure to apply into the sprinkler irrigation system and will obtain the satisfactory level of Coefficient Uniformity (CU).

Research Methodology and Data Collection

At this stage, there is "Catch Can" experiment need to be done for several times to get the satisfactory of Coefficient Uniformity (CU) value. Then, the data will be collected and evaluated by the CU formula.

Data Analysis and Discussion

Next, the data will be analyzed and make some comparison by using the Christiansen's Coefficient of Uniformity (CU) Value Basic Interpretation. Some discussion will be made, if there any error regarding to the experiment or future result.

Conclusion and Recommendations

This is the final stage of the studies. Some recommendation will be made in the study to get further improvements in future works.

3.1 Theory of Catch Can" Experiment

Figure 3.1: Example of "Catch Can" Experiment

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A "Catch Can" experiment is used to determine how long to run an irrigation for sprinkler system and how well the water is distributed over the landscape [11]. For this study, Catch Can experiment will be used to determine the volume of water that will be distributed to the area that will be tested soon.

In the test also, different type of sprinkler rotating head, different level of water pressure, and different height of riser will be used. Then the volume of the water inside of the container will be measured.

Then, the value of Christiansen's Coefficient of Uniformity (CU) will be calculated from the water distribution. The comparison will be made and choose the best combination of the three parameters to come out as the good solution for the sprinkler irrigation problem.

3.2 PROJECT ACTIVITIES - Equipments Used for Piping System in "Catch Can" Experiment

Before conducting the "Catch Can" experiment, the pump and piping system were installed. The equipments that used for the installation of pump and piping system are as follows:

Pumping System

i. Water Pump

It is used to bring up the water into the main pipeline from the water sources until the water is spreading out through the sprinkler system.

Figure 3.2: Water Pump

Specification of Water Pump;

Name : HISAKI Water Pump (1 HP)
Model : HP 32
Height Maximum : 32 Meter
Flow Rate, (Q) Maximum: 108 L/minute

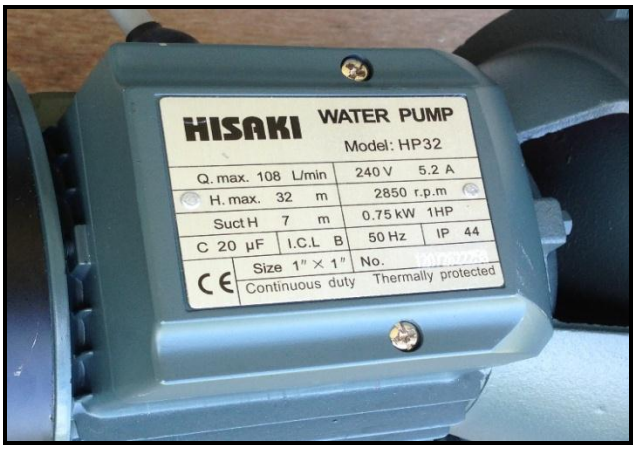

Figure 3.3: Specification of Water Pump

Piping System

i. PVC Pipes- 40 mm diameter

It is used as the main pipe of the sprinkler system that connected to the water pump. The size of the main pipes used in the piping system is 40 mm diameter.

Figure 3.4: PVC Pipe (Main Pipeline)

ii. PVC Pipes - 20 mm diameter

Figure 3.5: PVC Pipes 20 mm Diameter for Sprinkler Riser

Connectors (PVC Sockets)

i. Tees - 40 mm diameter

Figure 3.6: PVC Tees

ii. 90 Degrees Elbows – 40 mm diameter

Figure 3.7: PVC 90 Degrees Elbows

iii. Reducers 40 mm to 25 mm diameter - connected from pump

Figure 3.8: Reducers 40 mm to 25 mm diameter

iv. Reducers 40 mm to 20 mm diameter - connect to riser

Figure 3.9: Reducers 40 mm to 20 mm diameter

Other Equipments

i. Control Valve 20 mm

Figure 3.10: Control Valve 20 mm Diameter

ii. Pressure Gauge

Figure 3.11: Pressure Gauge

Here are the totals of each equipment that are used for the "Catch Can" Experiment:

No.	Equipments	Unit	Total
1.	Water Pump	Unit	1
2.	Pressure Gauge and Air Tank	Unit	1 each
3.	PVC Pipe 40 mm Diameter	Meter (m)	48
4.	PVC Pipe 20 mm Diameter	Meter (m)	4
5.	PVC Tees 40 mm Diameter	No.	5
6.	PVC Tees 40 mm to 20 mm Diameter	No.	1
7.	90 Degrees PVC Elbows 40 mm Diameter	No.	6
8.	Reducers 40 mm to 20 mm Diameter	No.	4
9.	Reducers 40 mm to 25 mm	No.	2
10.	PVC Sockets 40 mm	No.	25
11.	PVC Sockets 20 mm	No.	4
12.	Control Valve 20 mm	No.	1
13.	PVC Glue Pipe	No.	1
14.	Water Storage Tank 500 Gallons	No.	1

Table 3.0: Summary of Each Equipments Used for "Catch Can" Experiment

3.3 PROJECT ACTIVITIES - Installation of Water Pump and Piping System

3.3.1 Installation of Water Pump and Pressure Gauge

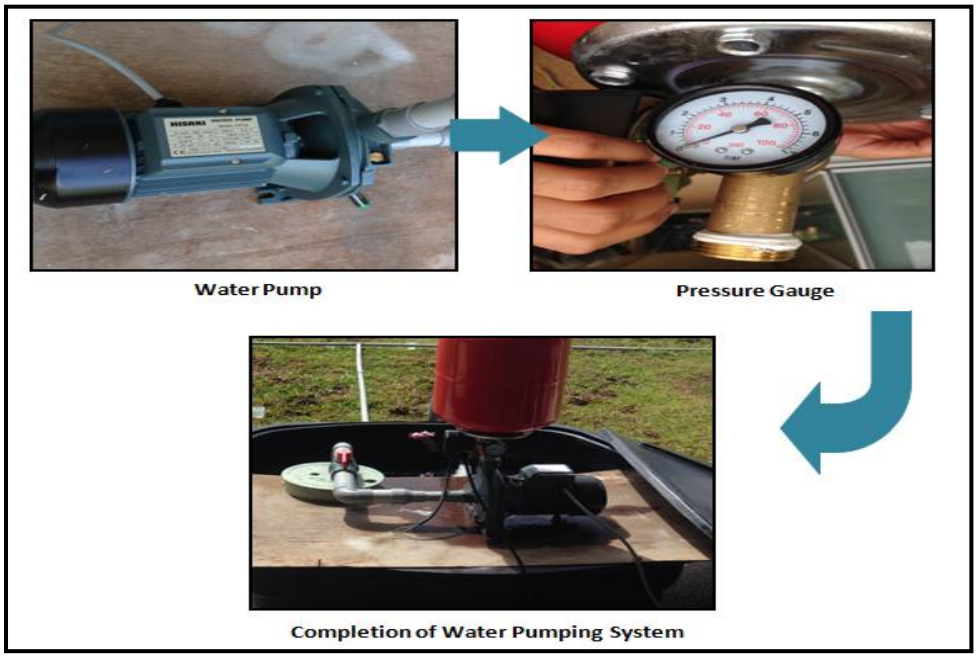

Figure 3.12: Installation of Water Pumping System with Pressure Gauge

Based on the figure 3.12 above, it shows that the installation of water pumping is begin with do the connection between water pump and pressure gauge. Then, it is connected to the main pipe by reducers and PVC sockets.

3.3.2 Installation of Piping System

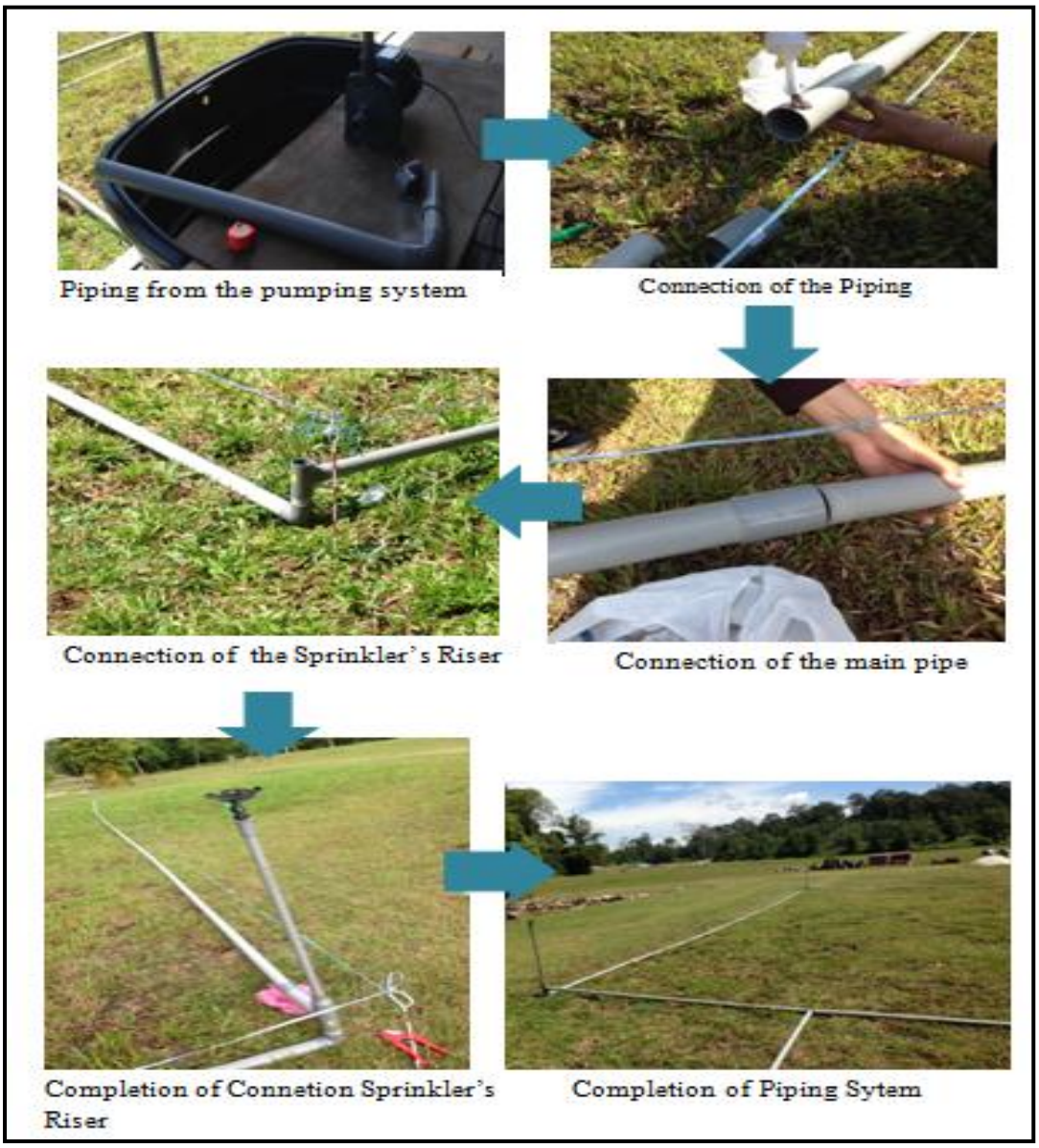

Figure 3.13: Installation of Piping System

Based on figure 3.13 above, it shows that the way of pipings that were installed, before “Catch Can” Experiment can be proceed. It is started with the piping system from the water pump is connected to the main pipe of the sprinkler system. Then, the sprinkler’s riser is glued together with reducer to the main pipe by using the PVC Tees and 90 degrees Elbows. It is applied to another sprinkler’s riser.

3.4 Project Activities – “Catch Can” Experiment on Site

3.4.1 Parameters for “Catch Can” Experiment

Here are the parameters that will be involved for the “Catch Can” experiment [8]:

i) Area for the “Catch Can” Experiment

Figure 3.14: Location of the Sprinkler

The area around of the “Catch Can” experiment will be divided based on the length of distribution of water in the sprinkler system. The sprinkler will be located at the center on area as shown as in figure 3.14 above.

ii) Arrangement of "Catch Can" Experiment

Figure 3.15: Arrangement of "Catch Can"

For this experiment, the author used radial arrangement of "Catch Can" as shown above. It is follows the guideline provided.

iii) Type of Sprinkler Rotating Head

There are three different rotating head of sprinkler that will be used for the method, which are Orbit Spinning, Bird and Plastic Impact Sprinkler in Rotating Head. The three type of rotating head will produce different way of distribution.

Figure 3.16: Plastic Impact Sprinkler Rotating Head

Figure 3.17: Plastic Impact Sprinkler Rotating Head

Figure 3.18: Orbit Spinning Sprinkler Rotating Head

iv) Height of Riser (m)

Three heights of risers are tested in the "Catch Can" experiment, which are 0.5, 0.75 and 1m respectively.

v) Water Pressure (Psi)

The sprinkler is tested by using low of water pressure. The water pressure that used in the test is 12, 15, and 18 Psi respectively which equal to 87.2, 103.4, 124.1 kPa respectively.

3.4.2 Equipment for "Catch Can" Experiment

i. Containers

Figure 3.19: 500 ml Plastic Beaker

The containers that used in the experiment are 500 ml Plastic Beaker. It is follows to the American Society of Agricultural Engineering Standard (ASAE) which required the height of container is 118 mm and 80 mm diameter of the container. Total of the container used in the experiment is 32 containers.

3.4.3 Procedure of "Catch Can" Experiment [1]

i. The containers are placed in the radial way as the layout of irrigation in figure 3.18 below, underneath the spray pattern of an area.

Figure 3.20: The Placement of "Catch Can"

ii. The pumping system and sprinklers is turned on the area for 45 minutes to 1 hour, as shown below.

Figure 3.21: The Pumping System

Figure 3.22: The Sprinkler System

iii. The sprinkler is turned off.

iv. The amount of the water that is collected in the each container will be measured.

