ASSESSMENT OF EFFECTS OF VARIOUS PRESSURE LOSSES OF LATERAL PIPES ON THE FORAGE CROP YIELDS IN THE HAND MOVE SPRINKLER IRRIGATION SYSTEMS

L'EVALUATION D'EFFETS DE DIVERSES PERTES DE PRESSION DE TUYAUX LATERAUX SUR LES RENDEMENTS DE RECOLTE D'AFFOURAGEMENT DANS L'ARROSEUR DE MOUVEMENT DE MAIN SYSTEMES D'IRRIGATION

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ABSTRACT

In developing agriculture, the goal is high crop yield and in order to get this purpose, water losses should be reduced and irrigation efficiency should be increased. Increasing allowable friction loss in laterals of sprinkler irrigation systems, the pressure required for the system and lack of uniformity of sprinklers' distribution will increase followed by more water losses. If laterals are designed with less allowable pressure variation, irrigation uniformity will be better and application efficiency and relative production of crops will increase. In this study, sample fields with sprinkler irrigation system displaced with hand were designed with 5 to 30% allowable pressure variation of application pressure of sprinkler for cultivating alfalfa in Khuzestan. In each field, system's uniformity coefficient, water application efficiency, and crop yield were obtained in different friction losses. Results showed that increase of 5 to 30% friction losses reduces system's uniformity efficiency by 4%, application efficiency by 5% and relative production of crops by 1%.

RÉSUMÉ ET CONCLUSIONS

pour obtenir l'haut rendement de récolte est l'objectif principal être considéré dans le développement agricole, et les pertes d'eau diminuent et l'augmentation d'efficacité d'irrigation est les outils principaux pour atteindre cet objectif. La sélection de variation de pression admissible est très significative en raison de son effet sur la pression exigée du système, l'efficacité d'irrigation de longueur des tuyaux latérale et le diamètre. Les pertes d'eau augmentent par la pression croissante, et il améliore le rendement de récolte. L'augmentation de perte de pression admissible de tuyau latéral dans l'arroseur système d'irrigation a pour résultat l'augmentation de pression exigée du système et le manque d'uniformité d'étalage d'arroseur, et donc les pertes de plus d'eau sont obtenues. Concevoir les tuyaux latéraux avec la variation de pression admissible plus basse ont pour résultat l'uniformité mieux d'irrigation et l'a crant, l'augmentation d'efficacité d'application et de récolte relative produit 6 champs ont choisi être conçus comme l'échantillon d'arroseur de mouvement de main

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système d'irrigation avec la variation de pression d'eau approximativement portée environ 5-30% et 5% croissance pour la culture de luzerne dans la région de khoozestan et l'efficacité d'application, le coefficient d'uniformité et le rendement de récolte est étudiée dans chaque champ. Khoozestan a beaucoup de grandes plaines et beaucoup de systèmes d'irrigation avec la luzerne comme une récolte d'affouragement majeure de ce modèle du champ agricole et la condition du plus d'eau en comparaison des autres récoltes d'affouragement. Si ses propriétés qui sont utilisés à la conception des champs. La région les données disponibles qui sont utilisées condescendent les champs avec un secteur de 50 ha, pour que le tuyau principal a localisé dans le centre de champ et dans la direction de baisse universelle de terre. Et les complots de champ ont nourri utilisant des tuyaux moitié-fondamentaux. Dans chaque complot, un latéral a irrigué le complot entier. La longueur d'irrigation de bride dans les plis en augmentant le pourcentage de perte de pression, et c'est acceptable jusqu'à un certain point qui n'a pas d'effet négatif sur l'uniformité d'étalage d'eau. Dans cette recherche, cette conçue longueur bridée de champs est dans la gamme acceptable dans le divers pourcentage de perte de pression. L'efficacité d'application et le coefficient d'uniformité du système ont obtenu fondé sur la relation disponible dans le livre de keller et bliesner (1990). Recadrer le rendement a obtenu aussi selon le coefficient d'uniformité de système et selon la suffisance de niveau d'irrigation de la table introduite dans ce livre. Les résultats indiquent qu'augmentant de la perte de pression de 5 à 30% a pour résultat la diminution de coefficient d'uniformité de système et l'efficacité d'application par 5% et qui de rendement de récolte relatif par 1%. Bien que ce taux n'est pas grand, c'est considérable dans les grands champs. La différence de réduction dans l'intervalle de perte de pression de 15-20% est le moins, et il double en 20-25%. Le plus d'effet de variation de perte de pression est observé dans l'efficacité d'application. Puisque l'efficacité d'application de consommation d'eau a beaucoup d'effet sur les coûts, le soin doit être pris pour choisir une perte de pression convenable. Cette recherche est appliquée au rendement de récolte de luzerne, à la région de Khoozestan et à l'arroseur de mouvement de main système d'irrigation. Il devrait être aussi utilisé aux divers types de systèmes d'irrigation, aux régions et aux autres récoltes pour la meilleure conclusion.

