Canal Geometry, Flow Velocity, Dallisgrass (*Paspalum dilatatum Poir.*) Density and Soil Phosphorous Effects on Hydraulic Resistance of Vegetated Canals

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ABSTRACT

Dallisgrass (*Paspalum dilatatum Poir.*) reduces discharges in irrigation canals and causes problems in operation and maintenance of canals. This study has been conducted to determine roughness coefficient in vegetated canals caused by dallisgrass and to investigate the relationship between available soil phosphorous and dry mass of dallisgrass. The study also aims to find out the relationships among roughness coefficient, dallisgrass density and soil phosphorous in vegetated canals in Moghan plain, Iran. The results showed that the roughness coefficient varied from 0.01 to 0.32 and averaged at 0.09. The variation in roughness coefficient in vegetated canals by dallisgrass may be explained solely by the flow velocity and canal slope, assuming that there are no spatial variability's of the other affecting variables. Therefore, a regression model comprises both the roughness coefficient as a dependent variable and the flow velocity and canal slope as an independent variable is developed. The available soil phosphorus both on the sides and at the bottom of vegetated canals were from 4.2 to 37 mg kg^{-1}. The highest dry mass of 16 kg per 100 m^2 was acquired from the canal with soil phosphorus of 16.7 mg kg^{-1}. Also, another model was developed to describe the roughness coefficient as a function of the flow velocity, canal slope, dallisgrass density and soil phosphorous. It is recommended that identifying phosphorus sources and limiting its distribution in irrigation canals is necessary to reduce the dallisgrass density in canals.

Keywords: Available soil phosphorous; Dallisgrass (*Paspalum dilatatum Poir.*); Hydraulic resistance; Irrigation canals; Roughness coefficient

Otlanmış Kanallarda Kanal Geometrisi, Akış Hızı, Adi Yalancı Darı (*Paspalum dilatatum Poir.)* Yoğunluğu ve Toprak Fosfor Oranının Hidrolik Direnç Üzerine Etkisi

ÖZET

Adi yalancı darı (*Paspalum dilatatum Poir.*) sulama kanallarında akışı azaltmakta ve işletme-bakım sorunlarına neden olmaktadır. Bu çalışma, otlanmış kanallarda Adi yalancı darı'nın pürüzlülük katsayısını nasıl etkilediğini ve topraktaki mevcut fosfor ile adi yalancı darı kuru ağırlığı arasındaki ilişkiyi araştırmak amacıyla yapılmıştır. Ayrıca; çalışma İran'da Mogan ovasında bulunan otlanmış kanallardaki pürüzlülük katsayısı ile adi yalancı darı yoğunluğu ve topraktaki mevcut fosfor miktarı arasındaki ilişkiyi belirlemeyi de amaçlamaktadır. Araştırma sonucunda; pürüzlülük katsayısı değerleri 0.01-0.032 arasında değişmiş ve ortalama olarak 0.09 olarak bulunmuştur. Diğer değişkenlerin olmadığı varsayıldığında, adi yalancı darı ile otlanmış kanallardaki pürüzlülük katsayısı değişkenlerini, sadece akış hızı ve kanal eğiminin etkilediği söylenebilir. Bu nedenle; bağımlı değişken olarak pürüzlülük katsayısını, bağımsız değişken olarak da akış hızı ve kanal eğimini kapsayan regresyon modeli geliştirilmiştir. Otlanmış kanalların kenarlarında ve tabanındaki mevcut fosfor miktarı 4.2'den 37 mg kg⁻¹'e kadar yükselmiştir. En yüksek kuru madde miktarı 16.7 mg kg⁻¹ fosfora sahip kanaldan 100 m²'ye 16 kg olarak elde edilmiştir. Ayrıca, akış hızı fonksiyonu, kanal eğimi, adi yalancı darı yoğunluğu ve mevcut toprak fosforunu pürüzlülük katsayısı olarak tanımlayan başka bir model de geliştirilmiştir. Sonuç olarak; kanallardaki adi yalancı darı yoğunluğunu azaltmak için fosfor kaynaklarının belirlenmesi ve sulama kanallarının dağılımının sınırlandırılmasının gerekli olduğu önerilmektedir.

