OPTIMIZATION PARAMETERS OF IRRIGATION PROCESS ACCORDING TO THE UNIFORMITY

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ABSTRACT*: In order to determine the optimal parameters of irrigation process in order to verify the accuracy of the numerical simulation results of experimental determination of the effective spray during irrigation [2], [6]. This paper will conduct empirical planning, establishing empirical mathematical model to determine the diameter of the nozzle, swirl coefficient and irrigation output according to the uniformity.*

Keyword: *Optimization, Irrigation, Uniformity.*

1. INTRODUCTION

Spray irrigation is a method that supplies water for crop plants in rain-drop or dew-drop form on a small area in around tree by injecting rain machine. Spray irrigation has developed for some decades in many countries with advanced agriculture [1], [3], [4]. By using pump systems, water-pipes and spray heads, we can make economical water irrigation to crop plants [5].

Design of experiment is planning to conduct experiments in an active order to minimize the number of experiments needed while ensuring the reliability and received empirical mathematical model fit.

2. EXPERIMENTAL MODEL

Experimental model of the swirling turbulent jets in spray irrigation technology is presented in figure 1.

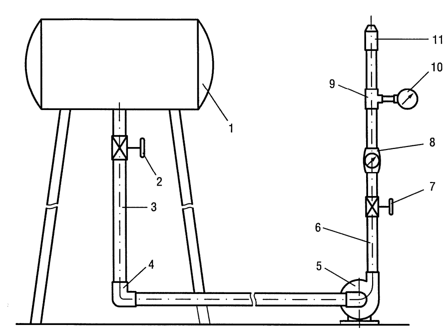


Figure 1. Experimental model: 1. Tank of water; 2. Valve Φ34; 3. Main tube Φ34; 4. Corner 900 (Φ34); 5. Centrifugal pump; 6. Tube level I; 7. Regulating valve Φ27; 8. Flow sensor; 9. Three-pronged fork Φ21; 10. Pressure gauge; 11. Spray head

Pipe is connected directly to the pump, spray head is associated at the end of the pipe. Using pumps outdoor water tank, taking water to conduct an experiment:

- Using flow and pressure gauge at the end of pipe.
- Using regulating valve to regulate flow and pressure.
- Using watch to follow.

For monitoring and measurement of technical parameters of the water jets, and intensity of the rain and uniform, experiment to be conducted in private rooms (no wind), height of spray head is 0.5m.

Model is selected to conduct experiments with an area of 200m^2 (10m x 20m). Layout of 8 nozzles (square) and the pipeline is shown in figure 2.

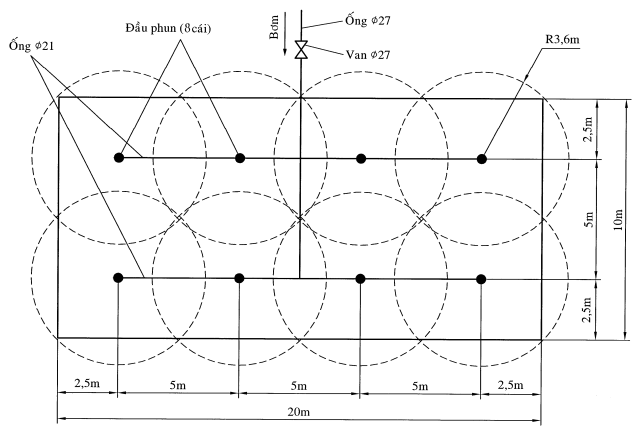


Figure 2 Layout of nozzles and the pipeline according to square way. Centrifugal pump 1DK15 with electric motor has technical parameters: N = 370W; n = 2900rpm; U = 220V; f = 50Hz; Q = 40l/m; $H_h = 4mH_2O$; $H_d = 8mH_2O$.

The experiment was conducted with the following parameters:

- Nozzle diameter d = 3,0 mm; 3,5 mm and 4,0 mm.
- Injection pressure p = 1,2 bar; 2,0 bar and 2,2 bar.
- Swirl coefficient S = 0,4; 0,7 and 1,2.