1. INTRODUCTION

Agricultural department in Iran is the biggest water consumer and about 95 percent of water sources of the country are applied by this department. It is while that water wastage is high in irrigation and total irrigation efficiency has been reported 33% in Iran (statistical office and information technology agricultural ministry, 2005). So in recent years development of sprinkler irrigation systems has been paid more attention. These systems compared with surface irrigation methods match well with land topography because of more efficiency and more uniform water distribution in the field and are applicable for different kinds of soil. Of important factors that should be considered in designing sprinkler irrigation systems is uniformity efficiency of water distribution in the field. Lack of uniform water distribution makes water wastage and reduces crops per area unit (Hasanli, 2003, Alizadeh, 2004, Montazer and Rahimikhoob 2009, Najafimood 2005). Sprinklers' arrangement, wind velocity, sprinkler size, operational pressure of sprinkler and water pressure variations with sprinklers which work simultaneously are the parameters that affect uniformity efficiency (Tarjolo.et.al, 1999). There is an optimum pressure range for diameter of sprinkler nozzle opening that produces the most distribution efficiency. Operational pressure of sprinkler and sprinklers’ arrangement are determined according to the table presented by the factory producing sprinkler and wind velocity considering maximum speed of allowable distribution. Only if the sprinkler is in recommended pressure range, it will be true otherwise the coefficient will reduce. Hydraulic load loss in length of lateral and land topography is factors of lack of pressure uniformity among sprinklers that operate simultaneously. Hydraulically, the sprinklers look like aperture and outlet flow rate is function of squares of water pressure behind them so pressure
variations cause lack of uniformity of water distribution in the land and reduce uniformity efficiency. One of principles of designing to determine the length and diameter of laterals is that water pressure changes among sprinklers should not exceed 20% (Alizadeh 2004, Keller and Blisner 1990, Monserrat 2009 and Najafimood 2005). There is no scientific reason to explain 20% allowable water pressure variations. Choosing allowable pressure changes is important to affect the pressure required for the system, irrigation efficiency, the length and diameter of laterals. Increase of pressure increases water losses and affects crop yield (Montazazr, 2007). In this study, six sample fields with Hand move sprinkler irrigation system have been designed with 5 to 30% water pressure changes with 5% growth for Khuzestan province and application efficiency, uniformity coefficient and crop yield were investigated.

2. MATERIALS AND METHODS

2.1 Study area and datas

Khuzestan province contains vast plains and many irrigation networks. Alfalfa is one of main plants of crop model in this region and needs much more water than other plants so it was used for designing the field. Maximum depth of alfalfa root is 1.5 meter and water coefficient is 0.5. Soil tissue of the studied range is silt loam and maximum moist retention is about 150mm per meter soil and basic infiltration rate of the soil is 14 mm per hour (consulting engineer Company of Mahabghods, 2002). According to national document of state water demand (Alizadeh, 2000), maximum water required by alfalfa in peak month (June) has been obtained 7.52 mm per day. Meteorological parameters were evaluated according to their averages during 10 years in meteorological station of Ahvaz. Maximum water requirement occurs in June so the fields were designed based on water demand and meteorological parameters in this month. Average temperature was 38.2 °c, average relative humidity 22.8%, and average wind velocity 9.42 kilometers per hour in a month.

2.2 Field design

According to average surface of lands ownership and region cultivation model, the most appropriate net area of alfalfa field has been determined 50 hectares for sprinkler irrigation (consulting engineer Company of Mahabghods, 2003). In this study by using data present in the region, the fields with 50 hectares areas were designed in a way that the main pipe is in the center and in direction of general gradient of the land and field units are fed by sub main pipes, a lateral has been considered in each unit to irrigate entire unit, the sprinkler with nozzle opening (5.5 × 2.5) and arrangement of 18 × 12 square meter was chosen in order to irrigate the field using tables of Keller and Blisner (1990) considering basic infiltration rate of soil and irrigation requirement in maximum application periods. This sprinkler with water pressure of 35 meters contains flow rate of 0.62 per liter in second and according to above table, its uniformity coefficient in the field with wind velocity of 9.42 kilometers is 85%. The time required for water distribution in maximum application period was estimated 11 hours so laterals will be displaced two times a day in this period.