Anahtar Kelimeler: Yarayışlı toprak fosforu; Adi yalancı darı (*Paspalum dilatatum Poir.)*; Hidrolik direnç; Sulama kanalları; Pürüzlülük katsayısı

1. Introduction

Dallisgrass (*Paspalum dilatatum* Poir.) grows in water conveyance canals and reduces water velocity and discharges in these canals. Consequently, dallisgrass causes problems in operation and maintenance of irrigation and drainage canals. Dallisgrass affects water velocity in irrigation canals and furrows.

Water velocity and soil infiltration along an irrigation canal and furrows depend on several factors such as time, canal or furrow characteristics (compaction and surface sealing), soil characteristics and flow (wetted perimeter and flow section area) characteristics (Kostiakov 1932; Izadi & Wallender 1985; Trout 1992; Nasseri et al 2004; Nasseri et al 2008). Also in surface irrigation, Heermann et al (1969) and Esfandiari & Maheshwari (1998) reported that surface roughness affects these factors and is one of the key input parameters in surface irrigation models. Accordingly, infiltration parameters could be affected by surface roughness which is often expressed in terms of Manning's roughness coefficient, *n* (Harun-Ur-Rashid 1990). Trout (1992) reported that roughness varies according to crop and soil characteristics such as

crop growth, residue management, tillage practices and soil type. On the other hand Kruse et al (1965) and Maheshvari & McMahon (1992) reported that roughness changes with depths of flow and then Trout (1992) related surface roughness with the power function of flow velocity. Kruse et al (1965) and Heermann et al (1969) stated that roughness is connected with absolute roughness and hydraulic radius. In suitable conditions for grass germination, its distribution was made by seed (Tropical Forages 2009). There are several factors affecting the growth and distribution of this grass in water canals. The moist and fertile environment are the basic factors in the growth of this grass. This grass grows in soils with a pH of 4.5 to 8.0 (Tropical Forages 2009) and its production ranges from 3 to 15 t ha⁻¹ year⁻¹. Research on dallisgrass response to soil nutrients and canal water properties is very limited. On the other hand, Moghan plain is one of the most important region for agricultural production in Iran and dallisgrass covers the majority of earth canals which are used for the transport of water to the farms.

This study has been conducted to determine roughness coefficient in vegetated canals caused by dallisgrass and to investigate the relationship between available soil phosphorous and dry mass of dallisgrass.

2. Material and Methods

The experimental area was Moghan plain located at the north-west of Iran with the latitude from 39º 22' to 39º 45' N, longitude from 47º 22' to 47º 45' E and sea level 32.0 m. The annual average air temperature, relative humidity and pan evaporation are 14.5º C, 72% and 111 mm month^{-1}, respectively. Annual rainfall in this plain is 332 mm (Nasseri 2000).

In the experimental area nine sections of earth canal that vegetated with dallisgrass (*Paspalum dilatatum* Poir.) were selected (Karimi 1995). The water flow velocity was measured by a flowmeter and canals geometric characteristics (with profilimetery devices) were measured by means of profilimetery devices at the 35 parts of these nine separate canals. The roughness coefficient was estimated by the Equation 1 (Manning's relation) (Chow 1959).

$$n = \frac{R^{0.67} S^{0.5}}{V} \qquad (1)$$

Where; n, R, S and V, are roughness coefficient, hydraulic radius (m), canals bed slop (mm^{-1}) and water flow velocity (m s^{-1}), respectively. Table 1 shows roughness coefficient values for different conditions and it indicates *n* varies with different effective factors which mentioned in Table 1.

