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The nozzles organization in center pivot irrigation system

تنظيم فوهات الرشاشات في نظام الري المحوري

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Abstract:

This study explained that the organization of nozzles in center pivot irrigation system is very important in quantity and quality to production, in this study we discussed the plan of irrigation in farm, steps of plan, methods of charts, size of nozzles, parts of sprinkler importance of sprinklers parts, kinds of regulators, the famous factories of sprinklers, and water management in farms.

Explained the problems of irrigation in center pivot system, presented the solutions of these problems, presented the factories advice, showed the special programs for charts, the manual and the automatic programs which prepared in exile sheet.

The results showed that it is better not to repeat one size of nozzle in chart as possible and no difference between automatic and manual charts in setting of sprinklers. Also the results showed that the size of nozzles are limit, not more than 46 size in Senninger company, start from (4, 4.5 to 26), and the flow rate of these sizes are (0.5g/t to 14.9g/t), whereas, in Nelson company the size of nozzles start from (6, 7 to 50) and the flow rate is (0.3g/t to 17g/t) depend on pressure in center pivot and regulator size.

Key wards: center pivot irrigation system **-** irrigation plan – nozzles – regulator – refractor – models of charts.

المستخلص:

اجريت هذه الدراسة لمناقشة مدى أهمية تنظيم فوهات الرش في نظام الري المحوري والذي يؤثر بصورة مباشرة في كمية وجودة الإنتاج. كما أوضحت هذه الدراسة ضرورة وضع خطة للري، وبينت خطوات هذه الخطة، وكيفية تنظيم الفوهات، وتدرج ومقاسات هذه الفوهات، وشح أجزاء الرشاشات وأهمية هذه الأجزاء، وأنواع منظمات الضغط، كما ذكرت الدراسة أشهر الشركات المصنعة للفوهات والرشاشات في العالم، ثم تطرقت لأهمية إدارة المياه في المشاريع الزراعية تحت نظام الري المحوري.

أيضا عرضت هذه الدراسة أهم المشكلات التي تواجه الري في هذا النظام مع تقديم الحلول المناسبة لهذه المشكلات، كما أوضحت توصيات الشركات المصنعة للرشاشات، قدمت هذه الدراسة إثنين من البرامج الخاصة التي تم اعدادها على برنامج (اكسل) أحدها يدوي والأخر أتوماتيكي وكلاهما يعملان على تنظيم الفوهات بنظام الري المحوري.

نجد من نتائج هذه الدراسة ضرورة الحد من تكرار نفس مقاس الفوهة في الترتيب التصاعدي للبرنامج المعد لتنظيم الفوهات، كما تبين عدم وجود اختلاف كبير في نتائج تنظيم الفوهات بين البرنامج اليدوي والاتوماتيكي ، كما تبين من نتائج هذه الدراسة أن عدد مقاسات الفوهات في اشهر الشركات يعتبر محدود مما يؤثر على جودة التوزيع فمثلا نجد العدد في شركة سننجر (46مقاس) تتدرج كالاتي (4-4.5الى26) و يتدرج التدفق من (0.5 جالون في الدقيقة الى 14.9جالون في الدقية)، بينما التدرج في شركة نيلسون من (6،7 الى50) ويتدرج التدفق من (0.3جالون في الدقيقة الى 17جالون في الدقيقة) وهذا التدفق يعتمد على مقدار ضغط المياه على جهاز الري المحوري ونوع منظم الضغط المستخدم.

مفتاح الكلمات: نظام الري المحوري- خطة الري - فوهات الرشاشات - منظم الضغط - أنواع برامج تنظيم فوهات الرشاشات.

INTRODUCTION-

Good irrigation management provides sufficient water to the crop to avoid drought stress, while avoiding over irrigation which can lead to runoff and/or deep percolation losses as well as poorly aerated (anoxic) conditions.