Input parameters are limited as follows:

- X_1: nozzle diameter, d = 3 ÷ 4mm
- X_2: swirl effect, S = 0,4 ÷ 1,2
- X_3: flow, Q = 5 ÷ 9l/ph

Output indicator is:

- Y_1: radius irrigation [m]
- Y_2: uniformity [%]
- Y_3: electricity [kwh]

3. RESULT OF DESIGN EXPERIMENT

3.1. Determination of experimental plan

Design of experiment was chosen quadratic form quadratic rotation plan. The rotation of the structure plan will be achieved by the formula[5]:

$\alpha = 2^{k/4} = 2^{3/4} = 1,682$ (2)

with: k – number of factors

Other variation and the values of input parameters are specified in Table 1.

Table 1. The value of the input parameter

Level		Parameters		
		X_1	X_2	X_3
Below (*)	−1,682	2,66	0,13	3,64
Below	−1	3	0,4	5
Base	0	3,5	0,8	7
Above	+1	4	1,2	9
Above (*)	1,682	4,34	1,47	10,64
Step change of the parameter		0,5	0,4	2

3.2. Making the experimental matrix

Empirical quadratic matrix in plan rotation, the number of experiments is defined as follows [4]:

$N = 2k + 2k + n_0 = 23 + 03.02 + 6 = 20$

where: k – number of factors, k = 3

2^k – number of experiments above and below

2k – number of experiments at the star point (*)

n_0 – the number of repeated experiments at the base, $n_0 = 6$

With plans empirical quadratic, quadratic polynomial form encoded as follows:

$$y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{\substack{i=1 \\ j>1}}^{k} b_{ij} x_i x_j + \sum_{i=1}^{k} b_{ii} x_i^2$$

where: x_i, x_j – coded values of the parameters X_i, X_j

b_0 – coefficient of freedom

b_i – the coefficient of linear

b_{ij} ($i \neq j$) – the pair interaction coefficients

b_{ii} – the coefficients of quadratic

k – number of factors

Encoded value x_i of the parameters are calculated by the formula:

$$x_i = \frac{X_i - X_i^0}{\Delta X_i} \qquad (5)$$

where: X_i – the real value of parameters

X_i^0 – actual value at the base

ΔX_i – step change of the parameter, $\Delta X = \frac{X_i^+ - X_i^-}{2}$

Experimental matrix was set up and randomized order with the program Statgraphic Vers 7.0.

Table 2. Experimental matrix and experimental results to quadratic form

TT	X_1	X_2	X_3	Y_1	Y_2	Y_3
1	0	0	1,68	3,02	68,3	5,52
2	0	0	0	1,86	42	3,4
3	1	1	1	2,71	61,3	4,95
4	0	−1,68	0	2,4	54,3	4,39
5	−1	1	−1	3,02	68,3	5,52
6	0	0	−1,68	2,64	59,5	4,81
7	0	0	0	1,78	40,3	3,25
8	−1	1	1	3,02	68,3	5,52
9	1,68	0	0	2,25	50,8	4,1
10	−1.68	0	0	3,26	73,5	5,94
11	0	0	0	1,78	40,3	3,25
12	1	−1	−1	2,4	54,3	4,39
13	−1	−1	1	2,79	63	5,09
14	0	1,68	0	2,87	64,8	5,24
15	0	0	0	1,86	42	3,4
16	−1	−1	−1	2,95	66,5	5,38
17	0	0	0	1,94	43,8	3,54
18	1	1	−1	2,25	50,8	4,1
19	0	0	0	1,78	40,3	3,25
20	1	−1	1	2,48	56	4,53

3.3. Experimental results and analysis of experimental results

Based on the results of experiments conducted analysis of variance with the first model in the form of a full quadratic polynomial uniformity are presented in Table 3.

Table 3. Analysis of variance function Y_2 (uniformity)

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A: Diameter	490.874	1	490.874	243.13	0.0000
B: Swirl effect	51.6496	1	51.6496	25.58	0.0039
C: Output	40.4368	1	40.4368	20.03	0.0065
AA	683.637	1	683.637	338.60	0.0000
AB	3.51125	1	3.51125	1.74	0.2444
AC	30.8113	1	30.8113	15.26	0.0113
BB	513.332	1	513.332	254.25	0.0000
BC	18.9112	1	18.9112	9.37	0.0281
CC	811.979	1	811.979	402.17	0.0000
Lack-of-fit	43.4413	5	8.68825	4.30	0.0676
Pure error	10.095	5	2.019		
Total (corr.)	2370.59	19			

The results of analysis of variance showed that the regression coefficient does not guarantee the reliability and eliminated the AB (coefficient of X_1X_2).

