Sprinkler test report

Introduction

In the cadre of the SWA program, it was decided to test sprinklers. The purpose is to obtain technical information about the performance of a number of sprinklers commonly used by Kenyan SME farmers, in order to evaluate their performance, and to be able to advise farmers about what sprinklers are suitable for their irrigation situation.

Every individual farmer has its own unique situation, in terms of field size, crop choices and cropping patterns. There is high variation in types and characteristics of their water supply situations. Some have piped gravity systems and directly connect the sprinkler to these pipes. Others have elevated storage tanks feeding the field pipes with a rather constant pressure, and again others connect their sprinklers to a fuel or solar pump. For each situation, a different sprinkler may be chosen.
However, in this test we concentrate on low pressure sprinklers that can be fitted to solar pumps and/or piped systems in (for example) Meru. Usually, fuel pumps produce higher pressures than the pressure ranges that we will evaluate, and other types of sprinklers may then be used.

Decisive for the sprinkler operation are the (dynamic) pressure and flow conditions.
Sprinklers can be evaluated in terms of how they behave at what water pressure.

1. **At what water pressures does the sprinkler start to operate?**

Some sprinklers can easily operate under (very) low pressures, whilst others require a minimum pressure in order to operate well.

2. **What is their wetted radius at a certain water pressure?**

How far does the sprinkler spray the water? This is important, because the larger the circle is, the less frequent the farmer has to replace the sprinkler, and the less sprinklers he/she needs to irrigate the land. He/she can comfortably leave the sprinkler spraying for a longer time, when the radius is higher.

3. **What is their flow at certain pressure?**

This largely depends on the nozzle size. The smaller the opening of the nozzle, the less water will go through. A large opening will result in a high flow.
A high flow is not always favourable. It means that the farmer has to frequently replace the sprinklers. On the other hand, when the flow is high, the farmer can irrigate more land.

4. **What is their water application rate over their wetted radius?**

If you know the radius of the sprinkler, you also know the surface over which the water spreads. Combine this with the flow rate, and you can calculate how much water is received by what surface. This figure is important, because:

a) the application rate should not be higher than what the soil can absorb; the infiltration rate. If this is higher, than water will run off, or form stagnant water.
b) You can then calculate how long you can leave the sprinkler at one place, before you need to remove it to another place.

5. **Uniformity of sprinkler spray over the wetted circle.**

Ideally, all the plants receive an equal same amount of water. So the more even the sprinkler sprays the water, the better it is.
Water does not infiltrate straight downward into the soil. It will spread to the sides also.
The roots of the plants also have a certain spreading in the soil. So a bit of unevenness is not a problem, neither to plant growth nor to water efficiency scores. However, when the uniformity is very low, this means that at some places, water application will be too much, whilst in other places in the wetted radius, the plants still will not have sufficient water.

There is one note to make: Sprinklers spray in circles. So if a farmer wants to spray all of the land, some overlap will need to be made to the spraying circles. This implies that it is not really a bad situation if there is less water application at the outer ends of the circle. As long as the farmer takes care that there is overlap between the circles.

Costs and lifetime of sprinklers
An important parameter we could not test is the lifetime of the sprinklers, as this requires running the sprinklers over an extended period of time. Still, durability and lifetime are important parameters, especially related to purchase costs.

Procedures of testing

Who did the testing?
The testing was carried out by Erik van de Giessen and Victor Muthuri, both engineers liaised to the SWA program. Erik is irrigation engineer and works for Practica Foundation in the Netherlands and provides technical support and backstopping to the SWA team. Victor is irrigation engineer and consultant contracted by SNV to support result achievement of Outcome 2 of the SWA program.
We were supported by two students who were doing their MSc Agronomy at the … in Meru.

How did we choose the sprinklers to be tested?
We went to the market in Meru and bought one sprinkler of each of the sprinklers types that were available. Under the sprinklers are the sprinklers most commonly used by farmers in Kenya.
We have tested 8 sprinklers.

Where did we test them?
The testing was hosted and facilitated by the Kaguru farmers training institute in Nkubu, Meru.

How did we test them?
We used 2 GI sprinkler stands of 1,20 meters high, stabilized by a tripod of iron bars.
We connected the sprinklers with connectors and hoses to the piped system of the training farm. Each sprinkler had its own connection. We installed Gate valves, so that we could stop the water supply when we wanted. We could also adjust the gate valve in order to put the pressure at the desired value.
We measured the pressure with pressure gauges with a range of -/-1 to +1,5 Bar. On top of each sprinkler stand, we mounted a pressure gauge on a T-Piece. This way, we could measure the (dynamic) pressure in the pipe, just under the sprinkler, whilst the sprinkler was spraying.
The needle of the pressure gauge started at minus 0.13 Bar because of the high elevation of Meru above sea level. In our readings, we compensated for this. For example, to reach a water pressure of 0.33 Bar, the needle reading was set at 0.2 Bar.

We measured the flow of each sprinkler at each pressure by putting the sprinkler head upside down in a bucket of 10,5 litres. We then measured the time it took until the bucket filled up with a stopwatch.
We measured the wetted radius with a measuring tape. We observed until what distance the drops were falling around the sprinkler.
We measured the evenness of flow by putting plastic bowls in a straight line from the sprinkler pole to the edge of the wetted circle. We let the sprinkler run for a while, until the bowls were sufficiently filled to do a good measurement. We then measured the volume of water caught in each of the bowls with a small kitchen water meter cup of 250 ml, with lines each 50 ml. So the accuracy of reading was about 10 ml.
In smaller wetted circles, we used small bowls to have more measuring points. In larger wetted circles, we used bowls with a larger surface and diameter.
Because we know the size of the bowls, this was also an extra way of confirming the measured wetted radius.

Testing conditions
Pressure in the feeder pipe was not always constant. At some occasions, the pressure dropped during a uniformity test. If the pressure drop was too high and too long, we stopped the test and restarted.
We learned to monitor to pressure during the uniformity test, and to adjust the pressure when we found it was dropping or rising by adjusting the gate valve until the desired pressure was set again. This fluctuation in pressure may have had some influence on the accuracy of the uniformity tests.

Wind was very light, but sometimes a bit stronger and then wetted radius changed. We measured the radius perpendicular to the wind direction in order to reduce this wind influence.

Categories of sprinklers
The sprinklers we tested can be put in 2 categories:
1) Butterfly sprinklers
2) Pulsating sprinklers

Butterfly sprinklers have their nozzle facing upwards. The water spray is interrupted by a piece that starts to rotate fast because of the speed of the water, and this piece changes the direction of the water flow to the side an upward.

Pulsating sprinklers have their nozzle facing sidewards and diagonally upwards. The jet spray pushes away a small arm, which then comes back by the force of a spring and hammers the head of the sprinkler. This hammer makes the entire sprinkler head and nozzle rotate around its axis. The small arm also interrupts and disperses the flow. Pulsating sprinklers often have means to adjust the sprinkler functioning inbuilt (spray, flow, rotation). Some sprinklers have an extra, smaller nozzle spraying to the opposite direction of the main nozzle.

General findings and conclusions

1. Butterfly sprinklers generally require a lower minimum pressure to operate well. Jet sprinklers generally do not operate well when pressure is lower than 6 m water head.
2. Almost all sprinklers tested gave a low to very low uniformity of water distribution over the wetted circle. This results for most sprinklers in situations where the inner parts of the wetted circles are grossly over-irrigated, and the local application rates are (much) higher than the soil infiltration capacity. This can be observed by the appearance of stagnant and runoff water in the central part of the wetted circle. At the same time, the outer parts of the circle receive too little water.
3. Most often, the soils in Kenya are heavy clay and clay-loamy soils with a low infiltration capacity of 1-5 mm/hour. Two sprinklers were found to have an application rate that grossly superseded this range of soil infiltration rates. Their nozzles' diameters were simply too large, or they were not capable to spray the water over sufficient distance.

Considerations for use of sprinklers

Multiple sprinklers in a row and multiple sprinkler systems

The low uniformity of the sprinklers, and the fact that the outer ends of the wetted circle receive (much) less water than the inner part of the circle, can be partially compensated by overlapping the wetted circles. In other words, the sprinkler poles should be place closer to each other than the width of their wetted circles. This reduces the "effective wetted circle radius".
For different sprinklers operating at different pressures, the effective wetted circle radius can be derived from the graphs presented in this report.