Irrigation systems may be or may not be well designed and used. It is necessary to find criteria for the evaluation of the irrigation systems at operation to determine system efficiency. The evaluation should measure and make clear the effectiveness of the current practice of irrigation. It also should indicate where the improvement should be made to increase the overall efficiency of the system. (Kelley. L -. Pg1. 2014)

The center pivot system is best choice for agricultural irrigation because it's low labor and maintenance requirements, convenience, flexibility, performance and easy operation. When properly designed and operated, and equipped with high efficiency water applicators, a center pivot system conserves three precious resources water, energy and time. The irrigation plan helps implement the irrigation component of an overall farm conservation resource management, very necessary to organize the nozzles in center pivot irrigation system because it effects directly increase or decrease the crops production.

During the past 20 years sprinkler manufactures have developed and marketed a large number of different sprinkler technologies that produce relatively large witted diameters at reduced pressures, thus, center pivots operators have a great number of sprinkler packages to meet goals of reduced wind drift, reduced energy costs and increase water application efficiency.

The goal of every sprinkler or spray nozzle package is to apply water uniformity. Some performance characteristics can affect the suitability of a package for specific set of field conditions, such items as the type of sprinkler or nozzle, the type and size of the orifice, the mounting position and spacing and the operating pressure greatly affects the performance of a package. (Bill Kranz, et al. operating characteristics of center pivot sprinkler. G1532.Pg1. 2005.)

MATERIALS AND METHODS -

Center pivot irrigation system: The center pivot irrigation system consists of one single sprayer or sprinkler pipeline of relatively large diameter, composed of high tensile galvanized light steel or aluminum pipes supported above ground by towers move on wheels, long spans, steel trusses and/or cables. One end of the line is connected to a pivot mechanism at the center of the command area; the entire line rotates about the pivot. The application rate of the water emitters varies from lower values near the pivot to higher ones towards the outer end by the use of small and large nozzles along the line accordingly.

The center pivot (CP) is a low/medium pressure fully mechanized automated irrigation system of permanent assemble. It has become very popular in the Near East region in recent years for irrigation of most of field crops, cereals, legumes, forage and vegetables.

The irrigation plan: The irrigation plan is the result of a joint effort between the consultant, owner, operator, and the irrigation decision maker in which technical knowledge and experience are pooled. (Agricultural engineering MT.59270-P.1,2. –May 1984).

An irrigation plan follows the nine steps of planning (NRCS National Planning Procedures Handbook) and encompasses all aspects of planning on irrigated land. The plan includes determining the water user's objectives and problems, SWAPA resource inventories, alternative analysis, and decision-making irrigation system operation and maintenance plans are a part of irrigation system planning.

Coordination with cropping system plans, irrigation system plans, drainage plans, irrigation water management plans, and follow up plans is essential.

Planning process steps are:

1. Identify the problem including resources of concern Water source, quality, and quantity; soil erosion; labor and energy.

2. Determine objectives of water user's desires and needs, community resources of concern, and other such information. Inventory the resources are Soils, water, air, plant, and animal resources, including drainage, salinity, existing irrigation system and labor available.
3. Inventory the resources—Soils, water, air, plant, and animal resources, including drainage, salinity, existing irrigation system, and labor available.
4. Analyze resource data consider the effect of each resource on the others.
5. Formulate alternatives Irrigation method, system, components. Include irrigation scheduling methods appropriate for the user.
6. Evaluate alternatives consider potential environmental impacts, costs, and on farm labor and skill availability.
7. Water user decision which irrigation method, system, and components to use; and, overall water management desires.
8. Water user implements irrigation plan.
9. Follow up evaluating results of plan implementation, onsite and offsite. (National Planning Procedures Handbook (NPPH) -jap10-1- seb-1997.)



Center pivot irrigation system

Sprinkler parts: the sprinkler contents of body, reflector, nozzle and pressure regulators**.** The pressure regulators are "pressure killers." They reduce pressure at the water delivery nozzle so that the appropriate amount of water is applied by each applicator. Selection of nozzle size is based on the rated delivery (psi) of the pressure regulators. Nozzles used with 10 psi regulators are smaller than those used with 6 psi regulators when the same amount of water is applied. Low rated (psi) pressure regulators, if used, allow center pivot design to be appropriate at minimum operating pressure.