Figure 3.23: Water Collected in the Container

v. The amount of the water (in ml) needs to be recorded in to the prepared form for each container.

vi. Water content in each container will be compared to determine if the amount is the same between them. If any discrepancies exist, changes will need to be made to sprinklers or piping so that the water is applied uniformly in the zone.

vii. The step one (1) to five (5) will be repeated by using Impact, Orbit and Bird Sprinkler with the level of water pressure is 12, 15 and 18 Psi respectively, and different height of riser which is 0.5, 0.7 and 1 m respectively.

3.5 Illustration of Sprinkler Irrigation System

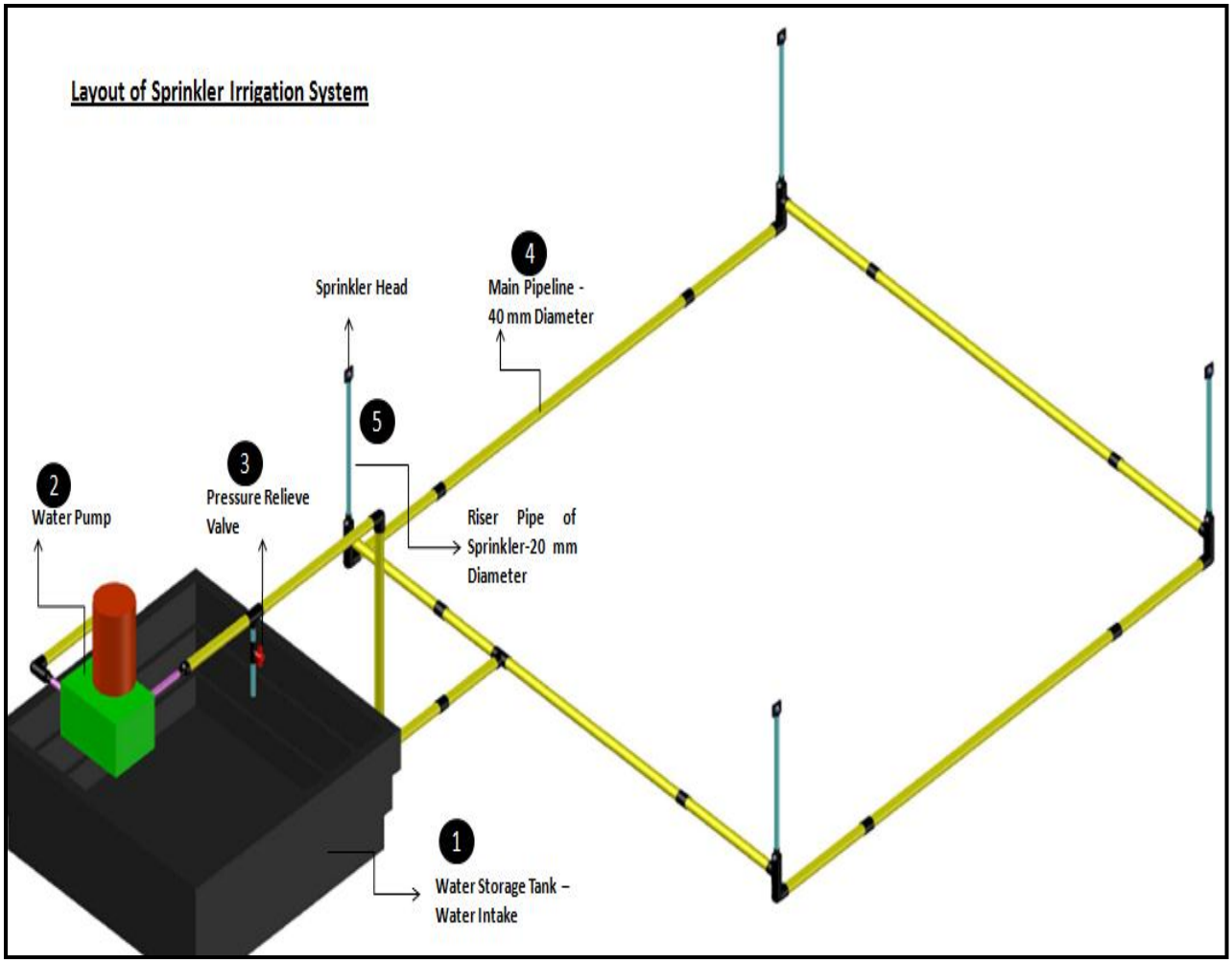

Figure 3.24: Illustration of Sprinkler Irrigation System

Figure 3.24 as above shows that the operation of the sprinkler Irrigation System. The system is started as follows:

1. The water storage tank is filled up with water from the nearby water sources.
2. The water pump is turned on for a few minutes until the flow get stable.
3. Then, the pressure relieve valve will take the main role to control the needed pressure of the water from the pump.
4. The water will go through to the main pipes.
5. Lastly, the water wills spread out from the sprinkler rotating head by the riser provided.

3.6 Evaluate Christiansen's Coefficient of Uniformity % (CU);

Since the Christiansen's method is frequently used for determining uniformity of the watering so, the result from the Catch Can test will be evaluated by using CU mathematical equation [2];

$$C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%) \qquad [2][7]$$

Where;

Cu = Christiansen's Coefficient of Uniformity (%)

a = Sum of the Deviations of Each Containers

m = Average Volume of Water Collected in Containers

n = The Number of Container Used

To evaluate sum of the deviations of each containers, ***a***;

$$|a| = V_i - m \;;\; m = \frac{\sum V_i}{n} \qquad [2][7]$$

Where;

Vi = Volume of water measured in each containers

m = Average Volume of Water Collected in Containers

n = The Number of Container Used

The coefficient uniformity of the water distribution will be compared and evaluate according the CU values interpretation as follows [7][9];

Cu Value Range (%)	Level Of Uniformity
< 65	Inadequate
65-75	Stable
75-85	Average
> 85	Good

Table 3.1: Christiansen's Coefficient of Uniformity Value Interpretation

GANTT CHART FOR FINAL YEAR PROJECT

A Study of Christiansen's Coefficient Uniformity (CU) of Water Distribution in a Sprinkler Irrigation System

No.	Details/Weeks	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15& 16	17& 18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	Topic Chosen								MID SEMESTER BREAK								STUDY WEEK & EXAM WEEKS	END OF SEMESTER MAY 2013 BREAK								MID SEMESTER BREAK						
2	Research Work (Jurnals & Materials related to the Topic)																															
3	Understanding the research topic																															
4	Consultation with Supervisor																															
5	Working on the Extended Proposal																															
6	Submission of Extended Proposal																															
7	Selection of Material for Experimental Works																															
8	Experimental Works																															
9	Data collection																															
10	Analyzing data collection																															
11	Working on Progress Report																															
12	Submission of Progress Report																															
13	Oral Presentation [FYP I & II]																															
14	Collecting materials for Poster Exhibition																															
15	Pre- SEDEX																															
16	Preparation and Submission of Technical Paper and Draft Report																															
17	Submission of Interim Report / Dissertation (soft bound) [FYP I & II]																															
18	Submission of Interim Report / Dissertation (hard copy) [FYP I & II]																															

Suggested Milestone of FYP 1

Suggested Milestone of FYP 2

Proggress Work

CHAPTER 4

RESULT AND DISCUSSION

4.0 Result and Analysis

The "Catch Can" Experiment was conducted for several times according to the parameters needed, to achieve the objective. The parameters involved in the experiment are by using three types of sprinkler in rotating head, three levels of water pressure and three numbers of pipes with different height. The summaries of parameters are as follows:

Parameters	Details
Types of Sprinkler in Rotating Head	Impact Sprinkler
	Bird Sprinkler
	Orbit Sprinkler
Levels of Water Pressure (Psi)	12
	15
	18
Height of Risers (m)	0.5
	0.75
	1

Table 4.0: Parameters Involved in "Catch Can" Experiment

The experiments are started by using the Impact Sprinkler, Bird Sprinkler and lastly Orbit Sprinkler with 1 meter height of riser while the level of pressure at the beginning of experiment is 12 Psi. The procedures of the experiment are repeated by using 0.75 and 0.5 m height of riser with 15 and 18 Psi for the level of water pressure. Then, the Coefficient Uniformity (CU) is calculated from the result of the experiment.

4.1 Combination Result of Coefficient Uniformity (%)Using Plastic Impact Sprinkler Rotating Head

Figure 4.0: Plastic Impact Sprinkler Rotating Head

Plastic Impact Sprinkler Rotating Head									
Height of Riser (m)	1	1	1	0.75	0.75	0.75	0.5	0.5	0.5
Water Pressure (Psi)	12	15	18	12	15	18	12	15	18
Diameter of Distribution (m)	11.04	11.20	11.84	11.60	12.60	14.0	14.2	14.4	14.9
Coefficient Uniformity (%)	38.6	55.33	55.49	48.1	52.2	61.1	29.7	38.2	45.1

Table 4.1: Details of Parameter Involved in “Catch Can” Experiment using Plastic Impact Sprinkler Rotating Head

4.1.1 Example of Calculation of Coefficient Uniformity (CU, %)

The example of calculation on getting the Coefficient Uniformity (CU) %, value is shows as follows:

Water Collected for Plastic Impact Sprinkler at 12 Psi Water Pressure

The Result Obtained as follows:

Line 1(ml)	Line 2 (ml)	Line 3(ml)	Line 4 (ml)	Line 5(ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
20	50	40	35	20	30	20	25
25	60	55	45	45	20	40	25
25	50	40	50	50	25	25	20
125	150	125	130	125	230	70	100
195	**310**	**260**	**260**	**240**	**305**	**155**	**170**

Table 4.2: Total Water Collected at Each Line for 12 Psi Pressure of Water

Total of Water in Containers =**1895 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 1895 ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (1895/ 32) = 59.22 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1(ml)	Line 2 (ml)	Line 3(ml)	Line 4 (ml)	Line 5(ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
39.22	9.22	19.22	24.22	39.22	29.22	39.22	34.22
34.22	0.78	4.22	14.22	14.22	39.22	19.22	34.22
34.22	9.22	19.22	9.22	9.22	34.22	34.22	39.22
65.78	90.78	65.78	70.78	65.78	170.78	10.78	40.78
173.44	**110.00**	**108.44**	**118.44**	**128.44**	**273.44**	**103.44**	**148.44**

Table 4.3: Sum of Deviation in Each Container for 12 Psi Pressure of Water

Total of "|a|" = 1164.06

The Coefficient Uniformity (CU %) Value = [1- (1164.06)/ (32 x 1895)] x100

= 38.6 %

Based on basic interpretation table of Coefficient Uniformity, the result is **inadequate uniformity.**

The calculation of Coefficient Uniformity (CU) % is repetitious with the same procedure for another height of riser, water pressures and type of sprinkler rotating head.

4.1.2 Table and Graphs for Combination of Coefficient Uniformity for Plastic Impact Sprinkler

From the experiment by use Impact Sprinkler of 1, 0.75 and 0.5 m height of riser respectively, the value of Coefficient Uniformity (CU) % for every level of water pressures is gathered as follows:

Height Of Riser (m)	Water Pressure (Psi)	Coefficient Uniformity (CU) %	Level Uniformity
1	12	38.6	Inadequate
1	15	55.33	Inadequate
1	18	55.49	Inadequate
0.75	12	48.1	Inadequate
0.75	15	52.2	Inadequate
0.75	18	61.1	Inadequate
0.5	12	29.7	Inadequate
0.5	15	38.2	Inadequate
0.5	18	45.1	Inadequate

Table 4.4: Value Coefficient Uniformity (CU %) for 12 Psi, 15 Psi, and 18 Psi Pressure of Water at 1 Meter Height by using Plastic Impact Sprinkler Rotating Head

1m Height of Riser

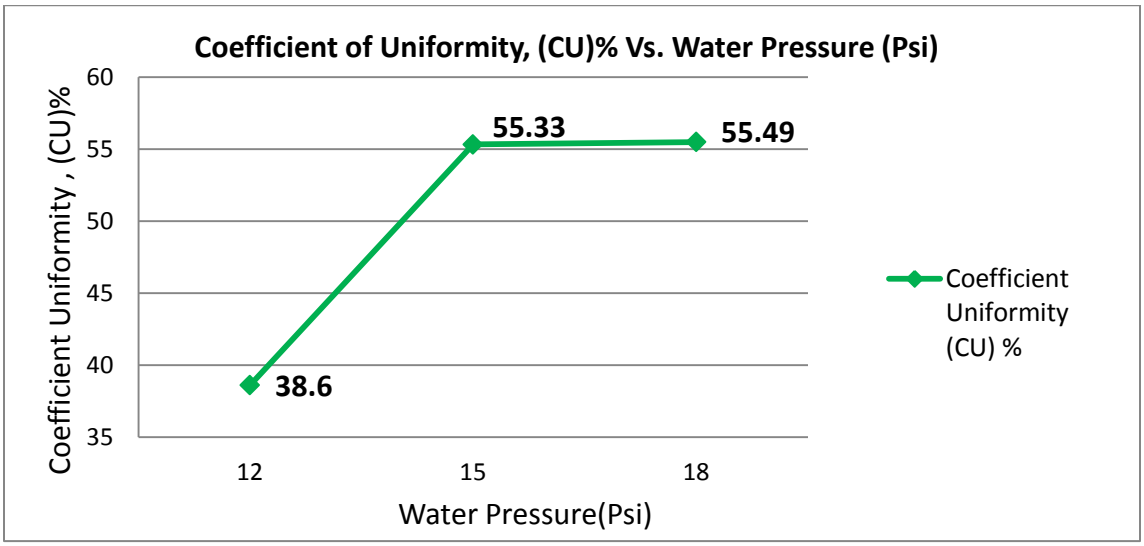

Figure 4.1: Graph of Water Pressure (Psi) and the Coefficient Uniformity (%) Value for 1 Meter Height of Riser using Plastic Impact Sprinkler Rotating Head

