BUILDING A REASONABLE IRRIGATION WITH FERTILIZING PROCESS FOR HUNG YEN ORANGE TREES IN PHU CU DISTRICT, HUNG YEN PROVINCE

Nguyen Quang Phi[1], Ha Thi Quyen[2]
Duong Thi Kim Thu[3], Nguyen Gia Vuong[3],
Hoang Thi Na[3], Nguyen Thi Xuan Thuy[3]
1. Thuyloi University
2. University of Engineering and Technology - Vietnam National University, Hanoi
3. Institute for Water and Environment – Vietnam Academy for Water Resources

Abstract: *Hung Yen orange trees, a type of orange that come from "Vinh oranges", which was cultivated in Hung Yen province, is one of the key fruit crops that is researched, planned and developed in priority by the government of Hung Yen province with purpose to become the brand name "Hung Yen oranges". Currently, the Hung Yen orange trees is cultivated in 8 of 10 districts/cities in the province grown most in Phu Cu district. Cultivation techniques of farmer (irrigation, fertilizing, etc.) for Hung Yen orange trees are mainly implemented by their experience then the productivity and quality of Hung Yen orange are affected. In the context reasonable irrigation with fertilizing process has been applied successfully in concentrated orange cultivation areas in the Northern Mountainous, North Central, Southeast regions… in Vietnam, the research on building a reasonable irrigation with fertilizing process for Hung Yen orange trees to solved mentioned above problems has very high practical significance. This paper presents the results of research on building a reasonable irrigation with fertilizing process for Hung Yen orange trees in its business period. The results show that with irrigation rates of 50÷60 (liters/tree/times) and 35÷40 times /year, using irrigation technique with fertilizing, orange productivity increases by at least 20%, reduction of fertilizer by 15%÷20%, saving labor and electricity costs... in comparation with traditional methods. The process has been approved by the Department of Science and Technology of Hung Yen province and is recommended for application for Hung Yen orange cultivation throughout the province.*

Keywords: *Hung Yen orange, saving-water irrigation, drip irrigation, fertilizing.*

1. INTRODUCTION

In recent years, orange trees cultivation area increases rapidly in 8 of 10 districts/cities in Hung Yen province with a total area of more than 1,600 ha, of which about 1,000 ha was cultivated according to Viet.GAP process. There are many orange farm was formed in large-scale with modern production farming processes in the safety-oriented, making good quality and beautiful products such as in communes of Tam Da (Phu Cu district), Dong Thanh (Kim Dong district), Tan Dan (Khoai Chau district)… There are many orange types was cultivated but the most delicious is the

"Hung Yen orange" type that is very popular with consumers.

Hung Yen orange is a type of orange that come from "Vinh oranges", which was cultivated in Hung Yen province, producing a product with special flavour characteristics and generating high income for farmers. Previously, Hung Yen orange trees was most cultivated in Phu Cu district, and it is disseminated in others area in the province recently. Now, Hung Yen orange is a key fruit crop in Hung Yen province that is recommended for cultivation to build the brand name "Hung Yen orange" step by step.

The farmers use manual traditional method for irrigation and fertilizing in production of Hung Yen orange cultivation leading to consumed a lot of water and fertilizer as well as make negative to soil and environment.

In recent years, water scarcity occurs with increasing frequency along with water pollution that affect to irrigation of farmers. Currently, some farmers have applied water-saving irrigation techniques such as sprinkler or drip irrigation systems for initiatively irrigation as well as saving water. In particular, the drip irrigation technique with many advantages such as saving water, fertilizer, labor as well as being able to combine with fertilizing through the irrigation system and can be applied automation in production, so it is very suitable for large-scale production. Saving-water irrigation with fertilizing technique is a solution helps saving irrigation water, fertilizer, labor as well as reducing production costs, managing pests and drought risks, improving productivity and quality of orange and contributing to enhancing the value of orange trees. This is an irrigation technique that has been widely applied in concentrated orange cultivation areas in the Northern Mountainous, North Central, South-East regions…[4] and it is also has been applied initially by a number of farmers and enterprises in the Hung Yen province.