Table 1- Roughness coefficient values for different conditions of irrigation

Çizelge 1- Farklı sulama koşulları için pürüzlülük katsayısı değerleri

Conditions	Applied models	n values	Effective factors	Reference
Basin irrigation	Volume balance	0.043	Irrigation events and systems	Harun-Ur-Rashid (1990)
Border irrigation		0.033		
Border irrigation for corn farm	Zero inertia model		Weed growth, border length and irrigation events	Khanjani & Barani (1997)
Overland flow		0.60		Ree (1949)
Bare soil		0.04	Crop covers	USDA (1974)
Bare soil		0.04		Chow (1959)
Cultivated areas		0.02		
Irrigated and smooth soil		0.02		Walker (1989)
Fresh tilled soil		0.04	Irrigation events	
The first irrigation event for wheat covered furrows	Volume balance	0.07-0.121		Sepaskhah & Bondar (2002)
The third irrigation event		0.047		
The seventh irrigation event		0.136		
Furrows under different flow rates	Hydrodynamic model	0.025-0.060	Infiltration parameters	Nasseri & Abbasi (2012)
C Channels with dense weeds, high as flow depth		0.050-0.120	Channels with weeds	Chow (1959)
General furrow		0.02	General furrow	Valipour & Montazar (2012a) Valipour & Montazar (2012b) Valipour & Montazar (2012c)
Border irrigation		0.048-0.189	Open and closed-end borders	Mahdizadeh Khasraghi et al (2014)
Furrow irrigation		0.15	Cutback and surge irrigation	Valipour (2013)

The dallisgrass density was measured by a wooden square plot. Then, the density was converted to the 100 m^2 (1 m width and 100 m length of canal). Dry mass of this grass was measured by an oven with temperature of 108 ℃ for 24 h. The bottom and sides of irrigation canals were subjected to soil samplings (Figure 1). The available soil phosphorus was measured by Olsen or sodium bicarbonate method (Olsen & Dean 1976). Electrical conductivity and pH of canal water were measured, as well in this study. The regression analysis with the least square procedure was applied to relate a dry mass of grass to the soil phosphorus.
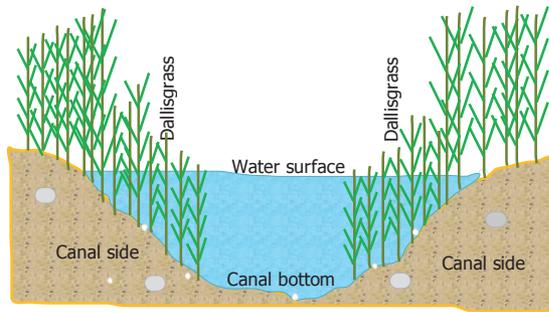

Figure 1- A cross section of vegetated irrigation canal with dallisgrass

Şekil 1- Adi yalancı darı ile otlanmış olan sulama kanalının kesiti

3. Results and Discussion

3.1. Dallisgrass resistance to the water flow in irrigation canals

The roughness coefficient variations with the flow velocity, flow section area, wetted perimeter, hydraulic radius and canals slopes were depicted by the Figure 2 (a-e). The results showed that the roughness coefficient varied from 0.01 to 0.32 and averaged as 0.09. The flow velocity ranged from 4 to 40 and averaged as 17 cm s^{-1}. The flow section area ranged from 75 to 6763 cm^2 and had an average value of 1840 cm^2. The wetted perimeter changed between 26-346 cm and averaged as 111 cm. The hydraulic radius averaged as 18 cm and was changed from 2 to 42 cm. The canal slopes ranged from 0.01 to 0.80 and averaged as 0.33 percent. Also, the flow

discharge varied from 400 to 149000 cm^3 s^{-1} and averaged as 33000 cm^3 s^{-1}.

The partial correlations of roughness coefficient were statistically significant by 5% (P≤0.05) for flow velocity and canal slope. According to the results of this study 25 to 45% of the variation of roughness coefficient in vegetated canals by dallisgrass (*Paspalum dilatatum* Poir.) is caused by the flow velocity and canal slope, respectively, when all the other variables are held constant. In other words, the variation in roughness coefficient in vegetated canals by dallisgrass (*Paspalum dilatatum* Poir.) may be explained solely by the flow velocity and canal slope, assuming that there are no spatial variability's of the other affecting variables. Therefore, a regression model comprises both of the roughness coefficients and in vegetated canals by dallisgrass (*Paspalum dilatatum* Poir.) as a dependent variable and the flow velocity (V, cm s^{-1} and S_0, %) and canal slope as independent variables is derived by Equation 2.

$$n = 2.257 \frac{\sqrt{S_o}}{V} \qquad (2)$$

The correlation coefficient of the model is 0.90 which explains more than 80% of the variability in roughness coefficient. Table 2 shows the analysis of variance in the estimated roughness coefficient in the regression model. Since the P value in the table is less than 0.005, there is a statistically significant relationship between the variables at P≤0.005.

