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

# EVALUATION DES EFFETS DE DIVERSES PERTES DE PRESSION DANS LES TUYAUX LATERAUX DES SYSTEMES D'IRRIGATION PAR ASPERSION PORTABLE SUR LES RENDEMENTS DE FOURRAGE

Sonia Zebardast[1], Ali Rahimi Khoob[2] and Isaac Rahimi[3]

## *ABSTRACT*

*In developing agriculture, the goal is high crop yield and in order to achieve this goal water losses should be reduced and irrigation efficiency should be increased. Higher friction losses in the laterals of sprinkler irrigation systems, would require higher driving pressure and will result to non-uniform water distribution, giving rise to more water losses. If laterals are designed with less allowable pressure variation, irrigation uniformity will be better, which will improve water application efficiency and enhance crop yield. In this study, sample fields with manually shifting sprinkler irrigation system were designed with 5 to 30% allowable variation of application pressure of sprinkler for irrigating alfalfa in Khuzestan. In each field, system's uniformity coefficient, water application efficiency, and crop yield were obtained for different friction losses. Results showed that an increase friction losses from 5 to 30% reduced system's uniformity efficiency by 4%, application efficiency by 5% and relative production of crops by 1%.*

***Key words:*** *Sprinkler system, pressure losses, alfalfa, Khuzestan, water application efficiency, distribution efficiency.*

1 Master science student of Irrigation and Drainage, University of Tehran, college of Aboureihan, Iran; E-mail: Sonia_zebardast@yahoo.com
2 Associate professor of Irrigation and Drainage, University of Tehran, college of Aboureihan, Iran; E-mail: akhob@ut.ac.ir
3 Master science student of water resources engineering, Shahid Bahonar University of Kerman, Iran; E-mail: Isaacrahimi@yahoo.com

# *RESUME 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 craint, 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 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 condescendre 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.*

***Mots clés:*** *Système d'aspersion, pertes de pression, luzerne, Khuzestan, efficacité d'application d'eau, efficacité de distribution.*

*(Traduction française telle que fournie par les auteurs)*

# 1. INTRODUCTION

Agricultural in Iran is the largest water consumer using about 95% of water resources of the country. Water wastage is high in irrigation and the irrigation efficiency has been reported 33% in Iran (Agriculture Ministry, 2005). So in recent years development of sprinkler irrigation systems has been given more attention. These systems, compared with flow irrigation methods, match better with land topography and soil types. It has a higher efficiency and ensures more uniform water distribution in the field. High uniformity coefficient is an important end result, which should be considered in designing sprinkler irrigation systems. Lack of uniform water distribution makes water wastage and reduces crops productivity (Hasanli, 2003, Alizadeh, 2004, Montazer and Rahimikhoob 2009, Najafimood 2005). Sprinklers' arrangement, wind velocity, sprinkler size, operational pressure of sprinkler and water pressure variations within the system, are the parameters that affect uniformity coefficient (Tarjolo.et.al, 1999). There is an optimum pressure range specific to the diameter of sprinkler nozzle opening that produces the best distribution efficiency. Operational pressure of sprinkler and sprinklers' arrangement are determined according to the table presented by the factory producing sprinkler and upon considering the wind velocity. Hydraulic load loss while water moves through the lateral and land topography are the factors that determine pressure uniformity among sprinklers. Hydraulically, the sprinkler outlet flow rate is a function of the square of water pressure. Hence, water pressure has a great impact on the uniformity of water distribution on the land that causes non-uniform water application over the irrigated region. According to the common thumb rule, a sprinkler design should keep the water pressure variation along the lateral within 20 % (Alizadeh, 2004; Keller and Bliesner, 1990; Monserrat, 2009 and Najafimood, 2005). Increase of pressure increases water losses and affects crop yield (Montazar, 2007). In this study, six sample fields with manually moved sprinkler irrigation system have been designed with 5 to 30% water pressure variation at 5% interval for Khuzestan province and application efficiency, uniformity coefficient and crop yield were investigated.

# 2. MATERIALS AND METHODS

## 2.1 Study area and data

Khuzestan province contains vast plains and many irrigation networks. Alfalfa is one of the main plants of this region and needs more water than other plants. Therefore alfalfa was the crop selected for designing sprinkler irrigation system. The maximum depth of alfalfa root is 1.5 meter. Soil of the study area is silt loam and maximum water holding capacity is about 150mm per meter depth soil. The basic infiltration rate of the soil is 14 mm per hour (consulting engineer Company of Mahabghods, 2002). According to national document on state water demand (Alizadeh, 2000), maximum water required by alfalfa in peak month (June) is 7.52 mm per day. Meteorological parameters collected from the meteorological station of Ahvaz were evaluated according to their averages during the last 10 years. Maximum water requirement occurs in June so the fields were designed based on water demand and meteorological parameters in this month. Average temperature is 38.20C, average relative humidity is 22.8%, and average wind velocity is 9.42 kmph in the month.