Currently, there is no drip irrigation with fertilizing process for orange trees in Red River Delta region in general and Hung Yen province in particular. Farmers mainly using traditional methods with their experience in irrigation and fertilize. This leads to low efficiency of production (productivity, quality…) and making negative impacts on orange production. Therefore, the research on building a reasonable drip irrigation with fertilizing process for Hung Yen orange trees saving irrigation water, fertilizer, reducing labor as well as improving productivity and quality of Hung Yen orange is very necessary.

2. METHODOLOGY

2.1. Research process

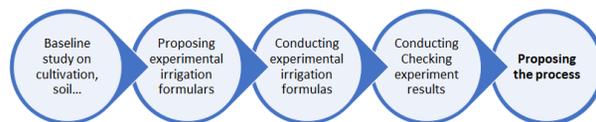The process of the study was designed as in Figure 1 belows

Figure 1: Research process

2.2. Research methods

2.2.1. Theoretical calculation method

Using Cropwat 8.0 software to calculate real time water demand for Hung Yen orange trees for comparison with experiment irrigation formulars.

2.2.2. Experiment method

This method aims to determine the optimal irrigation formula for Hung Yen orange trees in the experiment model.

The experimental model was designed in the orange farm of Mr. Tran Quang Vinh in Ngu Phuc village, Tam Da commune, Phu Cu district, Hung Yen province with a total area of 5,200 m2 as shown in Figure 2

- The experiment model area was divided into 4 zones, including 3 experiment of drip irrigation zones (A, B, C zones) and 1 controlled irrigation zone (ĐC zone).

- 03 experimental irrigation formulas (proposed in section 3.1) will be used in the experimental drip irrigation zones. In each experimental drip irrigation zones are divided into 3 irrigation lots of each zone for experiment of drip irrigation with 01 experimental irrigation formula per lot to ensure enough number of samples for analysis and evaluation of experimental irrigation formulas;

- The irrigation formula by experience of farmers which are being applied in Hung Yen province will be used in controlled irrigation zone.
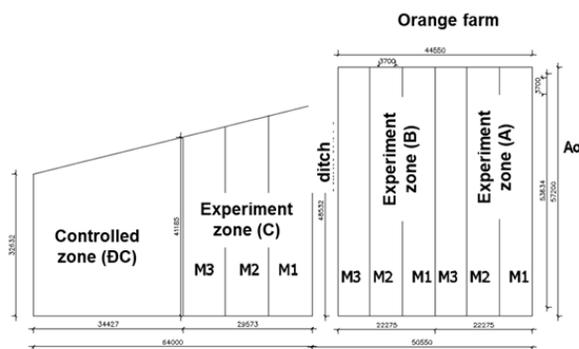

Figure 2: Designed experimental model

- Fertilization is applied in the experiment model as describe belows:

+ The recommendations of fertilization issued by the Department of Agriculture and Rural Development of Hung Yen province (Hung Yen DARD) [3] is be used in controlled irrigation zone;

+ In experimental drip irrigation zones: fertilizing through the drip irrigation system will increase the efficiency of fertilizer use, therefore the total amount of fertilizer N, P_2O_5 and K_2O will be adjusted with decreasing in comparison with the recommendation of the Hung Yen DARD [3] as follows: decreasing N

of 15%, K_2O of 15% and P_2O_5 of 20%.

- Other production techniquies are used recommendations from the Hung Yen DARD [3].

2.2.3. Checking method

This method aims to evaluate the effectiveness of the optimal irrigation formula for Hung Yen orange trees which selected through the experiment process.

This method is conducted at 03 Hung Yen orange farms in Tam Da commune, Phu Cu district, Hung Yen province, including:

- Farm 1: Mr. Tran Quang Vinh, Tam Da commune, Phu Cu district, Hung Yen province (experimented model);

- Farm 2: Mr. Tran Van Vuong, Tam Da commune, Phu Cu district, Hung Yen province;

- Farm 3: Mr. Nguyen Van Chuong, Tam Da commune, Phu Cu district, Hung Yen province.

There are two zones were divided in each farm: (1) the checking zone using the optimal drip irrigation formula that determined after experiment; and (2) the controlled zone using the traditional irrigation methods that being used of the farmers.

2.3. Research tools

The tools used in the research including:

- Cropwat 8.0 software to calculate water demands of orange trees [1],[6];

- Mplatform software for real time monitoring and supervising of real-time climate indicators and soil moisture;

- MS Excel, Irristat softwares for data statistics, analysis performents...