Pressure regulators require energy to function properly. Water pressure losses within the regulator can be 3 psi or more. So, entrance (or inlet) water pressure should be 3 psi more than the regulator rating. There for, regulators do not function properly when operating pressure is less than their rating plus 3 psi. Pressure regulator operating inlet pressure should be monitored with a gauge installed upstream adjacent to the regulator in the last drop at the outer end, and should be checked when the machine is up slope. Another gauge located in the first drop in span one will monitor operating pressure when the center pivot is located on down slope terrain.

Refractor: The refractor is a part of nozzle which creates the different shapes of water droplets overlap, also spray is part of nozzle which controlled the amount of water, find in different size (46 sizes), the body of the nozzle contains all the parts and the drop hose or drop pipe (¾") connects the nozzles to the main pipe, The factories Senniniger and Nelson advice to make the nozzles (1.3m to 1.5m) higher on the ground to make the best overlap.

The presser at center of the pivot should not more than 45psi and not less than 15psi at the end of the pivot.



Nozzles kinds in Senninger & Nelson companies

Nuzzling programs: we prepared a manual and Automatic programs to organize the nozzles in center pivot irrigation system. The manual program prepared in an excel sheet, we tack the main data from the chart of the factory, using this data into the excel sheet to prepare the manual chart depend on total flow, area, pressure, flow rate of nozzle, length of spans, diameter of main pipes and distance between the sprinklers. In this design of program, we choice the size of nozzle manually depending on our experience, we aim to distribute the amount of water on unit of area equally.

Automatic program as application program, itis upgraded version of the manual program, prepared with very confusion equation to give an easy using for the user, fast, excellent results, safe and it has special protection. The program divides in two side, the inputs is first side, to prepare the chart must be enter in this side the center pivot spans number, length of spans, number of nozzles, water flow rate, nozzle flow rate, and the distance between the water source and pivots Centre to calculated the friction loss automatically.

The output is second side, which choices the size and number of nozzles automatically. to give us the ready chart of nozzles.

The timing switch (timer) is located inside the control panel of center pivot, which controls the speed of the center pivot, numbering from zero to 100%, the design 7span or 8 span which cover 120fed, at 100% speed it completes the irrigation cycle within 9 to 10 hours. Appropriate speed for grass is 40% to complete the irrigation cycle within 22 to 24 hours.

Results & Discussion-

Although the factories of nozzles continue to approve the irrigation system, stile the center pivot has some problems that the size of nozzles are limit, not more than 46 size in Senninger company, start from (4, 4.5 to 26), the flow rate of these sizes are (0.3g/t to 14.9g/t). In Nelson company the size start from (6, 7 to 50) and the flow rate is (0.4g/t to 17g/t) depend on pressure and regulator size. So, the chart repeats one size many times to cover the center pivot which contains (140 to 220 nozzles in 400m). (Nelson and Senninger data sheet chart – 2016)

To calculate the nozzles flow using:

$$q = \mathrm{a.\,c}\sqrt{2\mathrm{gh}}$$

Where: q = nozzle flow rate m/s, a = sprinkler space area /mm, c = flow factor, g = gravity, h = head pressure. (A.M. Aljunied. pg7.1995.)

The other problem in center pivot irrigation system, this system losses a big area out of irrigation in the corners (21% of area), in fact the factories tapped maximum effort to find a solution. The end gun is one of these solutions, which fixed at the end of the center pivot to irrigate the area in the corners.