After removal of regression coefficients does not guarantee the reliability (AB) from the model and conduct analysis of variance model for the second time. Results of data processing to identify regression coefficients significant (P-value < 0.05) are presented in Table 4.

Table 4. Results of analysis of variance function Y_2 after removing the regression coefficient mismatch (AB)

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A: Diameter	490.874	1	490.874	243.13	0.0000
B: Swirl effect	51.6496	1	51.6496	25.58	0.0039
C: Output	40.4368	1	40.4368	20.03	0.0065
AA	683.637	1	683.637	338.60	0.0000
AC	30.8113	1	30.8113	15.26	0.0113
BB	513.332	1	513.332	254.25	0.0000
BC	18.9112	1	18.9112	9.37	0.0281

CC	811.979	1	811.979	402.17	0.0000
Lack-of-fit	46.9525	6	7.82542	3.88	0.0793
Pure error	10.095	5	2.019		
Total (corr.)	2370.59	19			

Table 5. Estimates of the interaction regression coefficient objective function Y_2

Effect	Estimate	Confidence Int.	V.I.F.
Average	41.516	+/- 1.4897	
A: Diameter	-11.9906	+/- 1.97677	1.0
B: Swirl effect	3.88945	+/- 1.97677	1.0
C: Output	3.44146	+/- 1.97677	1.0
AA	13.775	+/- 1.92433	1.01826
AC	3.925	+/- 2.58277	1.0
BB	11.9365	+/- 1.92433	1.01826
BC	3.075	+/- 2.58277	1.0
CC	15.0125	+/- 1.92433	1.01826
95.0 confidence intervals are based on pure error with 5 d.f. (t = 2.57059)			

Table 6. Regression coefficient function Y_2 (uniformity)

Coefficient	Estimate
Constant	41.516
A: Diameter	-5.99529
B: Swirl effect	1.94473
C: Output	1.72073
AA	6.88751
AC	1.9625
BB	5.96827
BC	1.5375
CC	7.50624

• *Student Test standard*

From the calculation results in Table 5, we have: t = 2.57059 is greater than the value distribution survey in the Student table, t (0.05, 20) = 2.086 (t = 2.57059 > 2.086). Thus, the regression coefficients to ensure reliability.

• *Check the compatibility of the model*

Based on the results of analysis of variance are presented in Table 4, the Lack-of-fit with P-value = 0.0894 > 0.05. Therefore able to confirm the regression model is appropriate. The regression coefficients in the form of coding is presented in Table 6 and is rewritten as follows:

$b_0 = 41{,}516$ $b_1 = –5{,}99529$

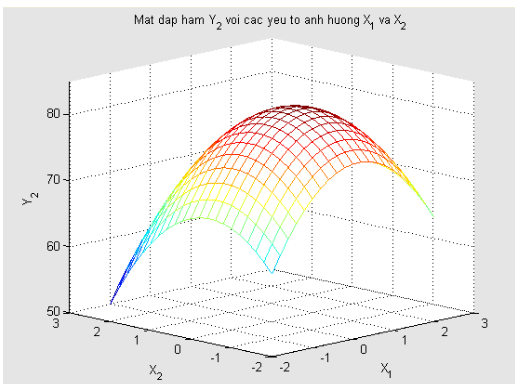
$b_2 = 1{,}94473$ $b_3 = 1{,}72073$

$b_{13} = 1{,}9625$ $b_{23} = 1{,}5375$

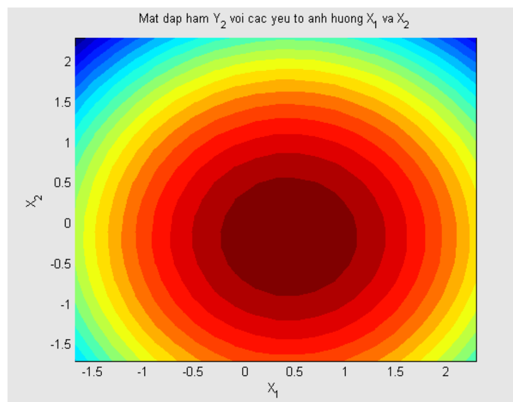
$b_{11} = 6{,}88751$ $b_{22} = 5{,}96827$ $b_{33} = 7{,}50624$