How to reduce overlap of water application with multiple sprinklers

Most multiple sprinkler systems are calibrated in a square setup. However, it can be demonstrated mathematically that a hexagonal / triangle setup is much more water efficient, and results in optimal overlap of wetted circles.
The easiest way of demonstrating this (without mathematics) is using a set of round coins. Put them all flat on your table. How do these coins fit together best, minimizing the empty space between the coins? You will find out that around each coin, 6 other coins can be placed, and this fills up the space best. Only 6% of the space is uncovered, (against 21% in a square setup). The centres of the coins are then connected with equal triangles.

Sprinkler use in combination with solar pumps

The flow and pressure of solar pumps are not constant, but depend on the irradiation of each moment. For example, when a cloud blocks the sunlight, flow and pressure decrease immediately. This characteristics makes it impossible to have a constant system pressure and flow, and thus sprinkler radius and application rate. It also affects the evenness over the (fluctuating) wetted circle.
In combination with solar pumps, butterfly sprinklers are more suitable than pulsating sprinklers, because butterfly sprinklers generally operate better under (very) low pressure conditions.
In order to solve the problem of fluctuating radius and pressure, the following may be tried:

Sprinkler use in combination with solar pumps and elevated storage

In order to create a more constant pressure, and thus higher water use efficiency, whilst using a solar pump, the solution is to work with elevated storage tanks. With a (relatively) constant and known water pressure, the best sprinkler spacing and irrigation duration can be calibrated, and water application and water use efficiency can be optimized.

As added advantage, the farmer is not obliged to operate his sprinklers the entire day every day: he/she can store the water of a day of solar pumping, and start irrigating the next morning when the tank is full from the previous day, or in the afternoon when the solar pump has filled up the tank during the day. Another added advantage of this practice is that irrigation during the hottest hours of the day is avoided: solar pumps have a higher yield during these hours.

The value for money

The value for money of a sprinkler is a combination of price and performance. Apart from that, it is important to know the lifetime. We could not test this, but by handling them, we obtained an impression of the sturdiness of the material and sprinkler in general. On the last page of this report, I have tried to rate the value for money, combining price, performance and sturdiness, but it remains quite a random exercise.

Information sheets per sprinkler tested

The Yellow Plastic Butterfly sprinkler

Description

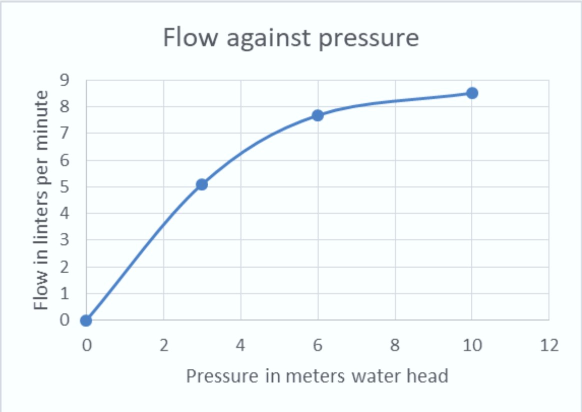
A sprinkler very commonly used, and reportedly highly popular amongst farmers. Sold to us under the name 261 A sprinkler.

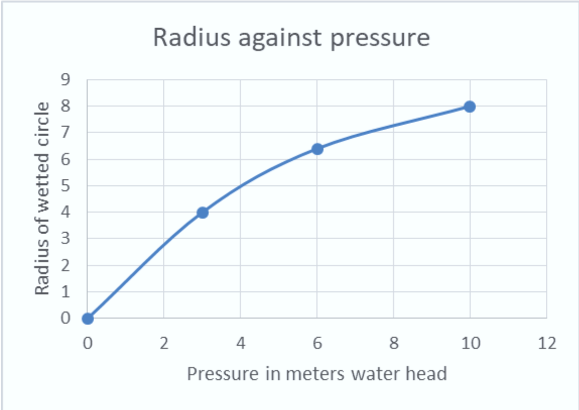
Price / Lifetime

One sprinkler costs 100 KSH. Their lifetime is reportedly limited to 1 or 2 irrigation seasons.

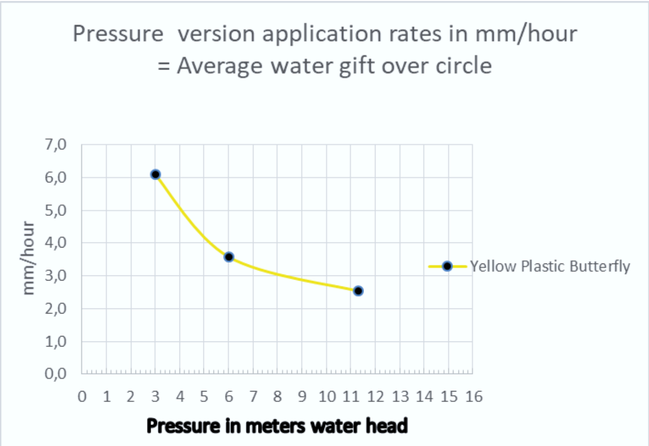
Flow and Radius against Pressure

This sprinkler gives a good radius of the wetted circle also in low pressure situations.





Application rate



Overall, the application rate is low compared to other sprinklers. This is favourable, because of the low infiltration rates of the soils. With a higher pressure, the sprinkler sprays of a wider radius, and the application rate decreases. The sprinkler can be left standing at one position relatively a long time compared to other sprinklers.

Note that this is the average application rate. Due to the low uniformity, the application rate in the first one meter radius is 48 mm/hour at P = 0.3 Bar.

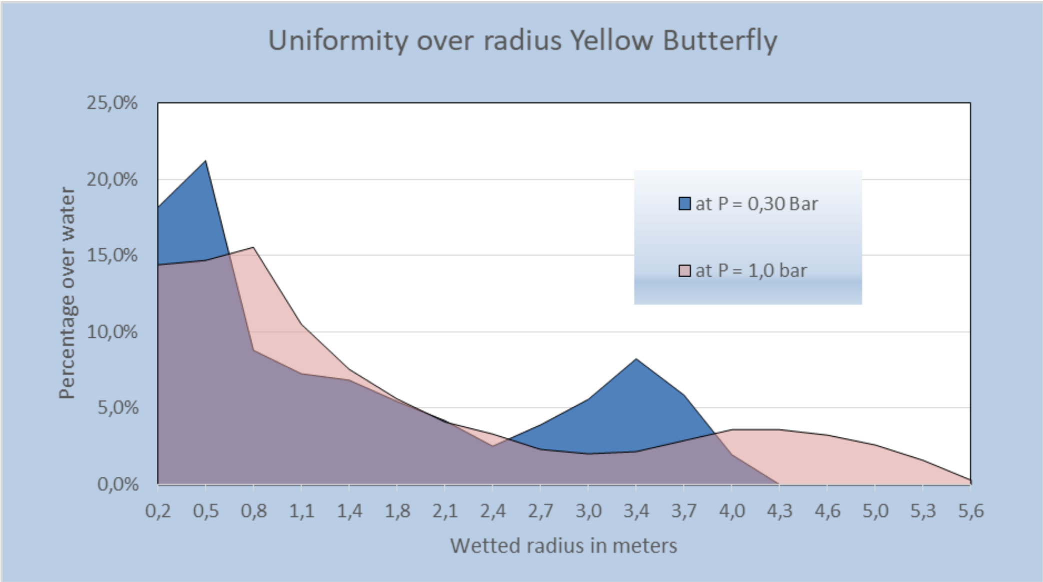
Uniformity over the wetted circle

The uniformity of this sprinkler is not good.

At P = 0.3 Bar (water H =3m) it sprays approximately 52% of the water in the first meter. The other half is applied on the remaining 3 meters of radius.

At P = 1.0 Bar, the uniformity is a bit less uneven, but still the soil receives 6x less water at 3 meters from the pole, compared to 1 m from the pole.

Note that the distribution first goes down over the radius, and then up again: A certain part of the water that is thrown away, all falls at the same distance from the pole.