0.75 m Height of Riser

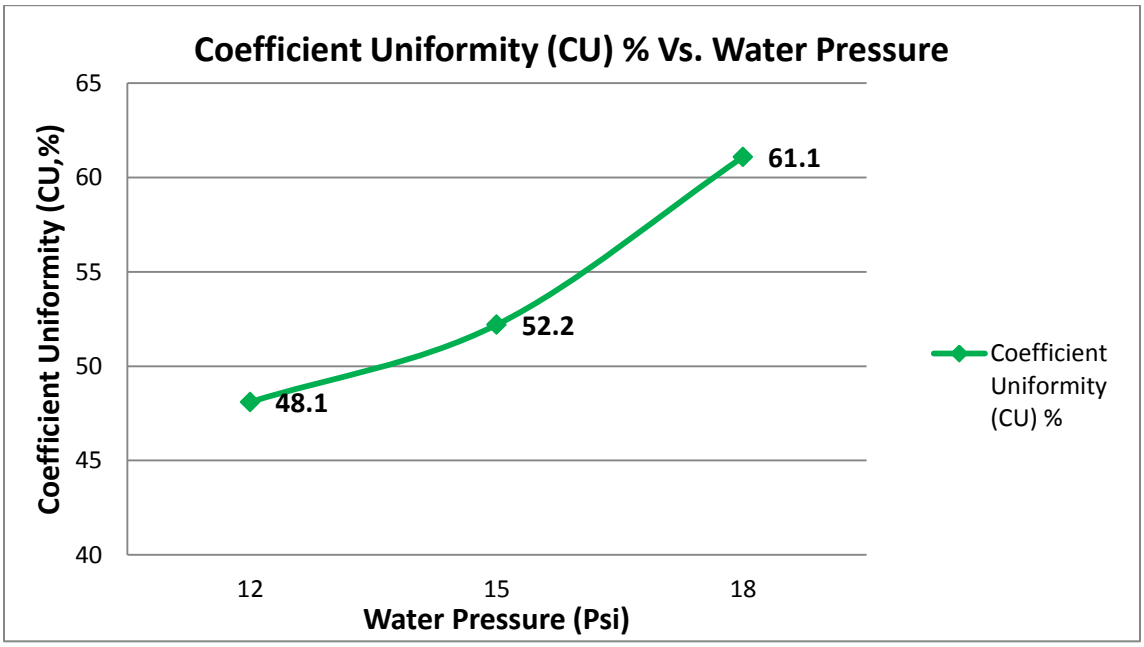

Figure 4.2: Graph of Water Pressure (Psi) and the Coefficient Uniformity (%) Value for 0.75 Meter Height of Riser using Plastic Impact Sprinkler Rotating Head

0.5m Height of Riser

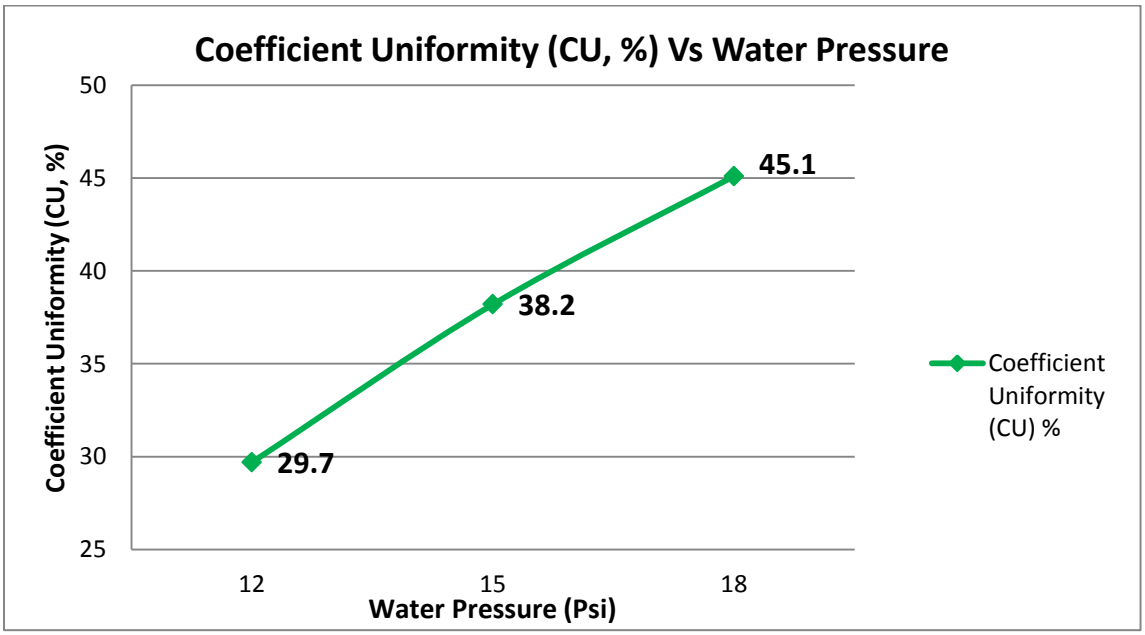

Figure 4.3: Graph of Water Pressure (Psi) and the Coefficient Uniformity (%) Value for 0.5 Meter Height of Riser using Plastic Impact Sprinkler Rotating Head

From the results of Coefficient Uniformity (CU, %) as graph on figure 4.1, 4.2 4.3, it shows that when the water pressure is increased, the CU value also will increase. It is also shows that the impact sprinklers not suitable to adapt with the low pressure of water and over irrigation will happen at this pressure.

4.1.3 Table and Graphs for Combination of Diameter of Water Distribution for Plastic Impact Sprinkler

While, here is the combination data for diameter water distribution based on each water pressure:

Height of Riser (m)	Water Pressure (Psi)	Diameter of Water Distribution (m)
1	12	11.04
1	15	11.20
1	18	11.84
0.75	12	11.60
0.75	15	12.60
0.75	18	14.00
0.5	12	14.20
0.5	15	14.40
0.5	18	14.90

Table 4.5: Comparison of Diameter Water Distribution for 12 Psi, 15 Psi, and 18 Psi Pressure of Water at 1 Meter Height by using Plastic Impact Sprinkler Rotating Head

1m Height of Riser

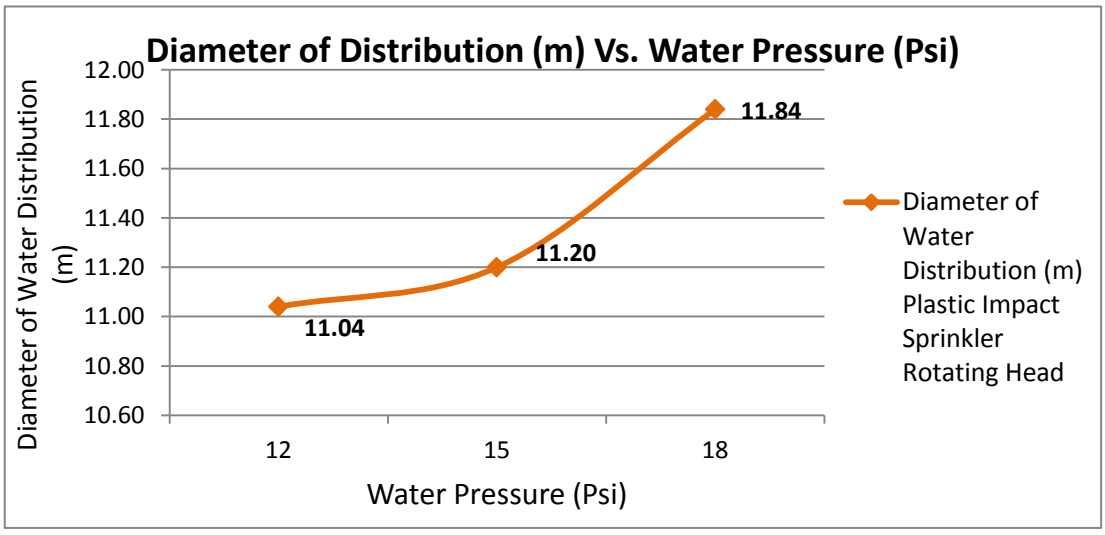

Figure 4.4: Graph of Water Pressure (Psi) and the Diameter of Water Distribution (m)

0.75m Height of Riser

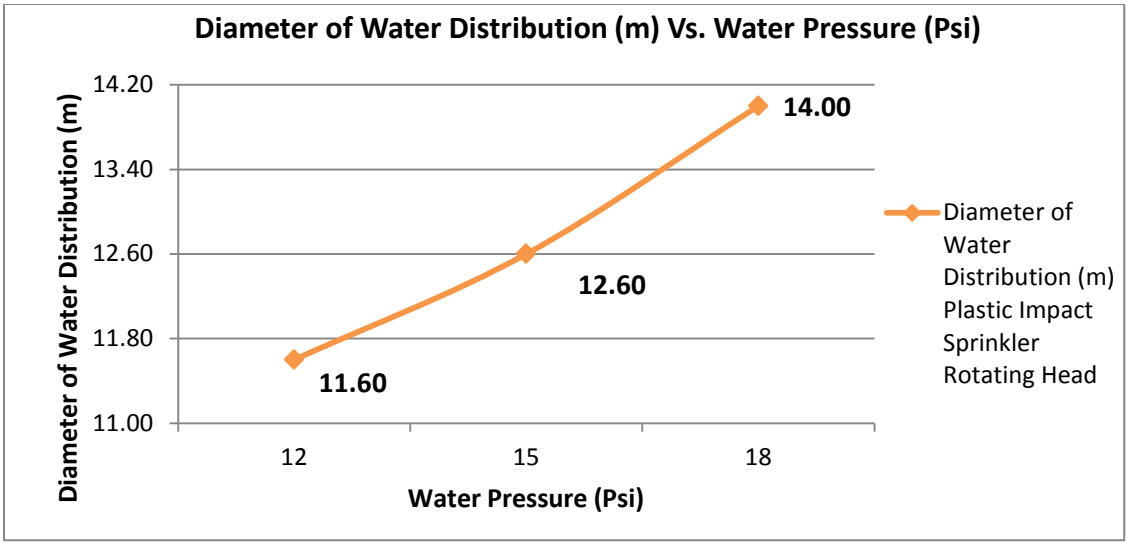

Figure 4.5: Graph of Water Pressure (Psi) and the Diameter of Water Distribution (m)

0.5m Height of Riser

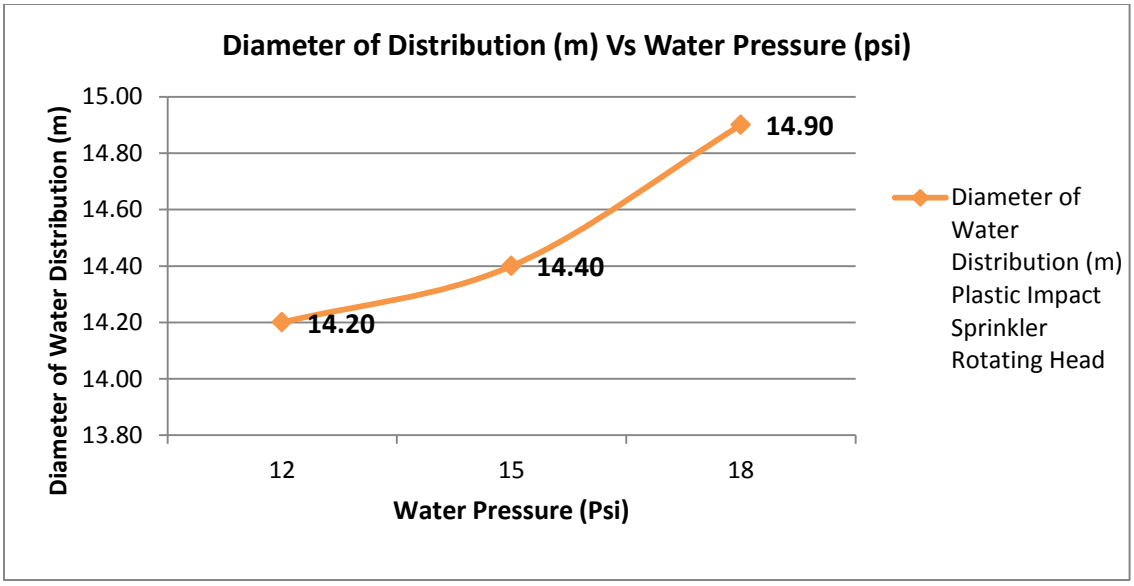

Figure 4.6: Graph of Water Pressure (Psi) and the Diameter of Water Distribution (m)

Figure 4.4, 4.5 and 4.6 shows the on the diameter of water distribution for each level of water pressure. It shows that when the water pressure is increased, the diameter of water distribution also increased.