- Control, supervision and monitoring system in experiment model site, including: (1) Mini smart meteorological station installed in the experiment model site, measuring climate indicators such as air temperature, rainfall, wind speed, wind direction, air humidity and number of sunny

hours; (2) Sensors measuring soil indexes (moisture, EC, pH...); (3) Pumping system combined with fertilization; and (4) control and monitoring devices (smartphones, computers). The control, supervision and monitoring system is arranged in the experiment model as shown in Figure 3 below. The same control, supervision and monitoring systems are arranged in checking models.
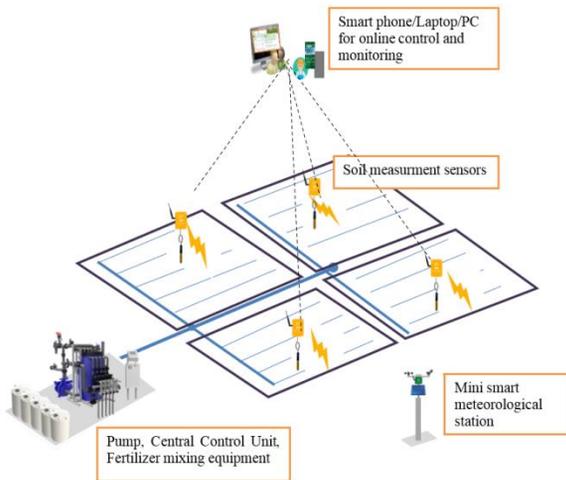

Figure 3: Automatic control, supervision and monitoring technology diagram

2.4. Data

- Meteorological data to calculate real time water demand for Hung Yen orange trees in the experiment model: using data from the mini smart meteorological station installed in the experiment model site;

- Soil data: using soil sample analysis results in the experiment model;

- Irrigation data: collected from the irrigation control system (for the experiment irrigation lots used experiment formulars) and the irrigation records from farmers (for the controlled lots).

3. RESULTS AND DISCUSSION

3.1. Building experimental irrigation formulars

In experimental zones

The experimental irrigation formula for Hung Yen orange trees in its business period is built base on maintaining reasonable value of soil moisture (β) for all growth periods of crop. The reasonable value of soil moisture should be in the range of effective moisture of soil (from β_{ghd} to β_{ght}), that leads to high productivity of crops. Of which:

- β_{ght}: upper limit of soil moisture, taken as the field capacity (FC);

- β_{ghd}: lower limit of soil moisture, not less than the permanent wilting point (PWP).

FC is determined by soil testing results.

Therefore, 03 irrigation formulas were proposed base on maintaining reasonable value of soil moisture in experiment of drip irrigation for Hung Yen orange trees in its business period with β_{ght} taken as FC and β_{ghd} taken as the values of $(60\%, 70\%$ and $80\%)$FC [5], [7]. Thus, there are 03 experimental irrigation formulars, including:

- Formular M1: maintaining value of soil moisture in range $(60 \div 100\%)$*FC;

- Formular M2: maintaining value of soil moisture in range $(70 \div 100\%)$*FC; and

- Formular M3: maintaining value of soil moisture in range $(80 \div 100\%)$*FC.

The total amount of fertilizer used in the experimental lots of drip irrigation with fertilizing was adjusted to decrease according to the recommendations of the Hung Yen DARD [3] as in Table 1 belows.

Table 1: Fertilizer used in the experimental lots

The amount of single fertilizer (g/tree/year)			The amount of commercial fertilizer (kg/tree/year)		
N	P_2O_5	K_2O	Urea	Supe	Kali clorua

920	375	1.200	2	2.5	2

In the controlled zone

The traditional irrigation method (by hand) that being applied in will be used. The total amount of fertilizer used according to the recommendations of the Hung Yen DARD [3].