In Hand move system, 6 meter aluminum parts with 3 inch diameters were used for laterals. In this study, laterals of sprinkler irrigation were placed in direction of contours on the land and considering flat and smooth central and southern plains of Khuzestan, water pressure change is resulted from hydraulic load loss in the length of lateral and friction loss resulted from friction and friction loss in main pipe, flow rate and pipes’ length were obtained from Keller’s equation. In designing the fields related to each of friction loss percentage, field specifications were chosen in which friction loss resulted from friction was near to allowable friction loss (that was obtained from multiplying friction loss percentage by operational pressure of sprinkler).

2.3 Water application efficiency
In methods of sprinkler irrigation, water losses in crop unit mainly resulted from water percolation, lack of uniformity of water distribution in sprinklers, losses of water leakage from pipes, joints inside the crop unit, losses of water distribution due to wind and losses of evaporation of water drops before reaching the surface. Considering these losses, water application efficiency was obtained by following relation (Tafazoli, 2004):

$$E_a = DE_{pa} \times R_e \times O_e$$

(1)

$E_a$: water application efficiency (%), $DE_{pa}$: distribution efficiency in terms of adequacy of irrigation (%), $R_e$: effective part of water distributed (in decimal), and $O_e$: water distribution efficiency in pipe lines inside the crop unit (in decimal).

Distribution efficiency based on adequacy of irrigation shows the relationship between uniformity coefficients of distribution (showing uniformity of water distribution in the field) and amount of adequacy of irrigation (a percentage of filed surfaces that reached net irrigation requirement or more than it). Considering statistical correlation between two parameters, distribution efficiency was obtained according to adequacy of irrigation from table presented in Keller’s book. In this relation, choosing proper amounts of adequacy of irrigation and uniformity coefficient are note worthy. Uniformity coefficient is recommended 85% for crops such as alfalfa and 80% for adequacy of irrigation (Tafazoli, 2004). Effective part of water distribution shows water discharged from sprinklers that reach the surface after subtracting losses of evaporation and wind and the plant is able to use it. Losses resulted from wind and evaporation is low when the wind velocity is low and vegetation density is high and is 5 to 10 % in general condition but when the wind blows severely the losses are far more. Water distribution efficiency in pipe lines inside crop unit shows losses resulted from leakage of pipes, joint or losses from discharging laterals while displacing or losses resulted from improper exploitation of laterals inside irrigation unit and is between 1 and 5%.

2.4 Uniformity coefficient of system

Uniformity coefficient of system has been obtained from following relation using minimum pressure and average pressure of sprinklers in the system (Keller and Bliesner, 1990):

$$CU_{sys} = CU \ [0.5 \ (1 + (H_m / H_n)^{1/2})]$$

(2)

$CU_{sys}$: Uniformity coefficient of system, $CU$: Uniformity coefficient of water distribution in the field, $H_n$: minimum pressure of sprinkler in the system (meter) and $H_m$: average pressure of sprinkler of system (meter)

Minimum pressure of the sprinkler at the bottom of terminal lateral occurs in the unit that will be obtained in terms of pressure of lateral head and friction loss in lateral and average pressure of the system was obtained by following relation regarding maximum and minimum pressure of sprinkler in the system (Keller and Bliesner, 1990):

$$H_m = (2H_n + H_x)/3$$

(3)

$H_x$: maximum pressure of sprinkler in the system that occurs at the head of lateral in the unit. The pressure at the beginning of the lateral is obtained by following relation (Keller and Bliesner, 1990):

$$H_o = H_a + 0.75 H_l + H_r$$

(4)
Friction loss resulted from friction has been obtained by below relation (Keller and Bliesner, 1990):

\[ H_f = 7.89 \times 10^{-7} \times (L/100) \times Q^{1.75} \times D^{-0.75} \times F \]  

(5)

\( H_f \): friction loss resulted from friction (meter), \( L \): length of lateral (meter), \( Q \): inlet flow rate to lateral (liter in second), \( D \): internal diameter of lateral (millimeter) and \( F \): Christiansen coefficient for pipes with different outlets. Relations of Keller and Bliesner were used to calculate \( F \) according to uniformity coefficients of the system in different percentages of friction loss; distribution efficiency was corrected according to adequacy of irrigation and application efficiency as mentioned methods.

