Pilot aeroponics cultivation of turmeric

Content

1. Turmeric

General

Turmeric (*Curcuma longa* L.) originated in the Indo-Malay area but is now found widespread across the Australian, Asian, and African continent (Sasikumar, 2005). The plant needs a high temperature (19-28 °C), a high relative humidity (70-90 %) (Nair, 2019) and can therefore be grown under glass or in tunnel in Northwest Europe (NWE). This species is part of the Zingiberaceae, a family which includes several woody herbs that produce rhizomes such as ginger. In addition to the rhizome containing curcumin, the flower can possibly also be traded and curcumin can be extracted from the stem.

Cultivation purpose

The rhizome of the turmeric plant is used in the medical world, in cosmetics and is processed into powder for use as colouring in religious and culinary contexts. Curcumin, the natural colorant in the rhizomes, can also be used as a biodegradable colorant in biobased packaging.

2. Hydro- and aeroponics

Soilless cultivation

Mostly, turmeric is grown in soil, but more and more research is being done on whether turmeric can also be grown on soilless systems, such as hydroponics or aeroponics. This is an agricultural production technique in which plants are grown without the use of soil and nutrients are delivered through a liquid solution. In these soilless cultivations, soil is replaced by an inert substrate or by air/water and the nutrients needed by the plant to grow are delivered via irrigation. These soilless systems have the advantage that soil-borne diseases or pests are out of the picture. Also, in regions where the soil fertility is low, soilless cultivation might offer a solution. In addition, it takes a lot of time to clear the rhizomes of soil after harvesting. This problem is of course also absent in soilless cultivation.

Hydroponics

Hydroponics is a soilless cultivation system where the plant grows in an inert substrate, for instance perlite, or water. Different hydroponic systems exist. The Kratky method or deep water culture method is by far the simplest and easiest hydroponic method. It consist of a container filled with water and nutrients, on top of which a plant grows. The roots of the plantlets grow in the water. Other, active systems also exist. Drip hydroponics systems are most suitable for growing turmeric. All over the world, people are testing these systems (for instance in growing bags) for the cultivation of turmeric.

Aeroponics

In this report, aeroponics as a cultivation method for turmeric was tested. Aeroponics is able to sustain a larger variety of plants that become water logged using hydroponics. Aeroponics supplies a plants root system with a fine mist of nutrients in an enclosed environment with bare roots exposed (Figure 1). The plants just grow on top of that enclosed environment, without the use of any substrate. The advantages of aeroponics systems compared to soil-bound cultivations are an efficient use of space, minimal water usage, less chance for diseases and continuous production. It's also easier to obtain a higher soil temperature.

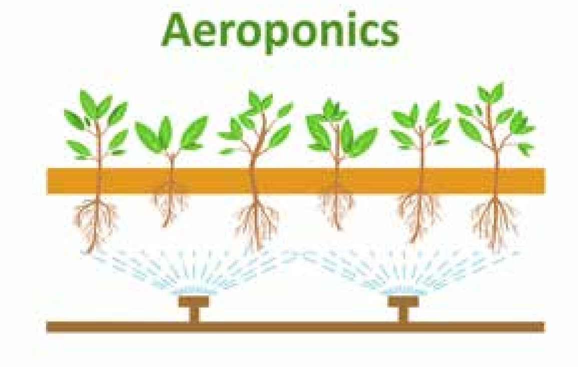

Figure 1: Mechanism of aeroponics (Source: www.growwithoutsoil.com).

3. Pilot set-up

In 2021, an aeroponic pilot was built to test the possibilities for the cultivation of turmeric. For this purpose, a container was made in which a system of nozzles was mounted, which spray upwards (Figure 2). A net was placed on top on which the plants can grow. The necessary pumping and piping to supply and remove the nutrient solution was also provided. The intention is for the turmeric plant to root through the net so that the roots hang in a mist of nutrient solution (in the container).