Senninger and Nelson companies Nozzles size and flow rate in pressure 45-15psi

Senninger factory		Nelson factory	
Nozzles size	Nozzles flow rate	Nozzles size	Nozzles flow rate
4	0.3	6	0.4
4.5	0.4	7	0.6
5	0.5	8	0.9
5.5	0.7	9	1.3
6	1	10	1.7
6.5	1.4	11	2.1
7	1.8	12	2.6
7.5	2.2	13	3.1
8	2.5	14	3.5
8.5	2.8	15	3.9
9	3.2	16	4.3
9.5	3.5	17	4.7
10	3.8	18	5.1
10.5	4.2	19	5.6
11	0.5	20	6.1
11.5	0.7	21	6.5
12	4.5	22	6.9
12.5	4.9	23	7.3
13	5.2	24	7.7
13.5	5.5	25	8.1
14	5.9	26	8.5
14.5	6.2	27	8.9
15	6.5	28	9.3
15.5	6.9	29	9.7
16	7.2	30	10.1
16.5	7.6	31	10.5
17	7.9	32	10.9
17.5	8.3	33	11.4
18	8.7	34	11.7
18.5	9.1	35	11.9
19	9.6	36	12.2
19.5	9.9	37	12.7
20	10.2	38	12.9
20.5	10.6	39	13.2
21	10.9	40	13.7
21.5	11.4	41	13.9
22	11.7	42	14.2
22.5	12.2	43	14.7

23	12.6	44	14.9
23.5	12.9	45	15.3
24	13.4	46	15.7
24.5	13.7	47	15.9
25	14.2	48	16.2
25.5	14.6	49	16.7
26	14.9	50	17.0

نسخة توضيحية مفصلة لهل البرمجة

المساحة الكلية	طول المحور	التدفق	عدد البخاخات		TOWER LENGTH											
T.AREA	T.LENGTH	T.GPM	T.QU/NOZ		50	50	50	54	54	54	54	61	61	0	488	LENGETH
74.8	488	1400	243.0		50	100	150	204	258	312	366	427	488	0	488	SH.LENGTH
IN-PSI	35	OUT-PSI	15		0.8	3.1	7.1	13.1	20.9	30.6	42.1	57.3	74.8	0.0	74.8	SHA REA /H
					0.8	2.4	3.9	6.0	7.8	9.7	11.5	15.2	17.5	0.0	74.8	TOW.AREA
مقاس البخاخ	NOZ-SIZE/GPM		تدفق البخاخ		17.0	25.0	25.0	28.0	28.0	28.0	28.0	32.0	32.0	0.0	243.0	NOZ.QU/A R
NOZ SIZE	NOZ-FLOW	NOZ SIZE	NOZ-FLOW		18.7											GPM/H
5	0.58	16	5.9		14.62	44.17	73.48	112.38	146.66	180.95	215.23	284.38	328.13	0.00	1400.00	GPM/A REA
5.5	0.7	16.5	6.3													
6	0.84	17	6.7					NOZ-PROGRA M								
6.5	1	17.5	7.1		area1				area2				area3			
7	1.14	18	7.4		NOZ SIZE	NOZ-FLOW	NOZ-Q	FLOW	NOZ SIZE	NOZ-FLOW	NOZ-Q	FLOW	NOZ SIZE	NOZ-FLOW	NOZ-Q	FLOW
7.5	1.3	18.5	7.8		5	0.58	3	1.74				0				0
8	1.5	19	8.2		6	0.84	3	2.52				0				0
8.5	1.7	19.5	8.7					0				0				0
9	1.9	20	9.1					0				0				0
9.5	2.12	20.5	9.5					0				0				0
10	2.34	21	9.9					0				0				0
10.5	2.6	21.5	10.3					0				0				0
11	2.83	22	10.9					4.26				0.00				0.00
11.5	3.1	22.5	11.3		area4				area5				area6			
12	3.4	23	11.8		NOZ SIZE	NOZ-FLOW	NOZ-Q	FLOW	NOZ SIZE	NOZ-FLOW	NOZ-Q	FLOW	NOZ SIZE	NOZ-FLOW	NOZ-Q	FLOW
12.5	3.6	23.5	12.3					0				0				0
13	3.9	24	12.7	16.5				0				0				0
13.5	4.3	24.5	13.2					0				0				0
14	4.6	25	13.7					0				0				0
14.5	4.9	25.5	14.1					0				0				0
15	5.2	26	14.5					0				0				0
15.5	5.6							0				0				0
								0.00				0.00				0.00
					area7				area8				area6			
					NOZ SIZE	NOZ-FLOW	NOZ-Q	FLOW	NOZ SIZE	NOZ-FLOW	NOZ-Q	FLOW	NOZ SIZE	NOZ-FLOW	NOZ-Q	FLOW