## 2.2 Field design

According to average land ownership and regional cultivation model, the most appropriate net area of alfalfa field has been determined as 50 ha for sprinkler irrigation (consulting engineer Company of Mahabghods, 2003). In this study by using data of the region, the fields with 50 ha 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 the entire unit. Sprinklers with nozzle opening (5.5mm × 2.5mm) and arrangement of 18m × 12m was chosen in order to irrigate the field. Design Tables of Keller and Blisner (1990) were referred to considering basic infiltration rate of the soil and irrigation requirement during peak demand periods. The sprinkler at a water pressure of 35 meters has a flow rate of 0.62 l s-1, and according to above table, its uniformity coefficient in the field with wind velocity of 9.42 kmph is 85%. The time required for water distribution during peak demand period was estimated 11 hours so laterals will be moved twice a day in this period. In manually moved system, 6 m long aluminum pipes of arts with 76 mm diameter were used as laterals. The laterals were placed along contours and considering flat and smooth central and southern plains of Khuzestan, water pressure change occurs only due to friction loss in the laterals. Friction loss in the 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 such that the friction loss was near the allowable friction loss.

## 2.3 Water application efficiency

In sprinkler irrigation, water losses occur due to percolation, lack of uniformity of water distribution in sprinklers, leakage from pipes and joints, wind effect and evaporation of water before reaching the surface. Considering these losses, water application efficiency was obtained by following relation (Tafazoli, 2004):

$$E_a = DE_{pa} \times R_e \times O_e \qquad (1)$$

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

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 resulting from wind and evaporation are low when the wind velocity is low and vegetation density is high and is 5 to 10 % in normal condition. Water distribution efficiency in pipe lines inside crop unit shows losses resulting from leakage of pipes, joint or losses from discharging laterals while moving them or losses due to improper placement of laterals inside irrigation unit, and is between 1 and 5%.

## 2.4 Uniformity coefficient of system

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

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

$CU_{sys}$: 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 end of the 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):

$$Hm = (2Hn + H_x)/3 \qquad (3)$$

Where $H_x$: 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 Blisner, 1990):

$$H_o = Ha + 0.75\ H_f + H_r \qquad (4)$$

Where $H_o$: the pressure at the head of lateral (meter), $H_a$: average operational pressure of the sprinkler (meter), $H_f$: friction loss resulted from friction (meter) and $H_r$: riser height (meter) Friction loss resulting was obtained from the relation (Keller and Bliesner, 1990):

$$H_f = 7.89 \times 10^7 \times (L/100) \times Q^{1.75} \times D^{-4.75} \times F \qquad (5)$$

Where $H_f$: friction loss resulted from friction (meter), L: length of lateral (meter), Q: inlet flow rate to lateral (l $s^{-1}$), D: internal diameter of lateral (mm) 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 Eq. 6 (Alizadeh, 2004). Keller and Blisner presented a table that shows the results obtained from Eq. 6 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.

$$Y_a/Y_p = 1 - K_y(1- ET_a/ET_p) \quad (6)$$

Where $Y_a$: 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 $ET_p$: potential evapotranspiration of the plant (mm) in the region of study.

# 3. RESULTS AND DISCUSSION

Increase of percentage of friction loss, Increase in the length of lateral increases the total friction loss. However, a larger area can be irrigated for longer lateral length. Increase of length of lateral is acceptable to the extent that does not seriously affect uniformity of water distribution. Length of lateral, field and unit area and number of irrigation units are shown in Table 1 in different friction losses and it is observed that length of lateral designed for the field is within the acceptable range 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)

| Friction loss (%) | Length of lateral (m) | Unit area (ha) | Number of field irrigation units | Field area (ha) |
|---|---|---|---|---|
| 5 | 126 | 3.80 | 14 | 53.22 |
| 10 | 162 | 4.84 | 10 | 48.38 |
| 15 | 186 | 5.53 | 10 | 55.30 |
| 20 | 210 | 6.22 | 8 | 49.77 |
| 25 | 234 | 6.91 | 8 | 55.30 |
| 30 | 246 | 7.26 | 6 | 43.55 |