4.2 Combination Result of Coefficient Uniformity (%)Using Rain Bird Sprinkler Rotating Head

Figure 4.7: Rain Bird Sprinkler Rotating Head

Rain Bird Sprinkler Rotating Head									
Height of Riser (m)	1	1	1	0.75	0.75	0.75	0.5	0.5	0.5
Water Pressure (Psi)	12	15	18	12	15	18	12	15	18
Diameter of Distribution (m)	7.44	8.00	9.40	6.80	7.00	8.00	6.30	6.60	6.80
Coefficient Uniformity (%)	82.4	74.2	69.3	67.9	75.8	83.3	76.9	79.8	85.9

Table 4.6: Details of Parameter Involved in “Catch Can” Experiment using Rain Bird Sprinkler Rotating Head

4.2.1 Table and Graphs for Combination of Coefficient Uniformity for Rain Bird Sprinkler

From the experiment by use Rain Bird Sprinkler Rotating Head of 1, 0.75, and 0.5 m height of riser, the value of Coefficient Uniformity (CU) % for every level of water pressures is gathered as follows;

Height Of Riser (m)	Water Pressure (Psi)	Coefficient Uniformity (CU) %	Level Uniformity
1	12	69.3	Stable
1	15	74.2	Stable
1	18	82.4	Average
0.75	12	67.9	Stable
0.75	15	75.8	Average
0.75	18	83.3	Stable
0.5	12	76.9	Stable
0.5	15	79.8	Stable
0.5	18	85.9	Good

Table 4.7: Value Coefficient Uniformity (CU %) for 12 Psi, 15 Psi, and 18 Psi Pressure of Water at 1, 0.75 and 0.5 Meter Height by using Rain Bird Sprinkler Rotating Head

1m Height of Riser

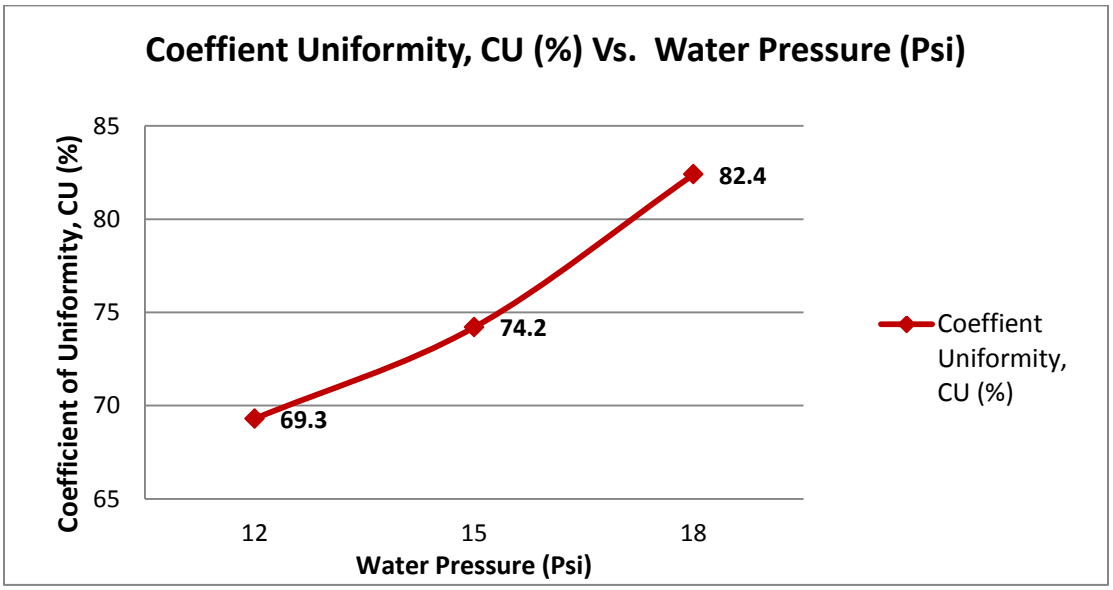

Figure 4.8: Graph of Water Pressure (Psi) and the Coefficient Uniformity (%) Value for 1 meter Height of Riser using Rain Bird Sprinkler Rotating Head

0.75m Height of Riser

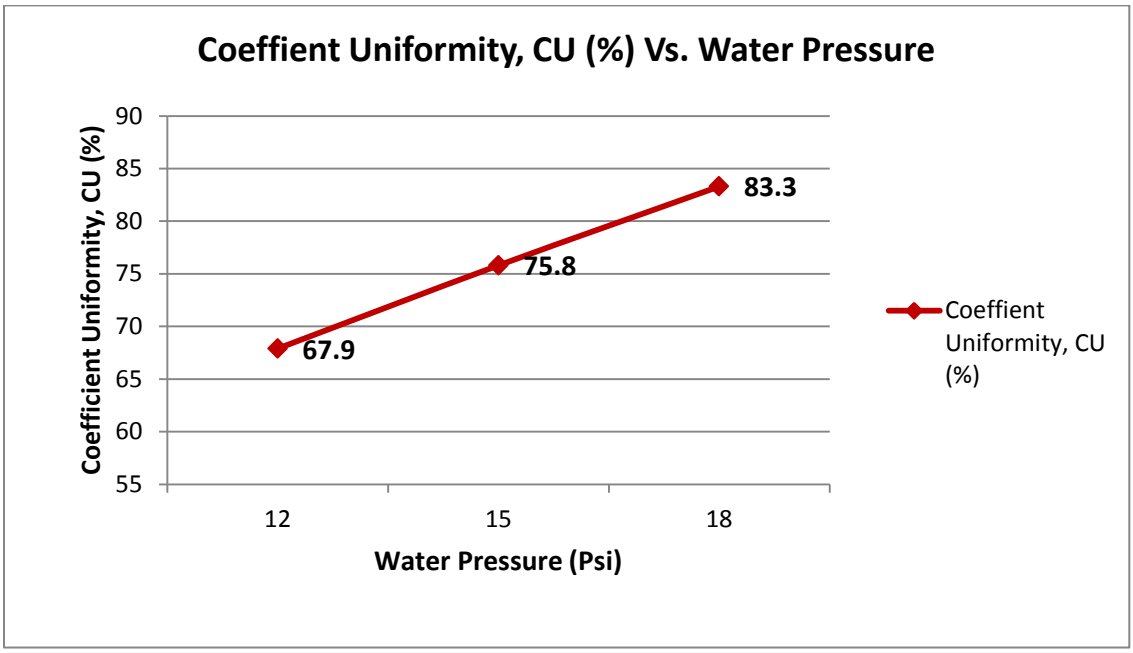

Figure 4.9: Graph of Water Pressure (Psi) and the Coefficient Uniformity (%) Value for 0.75 meter Height of Riser using Rain Bird Sprinkler Rotating Head

0.5m Height of Riser

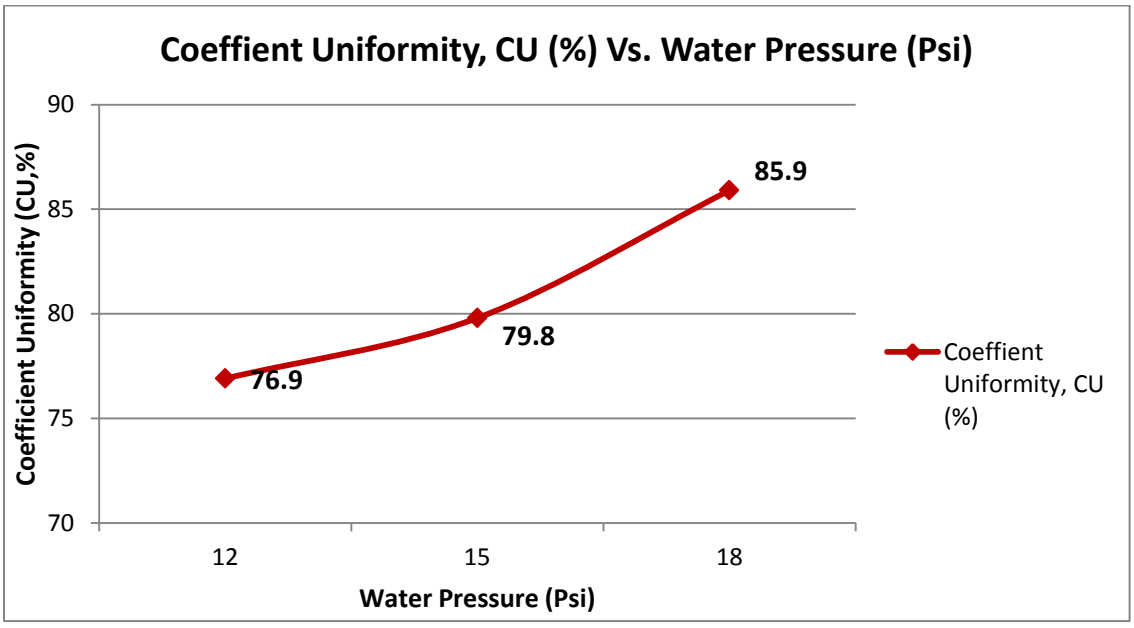

Figure 4.10: Graph of Water Pressure (Psi) and the Coefficient Uniformity (%) Value for 0.5 meter Height of Riser using Rain Bird Sprinkler Rotating Head

From the results of Coefficient Uniformity (CU, %) as graph on figure 4.8, 4.9 and 4.10, it shows that when the water pressure is increased, the CU value also will increase. It is also shows that the bird sprinklers are produced the average level of uniformity.

4.2.2 Table and Graphs for Combination of Diameter of Water Distribution for Rain Bird Sprinkler

This is the combination data for diameter water distribution based on each water pressure:

Height of Riser (m)	Water Pressure (Psi)	Diameter of Water Distribution (m)
1	12	7.44
1	15	8.00
1	18	9.40
0.75	12	6.80
0.75	15	7.00
0.75	18	8.00
0.5	12	6.30
0.5	15	6.60
0.5	18	6.80

Table 4.8: Comparison of Diameter Water Distribution for 12 Psi, 15 Psi, and 18 Psi Pressure of Water at 1, 0.75 and 0.5 Meter Height by using Rain Bird Sprinkler Rotating Head

1m Height of Riser

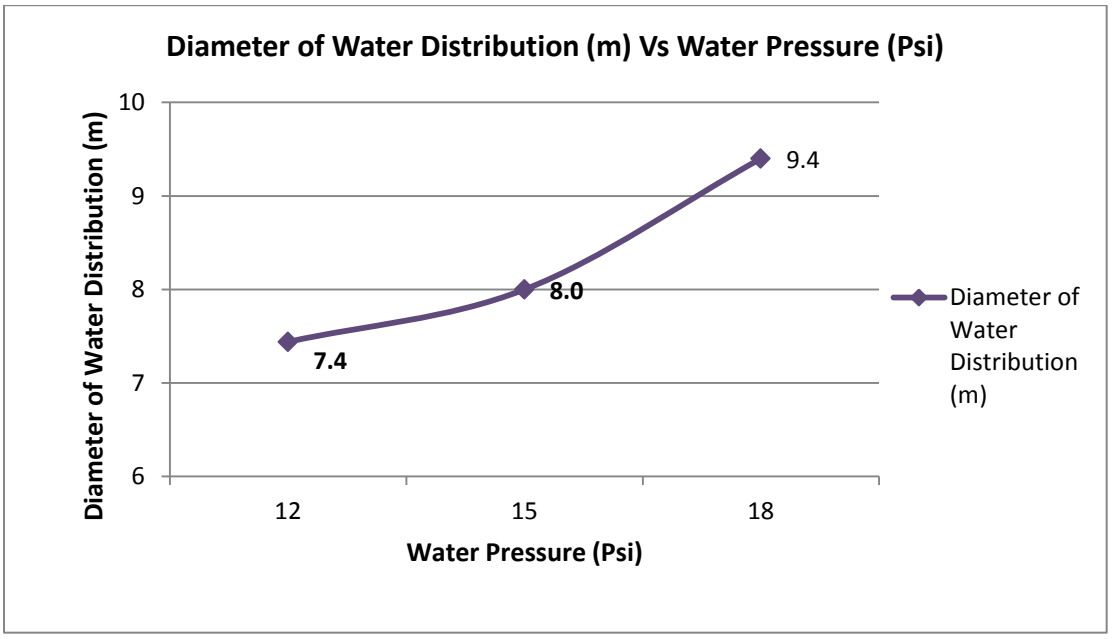

Figure 4.11: Graph of Water Pressure (Psi) and the Diameter of Water Distribution (m)

0.75m Height of Riser

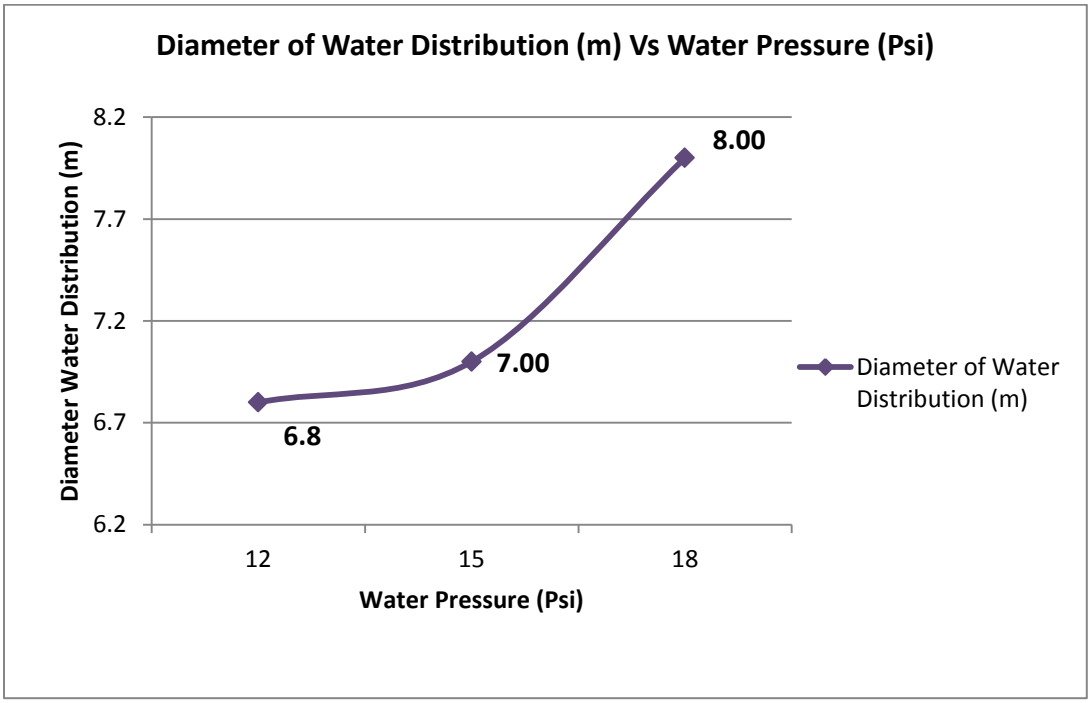

Figure 4.12: Graph of Water Pressure (Psi) and the Diameter of Water Distribution (m)

0.5m Height of Riser

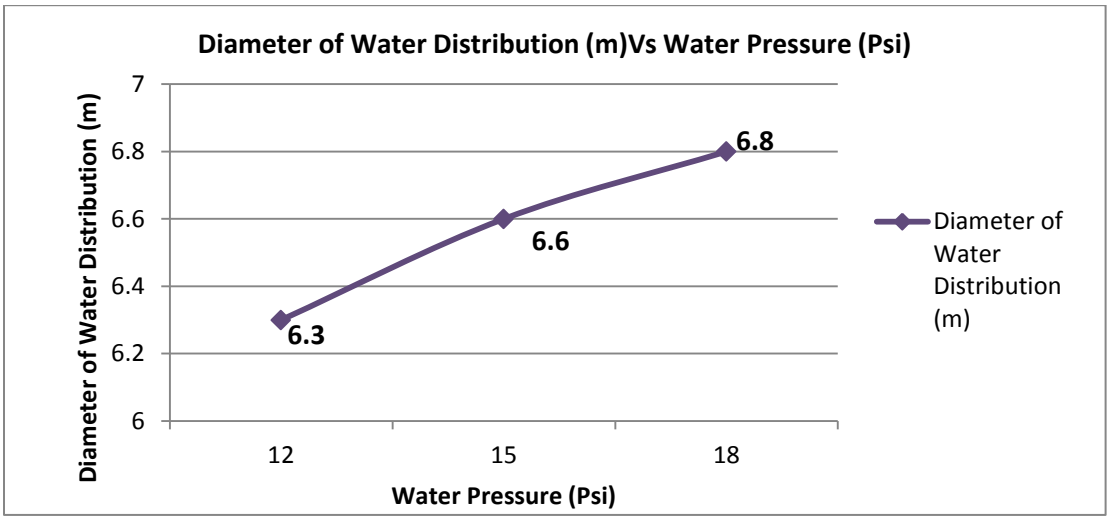

Figure 4.13: Graph of Water Pressure (Psi) and the Diameter of Water Distribution (m)

Based on the diameter of water distribution for each level of water pressure, as graph on figure 4.10, 4.11, and 4.12, it shows that when the water pressure is increased, the diameter of water distribution also increases.