Thus, in encrypted form Y_2 function depends on X_1, X_2 and X_3 is represented as follows:

$$Y_2 = 41{,}516 - 5{,}99529X_1 + 1{,}94473X_2 + 1{,}72073X_3 + \\ + 6{,}88751X_1^2 + 1{,}9625X_1X_3 + 5{,}96827X_2^2 + 1{,}5375X_2X_3 + 7{,}50624X_3^2$$

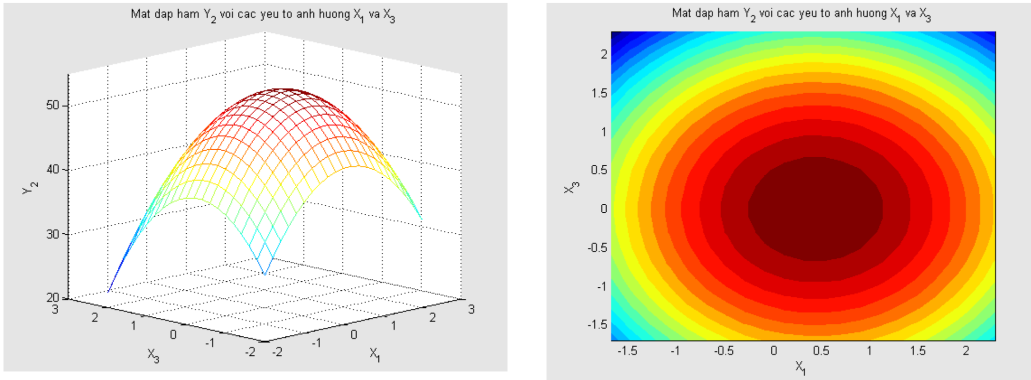


a)



b)

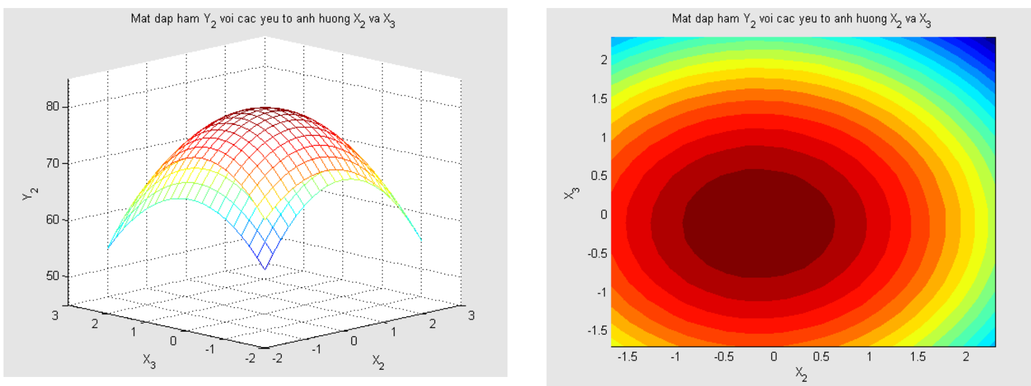
Figure 3 Relationship the surface response function Y_2 and pair parameters affect X_1-X_2:
a) Graph grid, b) As the graph



a) b)

Figure 4 Relationship the surface response function Y_2 and pair parameters affect X_1-X_3:

a) Graph grid, b) As the graph



a) b)

Figure 5 Relationship the surface response function Y_2 and pair parameters affect X_2-X_3:

a) Graph grid, b) As the graph

Based on the content in encrypted form to analyze the influence elements of the research to the uniformity Y_2:

Minus (–) in front of x_1 proved that diameter hose and sprinkler irrigation uniformity is inversely proportional relationship.

A plus sign (+) in front of X_2, X_3 demonstrate spin coefficients and irrigation flow proportional relationship.

Y_2 can be also a function through graphing pairs factors affecting sprinkler uniformity, the graph is drawn when the value of the remaining elements are kept at the base (Figure 3 ÷ 5). The graphs show that:

The responses of Y_2 functions has a parabole elliptic form and are in the experimental domain.