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)

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

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 along the 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)

| Friction loss (%) | Application efficiency (%) | Unifo rmity coefficient of system (%) | Crop yield (%) |
|---|---|---|---|
| 5 | 73.33 | 83.46 | 97.36 |
| 10 | 72.59 | 82.65 | 97.16 |
| 15 | 71.70 | 81.78 | 96.94 |
| 20 | 70.84 | 81.15 | 96.79 |
| 25 | 69.32 | 80.04 | 96.51 |
| 30 | 68.76 | 79.44 | 96.36 |

Increase of friction loss decreases uniformity coefficient of system and application efficiency by 4 to 5% and crop yield by 1%. Figure 1 shows these results. As shown, reduction in application efficiency, uniformity coefficient and crop yield is relatively low because of increase of percentage of friction loss in the design.

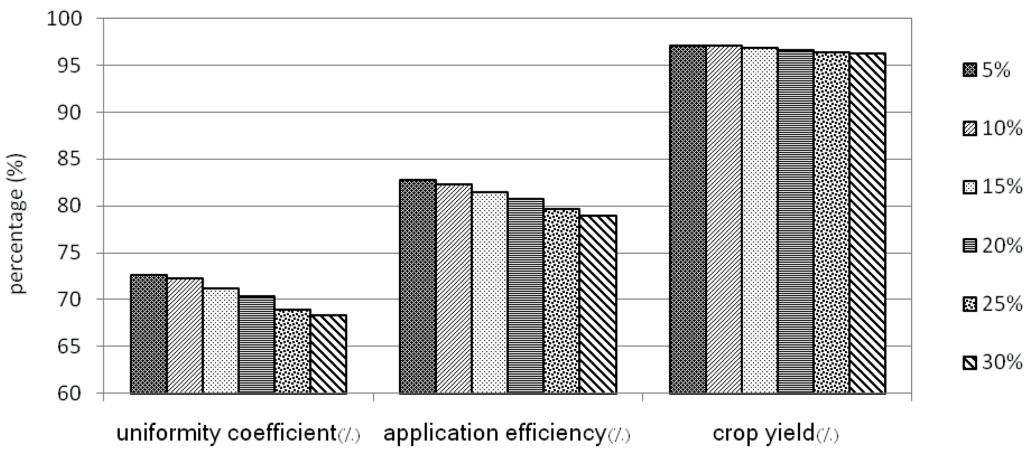


Fig. 1. diagram of changes of application efficiency, uniformity coefficient and crop yield in different percentages of friction loss (le diagramme de changements d'efficacité d'application, coefficient d'uniformité et récolte cède dans de différents pourcentages de perte de friction)

Linear equation in Table 4 for uniformity coefficient, 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)

| Crop yield | Application efficiency | Uniformity coefficient of system |
|---|---|---|
| Y= - 0.20x + 97.56 | Y= - 0.96x + 74.45 | Y= - 0.82 + 84.28 |

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. CONCLUSIONS

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.

# REFERENCES

Alizadeh, A. 2004. designing irrigation systems. university press of Imam Reza.

Alizadeh, A. 1998. net requirement of crop and garden products' irrigation in Iran.

Consulting engineer Company of Mahabghods. 2003. report of studies about integration and exploitation system from sources of Khuzestan. 300 pages.

Hasanli, A. Ghaemi, A.2003. pressurized irrigation systems: design and implementation. publication of agricultural training.

Keller, J. Bliesner, RD. 1990. Sprinkler and trickle irrigation.newyork ,n.y:van nostrand reinhold.

Monserrat, J. 2009. Allocation of flow to plots in pressurized irrigation distribution networks: analysis of the Clément and Galand method and a new proposal. Irrigation and drainage engineering. 1 : 1-6.

Montazar, A. Rahimikhoob, A. 2008. Optimal water productivity of irrigation networks in arid and semi-arid regions. Irrigation and Drainage. 57:411-423.

Najafimood, M. 2005. designing pressurized irrigation systems. press of Birjand University.

Agriculture Ministry, 2005. Agricultural statistics, assistance of planning. Economical and International Affairs of Agricultural Ministry. Statistical Office and Information Technology of Agriculture Ministry. 300 p.

Tafazoli, M. 2004. technical standards of pressurized irrigation. publication of management and planning organization of the country. 233 pages.

Tarjuelo, J. Montero, J. Honrubia, F. Ortiz, J. Ortega, J. 1999. Analysis of uniformity of sprinkle irrigation in a semi-arid area. Agricultural Water Management. 40: 315-331.