4.3 Combination Result of Coefficient Uniformity (%) Using Orbit Spinning Sprinkler Rotating Head

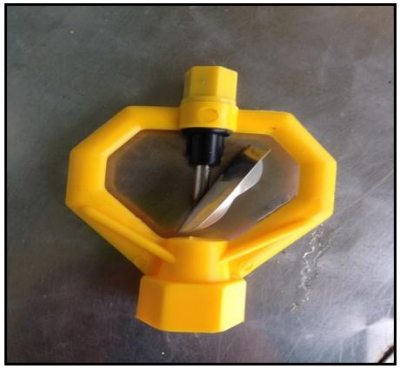

Figure 4.14: Orbit Spinning Rotating Head

Rain Bird Sprinkler Rotating Head									
Height of Riser (m)	1	1	1	0.75	0.75	0.75	0.5	0.5	0.5
Water Pressure (Psi)	12	15	18	12	15	18	12	15	18
Diameter of Distribution (m)	7.60	8.00	8.40	6.8	7.20	8.00	6.00	6.40	7.00
Coefficient Uniformity (%)	63.3	55.8	43.3	65.1	60.3	50.7	56.2	50.0	47.3

Table 4.9: Details of Parameter Involved in "Catch Can" Experiment using Orbit Spinning Sprinkler Rotating Head

4.3.1 Table and Graphs for Combination of Coefficient Uniformity for Orbit Spinning Sprinkler

From the experiment by use Orbit Spinning Sprinkler Rotating Head of 1, 0.75 and 0.5 m height of riser respectively, the value of Coefficient Uniformity (CU) % for every level of water pressures is gathered as follows;

Height Of Riser (m)	Water Pressure (Psi)	Coefficient Uniformity (CU) %	Level Uniformity
1	12	63.3	Inadequate
1	15	55.8	Inadequate
1	18	43.3	Inadequate
0.75	12	65.1	Stable
0.75	15	60.3	Inadequate
0.75	18	50.7	Inadequate
0.5	12	56.2	Inadequate
0.5	15	50.3	Inadequate
0.5	18	47.3	Inadequate

Table 4.10: Value Coefficient Uniformity (CU %) for 12 Psi, 15 Psi, and 18 Psi Pressure of Water at 1, 0.75 and 0.5 Meter Height by using Orbit Spinning Sprinkler Rotating Head

1m Height of Riser

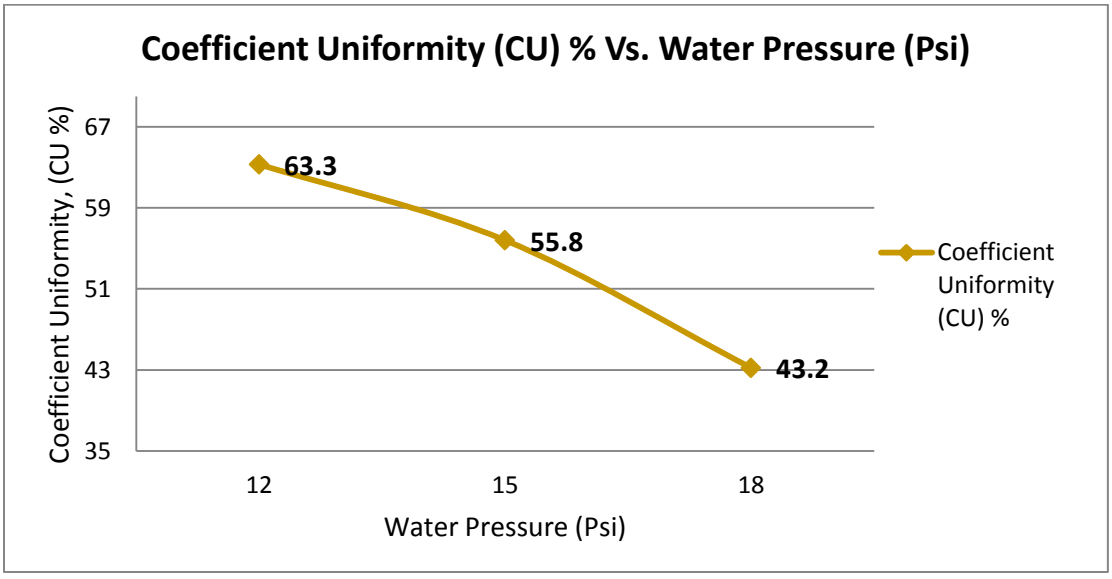

Figure 4.15: Graph of Water Pressure (Psi) and the Coefficient Uniformity (%) Value for 1 meter Height of Riser using Orbit Spinning Sprinkler Rotating Head

0.75m Height of Riser

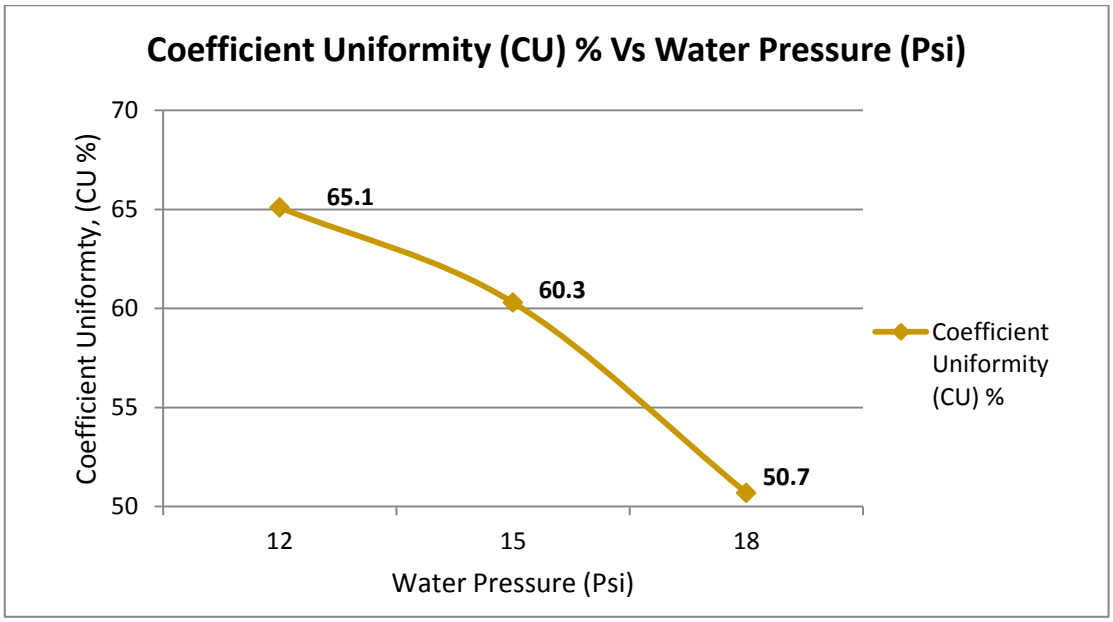

Figure 4.16: Graph of Water Pressure (Psi) and the Coefficient Uniformity (%) Value for 0.75 meter Height of Riser using Orbit Spinning Sprinkler Rotating Head

0.5m Height of Riser

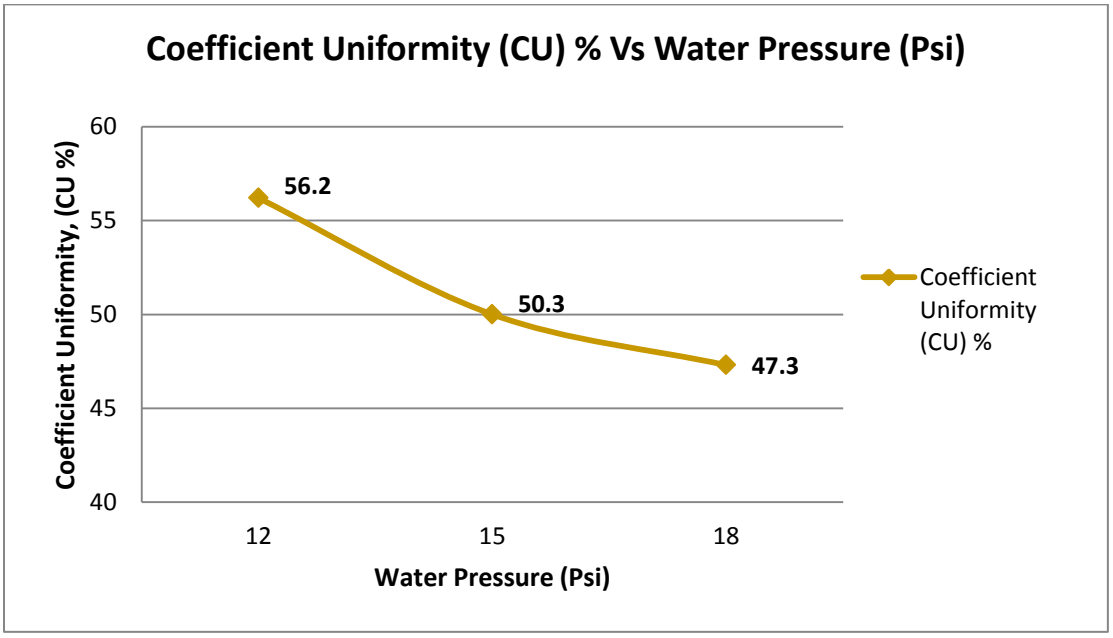

Figure 4.17: Graph of Water Pressure (Psi) and the Coefficient Uniformity (%) Value for 0.5 meter Height of Riser using Orbit Spinning Sprinkler Rotating Head

The graphs on figure 4.15, 4.16 and 4.17, indicate the results of Coefficient Uniformity (CU, %). It shows that when the water pressure is increased, the CU value also will decrease. It is also shows that orbit spinning sprinkler were producing the stable uniformity in low pressure of water.

4.3.2 Table and Graphs for Combination of Diameter of Water Distribution for Orbit Spinning Sprinkler

This is the combination data for diameter water distribution based on each water pressure:

Height of Riser (m)	Water Pressure (Psi)	Diameter of Water Distribution (m)
1	12	7.44
1	15	8.00
1	18	9.40
0.75	12	6.80
0.75	15	7.20
0.75	18	8.00
0.5	12	6.00
0.5	15	6.40
0.5	18	7.00

Table 4.11: Comparison of Diameter Water Distribution for 12 Psi, 15 Psi, and 18 Psi Pressure of Water at 1, 0.75 and 0.5 Meter Height by using Orbit Spinning Sprinkler Rotating Head

1m Height of Riser

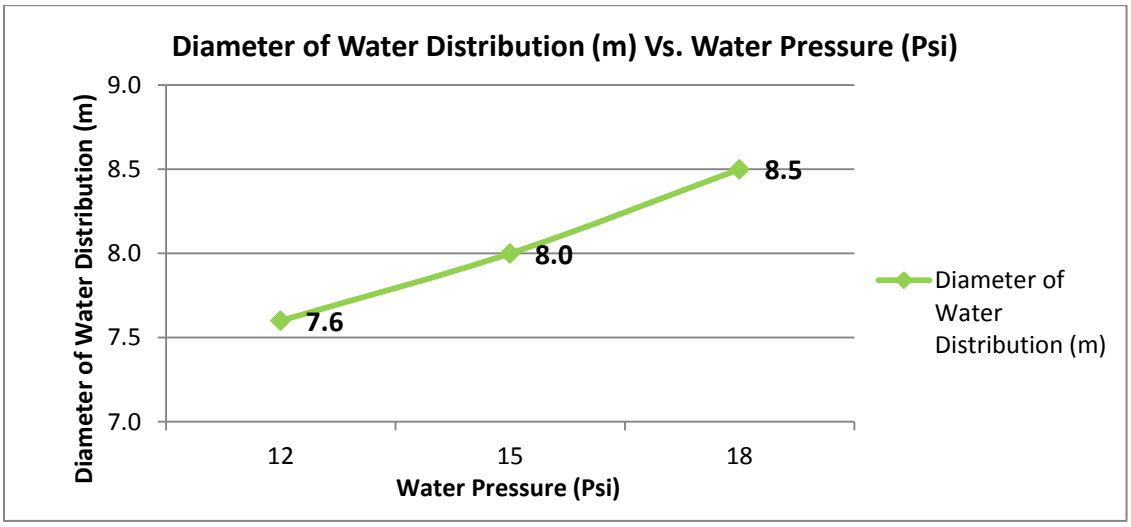

Figure 4.18: Graph of Water Pressure (Psi) and the Diameter of Water Distribution (m)