Manual program of chart

center pivot data input	
number of spans	7
length of span	54.6
number of nozzles in span	24
flow rate in center of pivot	1300
distance of flowmter reading	0
flow rate of source	1300

nozzle data input	
nozzle size	nozzle flow g/mnt
5	0.5
5.5	0.7
6	1
6.5	1.4
7	1.8
7.5	2.2
8	2.5
8.5	2.8
9	3.2
10	3.5
10.5	3.8
11	4.2
11.5	4.5
12	4.9
12.5	5.2
13	5.5
13.5	5.9
14	6.2
14.5	6.5
15	6.9
15.5	7.2
16	7.6
16.5	7.9
17	8.3
17.5	8.7
18	9.1
18.5	9.6
19	9.9
19.5	10.2
20	10.6
20.5	10.9
21	11.4
21.5	11.7
22	12.2
22.5	12.6
23	12.9
23.5	13.4
24	13.7
24.5	14.2
25	14.6
25.5	14.9
26	15.3

Automatic program input of chart

center pivot irrigation system- nozzles chart									
pressure par	3	number of spans		7	flow rate g/mnt		1300	number of nozzles		168
nozzle number	Sp1	Sp2	Sp3	Sp4	Sp5	Sp6	Sp7	Sp8	Sp9	total
5	5	0	0	0	0	0	0	0	0	5
5.5	3	0	0	0	0	0	0	0	0	3
6	3	0	0	0	0	0	0	0	0	3
6.5	4	0	0	0	0	0	0	0	0	4
7	5	0	0	0	0	0	0	0	0	5
7.5	4	0	0	0	0	0	0	0	0	4
8	0	3	0	0	0	0	0	0	0	3
8.5	0	3	0	0	0	0	0	0	0	3
9	0	5	0	0	0	0	0	0	0	5
9.5	0	0	0	0	0	0	0	0	0	0
10	0	3	0	0	0	0	0	0	0	3
10.5	0	3	0	0	0	0	0	0	0	3
11	0	5	0	0	0	0	0	0	0	5
11.5	0	2	1	0	0	0	0	0	0	3
12	0	0	4	0	0	0	0	0	0	4
12.5	0	0	3	0	0	0	0	0	0	3
13	0	0	4	0	0	0	0	0	0	4
13.5	0	0	4	0	0	0	0	0	0	4
14	0	0	3	0	0	0	0	0	0	3
14.5	0	0	4	0	0	0	0	0	0	4
15	0	0	1	3	0	0	0	0	0	4
15.5	0	0	0	3	0	0	0	0	0	3
16	0	0	0	5	0	0	0	0	0	5
16.5	0	0	0	3	0	0	0	0	0	3
17	0	0	0	4	0	0	0	0	0	4
17.5	0	0	0	4	0	0	0	0	0	4
18	0	0	0	2	3	0	0	0	0	5
18.5	0	0	0	0	5	0	0	0	0	5
19	0	0	0	0	3	0	0	0	0	3
19.5	0	0	0	0	4	0	0	0	0	4
20	0	0	0	0	4	0	0	0	0	4
20.5	0	0	0	0	3	0	0	0	0	3
21	0	0	0	0	2	4	0	0	0	6
21.5	0	0	0	0	0	3	0	0	0	3
22	0	0	0	0	0	5	0	0	0	5
22.5	0	0	0	0	0	5	0	0	0	5
23	0	0	0	0	0	3	0	0	0	3
23.5	0	0	0	0	0	4	1	0	0	5
24	0	0	0	0	0	0	4	0	0	4
24.5	0	0	0	0	0	0	5	0	0	5
25	0	0	0	0	0	0	4	0	0	4
25.5	0	0	0	0	0	0	4	0	0	4
26	0	0	0	0	0	0	6	0	0	6

Automatic program output of chart

Comparison between the manual and automatic programs of nozzles chart

The flow rate of pump is 1300 g/t and pressure 45 psi in center pivot and15 psi at the end, using nozzles of senninger factory.