3.2. Calculation of irrigation rates for experimental irrigation formulas

The irrigation rates in each irrigation times in experimental zones is calculated according to the Saccso - Ardro formula [5], [7] based on the tested results of soil, the root depth checking... as belows:

$m = 100 * \gamma_k * H * f * (\beta_{ght} - \beta_{ghd})$

Of which:

γ_k: Dry density of soil (T/m^3);

β_{ght}, β_{ghd}: lower and upper limit of soil moisture;

H: Depth of soil layer to be moistened as required (m)

Effective roots depth of Hung Yen orange trees in the experimental model is mainly in range of 0÷0.30m (mostly at 0÷0.20m), so the depth of soil needs to be moistened is H =0.30m is selected for calculation of irrigation rate in each irrigation times;

f: Ratio of the actual area needs to be moistened to the area of the experimental lots (the area in 0.30m of soil depth)

$f = B * 2L * n / S_1$

In which:

+ B: Moistened width along each drip irrigation line (m). In the experimental zone show that average moistened width along drip irrigation line B = 0.2 (m).

+ L: Average moistened length for each orange trees stump (m), it is distance between two orange trees in a row.

+ 2: There are two drip irrigation lines in two sides of each orange trees row.

+ n: The total number of orange trees per ha;

+ S_1: Area of 01ha (10.000 m^2).

The calculation results of irrigation rate in each irrigation times for Hung Yen orange trees during its business period in the experimental model correspond to experimental irrigation formulars as shown in table 2 below.

Table 2: Irrigation rate for Hung Yen orange trees in experimental model

Formular	β_{dr} (%)	β_{ghd} (%)	B (m)	L (m)	H (m)	Irr. lines/row	γ_k (T/m^3)	F (ha)	Irr. rate (l/tree)
M1 (60÷100%)*FC	31.78	19.07	0.2	3.7	0.3	2	1.21	0.10804	68.12
M2 (70÷100%)*FC	31.78	22.25	0.2	3.7	0.3	2	1.21	0.10804	51.09
M3 (80÷100%)**FC	31.78	25.43	0.2	3.7	0.3	2	1.21	0.10804	34.06
Controlled zone (using traditional irrigation methods by farmer's experience)									130.00

Source: Institute for Water and Environment, 2021

3.3. Results of experiment

Drip irrigation in experimental zones is

implemented based on the calculated irrigation rate in each irrigation times corresponding to each experimental irrigation formula. At irrigation lots, the next irrigation stage is implemented when the value of soil moisture reaches β_{ghd} to achieve the value of soil moisture at β_{ght} to as shown in Table 2. The monitoring results of experimental irrigation in 2021 at the experimental model as shown in Table 3 below.

Table 3: The monitoring results of experimental irrigation at the experimental model

No.	Criterias	Experimenal irrigation Formular			
		M1	M2	M3	ĐC
1	Number of irrigations	28	40	62	23
2	Irrigation rate per times (l/tree)	68	51	34	130
3	Irrigation rate per ha (m³/ha/times)	49,76	37,32	24,88	95
4	Irrigation volume per ha (m³/ha)	1.393	1.493	1.542	2.184

Source: Institute for Water and Environment, 2021

To compare the experimental results to the theory, the real time water demand (ETc) of Hung Yen orange trees was calculated by Crowat8.0 software [1],[6] by using climate data from the mini smart meteorological station that installed in the experimental model and results to ETc = 1,350 m³/ha. The comparison of irrigation volume between practical irrigation (by formulas M1, M2, M3 and ĐC) and theoretical water demand of Hung Yen orange trees calculation is shown in Figure 4 below.
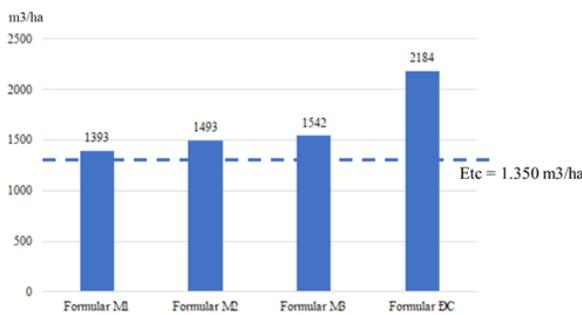

Figure 4: Comparison of irrigation volume between practical and theoretical irrigation

Source: Institute for Water and Environment, 2021

The results of experimental irrigation show that the practical irrigation formulars for Hung Yen orange trees in the experimental model are quite consistent with the theoretical calculation with the difference of 3.19% to 14.22% while the difference of irrigation volume between the traditional method at controlled zone and theoretical water demand calculation is 61,78%. Thus, it can be concluded that the experimental irrigation process for drip irrigation system for Hung Yen orange trees meets the reality water demand of Hung Yen orange trees during its business period.