0.75m Height of Riser

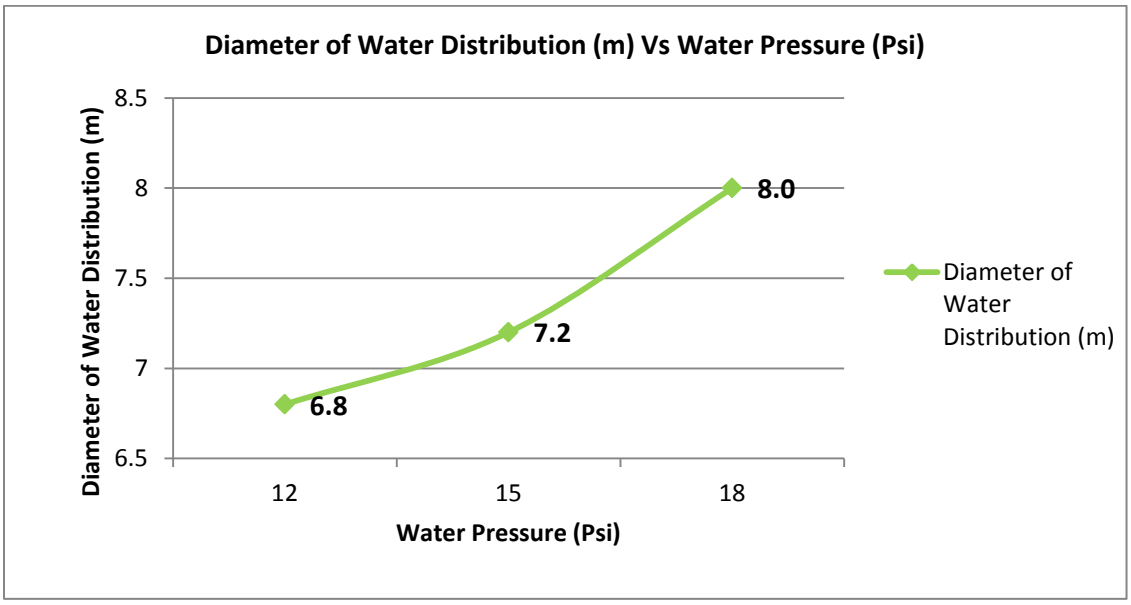

Figure 4.19: Graph of Water Pressure (Psi) and the Diameter of Water Distribution (m)

0.5m Height of Riser

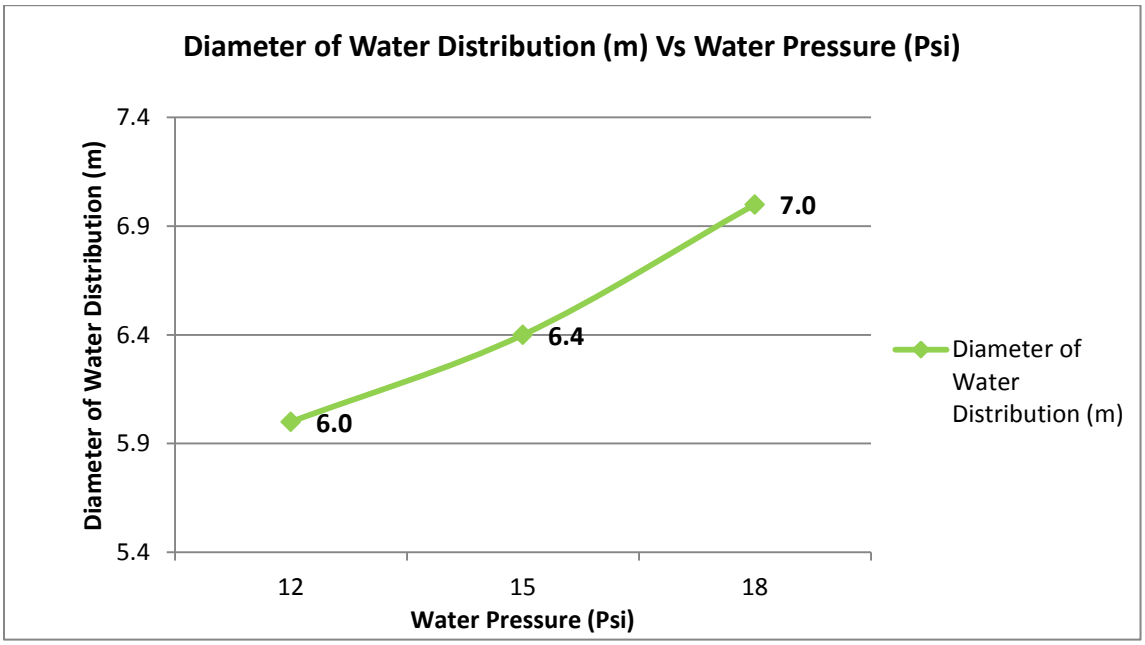

Figure 4.20: Graph of Water Pressure (Psi) and the Diameter of Water Distribution (m)

4.4 Combination Graph Coefficient Uniformity (CU, %) based on Height of Riser, Water Pressure and Type of Sprinkler Rotating Head

1m Height of Riser

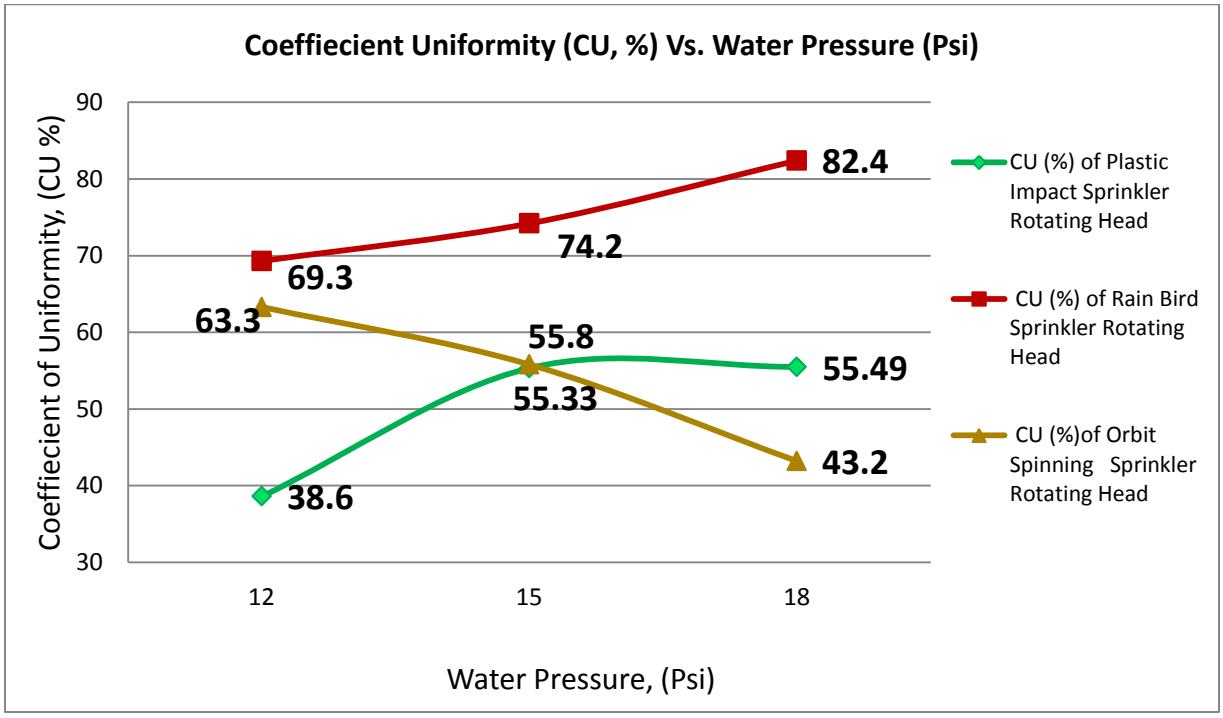

Figure 4.21: Combination Graph of Coefficient Uniformity (CU, %) for 1m Height of Riser

Figure 4.21 shows that the result of Coefficient Uniformity (CU,%) for 1 meter height of riser, by the combination of three level of water pressure and three type of sprinkler rotating head. It shows that the highest CU value for Plastic Impact Sprinkler is 55.49 % at pressure 18 Psi. While for Rain Bird Sprinkler obtained the stable level of uniformity with 82.4 %, also at 18 Psi of water pressure. For the Orbit Spinning Sprinkler obtain the highest value of CU, 63.3 % at 12 Psi which is low water pressure.

0.75m Height of Riser

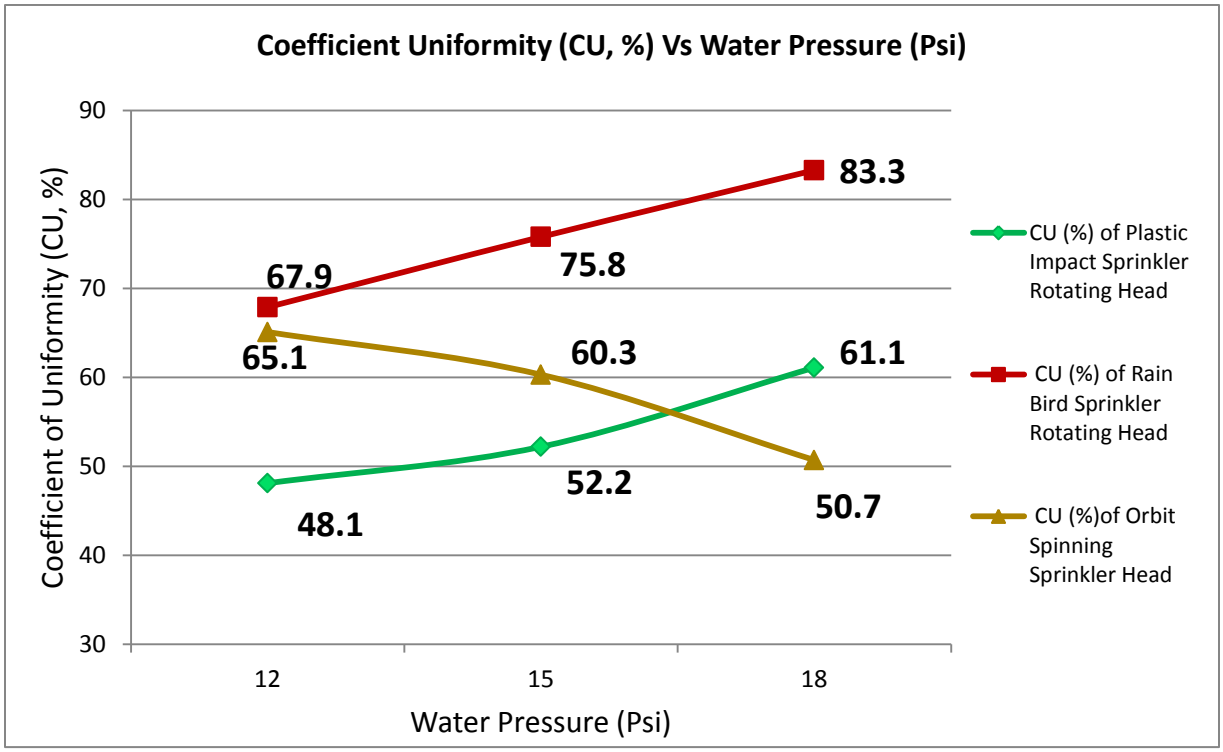

Figure 4.22: Combination Graph of Coefficient Uniformity (CU, %) for 0.75m Height of Riser

Figure 4.22 indicates that the result of Coefficient Uniformity (CU,%) for 0.75 meter height of riser, by the combination of three level of water pressure and three type of sprinkler rotating head. It shows that the highest CU value for Plastic Impact Sprinkler is 61.1 % at pressure 18 Psi. For Rain Bird Sprinkler obtained the stable level of uniformity with 83.3 %, also at 18 Psi of water pressure. While, the Orbit Spinning Sprinkler obtain the highest value of CU, 65.1 % at 12 Psi which is low water pressure.

0.5m Height of Riser

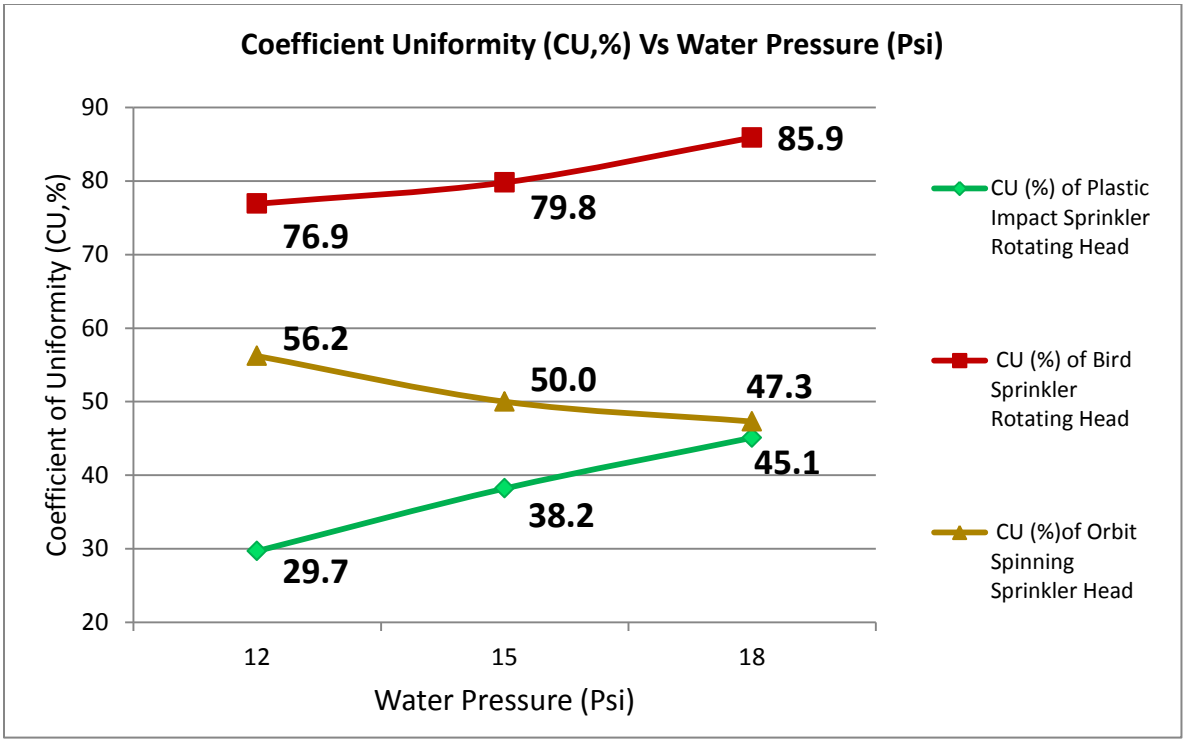

Figure 4.23: Combination Graph of Coefficient Uniformity (CU, %) for 0.5m Height of Riser

Based on figure 4.23 above, its indicates the result of Coefficient Uniformity (CU,%) for 0.5 meter height of riser, by the combination of three level of water pressure and three type of sprinkler rotating head. It shows that the highest CU value for Plastic Impact Sprinkler is 45.1 % at pressure 18 Psi. For Rain Bird Sprinkler obtained the good level of uniformity with 85.9%, at 18 Psi of water pressure. While, the Orbit Spinning Sprinkler obtain the highest value of CU, 56.2 % at 12 Psi which is low water pressure.