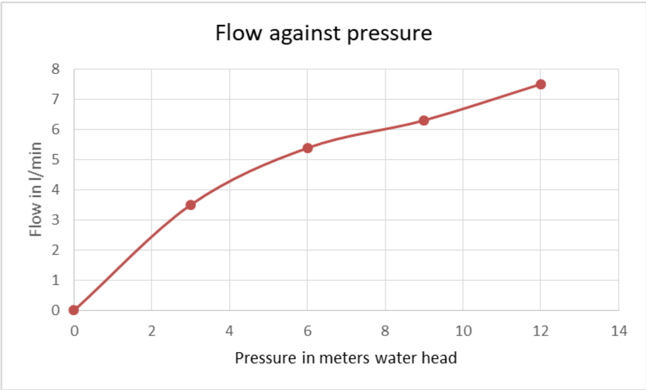
The effective wetted circles are determined by imagining that overlap occurs of two wetted circles at the same pressure, and then judging what overlap would result in the best uniformity situation.
At P = 0.3: 2.9 meters. Optimal sprinkler pole distance = 5.8 meters
At P = 1.0: 3.8 meters. Optimal sprinkler pole distance = 7.6 meters

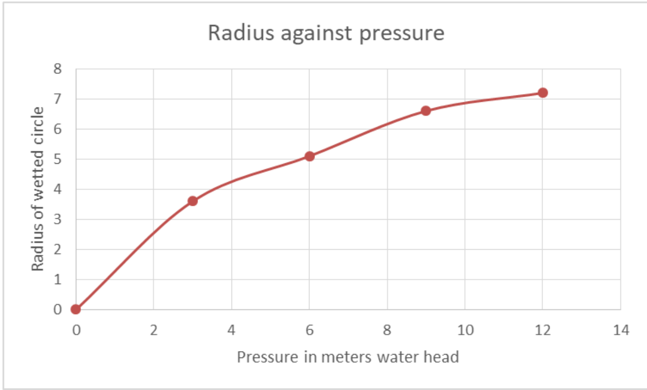
The iron butterfly sprinkler

This is the iron version of the plastic yellow butterfly sprinkler. On the market, we paid KSH 200. It was referred to as sprinkler 261 B.

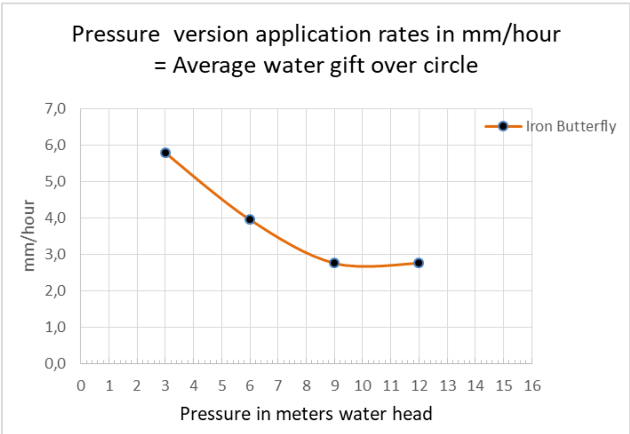
Price / Lifetime
We paid 200 KSH for this sprinkler. Their lifetime is probably much longer than its plastic version.

Flow and Radius against Pressure
This sprinkler gives a good radius of the wetted circle also in low pressure situations. The way it sprays is highly comparable to the plastic version.
Compared to the plastic version, the flow is a bit less (at 10 m pressure, 8.5 l/min versus 6.7 l/min), indicating a slightly smaller nozzle diameter. Also the radius is a bit less: at 10 m pressure, 8.0 m versus 6.9 m.





Application rate

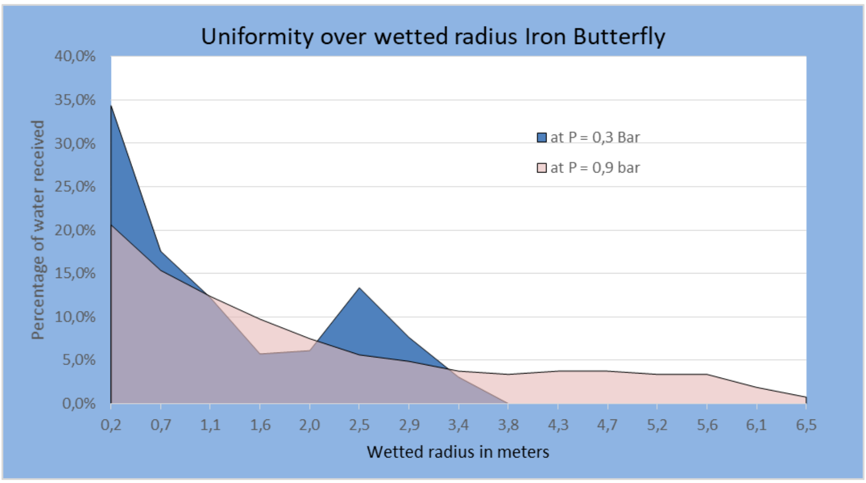


Overall, the application rate is low compared to other sprinklers, and almost similar to the plastic sprinkler. This is favourable, because of the low infiltration rates of the soils. With a higher pressure, the sprinkler sprays of a wider radius, and the application rate decreases. The sprinkler can be left standing at one position relatively a long time compared to other sprinklers.

Note that this is the average application rate. Due to the low uniformity, the application rate in the first one meter radius is 40 mm/hour at P = 0.3 Bar.

Uniformity over the wetted circle

The uniformity of this sprinkler is not good, and a bit lower than the plastic version.
At P = 0.3 Bar (water H =3m) it sprays approximately 60% of the water in the first meter. The other 40% is applied on the remaining 2.8 meters of radius.
At P = 0.9 Bar, the uniformity is a bit less uneven, but still the soil receives 6x less water at 3 meters from the pole, compared to 1 m from the pole.
Note that at P = 0.3 Bar, the distribution first goes down over the radius, and then up again: A certain part of the water that is thrown away, all falls at the same distance from the pole.



The effective wetted circles are determined by imagining that overlap occurs of two wetted circles at the same pressure, and then judging what overlap would result in the best uniformity situation.
At P = 0.3: 2.3 meters. Optimal sprinkler pole distance = 4.6 meters
At P = 0.9 Bar: 3.5 meters. Optimal sprinkler pole distance = 7.0 meters

The Blue Iron Butterfly

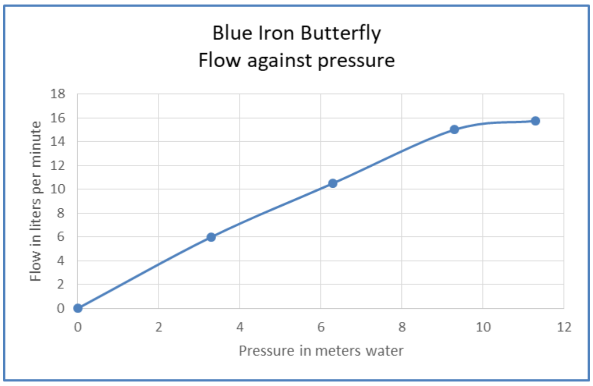
This is a locally produced version of the iron butterfly sprinkler. Note that the rotator is mounted on top, but not attached to the sprinkler base. The rotator is less smooth, and bending seems to be done by hand (using tools). It was painted blue by the manufacturer.

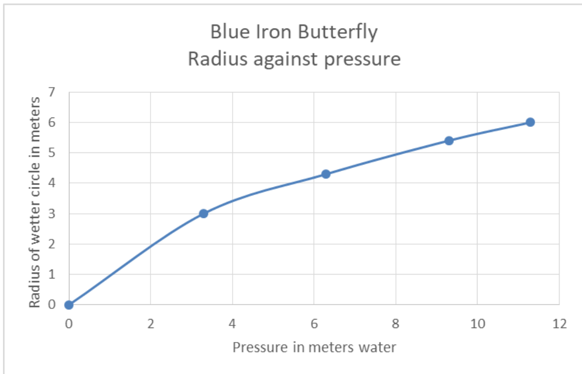
Price / Lifetime

We paid KSH for this sprinkler. Their lifetime is unknown.

Flow and Radius against Pressure

This sprinkler gives a good radius of the wetted circle also in low pressure situations. The way it sprays is highly comparable to the plastic version. Compared to the iron butterfly, the flow is more than double. (at 10 m pressure, 15 l/min versus 6.7 l/min), indicating a larger smaller nozzle diameter. The radius is a bit less: at 10 m it is 5.6 meters, versus 6.9 of the iron butterfly.

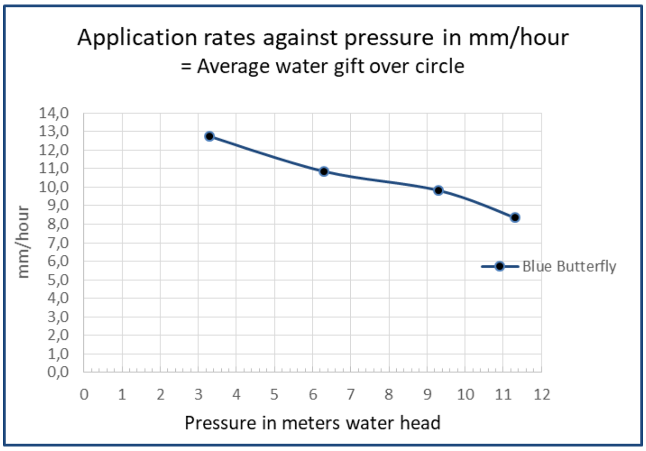




This indicates that the Blue Iron butterfly is spraying much more water over a more limited area, compared to the Iron Butterfly. This can be seen back at the application rate.