GENARAL		MANUAL DESIGN	AUTOMATIC DESIGN	MANUAL DESIGN	AUTOMATIC DESIGN
NOZZLE SIZE	NOZZLE FLOW	NOZZLE NUMBER	NOZZLE NUMBER	TOTAL FLOW	TOTAL FLOW
5	0.5	7	5	3.5	2.5
5.5	0.7	7	3	4.9	2.1
6	1	7	3	7	3
6.5	1.4	2	4	2.8	5.6
7	1.8	1	5	1.8	9
7.5	2.2	2	4	4.4	8.8
8	2.5	2	3	5	7.5
8.5	2.8	4	3	11.2	8.4
9	3.2	4	5	12.8	16
10	3.5	4	0	14	0
10.5	3.8	4	3	15.2	11.4
10.5	4.2	4	3	16.8	12.6
11	4.5	2	5	9	22.5
11.5	4.9	3	3	14.7	14.7
12	5.2	4	4	20.8	20.8
12.5	5.5	5	3	27.5	16.5
13	5.9	5	4	29.5	23.6
13.5	6.2	5	4	31	24.8
14	6.5	2	3	13	19.5
14.5	6.9	2	4	13.8	27.6
15	7.2	4	4	28.8	28.8
15.5	7.6	4	3	30.4	22.8
16	7.9	4	5	31.6	39.5
16.5	8.3	4	3	33.2	24.9
17	8.7	4	4	34.8	34.8
17.5	9.1	2	4	18.2	36.4
18	9.6	2	5	19.2	48
18.5	9.9	4	5	39.6	49.5
19	10.2	4	3	40.8	30.6
19.5	10.6	4	4	42.4	42.4
20	10.9	4	4	43.6	43.6
20.5	11.4	4	3	45.6	34.2
21	11.7	4	6	46.8	70.2
21.5	12.2	5	3	61	36.6
22	12.6	5	5	63	63
22.5	12.9	5	5	64.5	64.5
23	13.4	5	3	67	40.2
23.5	13.7	5	5	68.5	68.5
24	14.2	5	4	71	56.8
24.5	14.6	4	5	58.4	73
25	14.9	4	4	59.6	59.6
25.5	15.3	3	4	45.9	61.2
26	15.7	3	6	47.1	94.2
TOTAL		168	168	1319.7	1380.2

CONCLUSIONS:

This study concluded to:

- Select the appropriate irrigation system in farm is important.
- Select the appropriate kind of nozzles (the refractor) and appropriate regulator depend on crop and soil.
- Not repeat one size of nozzle in chart as possible and the nozzles organization (the chart) from smaller in the center to bigger size outside.
- No difference between automatic and manual charts in setting of sprinklers.
- The size of nozzles is limit, not more than 46 size in Senninger company, start from (4, 4.5 to 26), the flow rate of these sizes is (0.5g/t to 14.9g/t) depend on pressure and regulator size.
- In Nelson company the size of nozzles starts from (6, 7 to 50) and the flow rate is (0.3g/t to 17g/t) also depend on pressure and regulator size.

REFERENCES:

Agricultural engineering – center pivot irrigation-MT.59270-Pg.1,2. (May 1984)

A.M. Aljunied. Design of sprinkler irrigation network - pg7. 1995.

Bill Kranz, et al. operating characteristics of center pivot sprinkler. G1532.Pg1. (2005).

L. Kelley- Evaluating Irrigation System Uniformity. Pg 1http://www. Canr.msu.edu/uploads/235/67987/resouces/EvaluatingIrrigationSystemUniformity05.14 .pdf. (2014).

National Planning Procedures Handbook (NPPH)- Conservation Management Systems and Irrigation Planning-jap10-1. (seb-1997)

Nelson and Senninger data chart sheet. (2016).