The measured roughness coefficient versus estimated values from obtained model at a low limit, predicted and upper limit values are shown in Figure 3. The calibration line models were developed as the following for the measured and predicted roughness coefficient. As follows, there are satisfactory agreements between the measured and predicted values of roughness coefficient.

Upper limit line $\qquad n_{predicted} = 1.52 \ (n_{measured})$

One by one line $\qquad n_{predicted} = 1.00 \ (n_{measured})$

Regression line $\qquad n_{predicted} = 0.81 \ (n_{measured})$

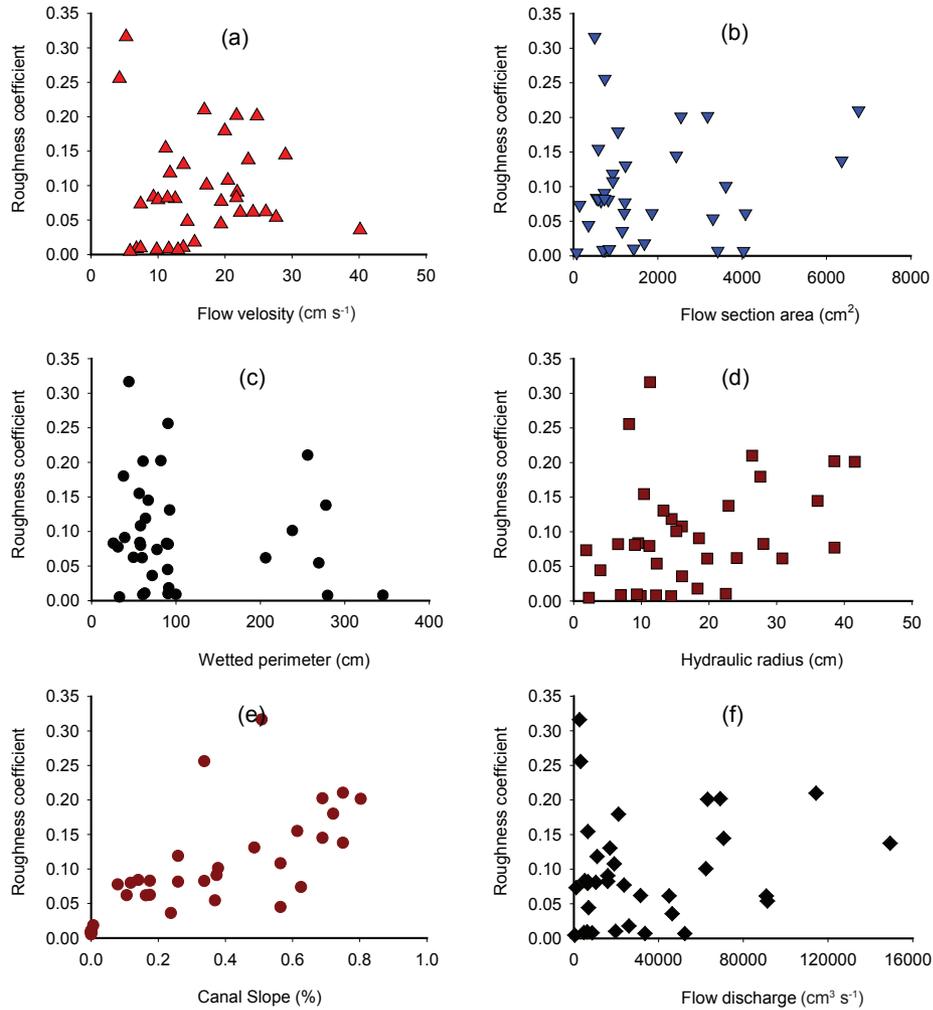Low limit line $\qquad n_{predicted} = 0.10 \ (n_{measured})$

Figure 2- The roughness coefficient variations versus variations of flow velocity a, flow section area; b, wetted perimeter; c, hydraulic radius; d, and canal slope w; e, and flow discharge f

Şekil 2- a, akış hızı; b, akış kesit alanı; c, ıslak çevre; d, hidrolik yarıçap; e, kanal eğimi ve f, debi değişimlerine bağlı pürüzlülük katsayısı değişimleri