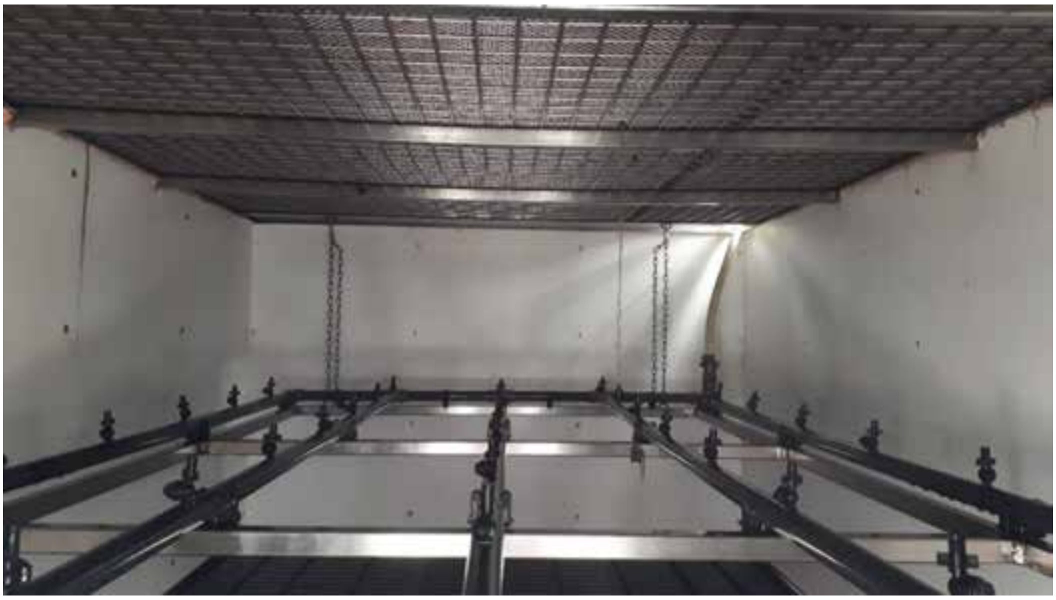

Figure 2: Inside of the aeroponics set-up.

Of course, the turmeric plant also produces rhizomes and these cannot grow through the net. Therefore, on top of the net, an additional 20 cm container is mounted. This is filled with a substrate (e.g. 70 % coco and 30 % perlite), in which the plants can be planted and in which the rhizomes can grow. After planting, a single layer of clay beads (Figure 3) is placed on top of this substrate to prevent the substrate from drying out and to prevent algae formation. The total plant area of the system is 4,2 m².

Figure 3: Clay beads at the top of the aeroponics set-up.

4. General trial set-up

The aeroponics container is placed in a heated greenhouse. Before plant, the substrate should be heated up to at least 19 °C. The container is connected to the fertigation unit, which regulates the supply of nutrient solution to the container, and a storage for the nutrient solution that was not taken up by the plants and drains from the container. This cultivation system generates a lot of drain water, but the fertigation unit will reuse this drain water with every demand for irrigation, so there is no wastage. Also, the substrate is first drip-fed with the nutrient solution, so that the plants have sufficient moisture available at moment of plant. The rhizomes, pre-germinated or not, should be planted 5 cm deep. It is especially important that the growth buds that are already developed, are planted upwards. The optimal planting period in NWE is from the end of March to the beginning of May, depending on the greenhouse and the weather circumstances. The plant density can vary from 10 to 13 plants/m². A high humidity (70 %) and temperature (day 28 °C/ night 19 °C) must be maintained throughout cultivation. By taking samples of the drain water, the nutrient solution can be monitored and, if necessary, be adjusted to suit the crop. After 5 to 8 months, the rhizomes can be harvested. Earlier is also possible, but lower yields can be expected.

Figure 4: Complete pilot set-up with turmeric.

5. Trial 2021

An initial proof-of-concept trial was conducted in 2021. On May 19, pre-germinated planting material from Peru was planted out in six rows with a row spacing of 40 cm and a planting distance of 25 cm (plant density of 10 plants/m²). The composition of the nutrient solution at the start of the trial can be found in Table 1. Several crop assessments were performed to follow the cultivation. The cultivation went very well (Figure 5 and Figure 6) and half of the plants were harvested on November 15 (Figure 7). Irrigation was also stopped at that time to allow the remaining plants to harden off. On December 2, the remaining half of the plants were harvested (Figure 8) to evaluate the effect of stopping irrigation combined with the slightly longer cultivation time.