Application rate

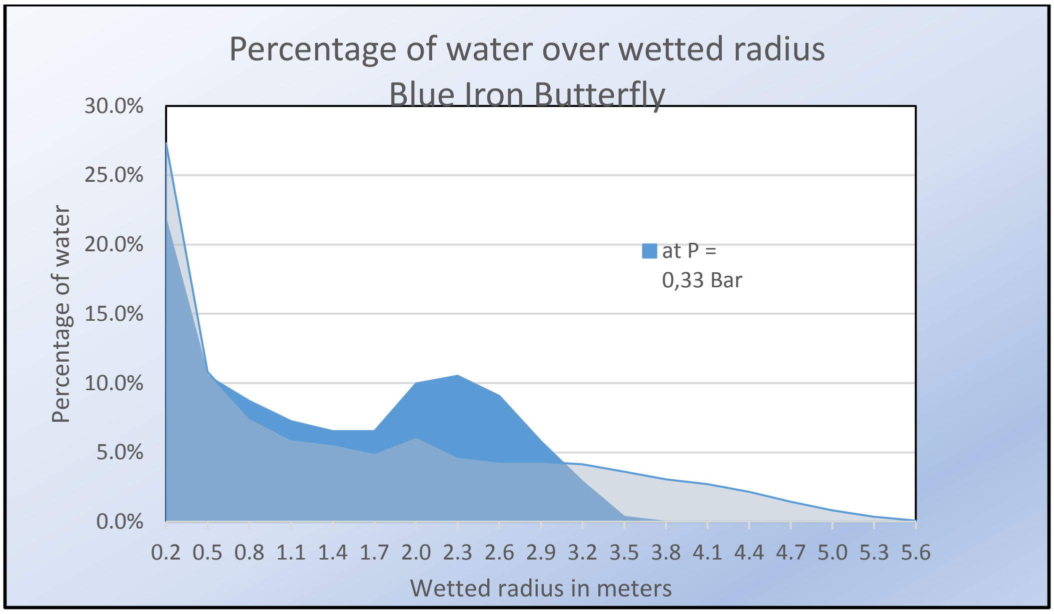
This sprinkler gives a very high application rate, and should therefore not be advised to farmers. The average application rate over the circle is much higher than the other yellow and iron butterfly sprinkler, and higher that the infiltration rates of most loamy and clay soils. It implies that the sprinkler has to be moved very often.



The application rate of the blue butterfly is 11 mm/hour at 0.6 Bar. The iron butterfly has an application rate of 4 mm/hour at 0.6 Bar.

Please note that this is the average application rate, and that the nearest 1 m circle to the pole receives much more (50%!) of the water.

Uniformity of spraying



The graph above shows the uniformity of spraying over the wetted area at P = 0.33 (dark blue) and P = 0.93 Bar (light blue). The same pattern can be seen for all 3 butterfly sprinklers. At the lowest pressure, the uniformity is less than at higher pressure; the water application right next to the pole is very high, and going further from the pole, this drops and then rises again to a peak.
A higher pressure, the uniformity is more even over the wetted circle, but the problem of high water application right next to the pole is always there.
This problem is even more important with this sprinkler, because of its high application rate.

The effective wetted circles are determined by imagining that overlap occurs of two wetted circles at the same pressure, and then judging what overlap would result in the best uniformity situation.
At P = 0.3, there are 2 alternatives for optimal sprinkler pole distance.
The first is to put the sprinkler poles 3.7 meter apart. In this situation, the second sprinkler would fill the “gap” at 1.4 meter with its application peak at 2.7 meter. However, this placing would result in an even higher application rate because of large overlap. So the better alternative seems to be to have little overlap between the wetted circles, and space two sprinklers at 6.0 meters from each other.
At P = 0.93 Bar, the uniformity line goes smoothly down. A distance of 7.2 meters would result in a very high uniformity over the overlapping wetted area, except near the sprinkler poles. In that case, the effective wetted circle is 3.6 meters.

The Bicycle Pedal sprinkler

This sprinkler is an example of local ingenuity and craftsmanship. A bicycle pedal frame is used to produce a rotor that is equipped with ball bearings. This is probably done to try and answer to the problem of fast wear and tear of other sprinklers. As such, this is a brilliant idea. Unfortunately its' implementation was not very successful.

The rotor blade is bent in such an uneven way that it does not spray the water very far. At 0.3 Bar, the radius was only 2 meters, at even at 1.13 Bar, the radius was only 5 meters.
Furthermore, it is difficult to fix the sprinkler on a standard sprinkler head.
The nozzle is too wide, so the water flow is very high. This sprinkler has the highest application rate of all sprinklers, which is highly unfavourable for heavy loam and clay soils.
The uniformity of spraying is very low, with more than 55% of the water falling in the first meter even at higher pressures and a wetted circle of 5 m (at 1.13 Bar).

Because of its unfavourable characteristics, we decided not to show any graphs for this sprinkler in order to save document space. Use of this sprinkler should be highly discouraged.

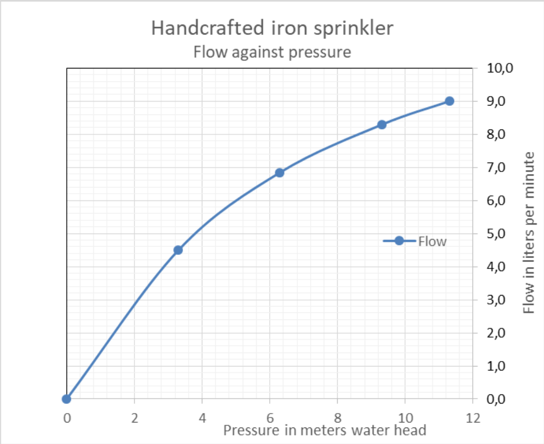
Handcrafted Iron Sprinkler (with PVC connector)

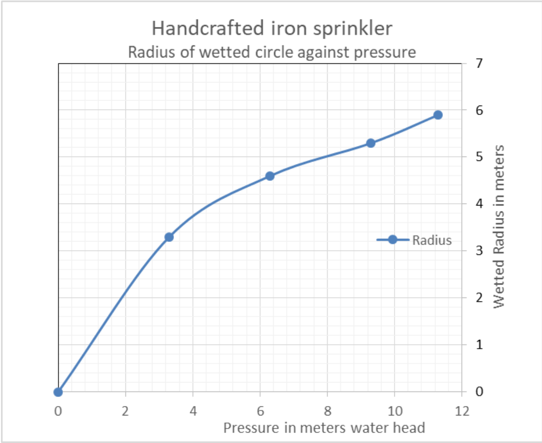
Description
This other example of local craftsmanship. The sprinkler itself looks rather improvised, and we doubt the lifetime of it. To our surprise, it is more successful than the bicycle pedal sprinkler in terms of functioning of the sprinkler.
The PVC connection makes it a bit difficult to attach the sprinkler to the sprinkler head, but not impossible.
The rotor blade is well shaped, so that the projection of the water is reasonable, and it rotates well.

Because the sprinkler is handcrafted, we cannot guarantee that other sprinklers with the same looks have the same characteristics: especially the nozzle size but also the shape of the rotor blade have great influence on how the sprinkler functions.

Price / Lifetime
We bought this sprinkler at the Nkubu market for KSh ….
We could not measure the lifetime, but the sprinkler makes an impression that it could defect quite easily, for example the nozzle plate falling off, or iron holders bending.

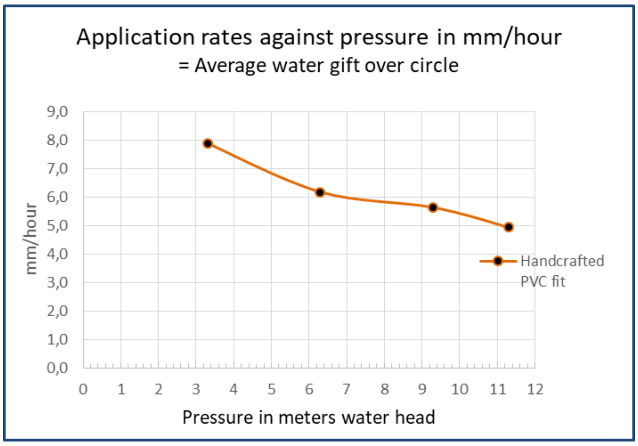
Flow and Radius against Pressure





The sprinkler flow is relatively low, indicating a small nozzle size. At 6 m water head this sprinkler has a flow of 6.6 l/min, which is less than the yellow butterfly sprinkler.
The radius is less than the yellow butterfly sprinkler. At 10 meters water head it has a radius of 5.5 meters, versus 8 meters for the yellow butterfly sprinkler.

