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Determining possible optimal values of required flow, nozzle diameter, and wetted area for linear traveling laterals

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Abstract

Special benefits of linear traveling systems into the other sprinkler irrigation systems include resolve problems related to the runoff and lack of irrigation in corners of the field (center pivot systems), has led to the popularity of these systems. More detailed design of linear traveling irrigation systems, while raising the water use efficiency (WUE) can be considered a step to development sustainable agriculture. In this paper, using PivNoz software (USDA-ARS-NWISRL) values of required flow, nozzle diameter, and wetted area for linear traveling laterals optimized. The most changes to reach to the optimal values were related to the required flow 56% caused by the system gross capacity changes, then wetted area 49% due to the nozzled length changes, and then required flow 43% caused by the nozzle spacing. However, nozzle diameter was the only parameter that its values not remained constant for changes of system design factors.

Keywords - linear traveling system, sprinkler irrigation, sustainable agriculture, water use efficiency.

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I Introduction

Research history about sprinkler irrigation design, showed that many studies have been done to determining optimal values for these systems, which some of them will be described in the following. Amir et al. [1] analyzed labor to operate linear move irrigation machines. For moving a linear lateral type fed by a flexible hose, the analysis clearly showed that machine width affects labor consumption significantly. Amir et al. [2] in another research, analyzed energy of lateral move irrigation machines. Anwar [3] presented an adjusted factor for pipelines with multiple outlets and outflow. He claimed that this factor might find application in the design of tapered sprinkle and trickle irrigation pipelines. Chávez et al. [4] compensated inherent linear move water application errors using a variable rate irrigation system. This study has shown that irrigation application errors were reduced from over 20% to around 5%, in the subsequent irrigation event. Chávez et al. [5] also presented a remote irrigation monitoring and control system (RIMCS) for continuous move systems. Dogan et al. [6] investigated effect of varying the distance of collectors below a sprinkler head and travel speed on measurements of mean water depth and uniformity for a linear move irrigation sprinkler system. Evans et al. [7] adopted site-specific variable rate sprinkler irrigation systems. Hanson et al. [8] evaluated continuous-move sprinkler machines using time-series statistics. They concluded that time-series statistics is an evaluation tool to be used in identifying periodic patterns of variability. Kale et al. [9] designed pressurized irrigation subunit as optimal. The verification of operating inlet pressure head obtained by the proposed model with accurate numerical step-by-step method suggested that it was mostly accurate. Kamey and Podmore [10] studied performance of stationary gun irrigation systems. King et al. [11] presented computer control system for spatially varied water and chemical application studies with continuous-move irrigation systems. The results showed that spatially varied water and chemical application was achieved with the same accuracy as that of conventional uniform application. McDermott et al. [12] studied groundwater travel times near spreading ponds. Oron [13] presented technical and economic considerations in the design of closed conduit irrigation systems. Oron [14] also presented a universal nomogram for determining the traveling velocity of a movable frontal lateral. Sepúlveda et al. [15] used handheld computers for hydraulic calculations of microirrigation subunits. They presented an intermediate correction factor was developed that allows computation of head loss between any two points of a ultiple outlet line. Valiantzas [16, 17], designed microirrigation submain units using tapered manifold and laterals. The design variables were the lengths of two given pipe sizes for the laterals as well as the appropriate lengths of the available pipe sizes for the manifold. Tapered laterals and manifold were selected in such a way that the sum of the costs of the laterals and the manifold is minimized, while the hydraulic design criterion was ensured. The case of a single-diameter lateral with tapered manifold pipeline was also examined. The design procedure could be also applied in sprinkle irrigation tapered laterals. Valipour [18] adjusted pressure loss in sprinkle and trickle irrigation system design using tapered pipes. He showed that in single lateral-tapered manifold system due to the lower pressure loss in laterals, could be use from several types of pipe diameters for manifolds but in tapered lateral-tapered manifold system due to the more pressure loss in laterals, the choice was limited. Valipour [19] also using PipeLoss software, survived amounts of pressure loss, friction slope, inflow velocity, velocity head, and Reynolds number in center pivot systems. The results showed that pressure loss was more sensitive compared to other. In addition, amount of inside diameter was very important in a center pivot irrigation system. Vries and Anwar [20] scheduled irrigation with travel times. Yazar et al. [21] studied LEPA and trickle irrigation of cotton in the Southeast Anatolia Project (GAP) area in Turkey. The research results revealed that both the trickle and LEPA irrigation systems could be used successfully for irrigating cotton crop under the arid climatic conditions of the GAP area in Turkey. Most previous studies focused on one or maximum two, sprinkler irrigation design parts and neglected role of all-important system design factors. In this study, using PivNoz software, possible optimal values for designing of linear traveling laterals studied.