At the beginning of cultivation, there was a large heterogeneity in emergence/size of rhizomes, as was also evident during the first crop assessment on 49 DAP (

Table 2). As the crop grew, these differences became smaller and the plants eventually all became about the same size and had an average of 8 stems per plant at harvest. There was no dropout of turmeric plants during cultivation.

In the first harvest on 15/11/2021 (180 DAP), an average of 893.90 grams of rhizomes per plant was harvested (Table 3). At the second harvest on 2/12/2021 (197 DAP), that average weight of rhizomes per plant dropped to 753.25 grams. This can be explained by the cessation of water and nutrient feeding at the first harvest. Presumably, the water content in the harvested rhizomes decreased at the second harvest. Compared with a soil cultivation in the same greenhouse, it can be noted that the plants on the aeroponic system have on average many more stems per plant (8 versus 4 in a soil crop) and lower yields (82 tonnes/ha versus 125 tonnes/ha). Presumably, in the aeroponic system, too much control is given to vegetative growth, as the nutrient solution in this system was continuously adapted based on fortnightly sampling.

Table 1: Adjustments to the nutrient solution recipe throughout cultivation in 2021.

	EC	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	Cl^-	SO_4^{2-}	$H_2PO_4^-$	HCO_3^-	Si	Fe	Mn	Zn	B	Cu	Mo
	(µS/cm)	(mmol/l)										(µmol/l)					
10/05/2021	2	0,50	8,00	4,00	1,75	15,00	0,00	1,00	3,00	0,00	0,00	50,00	16,00	4,00	30,00	0,80	0,40
11/06/2021	2	0,50	8,00	4,00	1,75	15,00	0,00	1,00	3,00	0,00	0,00	50,00	8,00	4,00	30,00	0,60	0,40
29/07/2021	2,5	0,63	10,00	5,00	2,19	18,75	0,00	1,25	3,75	0,00	0,00	62,50	10,00	5,00	37,50	0,75	0,50
12/08/2021	2,5	0,63	10,00	5,00	2,19	18,75	0,00	1,25	3,75	0,00	0,00	62,50	10,00	5,00	37,50	0,75	0,50
24/08/2021	2,5	0,63	10,00	5,00	2,19	18,75	0,00	1,25	3,75	0,00	0,00	62,50	10,00	5,00	37,50	0,75	0,50
9/09/2021	2,5	0,63	10,00	5,00	2,19	18,75	0,00	1,25	3,75	0,00	0,00	62,50	10,00	5,00	37,50	0,75	0,50

Table 2: Crop assessments during cultivation in 2021.

Date	Dropout (%)	Uniformity	Crop volume	Leaf health	Substrate temperature (°C)	Number of stems per plant	Length main stem (cm)
7/07/2021	0	3	5	7	24	1.3	35.8
12/08/2021	0	5	5	6	23	3.7	150.0
6/10/2021	0	7	7	6.5	21	4.7	220.0
1=		heterogeneous	small	dead			
9=		completely uniform	big	healthy			

Figure 5: Top view of crop 49 DAP.

Figure 6: Top view of crop 85 DAP.

Figure 7: First harvest 180 DAP.

Figure 8: Second harvest 197 DAP.

Table 3: Harvest results 2021.

Date	Number of stems per plant	Weight rhizomes per plant (g)	Yield (tonnes/ha)
15/11/2021	8.1	893.90	89.39
2/12/2021	8.2	753.25	75.33
Average	8.15	823.58	82.36

6. Trial 2022

In 2022, attempts were made to mitigate that vegetative growth. On 29 April, purchased plants were planted out in six rows with a row spacing of 40 cm and a planting distance of 25 cm (plant density of 10 plants/m²). The composition of the nutrient solution at the start of the trial can be found in Table 4. Several crop assessments were performed to follow the cultivation. The cultivation went very well (Figure 9) and the plants were harvested on 23 and 24 November.

Table 4: Adjustments to the nutrient solution recipe throughout cultivation in 2022.