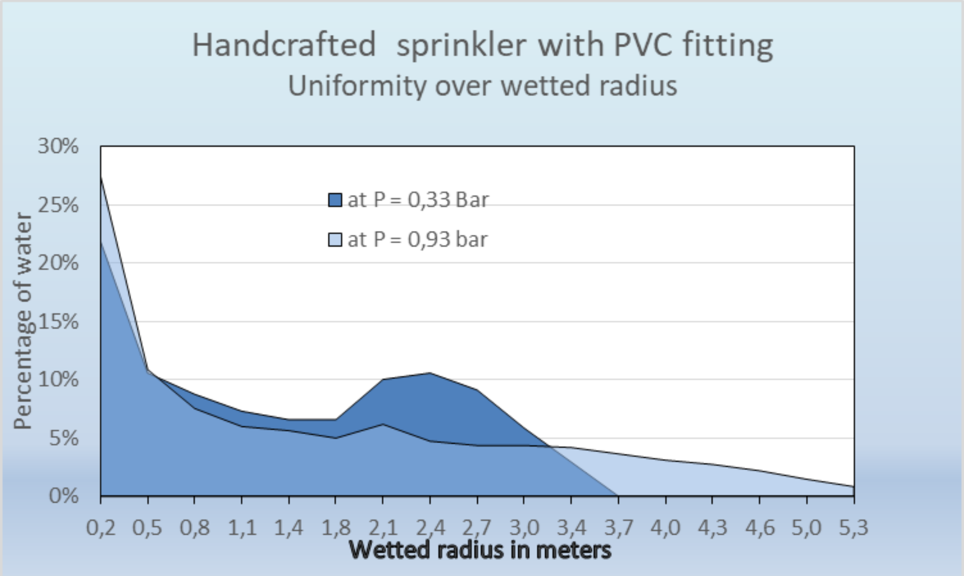
Application rate



The application rate of this sprinkler is relatively high compared to most other sprinklers. This is due to the fact that the radius of the sprinkler is limited. It appears that the rotor blade is not very effective in spreading the water.

Uniformity over the wetted circle

The uniformity of this sprinkler is even slightly better than other butterfly sprinklers, but still not good. The problem of too much water in the first meter of radius is persistent for all butterfly sprinklers.
At P = 0.3 Bar (water H =3m) it sprays approximately 45% of the water in the first meter. The other half is applied on the remaining 2.7 meters of radius.
At P = 0.93 Bar, the uniformity is quite reasonable, but still the soil receives 2x less water at 4 meters from the pole, compared to 1 m from the pole.
Note that at the lower pressure, the distribution first goes down over the radius, and then up again: A certain part of the water that is thrown away, all falls at the same distance from the pole.

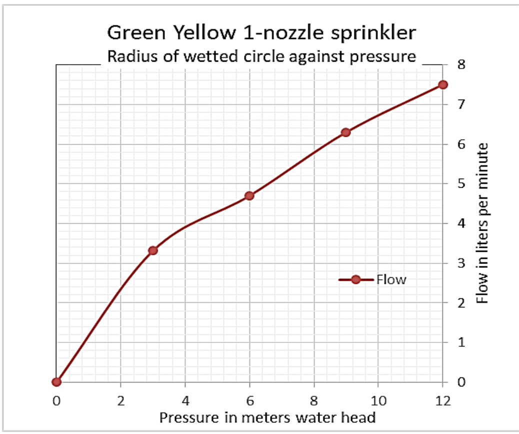


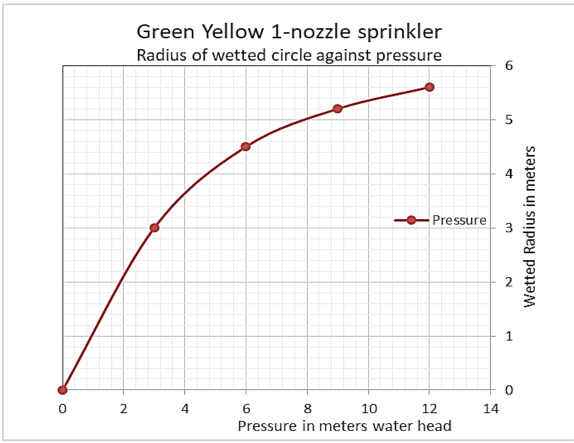
Green-Yellow 1-nozzle sprinkler

This sprinkler comes from an advanced sprinkler manufacturer. Probably, it is part of an irrigation hardware package that can be purchased. We do not know the producer or dealer. The angle of operation can be adjusted, meaning that the farmer can choose what part of the circle will be wetted. With a knob on top, the flow can be adjusted as well.
We tested the sprinkler whilst wetting the entire circle, with the flow knob in middle position.

Price/lifetime.
Practica bought this sprinkler in Kenya during a previous visit, and the price was not retrievable.

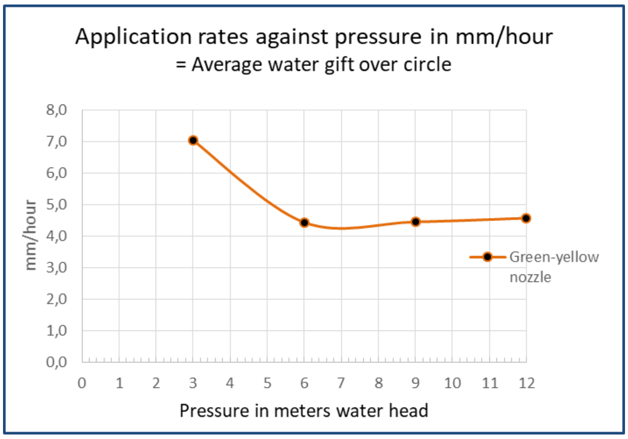
Flow and Radius against Pressure





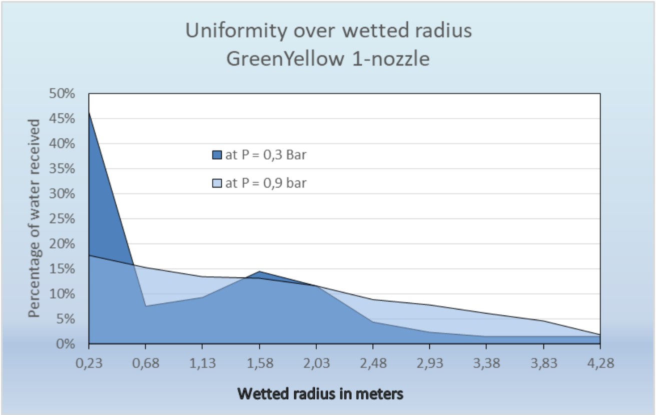
The flow is a little bit less than the flow of the yellow butterfly sprinkler. Also, the wetted radius is smaller. It gives a radius of 5,5 m at a pressure of 1 Bar, whilst the yellow butterfly gives a radius of 8 m at a pressure of 1 Bar. The advantage of this sprinkler is that the flow is adjustable. We did not test this sprinkler at different knob positions. Probably, also the radius will vary with different knob positions.

Application rate



The average application rate is quite low, and therefore favourable for low infiltration rates of heavy soils.

Uniformity over the wetted circle



As can be seen in the graphic, the sprinkler does not operate well under the low pressure of 0.3 Bar. At this pressure, the uniformity of this sprinkler is not good at all. Pity we did not test the uniformity at 0,6 Bar. It can be concluded that this sprinkler should not be recommended as low pressure sprinkler.

At P = 0,9 Bar however, the uniformity is far better.

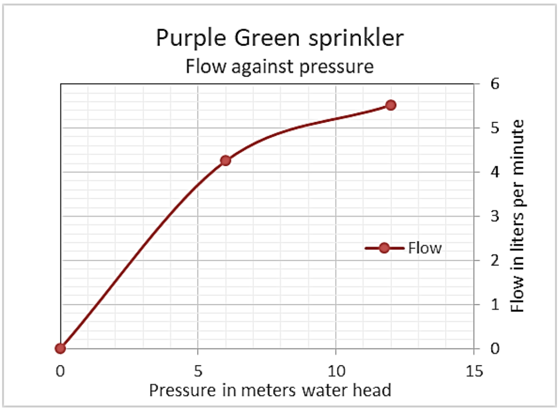
In this graph, we wonder why the recorded wetted radius at P = 0,9 Bar is so much less than shown in the graphic of radius against pressure. Probably, during the measurement, the pipeline pressure dropped and we did not notice. So probably, in reality this uniformity graph shows the uniformity under a pressure less than 0,9 Bar.