The total amount of fertilizer used in the experimental zones reduced in comparison to the controlled zone (fertilizing according to recommendations of the Hung Yen DARD [3]) by 15% of N, 15% of K_2O and 20% of P_2O_5.

Conclusions

The experiment results of drip irrigation with fertilizing process using proposal irrigation formulars in the experimental model in 2021 (after 01 year of application) as follows:

- Regarding the water volume of irrigation: total amount of irrigation water in the formular M1 is 63.8%, in the formular M2 is 68.3% and in the formular M3 is 70.6% in comparison to irrigation formular ĐC (using traditional irrigation method with farmer's experience) in

the controlled zone as well as consistent with the real-time theoretical water demand calculation results.

- Regarding productivity: productivity of Hung Yen orange in experimental zones of drip irrigation with fertilizing is increased by over 20% in comparison to the controlled zone. Specifically, the productivity of Hung Yen orange increased by 20.2% in lots use M1 irrigation formular, by 23.4% in lots use M2 irrigation formular and by 21.8% in lots use M3 irrigation formular in comparison to controlled zone.

- Production cost (labor for irrigation and electricity consumption) in controlled zone is higher than in experimental zones.

- Regarding fertilization: fertilizing through a drip irrigation system helps save 15% to 20% of fertilizer in comparison to other manual fertilization techniques due to reducing fertilizer loss. In the other hand, the reasonable fertilizing also helps improve the quality of oranges (such as the Brix value increased from 6% to 18%).

The experimental irrigation results shows that the total volume of irrigation water in the formular M2 ((70÷100%)*FC) is not the lowest but gives the highest productivity of orange. Besides, fertilizing through a drip irrigation system with reducing volume of fertilizer in comparison to the traditional method (with recommendations the Hung Yen DARD) but still ensures the productivity as well as the quality of oranges. Therefore, the M2 experimental irrigation formula was proposed as the optimal irrigation formula for Hung Yen orange and will be used in checking models.

3.4. Checking results

After determining the optimal irrigation formula M2 from the experiment process, it is checked in 03 orange farms in Tam Da commune, Phu Cu district, Hung Yen province with a total area of 3.0 ha (which describe in section 2.2.3). There are two zones were divided in each farm: (1) the checking zone using the drip irrigation with fertilizing using M2 formula (maintaining value of soil moisture in range (70% ÷100%)*FC in all 03 farms); and (2) the controlled zone using the traditional irrigation methods that being used of the farmers with recommendations from the Hung Yen DARD on fertilization [3]. The checking results in 2022 are summarized in Table 4 below.

Table 4: Checking results of irrigation formular M2

Indicators	Farm 1		Farm 2		Farm 3	
	Checking zone	Controlled zone	Checking zone	Controlled zone	Checking zone	Controlled zone
Number of irrigations	38	22	38	22	37	24
Irrigation rate (m³/ha-time)	37.32	94.96	37.64	94.96	37.64	94.96
Total volume of irrigation water (m³/ha/year)	1,418	2,089	1,430	2,089	1,393	2,279

Source: Institute for Water and Environment, 2022

The results of checking were monitored in 03 mentioned orange farms in 2022 shows that the

productivity and quality of orange as well as production efficiency (labor, cost…) in checked lots are better than in controlled lots where use traditional production method with manual irrigation and fertilizing as follows:

- Saving irrigation water from 31.5% ÷ 38.9%;

- Productivity of orange increased by at least 20%;

- Labor for irrigation and fertilizing reduced by 10 times;

- Decreasing electricity consumption;

- Saving fertilizer from 15 ÷ 20%;

- Improving quality of oranges (sweetness of orange increased by 10%÷15% with Brix indicator testing results);

- The physical and chemical properties of the soil in farm was not changed.

3.5. Proposing a drip irrigation with fertilizing process for Hung Yen orange

By experiment to determining the optimal irrigation formular in 01 year as well as checking the effective of the proposed irrigation formular on checked models in next 01 year in orange farms in Phu Cu district, Hung Yen province, in combination with: (1) results of theoretical water demand calculation for Hung Yen orange by Cropwat 8.0 software [1], [6]; (2) experiences from farmer in Hung Yen orange cultivation area; and (3) The other research results on building the irrigation process that is published [2], [4], [7], the drip irrigation with fertilizing process for Hung Yen orange was proposed as in Table 5 belows.