II MATERIALS AND METHODS

Number of five parameters includes system gross capacity (SGC), travel distance (TD), nozzled length (NL), nozzle pressure (NP), and nozzle spacing (NS) was selected for scrutiny of required flow, wetted area, and nozzle diameter in linear traveling irrigation systems. For this purpose by choosing ten different scenarios and using PivNoz software, Supported by United Stated Department of Agriculture (USDA), Agricultural Research Service (ARS), and NorthWest Irrigation and Soil Research Laboratory (NWISRL) sensitivity of mentioned parameters investigated. PivNoz was developed to aid in the design and analysis of center pivot and traveling lateral sprinkler irrigation systems. All of the scenarios were in a reasonable range. In most cases initial data were average of own range and almost in most projects, these amounts is selected for linear traveling system. Increase or decrease for each scenario was based on actual values. For example, values of nozzle pressures less than 414 kilo Pascal and values of nozzle spacings less than 50 meters were related to the commonly sprinklers and values of nozzle pressures more than 414 kilo Pascal and values of nozzle spacings more than 50 meters were related to the gun sprinklers.

Table 1 shows initial input and output data in this study.

Table 1. Values of initial input and output

Input	System gross capacity (mm/day)	Travel distance (m)	Nozzled length (m)	Nozzle pressure (kPa)	Nozzle spacing (m)
	10	80	350	414	70
Output	Required flow (L/min)	Wetted area (ha)	Nozzle diameter (mm)		
	48.61	0.21	6.15		

III RESULTS AND DISCUSSION

Table 2 shows scenarios related to the system gross capacity.

Table 2. Scenarios related to the system gross capacity

System gross capacity (mm/day)	Required flow (L/min)	Δ (%)	Nozzle diameter (mm)	Δ (%)	Wetted area (ha)	Δ (%)
2	9.72	80	2.77	55	0.21	0
4	19.44	60	3.96	36	0.21	0
6	29.17	40	4.78	22	0.21	0
8	38.89	20	5.56	10	0.21	0
10	48.61	0	6.15	0	0.21	0
12	58.33	20	6.76	10	0.21	0
14	68.06	40	7.14	16	0.21	0
16	77.78	60	7.54	23	0.21	0
18	87.50	80	8.33	35	0.21	0
20	97.22	100	8.74	42	0.21	0
Average (%)		56		28		0

According to the Table 2 for decreasing values of system gross capacity, required flow and nozzle diameter decreased and for increasing values of system gross capacity, required flow and nozzle diameter increased but values of wetted area, did not change. Average of all changes in this state was 28%.

Table 3 shows values of travel distances.

Table 3. Scenarios related to the travel distances

Travel distance (m)	Required flow (L/min)	Δ (%)	Nozzle diameter (mm)	Δ (%)	Wetted area (ha)	Δ (%)
30	18.23	62	3.76	39	0.08	62
50	30.38	38	4.78	22	0.13	38
60	36.46	25	5.36	13	0.16	24
70	42.53	13	5.77	6	0.18	14
80	48.61	0	6.15	0	0.21	0
90	54.69	13	6.55	7	0.23	10
100	60.76	25	6.76	10	0.26	24
110	66.84	38	7.14	16	0.29	38
120	72.92	50	7.54	23	0.31	48
135	82.03	69	7.95	29	0.35	67
Average (%)		37		18		36

According to the Table 3 decreasing of travel distance caused decrease in all parameters and increasing of inside diameter caused increase in all parameters. Average of all changes in this state was 30%.