4.4.1 The Best Combination Height of Riser and Water Pressure based on Type of Sprinkler Rotating Head

As observed and analyzed the results from each experiments, the author got the best combinations of height of riser, water pressure based on each type of sprinkler head that had been tested before. The best combinations are as follows:

Type of Sprinkler Rotating Head	Height of Riser (m)	Water Pressure (Psi)	Coefficient Uniformity (CU, %)
Plastic Impact Sprinkler	0.75	18	61.1
Rain Bird Sprinkler	0.5	18	85.9
Orbit Spinning Sprinkler	0.75	12	65.1

Table 4.12: The Best Combination of Height of Riser and Water Pressure for Each Type of Sprinkler

4.5 Combination Graph Diameter of Water Distribution based on Height of Riser, Water Pressure and Type of Sprinkler Rotating Head

1m Height of Riser

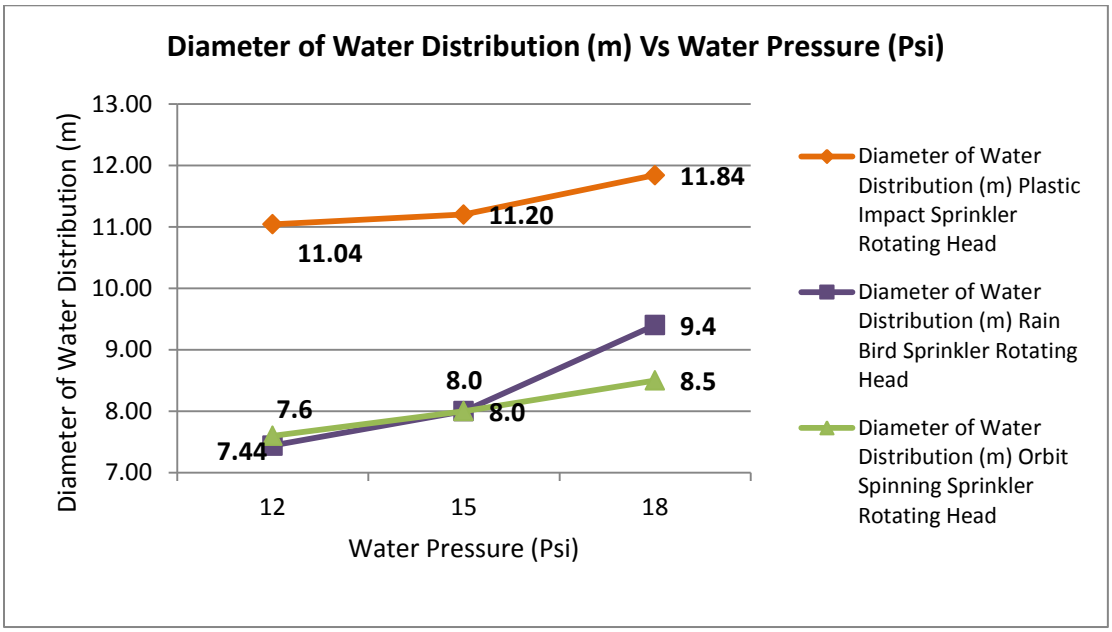

Figure 4.24: Combination Graph of Diameter Water Distribution for 1 m Height of Riser

0.75m Height of Riser

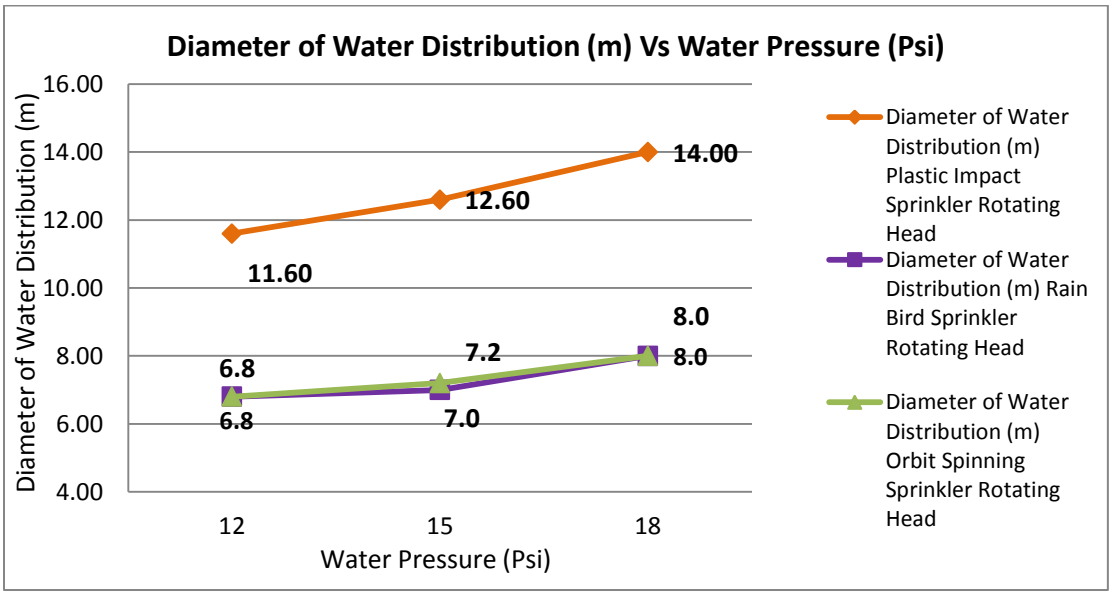

Figure 4.25: Combination Graph of Diameter Water Distribution for 0.75 m Height of Riser

0.5m Height of Riser

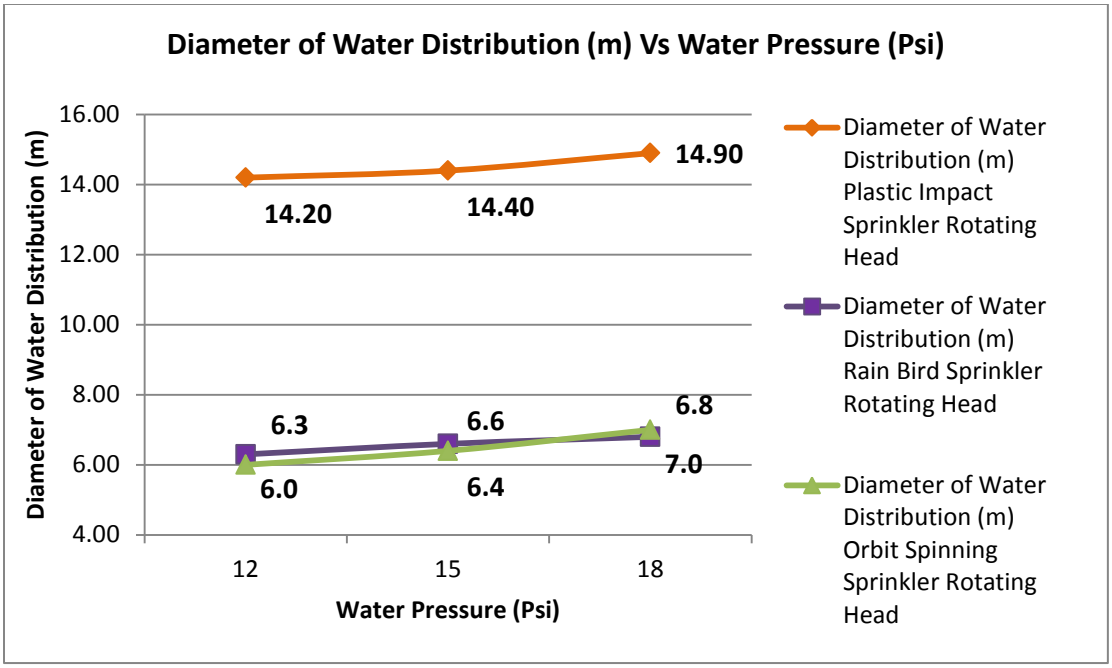

Figure 4.26: Combination Graph of Diameter Water Distribution for 0.5 m Height of Riser

Figure 4.24, 4.25 and 4.26 shows that the combination graphs for diameter of water distribution on 1, 0.75 and 0.5 meter height of riser at 12, 15, 18 Psi respectively. It is indicated that when the pressure of water was increased the diameter of water distribution also increased.

From the experiments that were conducted, Plastic Impact Sprinkler has the long distribution of water for each height of riser and level of water pressure. While, the Rain Bird and Orbit Spinning sprinkler head obtain the equal length of distribution for each height of riser and level of water pressure.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Sprinkler irrigation system is important to growth the crops and to maintain the green on landscape or plants. So that, the author is doing some improvement on the sprinkler system by using the combination of type of sprinkler rotating head, height of riser and levels of water pressure.

This is to obtain the good level of Coefficient Uniformity (CU) of the sprinkler irrigation system. This is made based on the objective which is to evaluate the uniformity of water distributions on the sprinkler system based on Christiansen's Coefficient of Uniformity (CU).

From some "Catch Can" experiment that had done by the author, it shows that every sprinkler rotating head will produces the different pattern of distribution. The value of Coefficient Uniformity (CU, %) are different, since the various change in combination height of riser, sprinkler head and pressure of water.

Some of the CU values will high at the low pressure, while some other sprinkler will good in high pressure of water. The suitable combination of height of riser, water pressure and type of sprinkler head is determined by choose the high value of CU

From this research, the high value of CU for Plastic Impact Sprinkler is 61.1 % which at 0.75 m height of riser and 18 Psi on water Pressure. For Rain Bird Sprinkler the high CU value is 85.9% which at 0.5 m riser height and 18 Psi of Water Pressure. The Orbit Spinning Sprinkler head was produced high value of CU on low pressure of water (12 Psi) which is 65.1 % at 0.75 m height of riser.

By conducting this research, and done the "Catch Can" experiment, the objective of this study was achieved, when the author has got the Coefficient Uniformity (CU, %) value by using the Christiansen's Formula.

5.2 Recommendation

Further studies will be made in future, on determine the Coefficient Uniformity (CU,%) for other sprinkler system such as Jet Sprinkler System and Portable Sprinkler System by use same variables as in this study which are height of riser, different level of water pressure.

Figure 5.0: Jet Sprinkler System

Figure 5.1: Portable Sprinkler System

5.2.1 Soil Moisture Content

The purpose on testing the soil moisture content is to determine the water that contains the soil. In further studies also, this test can be used, to make the comparison between of water contain in the soil and water collected in the “Catch Can” either obtain the same value or not. By do this test also, it can determine the plant or crops either there is over irrigation or under irrigation problem.

CHAPTER 6

REFERENCES

6.0 REFERENCES

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APPENDIX

METHOD OF CALCULATION COEFFICIENT UNIFORMITY (CU) %

Catch Can" Experiment for 1 (m) Height of Riser using Impact Sprinkler, Bird Sprinkler and Orbit Spinning Sprinkler of Rotating Head

Parameters	Details
Height of Riser	1
Water Pressure (Psi)	12
Day and Time	8/11/2013; Friday
Length between Container (m)	1.38

Details of Parameter Involved

Result of CU (%) for Impact Sprinkler – 12 Psi

The Result Obtained as follows:

Line 1(ml)	Line 2 (ml)	Line 3(ml)	Line 4 (ml)	Line 5(ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
20	50	40	35	20	30	20	25
25	60	55	45	45	20	40	25
25	50	40	50	50	25	25	20
125	150	125	130	125	230	70	100
195	**310**	**260**	**260**	**240**	**305**	**155**	**170**

Total Water Collected at Each Line for 12 Psi Pressure of Water

Total of Water in Containers = **1895 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 1895 ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (1895/ 32) = 59.22 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1(ml)	Line 2 (ml)	Line 3(ml)	Line 4 (ml)	Line 5(ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
39.22	9.22	19.22	24.22	39.22	29.22	39.22	34.22
34.22	0.78	4.22	14.22	14.22	39.22	19.22	34.22
34.22	9.22	19.22	9.22	9.22	34.22	34.22	39.22
65.78	90.78	65.78	70.78	65.78	170.78	10.78	40.78
173.44	**110.00**	**108.44**	**118.44**	**128.44**	**273.44**	**103.44**	**148.44**

Sum of Deviation in Each Container for 12 Psi Pressure of Water

Total of "|a|" = 1164.06

The Coefficient Uniformity (CU %) Value = [1- (1164.06)/ (32 x 1895)] x100

= 38.6 %

Based on basic interpretation table of Coefficient Uniformity, the result is **inadequate uniformity.**

Result of CU (%) for Impact Sprinkler – 15 Psi

Here are the details of parameters involved:

Parameters	Details
Height of Riser (m)	1
Water Pressure (Psi)	15
Type of Sprinkler	Impact Sprinkler
Day and Time	11/11/2013; Monday
Pattern of Distribution	Radius
Length between Container (m)	1.40

Details of Parameter Involved

The Result Obtained as follows:

Line 1(ml)	Line 2 (ml)	Line 3(ml)	Line 4 (ml)	Line 5(ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
10	50	40	25	15	30	25	25
50	45	50	50	20	35	30	50
50	45	30	45	75	25	35	25
75	90	90	100	90	100	100	100
185	**230**	**210**	**220**	**200**	**190**	**190**	**200**