	EC (µS/cm)	NH_4^+ (mmol/l)	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	Cl^-	SO_4^{2-}	$H_2PO_4^-$	HCO_3^-	Si	Fe (µmol/l)	Mn	Zn	B	Cu	Mo
21/04/2022	2	0,50	8,00	4,00	1,75	15,00	0,00	1,00	3,00	0,00	0,00	50,00	16,00	4,00	30,00	0,80	0,40
23/05/2022	2	0,55	8,80	4,40	1,93	15,40	0,00	1,10	4,40	0,00	0,00	55,00	8,80	4,40	33,00	0,66	0,44
13/06/2022	1,5	0,43	6,80	3,40	1,49	12,75	0,00	0,85	2,55	0,00	0,00	42,50	6,80	3,40	25,50	0,51	0,34
12/08/2022	1,8	0,63	10,00	5,00	2,19	18,75	0,00	1,25	3,75	0,00	0,00	62,50	10,00	5,00	37,50	0,75	0,50

Figure 9: Roots hanging in the nutrient solution mist 67 DAP.

Table 5: Crop assessments during cultivation in 2022.

Date	Dropout (%)	Uniformity	Crop volume	Leaf health	Number of stems per plant	Length main stem (cm)
12/06/2022	0	6	6	7	4.6	46.4
7/07/2022	0	7	7	7	5.0	95.5
12/09/2022	0	8	7	8	6.3	/
21/10/2022	0	5	6	7	8.7	/
1=		Heterogeneous	small	dead		
9=		completely uniform	big	healthy		

Table 6: Harvest results 2022.

	Number of stems per plant	Weight stems (g)	Weight rhizomes per plant (g)	Yield(tonnes/ha)	Root/shoot ratio
Average	9.28	3243.89	1042.22	104.22	0.32

By working with purchased plants instead of pre-germinated plants, there was good uniformity right from the start. The plants always looked healthy and soon formed several stems per plant. There was no dropout of turmeric plants during cultivation. To make things a little more 'difficult' for the plants and thus perhaps encourage more generative growth compared to the 2021 trial, the EC of the nutrient solution was reduced to 1.5 µS/cm in June 2022. However, the plants started looking much paler and turning brown in August, so the EC of the nutrient solution was raised to 1.8 µS/cm again in August.

At harvest, an average of 1042.22 grams of rhizomes per plant was harvested. Compared to the 2021 crop, this is a remarkable increase in yield of almost 20 tonnes/ha. However, this can be explained by the fact that a different variety was grown in 2022, which were then also purchased as plants (as opposed to the pre-germinated plants in 2021). This Claus variety also yielded more in the soil-bound cultivation (10 % more in a tunnel cultivation) than the Peruvian variety that was grown on the aeroponics system in 2021. Compared to the soil-bound cultivation in the heated greenhouse in 2022 of this Claus variety, the aeroponics installation produced significantly more than the ground crop (104.2 tonnes/ha versus 86.5 tonnes/ha). Worth noting: the plant density in the aeroponics installation was higher (10 plants/m²) compared to the soil-bound cultivation (8 plants/m²). But experience tells us that this is not the only explanation for the higher yield in the aeroponics plant.

Compared to a soil-bound cultivation of the same variety, the plants had more stems and more foliage (more than 3 kg per plant), but the yield was also higher. However, the root/shoot ratio of 0.3 shows that there is probably still too much steering for vegetative growth. Further refinement of cultivation control is needed.

7. Demonstrations for growers

During these two pilot trials, growers were also regularly invited to come and see the set-up. A window was especially provided to view the inside of the set-up (Figure 10). Growers show enthusiasm for this pilot setup. However, they do not yet see it being immediately applicable on a large scale.

Figure 10: Window to view the inside of the set-up.

8. Conclusion

Aeroponics cultivation of turmeric is certainly possible, provided a slight modification is made: the addition of a substrate layer is necessary as a growth medium for the rhizomes. High yields towards 100 tonnes per ha can be achieved. Further refinement to increase the root/shoot ratio, together with the very clean product, could make this rather expensive cultivation technique pay off after all.

9. Bibliography

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