The stop point of the surface is located in the experimental area and has a maximum value.

3.4. Determination of parameters and optimization criteria

Optimal indicator is an uniformity, the results are as follows:

Object: $Y_2 \rightarrow \max$:

$$Y_2 = 41{,}516 - 5{,}99529X_1 + 1{,}94473X_2 + 1{,}72073X_3 + \\ + 6{,}88751X_1^2 + 1{,}9625X_1X_3 + 5{,}96827X_2^2 + \\ + 1{,}5375X_2X_3 + 7{,}50624X_3^2 \rightarrow \max$$

Condition: $+1{,}68179 \geq X_i \geq -1{,}68179$

Define the optimal criterion: C_{Umax} = 77,3%. Results of the optimization problem as follows:

Diameter of nozzle at the value encoded $X_1 = -1{,}526$; in real value d = 2,737mm.

Spray at encrypt the value X_2 = 0,112; in real value S = 0,822.

Flow irrigation in encrypted value $X_3 = -0{,}025$; in real value Q = 6,95l/min.

4. CONCLUSION

Empirical model and rotate the injection technique used in sprinkler irrigation was built as a basis for verifying the results of the numerical simulation from theoretical studies of the injection technique [2], [4].

Through theoretical studies and experimental studies show that the nozzle diameter
d = 2,737mm, swirl effect S = 0,822 and water flow output Q = 6,95l/min to ensure optimal parameters according to the uniformity C_{Umax} = 77,3%.

XÁC ĐỊNH GIÁ TRỊ TỐI ƯU CHO CÁC THÔNG SỐ CỦA QUÁ TRÌNH TƯỚI PHUN THEO ĐỘ ĐỒNG ĐỀU HẠT MƯA

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TÓM TẮT: *Với mục đích xác định các thông số tối ưu của quá trình tưới phun từ kết quả thực nghiệm khi xác định hệ số xoáy có hiệu quả trong quá trình tưới [2], [6]. Bài báo tiến hành quy hoạch thực nghiệm, thiết lập các mô hình toán học thực nghiệm để xác định các giá trị tối ưu cho các thông số của quá trình tưới phun như đường kính vòi phun, hệ số xoáy và lưu lượng tưới theo độ đồng đều của hạt mưa.*

Từ khóa: *Tối ưu hóa, tưới phun, Độ đồng đều.*

REFERENCES

[1]. Hoang Duc Lien, Vo Tuyen, Nguyen Thanh Nam, Research Impact of Swirl *Effect to the Distribution of Rain-Spray Intensity and Uniform when Irrigated in Spray Irrigation Technology*, Bùi Hiếu, Lương Văn Hào, *Kỹ thuật tưới cho một số cây lương thực và hoa màu*, Nhà xuất bản Nông nghiệp, Hà Nội (2000).

[2]. Hoang Duc Lien, Vo Tuyen, Nguyen Thanh Nam, Research Impact of Swirl Effect to the Distribution of Rain-Spray Intensity and Uniform when Irrigated in Spray Irrigation Technology, *The International Workshop on "Thermal Hdrodynamics of Multiphase Flows and Applications,* Hanoi, (05/2009).

[3]. Kostov K., K. Atanasov, N. Krystev, An effective degree of rotation of axial and injection swirling devices, Proceedings of "*Scientific works – Food Science, Technique and Technologies*", University of Food Technologies – Plovdiv, vol. 51, ISSN 0477-0250, 370, (2004).

[4]. Lê Sâm, *Kỹ thuật tưới tiết kiệm nước*, Nhà xuất bản Nông nghiệp, Hà Nội (2005).

[5]. Nguyễn Cảnh, *Quy hoạch thực nghiệm*, Nhà xuất bản Đại học Quốc gia Tp. Hồ Chí Minh (2004).

[6]. Võ Tuyển, Nguyễn Thanh Nam, *Nghiên cứu chế tạo đầu phun tạo xoáy và ảnh hưởng của hiệu ứng xoáy tới góc phun trong kỹ thuật tưới phun*, Hội nghị khoa học công nghệ Cơ khí chế tạo toàn quốc lần thứ nhất Tp.HCM (12/2008).