Total Water Collected at Each Line for 15 Psi Pressure of Water

Total of Water in Containers = **1625 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 1625 ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (1625/ 32) = 50.8 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1(ml)	Line 2 (ml)	Line 3(ml)	Line 4 (ml)	Line 5(ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
40.78	0.78	10.78	25.78	35.78	20.78	25.78	25.78
0.78	5.78	0.78	0.78	30.78	15.78	20.78	0.78
0.78	5.78	20.78	5.78	24.22	25.78	15.78	25.78
24.22	39.22	39.22	49.22	39.22	49.22	49.22	49.22
66.56	**51.56**	**71.56**	**81.56**	**130.00**	**111.56**	**111.56**	**101.5**

Sum of Deviation in Each Container for 12 Psi Pressure of Water

Total of "|a|" = 725.94

The Coefficient Uniformity (CU %) Value = [1- (725.94)/ (32 x 1625)] x100

= 55.43 %

Based on basic interpretation table of Coefficient Uniformity, the result is **inadequate uniformity**

Result of CU (%) for Impact Sprinkler – 18 Psi

Here are the details of parameters involved:

Parameters	Details
Height of Riser (m)	1
Water Pressure (Psi)	18
Type of Sprinkler	Impact Sprinkler
Day and Time	6/11/2013;Tuesday
Pattern of Distribution	Radius
Length between Container (m)	1.48

Details of Parameter Involve

The Result Obtained as follows:

Line 1(ml)	Line 2 (ml)	Line 3(ml)	Line 4 (ml)	Line 5(ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
25	30	25	40	40	30	30	25
50	50	35	50	25	40	50	50
30	25	50	30	50	30	30	25
100	100	100	75	100	100	100	100
205	**205**	**210**	**195**	**215**	**200**	**210**	**200**

Total Water Collected at Each Line for 18 Psi Pressure of Water

Total of Water in Containers = **730 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 1640 ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (730/ 32) = 51.25 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1(ml)	Line 2 (ml)	Line 3(ml)	Line 4 (ml)	Line 5(ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
26.25	21.25	26.25	11.25	11.25	21.25	21.25	26.25
1.25	1.25	16.25	1.25	26.25	11.25	1.25	1.25
21.25	26.25	1.25	21.25	1.25	21.25	21.25	26.25
48.75	48.75	48.75	23.75	48.75	48.75	48.75	48.75
97.5	**97.5**	**92.5**	**57.5**	**87.5**	**102.5**	**92.5**	**102.5**

Total Water Collected at Each Line for 18 Psi Pressure of Water

Total of "|a|" = 730

The Coefficient Uniformity (CU %) Value = [1- (730)/ (32 x 1640)] x100

= 55.49 %

Based on basic interpretation table of Coefficient Uniformity, the result is **inadequate uniformity.**

Result of CU (%) for Bird Sprinkler – 12 Psi

Here are the details of parameters involved:

Parameters	Details
Height of Riser (m)	1
Water Pressure (Psi)	12
Type of Sprinkler	Bird Sprinkler
Day and Time	12/11/2013; Tuesday
Area of Distribution	Radius (3.72 m)
Length between Container (m)	0.93

Details of Parameter Involved

The Result Obtained as follows:

Line 1(ml)	Line 2(ml)	Line 3(ml)	Line 4 (ml)	Line 5 (ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
30	40	50	40	30	40	25	25
125	125	125	125	125	100	130	100
75	75	75	75	80	85	80	100
70	70	70	70	75	75	75	75
300	**310**	**320**	**310**	**310**	**300**	**310**	**300**

Total Water Collected at Each Line for 12 Psi Pressure of Water

Total of Water in Containers = **2460 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 2460 ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (2460/ 32) = 76.87 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1(ml)	Line 2(ml)	Line 3(ml)	Line 4 (ml)	Line 5 (ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
46.88	36.88	26.88	36.88	46.88	36.88	51.88	51.88
48.13	48.13	48.13	48.13	48.13	23.13	53.13	23.13
1.88	1.88	1.88	1.88	3.13	8.13	3.13	23.13
6.88	6.88	6.88	6.88	1.88	1.88	1.88	1.88
103.77	**93.77**	**83.77**	**93.77**	**100.02**	**70.02**	**110.02**	**100.02**

Sum of Deviation in Each Container for 12 Psi Pressure of Water

Total of "|a|" = 755.16

The Coefficient Uniformity (CU %) Value = [1- (755.16)/ (32 x 2460)] x100

= 69.3 %

Based on basic interpretation table of Coefficient Uniformity, the result is **stable uniformity.**

Result of CU (%) for Bird Sprinkler – 15 Psi

Here are the details of parameters involved:

Parameters	Details
Height of Riser (m)	1
Water Pressure (Psi)	15
Type of Sprinkler	Bird Sprinkler
Day and Time	12/11/2013; Tuesday
Area of Distribution	Radius (4 m)
Length between Container (m)	1

Details of Parameter Involved

The Result Obtained as follows:

Line 1(ml)	Line 2(ml)	Line 3(ml)	Line 4 (ml)	Line 5 (ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
30	50	40	40	30	40	30	40
100	125	125	100	100	100	100	85
85	80	75	75	80	75	90	65
75	75	70	75	70	75	75	75
290	**330**	**310**	**290**	**280**	**290**	**295**	**265**

Total Water Collected at Each Line for 15 Psi Pressure of Water

Total of Water in Containers = **2350 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 2350 ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (2350/ 32) = 73.44 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1(ml)	Line 2(ml)	Line 3(ml)	Line 4 (ml)	Line 5 (ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
46.88	36.88	26.88	36.88	46.88	36.88	51.88	51.88
48.13	48.13	48.13	48.13	48.13	23.13	53.13	23.13
1.88	1.88	1.88	1.88	3.13	8.13	3.13	23.13
6.88	6.88	6.88	6.88	1.88	1.88	1.88	1.88
103.77	**93.77**	**83.77**	**93.77**	**100.02**	**70.02**	**110.02**	**100.02**

Sum of Deviation in Each Container for 15 Psi Pressure of Water

Total of "|a|" = 605.63

The Coefficient Uniformity (CU %) Value = [1- (605.63)/ (32 x 2350)] x100

= 74.2 %

Based on basic interpretation table of Coefficient Uniformity, the result is **Average Level of uniformity.**

Result of CU (%) for Bird Sprinkler – 18 Psi

Here are the details of parameters involved:

Parameters	Details
Height of Riser (m)	1
Water Pressure (Psi)	18
Type of Sprinkler	Bird Sprinkler
Day and Time	13/11/2013; Wednesday
Area of Distribution	Radius (4.7 m)
Length between Container (m)	1.12

Details of Parameter Involved

The Result Obtained as follows:

Line 1(ml)	Line 2(ml)	Line 3(ml)	Line 4 (ml)	Line 5 (ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
40	50	40	40	50	50	50	40
90	80	90	85	85	90	85	80
75	70	75	70	75	70	75	80
70	75	70	75	70	75	75	75
275	**275**	**275**	**270**	**280**	**285**	**285**	**275**

Total Water Collected at Each Line for 18 Psi Pressure of Water

Total of Water in Containers = **2220 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 2220 ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (2350/ 32) = 69.37 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1(ml)	Line 2(ml)	Line 3(ml)	Line 4 (ml)	Line 5 (ml)	Line 6(ml)	Line 7(ml)	Line 8(ml)
29.38	19.38	29.38	29.38	19.38	19.38	19.38	29.38
20.63	10.63	20.63	15.63	15.63	20.63	15.63	10.63
5.63	0.63	5.63	0.63	5.63	0.63	5.63	10.63
0.63	5.63	0.63	5.63	0.63	5.63	5.63	5.63
56.25	**36.25**	**56.25**	**51.25**	**41.25**	**46.25**	**46.25**	**56.25**

Sum of Deviation in Each Container for 18 Psi Pressure of Water

Total of "|a|" = 390.00

The Coefficient Uniformity (CU %) Value = [1- (390.00)/ (32 x 2220)] x100

= 82.4 %

Based on basic interpretation table of Coefficient Uniformity, the result is **Average Level of uniformity.**

Result of CU (%) for Orbit Sprinkler – 12 Psi

Here are the details of parameters involved:

Parameters	Details
Height of Riser (m)	1
Water Pressure (Psi)	12
Type of Sprinkler	Orbit Sprinkler
Day and Time	15/11/2013; Tuesday
Area of Distribution	Radius (3.80 m)
Length between Container (m)	0.95

Details of Parameter Involved

The Result Obtained as follows:

Line 1 (ml)	Line 2 (ml)	Line 3 (ml)	Line 4 (ml)	Line 5 (ml)	Line 6 (ml)	Line 7 (ml)	Line 8(ml)
50	25	15	25	25	25	25	20
55	65	50	50	50	45	50	60
75	75	75	70	70	75	70	75
100	90	100	100	110	100	100	80
280	**255**	**240**	**245**	**255**	**245**	**245**	**235**

Total Water Collected at Each Line for 12 Psi Pressure of Water

Total of Water in Containers = **2000 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 2000 ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (2000/ 32) = 62.5 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1 (ml)	Line 2 (ml)	Line 3 (ml)	Line 4 (ml)	Line 5 (ml)	Line 6 (ml)	Line 7 (ml)	Line 8(ml)
12.50	37.50	47.50	37.50	37.50	37.50	37.50	42.50
7.50	2.50	12.50	12.50	12.50	17.50	12.50	2.50
12.50	12.50	12.50	7.50	7.50	12.50	7.50	12.50
37.50	27.50	37.50	37.50	47.50	37.50	37.50	17.50
70.00	**80.00**	**110.00**	**95.00**	**105.00**	**105.00**	**95.00**	**75.00**

Sum of Deviation in Each Container for 12 Psi Pressure of Water

Total of "|a|" = 735.00

The Coefficient Uniformity (CU %) Value = [1- (735.00)/ (32 x 2000)] x100

= 63.3 %

Based on basic interpretation table of Coefficient Uniformity, the result is **Inadequate Level of Uniformity.**

Result of CU (%) for Orbit Sprinkler – 15 Psi

Here are the details of parameters involved:

Parameters	Details
Height of Riser (m)	1
Water Pressure (Psi)	15
Type of Sprinkler	Orbit Sprinkler
Day and Time	15/11/2013
Area of Distribution	Radius (4.0 m)
Length between Container (m)	1

Details of Parameter Involved

The Result Obtained as follows:

Line 1 (ml)	Line 2 (ml)	Line 3 (ml)	Line 4 (ml)	Line 5 (ml)	Line 6 (ml)	Line 7 (ml)	Line 8(ml)
25	20	10	20	15	20	20	25
50	45	15	45	45	45	45	50
70	75	55	75	55	55	60	75
95	75	100	100	100	95	95	95
240	**215**	**180**	**240**	**215**	**215**	**220**	**245**

Total Water Collected at Each Line for 15 Psi Pressure of Water

Total of Water in Containers = **1770 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 1770ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (1770/ 32) = 55.31 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1 (ml)	Line 2 (ml)	Line 3 (ml)	Line 4 (ml)	Line 5 (ml)	Line 6 (ml)	Line 7 (ml)	Line 8(ml)
30.31	35.31	45.31	35.31	40.31	35.31	35.31	30.31
5.31	10.31	40.31	10.31	10.31	10.31	10.31	5.31
14.69	19.69	0.31	19.69	0.31	0.31	4.69	19.69
39.69	19.69	44.69	44.69	44.69	39.69	39.69	39.69
90.00	**85.00**	**130.63**	**110.00**	**95.63**	**85.63**	**90.00**	**95.00**

Sum of Deviation in Each Container for 12 Psi Pressure of Water

Total of "|a|" = 788.88

The Coefficient Uniformity (CU %) Value = [1- (788.00)/ (32 x 1770)] x100

= 55.8 %

Based on basic interpretation table of Coefficient Uniformity, the result is **Inadequate Level of Uniformity.**

Result of CU (%) for Orbit Sprinkler – 18 Psi

Here are the details of parameters involved:

Parameters	Details
Height of Riser (m)	1
Water Pressure (Psi)	18
Type of Sprinkler	Orbit Sprinkler
Day and Time	15/11/2013; Tuesday
Area of Distribution	Radius (4.2 m)
Length between Container (m)	1.05

Details of Parameter Involved

The Result Obtained as follows:

Line 1 (ml)	Line 2 (ml)	Line 3 (ml)	Line 4 (ml)	Line 5 (ml)	Line 6 (ml)	Line 7 (ml)	Line 8(ml)
10	10	15	15	20	15	20	15
40	20	35	30	30	40	30	35
60	65	70	65	70	75	75	75
100	110	100	100	100	100	100	100
210	**205**	**220**	**210**	**220**	**230**	**225**	**225**

Total Water Collected at Each Line for 15 Psi Pressure of Water

Total of Water in Containers = **1745 ml**

Result of Coefficient Uniformity, CU (%):

By using the formula of $C_u = 100\left[1 - \frac{\sum|a|}{m \cdot n}\right] \quad (\%)$ the result of CU was obtained as follows;

Total Water in Containers = 1745ml

Number of Container Used, (n) = 32

To get **"m"** = **(Total Water Collected/Number of Container Used) = (1745/ 32) = 54.53 ml**

"|a|" is sum of the deviations of each containers and the result obtained was:

Line 1 (ml)	Line 2 (ml)	Line 3 (ml)	Line 4 (ml)	Line 5 (ml)	Line 6 (ml)	Line 7 (ml)	Line 8(ml)
44.53	44.53	39.53	39.53	34.53	39.53	34.53	39.53
14.53	35.31	20.31	25.31	25.31	15.31	25.31	20.31
5.47	10.47	15.47	10.47	15.47	20.47	20.47	20.47
45.47	55.47	45.47	45.47	45.47	45.47	45.47	45.47
110.00	**145.78**	**120.78**	**120.78**	**120.78**	**120.78**	**125.78**	**125.78**

Sum of Deviation in Each Container for 18 Psi Pressure of Water

Total of "|a|" = 990.47

The Coefficient Uniformity (CU %) Value = [1- (990.47)/ (32 x 1745)] x100

= 43.2 %

Based on basic interpretation table of Coefficient Uniformity, the result is **Inadequate Level of UniformiY**