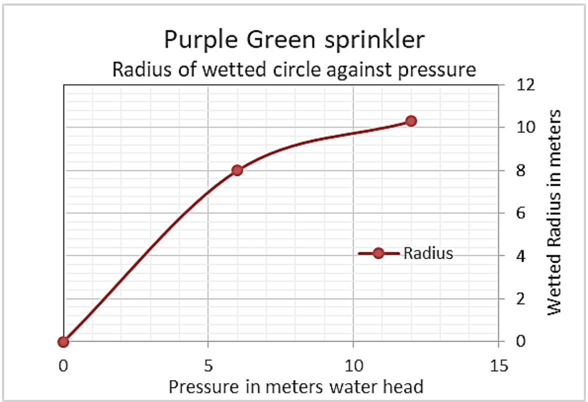
Purple Green Sprinkler

This sprinkler is also manufactured professionally, and is part of an irrigation package that can be bought. The producer produces a sprinkler body, upon which different sprinkler nozzles, with different colours, can be mounted in order to adjust the spraying characteristics of the sprinkler.
The sprinkler has two nozzles: the purple nozzle is the “main nozzle” having the largest opening and flow. It also has a green nozzle spraying in opposite direction.

Price/lifetime.
Practica bought this sprinkler in Kenya during a previous visit, and the price was not retrievable.

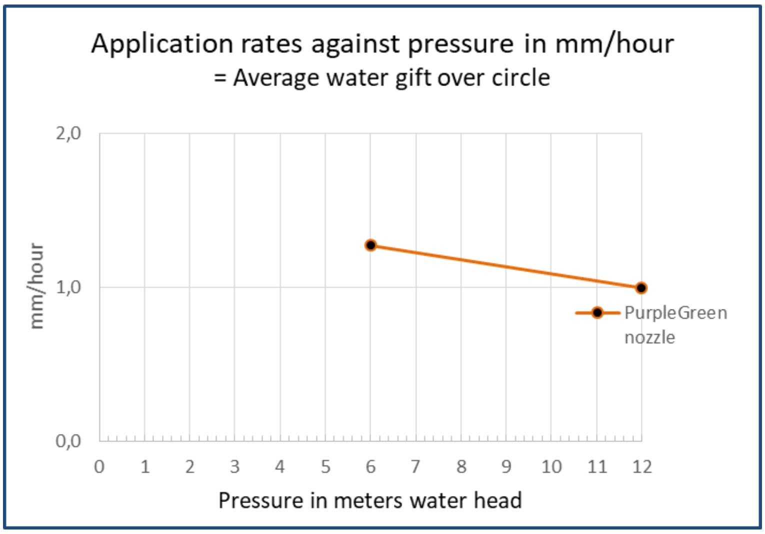
Flow and Radius against Pressure
This sprinkler did not operate well under a pressure of 0,3 Bar. It refused to rotate. It is clearly produced to operate under higher pressures. So we started measuring at 0,6 Bar and we also measured the flow and radius at 1,2 Bar.
At 0,6 Bar, it gives a flow of 4,2 liters per minute, compared to 7,8 l/min of the yellow butterfly sprinkler. At 0,6 Bar, it gives a wetted radius of 8 meters, which is higher than the yellow butterfly sprinkler that give a wetted radius of 6,2 meters at the same pressure.
At 1,0 Bar, it gives an estimated flow of 5,2 l/min, against 8,5 l/min of the yellow butterfly, and a wetted radius of 9,8 meters, against 8 of the yellow butterfly.





This makes this sprinkler have a low application rate.

Application rate

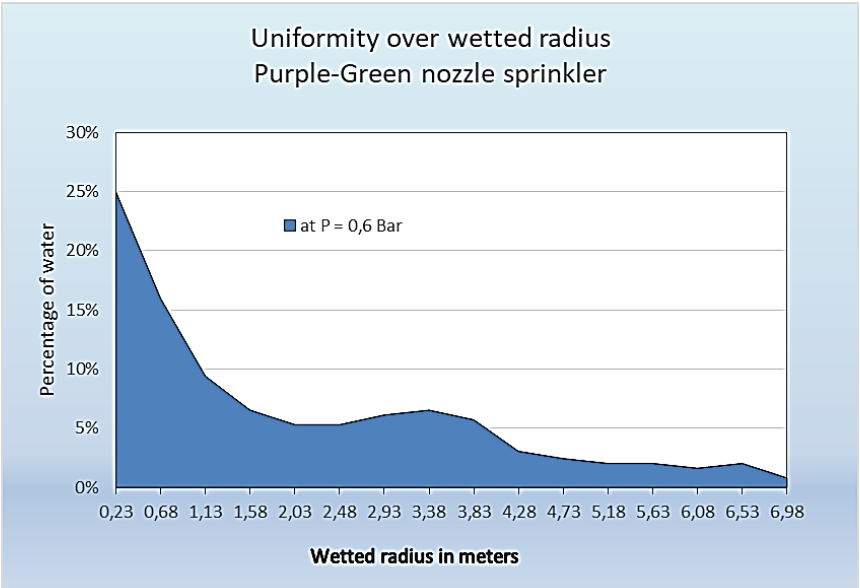


The average application rate is the lowest of all sprinklers tested. This sprinkler sprays the water with the smallest flow over the largest area. This indicates that the nozzles are very fine. For a water gift of 3 mm, this sprinkler needs to be left working during almost 3 hours.

The sprinkler is clearly designed for operation in a sprinkler system with multiple sprinklers at fixed positions, and operating at a higher pressure range. This type of systems can be found in larger glass houses.

Uniformity of application

We measured the uniformity only at 0.6 Bar. The following graph results:



This graph shows that the uniformity of this sprinkler is not good at 0.6 Bar. Almost 50% of the water falls in the first meter radius.

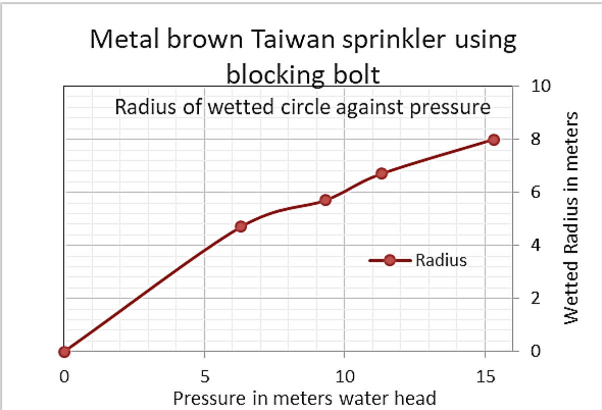
Although not demonstrated, it is likely that the uniformity is better under higher pressures.

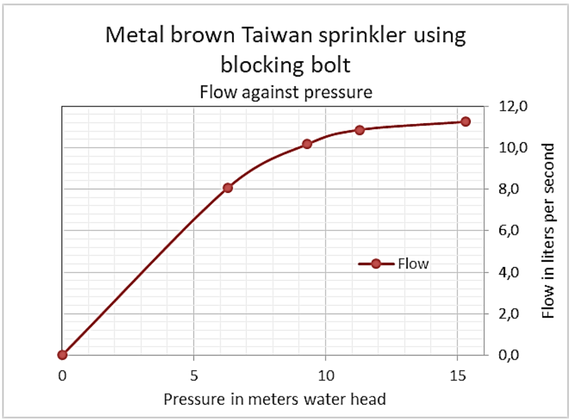
Brown Metal Taiwanese sprinkler

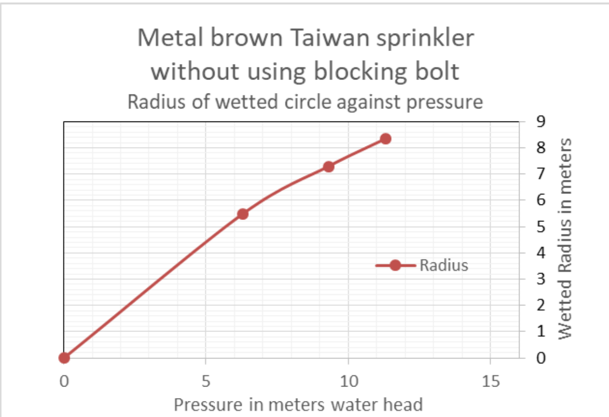
This sprinkler feels heavy and sturdy, and makes a very durable impression. The metal paint is stoved, meaning that it was heated after application. The sprinkler is equipped with an adjustable bolt that can block the jet spray. This bolt enables manipulation of the wetted radius.
It is also equipped with a second nozzle spraying in the opposite direction of the main nozzle.
We measured this sprinkler in 2 bolt positions.