### 2.5 Crop yield

Relative production of the crop is obtained by following relation (Alizadeh, 2004). Keller and Blisner presented a table that shows the results obtained from below relation and will be proper to use this table in order to obtain relative production of the crop in terms of uniformity coefficient of the system and adequacy of irrigation.

\[ \frac{Y_a}{Y_p} = 1 - K_y (1 - \frac{ET_a}{ET_p}) \]  

(6)

\( Y_a \): true value of productive crop (tone per hectare), \( Y_p \): potential of productive crop (tone per acre), \( K_y \): total sensitivity coefficient of the plant to water, \( ET_a \): true evapotranspiration (millimeter) and \( ET_p \): evapotranspiration of plant potential (millimeter) in mentioned region.

### 3. RESULT AND DISCUSSION

Increase of percentage of friction loss, increases length of lateral so a large area can be irrigated using a lateral. Increase of length of lateral is acceptable to the extent that does not affect negatively on uniformity of water distribution. Length of lateral, field and unit area and number of irrigation units are shown in table 1 in different percentages of friction loss and it is observed that length of lateral designed for the field is in acceptable range in different percentages of friction loss.

**Table 1.** specifications of field and irrigation units in different percentages of friction loss (les spécifications d’unités de terrain et d’irrigation dans de différents pourcentages de perte de friction)

<table>
<thead>
<tr>
<th>Friction loss (%)</th>
<th>Length of lateral (m)</th>
<th>Unit area (ha)</th>
<th>Number of field irrigation units</th>
<th>Field area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>126</td>
<td>3.80</td>
<td>14</td>
<td>53.22</td>
</tr>
<tr>
<td>10</td>
<td>162</td>
<td>4.84</td>
<td>10</td>
<td>48.38</td>
</tr>
<tr>
<td>15</td>
<td>186</td>
<td>5.53</td>
<td>10</td>
<td>55.30</td>
</tr>
<tr>
<td>20</td>
<td>210</td>
<td>6.22</td>
<td>8</td>
<td>49.77</td>
</tr>
<tr>
<td>25</td>
<td>234</td>
<td>6.91</td>
<td>8</td>
<td>55.30</td>
</tr>
<tr>
<td>30</td>
<td>246</td>
<td>7.26</td>
<td>6</td>
<td>43.55</td>
</tr>
</tbody>
</table>

Values of friction loss, pressure at the beginning of lateral and maximum and minimum pressure of sprinkler in the system are shown in table 2 in different percentages of friction loss.
Table 2. Pressurized field specifications in different percentages of friction loss (les spécifications pressurisées de terrain dans de différents pourcentages de perte de friction)

<table>
<thead>
<tr>
<th>Friction loss (%)</th>
<th>Friction loss of lateral (m)</th>
<th>Pressure at the head of lateral (m)</th>
<th>Minimum sprinkler pressure in the system (m)</th>
<th>Maximum sprinkler pressure in the system (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.85</td>
<td>38.25</td>
<td>36.40</td>
<td>39.19</td>
</tr>
<tr>
<td>10</td>
<td>3.53</td>
<td>39.52</td>
<td>35.98</td>
<td>40.31</td>
</tr>
<tr>
<td>15</td>
<td>5.07</td>
<td>40.66</td>
<td>35.60</td>
<td>41.68</td>
</tr>
<tr>
<td>20</td>
<td>6.97</td>
<td>42.09</td>
<td>35.12</td>
<td>42.47</td>
</tr>
<tr>
<td>25</td>
<td>9.27</td>
<td>43.81</td>
<td>34.55</td>
<td>44.27</td>
</tr>
<tr>
<td>30</td>
<td>10.58</td>
<td>44.80</td>
<td>34.22</td>
<td>45.30</td>
</tr>
</tbody>
</table>

Increase in percentages of friction loss is necessary to supply operational pressure of sprinklers in the system and the pressure at the head of lateral and maximum sprinkler pressure in the system will increase. Due to increase of loss in length of lateral, minimum sprinkle pressure in the system will decrease. Pressure changes of sprinklers in the field have significant effect on uniformity coefficient of the field and application efficiency and crop yield and results are shown in table 3.