Table 2- Analysis of variance and regression for acquired model of roughness coefficient

Çizelge 2- Elde edilen pürüzlülük katsayısı modelinin istatistiksel analizleri

Source	Sum of squares	Df	Mean square	F-value	P-value
Model	0.415	1	0.415	148.260	0.000
Residual	0.095	34	0.003		
Total	0.511	35			

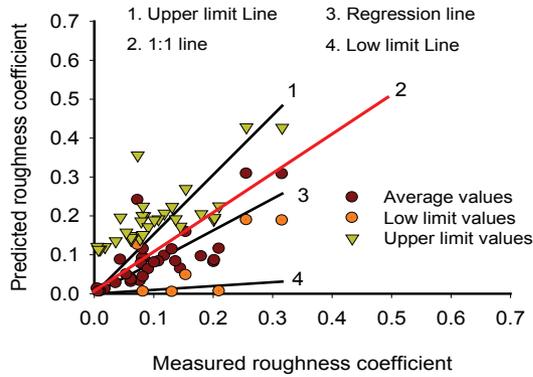| Parameter	Estimate		Standard error	t- statistic	P-value
	2.257		0.185	12.176	0.000

Figure 3- Predicted roughness coefficient versus measured values

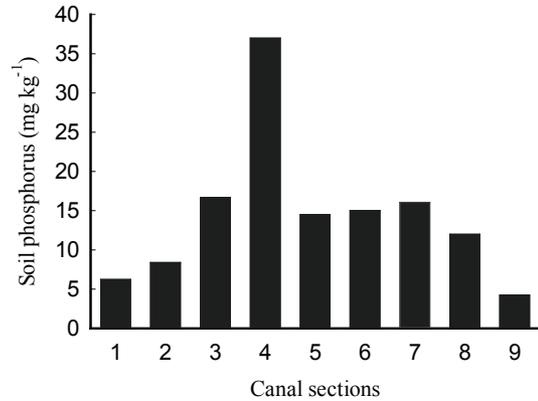*Şekil 3- Ölçülen ve tahmin edilen pürüzlülük katsayısı değerleri*

Figure 4- Available soil phosphorus from nine sections of canals (mg kg⁻¹)

Şekil 4- Kanalın dokuz kesitinde yarayışlı toprak fosforu (mg kg⁻¹)

3.2. Dallisgrass response to the soil phosphorous

The measured available soil phosphorous values are shown in Figure 4. The water electrical conductivity (EC), pH and soil phosphorous averaged as 750.60±9.42 (mmhos cm⁻¹), 8.55±0.01 and 14.45±3.19 mg kg⁻¹, respectively.

A regression model for dry mass of dallisgrass as a function of soil phosphorus was obtained (Moghaddam 2008) as shown in Equation 3.

$$DM = -0.05\ P^2 + 1.70\ P \qquad (3)$$

Where; DM and P, are dry mass of dallisgrass (kg per 100 m²) and soil phosphorus (mg kg⁻¹), respectively. This model and its paramerts of P and P² are significant in the model (Table 3). The

determination coefficient (R^2) of this model is determined as 0.76, which means that about 76% of variation in dry mass can be explained by soil phosphorus. Measured and predicted dry mass of dallisgrass versus soil phosphorus values were shown in Figure 5.

3.3. Relationship between roughness coefficient, dallisgrass density and soil phosphorous

A model comprise roughness coefficient as a function of the flow velocity, canal slope, dallisgrass density and soil phosphorous was developed by regression analysis and presented in Equation 4.

Table 3- Analysis of variance and regression for acquired model of dry mass

Çizelge 3- Elde edilen kuru madde modelinin istatistiksel analizleri

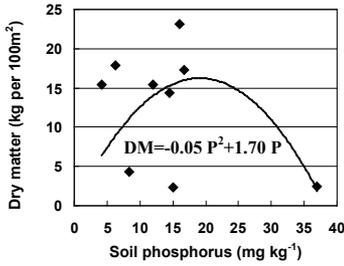| Source	Sum of squares	Df	Mean square	F-value	P-value
Model	1424.14	2	712.07	11.31	0.006
Residual	440.84	7	62.98		
Total	1864.98	9			
Parameter	Estimate		Standard error	t- statistic	P-value
P²	-0.05		0.01	-3.29	0.01
P	1.70		0.39	4.39	0.00