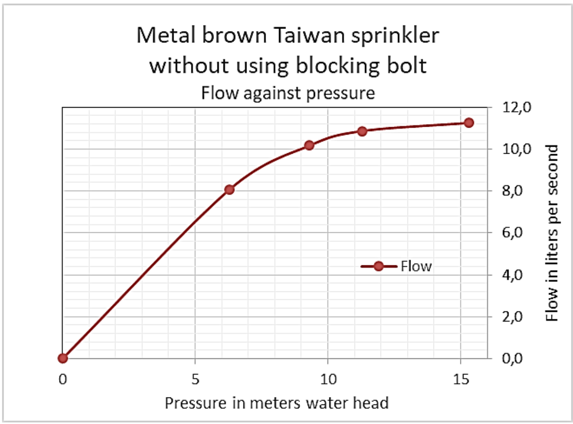
Price / lifetime
As said, this sprinkler makes a very sturdy impression and probably has a (very) long lifetime. Its price was … KSH.

Radius and Flow
We measured the sprinkler under two conditions. The first condition is using the blocking bolt at quite a tight position, so that the water flow was clearly blocked by the bolt.
We did not test at P = 0,3 Bar, as the sprinkler did not rotate well under this pressure.



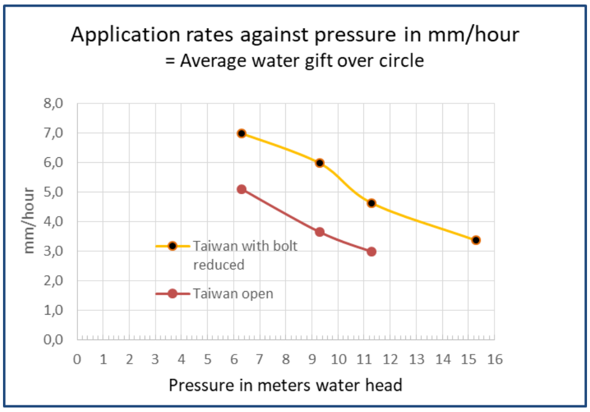






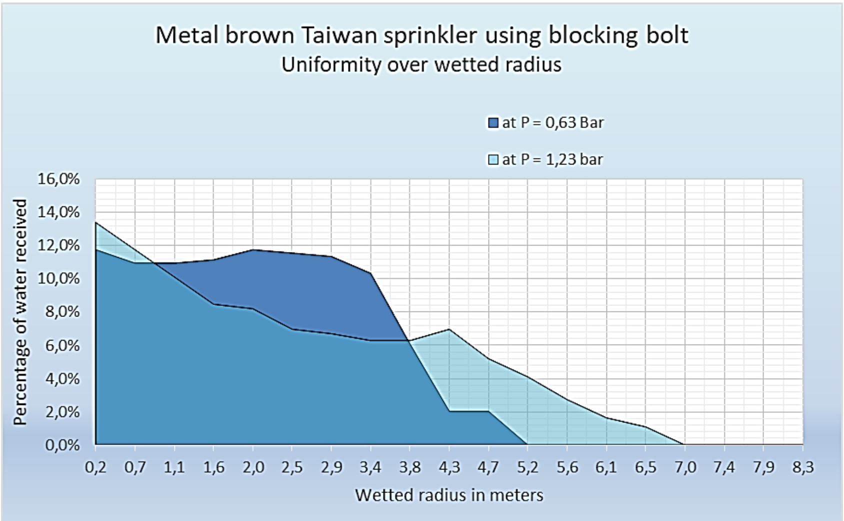
As expected, the flow against pressure is equal, because the flow at certain pressure largely depends on the size of the nozzle opening and this did not change. The bolt is influencing the wetted radius, and the way the water spreads over the wetted circle. With the bolt blocking, the wetted radius at 1 Bar is 6 meters, against 7.6 meters without blocking.

Application rates

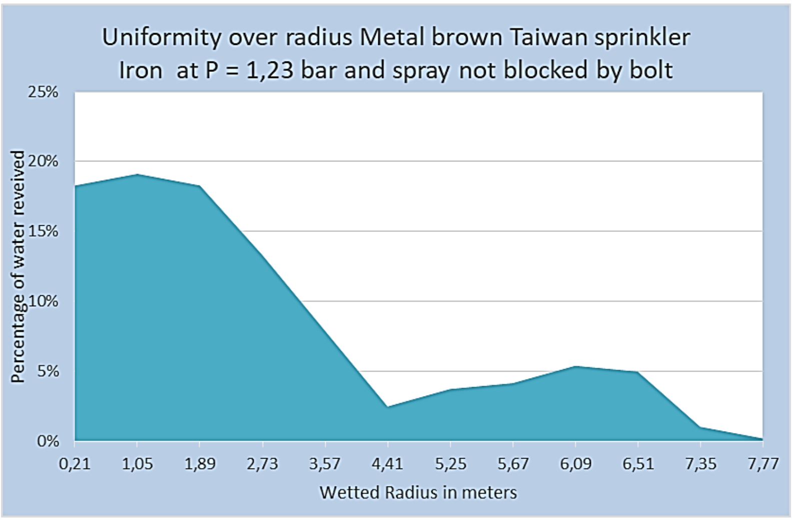


As the water flows in the two bolt positions are equal, the average application rates depend only on the sizes of the wetted circles.
When the bolt reduces the wetted circle, the same water spreads over a smaller area, causing a higher application rate.
In general, the application rate is acceptable.

Uniformity of application

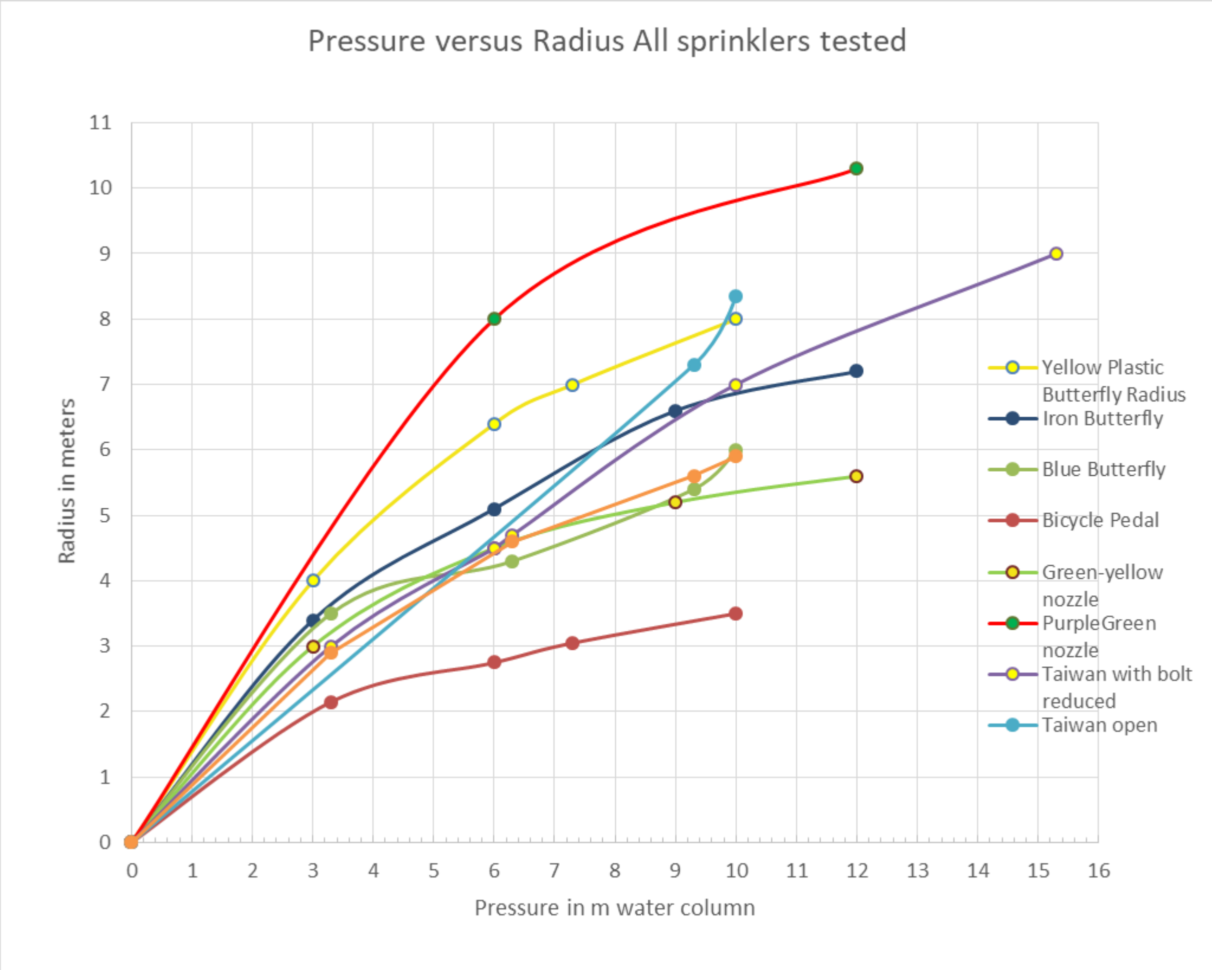


When using the blocking bolt, the uniformity of application is good, especially at P = 0.63 Bar. Over the longest part of the circle, the water application rate is between the 11% and 12% of all water sprayed. At P = 1,23 Bar, uniformity is lower, with a higher proportion of the water falling in the first meter. However, compared to most sprinklers, this is a very good picture of uniformity.
Without using the blocking bolt, water uniformity is less good.