Table 3. Application efficiency, uniformity coefficient and crop yield in different percentages of friction loss (l’efficacité d’application, le coefficient d’uniformité et la récolte cèdent dans de différents pourcentages de perte de friction)

<table>
<thead>
<tr>
<th>Friction loss (%)</th>
<th>Application efficiency (%)</th>
<th>Uniformity coefficient of system (%)</th>
<th>Crop yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>73.33</td>
<td>83.46</td>
<td>97.36</td>
</tr>
<tr>
<td>10</td>
<td>72.59</td>
<td>82.65</td>
<td>97.16</td>
</tr>
<tr>
<td>15</td>
<td>71.70</td>
<td>81.78</td>
<td>96.94</td>
</tr>
<tr>
<td>20</td>
<td>70.84</td>
<td>81.15</td>
<td>96.79</td>
</tr>
<tr>
<td>25</td>
<td>69.32</td>
<td>80.04</td>
<td>96.51</td>
</tr>
<tr>
<td>30</td>
<td>68.76</td>
<td>79.44</td>
<td>96.36</td>
</tr>
</tbody>
</table>

Increase of friction loss decreases uniformity coefficient of system and application efficiency by 4 to 5% and crop yield by 1%. Fig.1 shows these results. As shown, gradient of decrease of application efficiency, uniformity coefficient of system and crop yield is relatively low because of increase of percentage of friction loss in the design.
**Figure 1.** diagram of changes of application efficiency, uniformity coefficient and crop yield in different percentages of friction loss (le diagramme de changements d’efficacité d’application, coefficient d’uniformité et récolte cède dans de différents pourcentages de perte de friction)

Linear equation in table 4 for uniformity coefficient of system, application efficiency and crop yield in different losses shows that changes of friction loss have more effects on application efficiency.

**Table 4.** linear equation of application efficiency, uniformity coefficient and crop yield in different percentages of friction loss (l’équation linéaire d’efficacité d’application, uniforme)

<table>
<thead>
<tr>
<th>Crop yield</th>
<th>Application efficiency</th>
<th>Uniformity coefficient of system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y = - 0.20x + 97.56</td>
<td>Y = - 0.96x + 74.45</td>
<td>Y = - 0.82 + 84.28</td>
</tr>
</tbody>
</table>

Considering other effective factors such as wind velocity, kind of climate, for mobile systems and stationary systems with average to high distribution velocity and good uniformity, water application efficiency is 70 to 75% in most of climates and winds (Alizadeh 2004 and Keller 1990). Values of irrigation efficiency obtained in this study is in acceptable range but its 4.5% reduction in increase of friction losses is effective on volume of water required and systems costs.

**4. CONCLUSION**

Increase in percentage of friction loss in lateral in Hand move irrigation system decreases uniformity coefficient, water application efficiency and crop yield of the field. Although the amount of reduction is not much, in big fields, it will be very significant. Changes of friction loss show its most effect on application efficiency and because water application efficiency has much effect on the costs, care should be taken to choose proper friction loss. Friction loss is effective on costs of establishing, exploiting and maintaining pressurized irrigation system of the field and irrigation networks. Further research is needed to choose proper friction loss range in each region. This study was done for alfalfa crop, Khuzestan region and Hand move irrigation system and these results are not true for kinds of irrigation systems of different regions and other crops.

**5. REFERENCES**


Pressure Losses

Until recently, the industry had been divided on the effects of drillpipe rotation on pressure losses. Some researchers have explicitly stated that rotation acts to increase axial pressure drop, while others have taken the opposing view, that an increase in rotation rate decreases annular pressure drop. In fact, both of these seemingly conflicting views can be correct, and both effects have been observed. Annular pressure losses or axial pressure drop depend upon which part of the flow regime predominates when the rotation rate is changed (below). Turbulent. Flow rate. This study was conducted to determine the effect of using a device called Adjustable Pressure-Loss Lateral Takeoff Valves (APLTVs) on water distribution uniformity of both types of drip systems under sloping conditions at various operating heads. On the other hand, the button-type. drip irrigation system remains untested for water distribution uniformity with and without pressure regulators. Hence, this study was conducted to determine and evaluate the effect of. Assessment of the effect of topography and operating heads on the emission uniformity distribution in drip irrigation systems is important in irrigation water management and could serve as basis for optimizing water use efficiency and crop productivity. CP Effect of crop protection. P Effect of pesticide use Attainable yield I. Loss potential. CP. Effective crop protection cannot rely solely on the use of chemical pesticides and as early as 1959, Stern et al. introduced the concepts of economic thresholds, economic levels and integrated control (Stern et al.). The assessment of crop losses despite actual crop protection strategies are needed for demonstrating where future action is needed and for decision making by farmers as well as at the governmental level (Smith et al. 1984). Early reports. According to German authorities in 1929, animal pests and fungal pathogens each caused a 10% loss of cereal yield.