Figure 5- Measured and predicted dry mass of dallisgrass versus soil phosphorus values, where DM and P are dry mass of dallisgrass (kg per 100 m²) and soil phosphorus (mg kg⁻¹)

Şekil 5- Ölçülen ve tahmin edilen adi yalancı darı kuru madde miktarına bağlı toprak fosfor değerleri, (DM ve P adi yalancı darı kuru madde miktarı (kg 100 m⁻²), toprak fosforu (mg kg⁻¹)

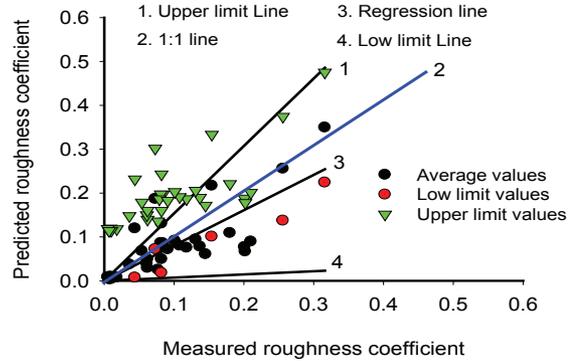**Figure 6- Measured and predicted roughness coefficient values**

Şekil 6- Ölçülen ve tahmin edilen pürüzlülük katsayısı değerleri

$$n = 0.289(DD.P)^{0.25} \frac{\sqrt{S_o}}{V} \qquad (4)$$

Where; DD, is dallisgrass density per 1 m².

The determination coefficient of the model is 0.80 which fitted models explain 80% of the variability in roughness coefficient with mentioned variables. The analysis of variance for the estimated roughness coefficient by the regression model was shown in Table 4. Since the P value in the table is less than 0.005, there is a statistically relationship between the variables at the 0.5% level (P≤0.005).

Figure 6 shows the measured roughness coefficient versus estimated values from Equation 4 as low limit, predicted and upper limit values. The calibration line models were developed as the following for the measured and predicted roughness coefficient. There are satisfactory agreements between the measured and predicted values of roughness coefficient.

Upper limit line $\qquad n_{predicted} = 1.53\,(n_{measured})$

One by one line $\qquad n_{predicted} = 1.00\,(n_{measured})$

Regression line $\qquad n_{predicted} = 0.80\,(n_{measured})$

Low limit line $\qquad n_{predicted} = 0.07\,(n_{measured})$

4. Conclusions

Investigation of dallisgrass *(Paspalum dilatatum Poir.)* resistance to the water flow in irrigation canals and dalligrass response to the soil phosphorous indicates the following results.

The roughness coefficient varied from 0.01 to 0.32 and averaged at 0.09. The variation in roughness coefficient in vegetated canals by dallisgrass may be explained solely by the flow velocity and canal slope, assuming that there are no

Table 4- Analysis of variance and regression for acquired model of roughness coefficient

Çizelge 4- Elde edilen pürüzlülük katsayısı modelinin istatistiksel analizleri

Source	Sum of squares	Df	Mean square	F-value	P-value
Model	0.411	1	0.41	139.94	0.000
Residual	0.099	34	0.003		
Total	0.511	35			
Parameter	Estimate		Standard error	t- statistic	P-value
	0.289		0.024	11.83	0.000

spatial variability's of the other affecting variables. Therefore, a regression model comprises both of the roughness coefficient as a dependent variable and the flow velocity and canal slope as independent variables is provided. The available soil phosphorus of the sides and bottom of vegetated canals changed between 4.2 to 37 mg kg^{-1}. The highest dry mass of was acquired as 16 kg per 100 m^2 from the canal with soil phosphorus of 16.7 mg kg^{-1}. A model was developed to describe the roughness coefficient as a function of the flow velocity, canal slope, dallisgrass density and soil phosphorous. It is suggested that phosphorous sources should be identified and the distribution of phosphorous should be limited in irrigation canals so that the density of dalligrass in canals can be reduced. Research on roughness coefficient for other types of vegetation in irrigation and drainage canals is recommended.

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