Table 4 shows different values of nozzled lengths.

Table 4. Scenarios related to the nozzled lengths

Nozzled length (m)	Required flow (L/min)	Δ (%)	Nozzle diameter (mm)	Δ (%)	Wetted area (ha)	Δ (%)
150	41.67	14	5.77	6	0.10	52
200	55.56	14	6.55	7	0.10	52
250	46.30	5	5.94	3	0.16	24
300	41.67	14	5.77	6	0.21	0
350	48.61	0	6.15	0	0.21	0
400	44.44	9	5.94	3	0.26	24
450	41.67	14	5.77	6	0.31	48
500	39.68	18	5.56	10	0.36	71
550	43.65	10	5.77	6	0.36	71
600	41.67	14	5.77	6	0.42	100
Average (%)		13		6		49

According to the Table 4 changes that occur for different values of nozzled length, does not follow a trend. This is attributable to the choosing optimal values by PivNoz software. When nozzled length increased from 200 meters to 250 meters, nozzle diameter did not increased from 6.55 millimeters to 6.74 millimeters because in this case, required flow also increased and thus system gross capacity was more than 10 millimeters per day (Table 1). To prevent this and increase water use efficiency, nozzle diameter decreased from 6.55 millimeters to 5.94 millimeters and as a result, required flow also decreased but instead of wetted area increased for considered system gross capacity (10 mm/day) was obtained. Average of all changes in this state was 23%. It is also effective in other cases.

Table 5 shows different values of nozzle pressures.

Table 5. Scenarios related to the values of nozzle pressures

Nozzle pressure (kPa)	Required flow (L/min)	Δ (%)	Nozzle diameter (mm)	Δ (%)	Wetted area (ha)	Δ (%)
240	48.61	0	6.93	13	0.21	0
310	48.61	0	6.55	7	0.21	0
345	48.61	0	6.35	3	0.21	0
380	48.61	0	6.35	3	0.21	0
414	48.61	0	6.15	0	0.21	0
483	48.61	0	5.94	3	0.21	0
552	48.61	0	5.77	6	0.21	0
621	48.61	0	5.56	10	0.21	0
689	48.61	0	5.36	13	0.21	0
827	48.61	0	5.16	16	0.21	0
Average (%)		0		8		0

According to the Table 5 changes of nozzle pressures only were effective on nozzle diameter. Increasing nozzle pressures decreased nozzle diameter and decreasing nozzle pressures increased nozzle diameter. Average of all changes in this state was 3%.

Table 6 shows different values of nozzle spacings.

Table 6. Scenarios related to the nozzle spacings

Nozzle spacing (m)	Required flow (L/min)	Δ (%)	Nozzle diameter (mm)	Δ (%)	Wetted area (ha)	Δ (%)
20	11.44	76	2.97	52	0.25	19
40	24.31	50	4.37	29	0.24	14
50	27.78	43	4.57	26	0.26	24
60	38.89	20	5.56	10	0.22	5
70	48.61	0	6.15	0	0.21	0
80	48.61	0	6.15	0	0.24	14
90	64.81	33	7.14	16	0.20	5
100	64.81	33	7.14	16	0.22	5
110	64.81	33	7.14	16	0.25	19
130	97.22	100	8.74	42	0.19	10

According to the Table 6 the maximum of changes related to the required flow. For increasing of nozzle spacing values of required flow and nozzle diameter increased and for decreasing of nozzle spacing values of required flow and nozzle diameter decreased. But, trends of wetted area was variable. When nozzle spacing increased from 20 meters to 40 meters, wetted area decreased from 0.25 hectares to 0.24 hectares to prevent from system gross capacity more than 10 millimeters per day (Table 1). It is also effective in other cases. Average of all changes in this state was 26%.The most changes to achieve to the optimal values were related to the required flow 56% due to the system gross capacity changes, then wetted area 49% due to the nozzled length changes, and then required flow 43% due to the nozzle spacing. However, if consider average of all changes in each state, travel distance with 30% changes was maximum.

Figure 1 shows a compression between all optimized parameters in linear traveling irrigation systems.