Table 5: The drip irrigation with fertilizing process for Hung Yen orange

Growth stage	Irrigation process						Fertilizing (*)		
	Irr. periods (month)	Irr. rate		Time between 02 irrigation cycles (days/time)	Number of irrigation cycles (times)	Volumme of Irr. water (m3/ha)	Fertilizing time	Number of Fertilizing cycles (time)	Type of Fertilizer
		(l/tree/time)	(m3/ha/time)						
Splitting flower sprouts	1÷2			No irrigation					
Flower	2÷3	50÷60	25÷30	(01 time per/day in the first 3 days)	8÷10	225÷270	February	3÷4	N, K
Growth of fruit before rainy season	3÷4	50÷60	25÷30	3÷4	14÷16	375÷450			
Growth of fruit in rainy season	5÷10	50÷60	25÷30	5÷7 (Irrigation in 7 days after rain in case of rainfall >20mm)	7÷9	200÷220	May	3÷4	N, K
							August	3÷4	K
Harvesting	11÷12	50÷60	25÷30	10÷15	2÷3	63÷69			
Post harvesting	12÷1	50÷60	25÷30	6÷7	4÷5	113÷135	December	3÷4	N, P
Total annual average (rounded)					**35÷43**	**1.000÷ 1.100**		**12÷16**	

(*) In case of fertilizing through the drip irrigation system, the process of soil moistening, irrigation with fertilizing and pipeline cleaning irrigation need to be implemented strictly. Total amount of fertilizer was adjusted to decrease by 15% of N, 15% of K_2O and 20% of P_2O_5 in comparison with recommendations from the Hung Yen DARD.

In case do not use the drip irrigation system for fertilization (manual traditional method), the process of soil moistening, fertilizing and irrigation is recommended to use with amount of fertilizer follows recommendations from Hung Yen DARD.

4. CONCLUSIONS

The drip irrigation with fertilizing process for Hung Yen orange was built on the basis of combination between theorical and practical study as well as taking the local conditions such as climate, soil, exprinces of cultivation... into account. The process was applied in orange farms in Phu Cu district, Hung Yen province and leading to high effective production such as increasing the productivity, improving the orange quality, reducing labors, irrigation water and fertilizer, avoiding fertilizer go to the environment (irrigation canals/pond/lake…). The process has been approved by the Department of Science and Technology of Hung Yen province and is recommended for application for Hung Yen orange cultivation throughout the province.

The process will help the farmers applying advanced technologies on irrigation and fertilizing synchronously to improve effective production with high product and low cost for Hung Yen orange development in a sustainable way. It is also a useful decision support tool that helps farmers, local governments and state management agencies in production, planning, designing, policies making… for Hung Yen orange development in export orientation. Specially, the advanced irrigation technologies, digital tools, IoT equipments… can be applied with the process in production automation as well as nutrition management for large-scale production of Hung Yen orange.

REFERENCES

[1] Allen, R. G., Pereira, L. S., Raes, D., & Smith, M.: "Crop evapotranspiration Guidelines for computing crop water requirements (FAO Irrigation and drainage paper 56)", Rome, Italy, 1998.

[2] Dang Minh Tuyen, "Research on building saving-water irrigation model for upland crops in Cao Phong district, Hoa Binh province", Hanoi, Vietnam, 2012.

[3] Department of Agriculture and Rural Development of Hung Yen province, "Cultivation technique manual for orange in Hung Yen province", Hung Yen, Vietnam, 2020.

[4] Directorate of Water Resources, "Irrigation with fertilizing process for orange trees in business periods in Northern Mountainous, North Central and South-East regions", Hanoi, Vietnam, 2020.

[5] Nguyen Quang Trung, "Research on application of saving-water irrigation technology for grapes and dragon fruit trees in drough area in South Central region according to Israeli technology", Hanoi, Vietnam, 2008.

[6] Smith, M.; Kivumbi, D.; Heng, L.K, "Use of the FAO CROPWAT model in deficit irrigation

studies - In Deficit Irrigation Practices", Rome, Italy, 2002.

[7] Tran Hung, "Research on building the irrigation with fertilizing process for some key crops", Hanoi, Vietnam, 2020.