Overview of test findings and conclusions

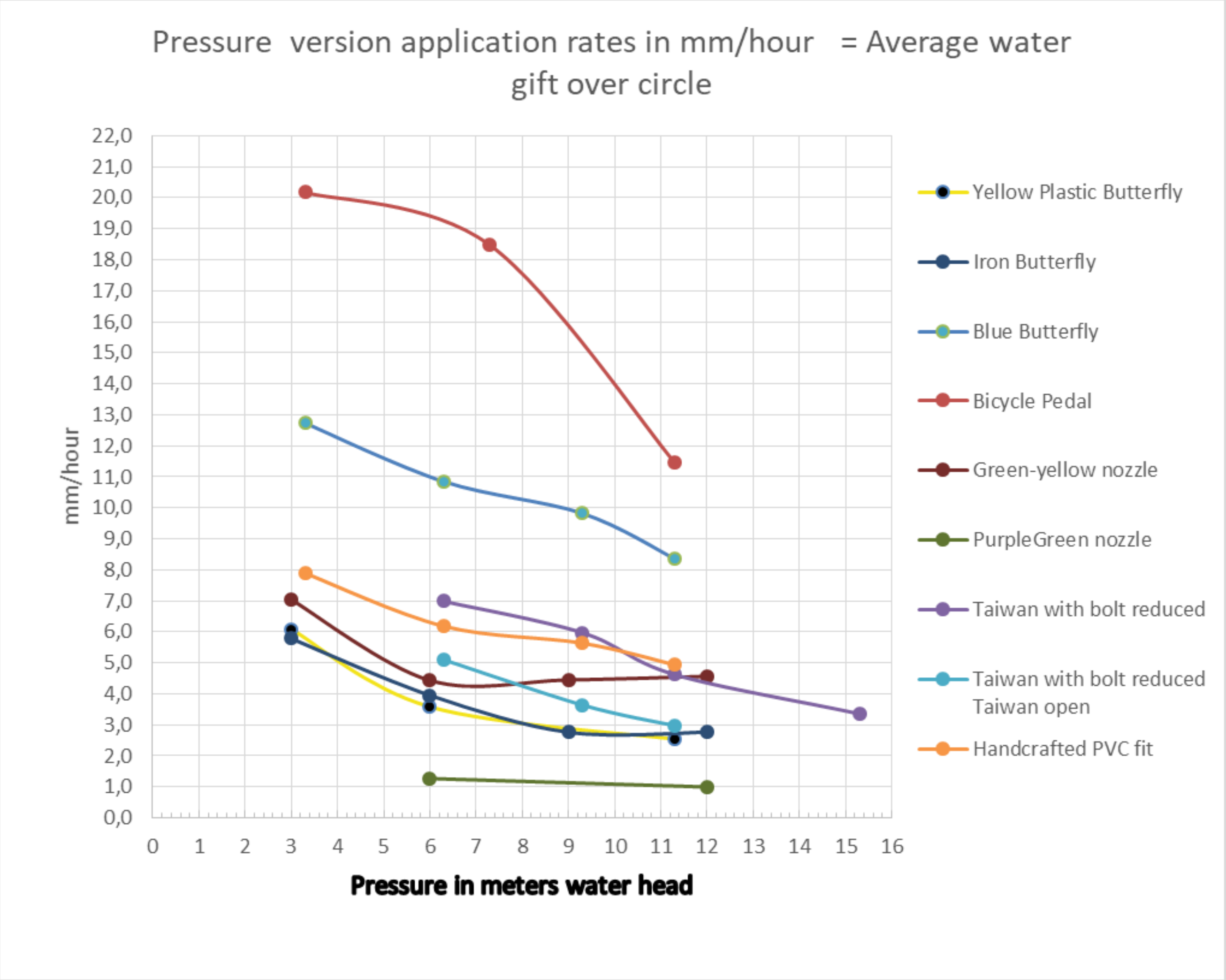
The wetted radius of all tested sprinklers in 1 graph gives the following picture:



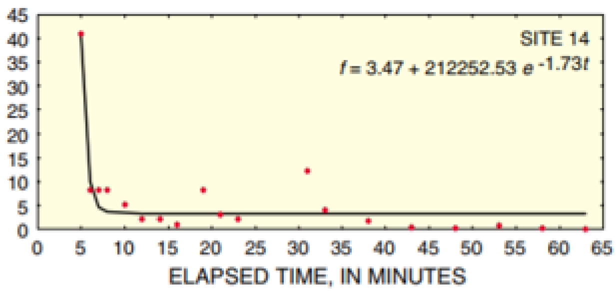
Generally, a large wetted radius is to be preferred, because this reduces the need for replacing the sprinkler often. A larger wetted radius usually also implies a low average application rate.

Average application rates over wetted circles

The average application rates of all sprinklers give the following graph:



The stable soil infiltration rates of the more heavy soils in Kenya can be as low as 1-5 mm/hour. For a heavy clay soil, the infiltration rate curve resembles to the following graph:



This implies that in the first 5 minutes, the soil is able to absorb a lot of water. This graph shows what happens if indeed all water absorption capacity is supplied: the top layer of the soils is saturated after a short time, and after this, the infiltration rate reduces to a stable (approximately) 3 mm per hour.

Applying water through sprinkler irrigation does not result in such a drastic curve, because not all water required to saturate the top layer is provided as fast as in the picture: This picture is used to demonstrate the limited soil infiltration rate after a period of time.

This implies that low average application rates are generally more favourable in Kenya. It can be concluded that the Bicycle pedal sprinkler and the Blue Butterfly sprinkler have too high application rates.

General observations about uniformity

In general, the uniformity of water application of most sprinklers tested is quite dramatic.
Exceptions encountered are the following:

1) The jet spray of the metal brown Taiwan sprinkler can be adjusted with a bolt. With the proper adjustment, a very good uniformity can be achieved.
2) For the higher pressure range, the Green-Yellow 1-nozzle sprinkler gives a good uniformity.

3) All butterfly sprinklers are weak in uniformity, because too much water is provided in the first 1 m circle around the pole. Some are better however than others: The yellow butterfly sprinkler seems to be the best performing sprinkler in this respect.

Summary of observations

In the below table, I give my personal interpretation of the information that results from this test, comparing the data of all sprinklers and judging their performance, price and sturdiness.
It remains to be repeated that under very low pressure situations, the butterfly sprinklers are the only option. Under higher pressure situations, the jet sprinklers are generally performing better, but this also comes at a higher price.

	Yellow Plastic Butterfly	**Iron Butterfly**	**Blue Butterfly**	**Bicycle Pedal**	**Handcrafted PVC fit**	**Green-yellow nozzle**	**PurpleGreen nozzle**	**Taiwan with bolt reduced**	**Taiwan open**
Min. Operating pressure (approximately)	0,3	0,3	0,3	0,3	0,3	0,6	0,9	0,6	0,6
Radius 1)	++	+	-	-	+	+	++	+	++
Application rate 2)	+	+	--	--	+	++	++	+	+
Price	100	200	150	350	70	?	?	700	700
Sturdiness / Lifetime	-	+	-	+	--	+	+	++	++
Price-lifetime ratio	+	+	-	-	-	?	?	+	+
Uniformity	-	-	--	-	-	+ 3)	-	+	-
Performance score 1-10	5	5	3	1	1	7	6	9	7
Value for money score	6	5	4	2	3	?	?	6	5
1) Higher = better									
2) Lower = better									
3) At higher pressures									