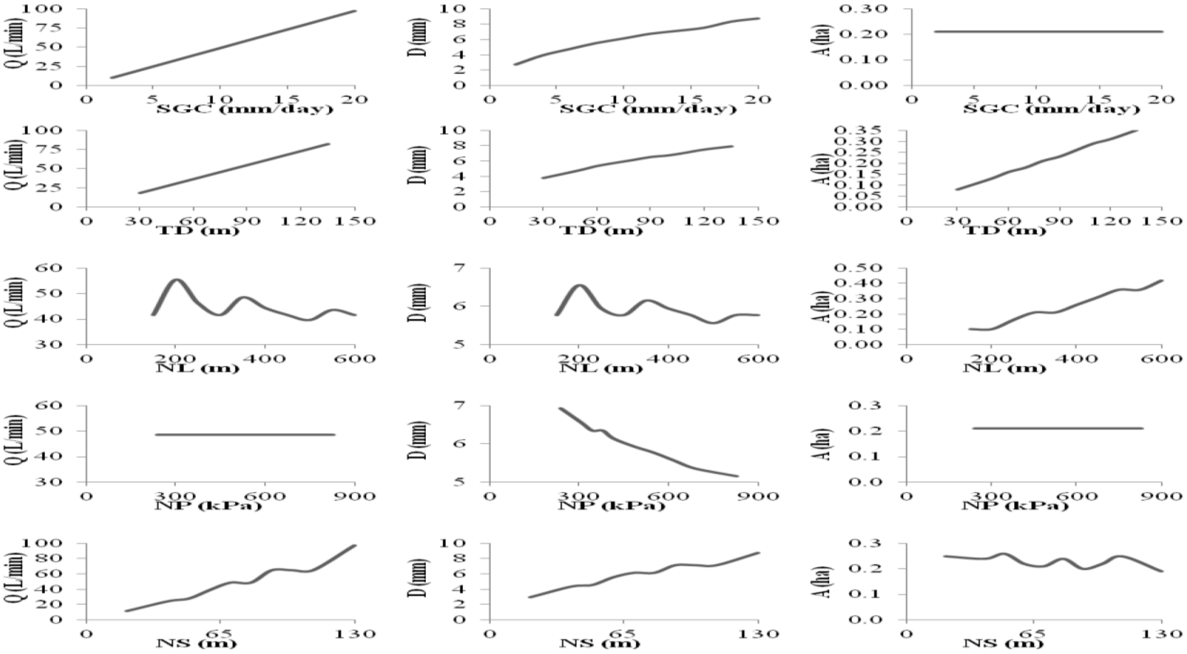

Figure 1. Obtained results for each of five linear traveling design parameters

Compression of five linear traveling design parameters in Figure 1 showed that for changes of SGC, required flow changed as linear, nozzle diameter changed as almost linear, and wetted area was fixed. For changes of TD, required flow changed as linear and nozzle diameter and wetted area changed as almost linear. For changes of NL, wetted area changed as stepped but required flow and nozzle diameter changed without any special trend. For changes of NP, nozzle diameter changed with a steep slope but required flow and wetted area were fixed. For changes of NS, wetted area changed without any special trend but required flow and nozzle diameter changed as almost stepped.The mentioned cases shows that in linear traveling system design should be noted to travel distance as input and required flow as output, more than other inputs and outputs parameters, respectively. However, role of other inputs and outputs due to their undeniable effects should not be ignored.

IV CONCLUSION

Due to the benefits of linear traveling irrigation system into the other techniques especially surface irrigation, more accurate design of this systems for saving in water resources, increasing irrigation efficiency, and finally encourage farmers to use of this system (when using this method is economical), recognition of effective parameters on linear traveling have a great importance.In this study, using PivNoz software, possible optimal values of required flow, nozzle diameter, and wetted area determined. The results showed that:The most changes to achieve to the optimal values were related to the required flow 56% due to the system gross capacity changes, then wetted area 49% due to the nozzled length changes, and then required flow 43% due to the nozzle spacing. However, if consider average of all changes in each state, travel distance with 30% changes was maximum.In linear traveling system design should be noted to travel distance as input and required flow as output, more than other inputs and outputs parameters, respectively.

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