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NOTE

SIMULATION OF ADVANCE PHASE IN FURROW IRRIGATION BY "ZIFA" MODEL WITH STANDARD CROSS SECTION

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ABSTRACT

The purpose of this study was to present an economic and accurate model to determine the advance curve for furrow irrigation system. For this purpose, a mathematical model based on analytical solution of zero inertia (ZI) differential equations is developed to simulate advance "ZIFA", in standard furrow cross section. Standard furrow cross section is a discharge-equivalent semicircular shape. The Kostiakov-Lewis formula is used for modeling infiltration phenomenon. Six observed data set and outcome of "numerical ZI of Oweis" and " Schmitz Seus "ZIFA" model are used to verify the presented model. In all comparisons, "standard ZIFA" shows good agreement with observed and calculated data.

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شبیه سازی فاز پیشروی در آبیاری شیاری بوسیله مدل ZIFA با سطح مقطع استاندارد

پیمان دانش کار آراسته

دانشجوی سابق کارشناسی ارشد آبیاری، دانشکده کشاورزی دانشگاه تبریز.

چکیده

هدف ازاین مقاله ارائه یک مدل دقیق واقتصادی برای ارزیابی طرح های آبیاری شیاری است. بدین منظور یک مدل ریاضی براساس حل آنالیتیکی معادلات دیفرا نسیل اینرسی صفر(ZI) برای شبیه سازی فاز پیشروی درشیار با مقطع استانداردبدست آورده شد . مقطع استاندارد به یک مقطع نیمدایره ای شکل با دبی معادل دبی مقطع اصلی، اطلاق می شود. برای تعیین مقدار نفوذ از معادله Kostiakov- Lewis استفاده شد و مدل با نتایج حاصل از مشاهدات صحرائی ، مدل عددی اینرسی صفر ومدل آنالیتیک اینرسی صفر مقایسه گردید. درتمام مقایسه های انجام شده ، مدل استاندارد ZIFA بامشاهدات صحرائی و نتایج حاصل از دو مدل دیگر مطابقت داشت.

INTRODUCTION

One of the most important parts of the surface irrigation system design and evaluation is the control of advance and recession phases. To describe the advance phase in a furrow, several models have been developed. One of these models is the zero intertia (ZI) model (5). In which, the acceleration terms are neglected. Although this assumption simplifies the St. Venant differential equations, the model is still complex. Because of complexity of the ZI model, an analytical model had been developed to simulate the advance phase of furrow irrigation, ZIFA (4). ZIFA simulates furrow irrigation advance for three different types of furrow cross section shape (triangular, parabolic and general shapes). Schmitz-Seus' ZIFA model determines surface flow cross section as:

$$A(x,t)/Ao(t) = [1-X(t)/Xtip(t)]^m \text{ , } m>0 \qquad [1]$$

where Ao(t) and A(x,t) are the area of cross section at the entrance of the furrow and at distance x and time t, respectively. Xtip (t) and X(t) are the location of advance wave and a point between the entrance and wave tip and m, the exponent, is a geometric coefficient. The flow area at furrow inlet, Ao, is determined, based on normal flow conditions. The exponent, m, for each type of cross section is determined by a special formula (4) , in which m is related to the geometry of furrow. Thus m will have different values.

The objective of this study is to transform the surface flow cross section and to determine the geometric coefficient m, for this section. The procedure is called standardization of cross section. Thus for m, only one value is determined. Meanwhile, the standard ZIFA is programmed to simulate the advance phase for six types of furrow cross section shapes (triangular, rectangular, trapeziodal, semicircular, parabolic and general shapes).

Standardization of Cross Section

According to the definition, standard cross section is a semicircular cross section with equivalent discharge (7). According to Manning's formula for constant discharge, slope and roughness coefficient, the value $AR^{(2/3)}$ must be constant:

$$Q=(A/n)R^{(2/3)}S^{o\ 0.5} = \text{const.} \quad [2]$$

$$AR^{(2/3)} = \text{const.} \quad [3]$$

where Q= flow rate; A= flow area; R= hydraulic radius; n= Manning's roughness coefficient and So= bed slope.

For any shape of furrow with a flow area AF, and perimeter Pf, there is an equivalent semicircular section with radius r:

$$r= (2Af)^{(5/8)}/[\ (\pi)^{(3/8)}\ Pf^{0.25}] \quad [4]$$

Determination of m

The shape factor, m , is determined as Walker and Skogerboe (6) proved:

$$m=1/[\ \beta + \theta - 2] \quad [5]$$

and

$$Y= \alpha A^{\beta} \quad [6]$$

$$A^2\ R^{(4/3)} = \sigma A^{\theta} \quad [7]$$

where α, β,σ and θ are geometric parameters and Y is flow depth.

For semicircular cross section (standard section):

$$r= (2/\pi)^{1/2}\ A^{1/2} \quad [8]$$

$$A^2\ R^{(4/3)} = (2\pi)^{(-2/3)}\ A^{(8/3)} \quad [9]$$

Geometric parameters for standard section are:

$$\alpha= (2/\pi)^{1/2}\ ;\ \beta= 1/2\ ;\ \sigma= (2\pi)^{(-2/3)}\ ;\ \theta = 8/3\ .$$

The shape factor m, is determined by substituting the values of β and θ in Eq. [5], thus: m=6/7.

Input data

Needed initial data consist of inflow rate Q; furrow length L; Manning's roughness coefficient n; average furrow slope So; coefficients of Kostiakov-Lewis formula (kt^a +fot) and coefficients of furrow geometry. Geometric coefficients of each type of furrow cross section shape enter the model depending on the shape of furrow. A concise description of these factors is given in Table 1.

Standard ZIFA determines normal depth and other hydraulic parameters of furrow, then changes the cross section of furrow to the standard semicircular shape and simulates advance phase.

RESULTS AND DISCUSSION

Schmitz-Seus' ZIFA has been reconstructed for standard section (m=6/7), then it compared with field experiment and numerical ZI (2) and Schmitz-Seus'ZIFA (4) data set. Input data are summarized in Table 2.

Results of standard ZIFA in comparison with field experiments and mentioned models are shown in Figs. 1-6, In all six comparisons, "standard ZIFA " shows excellent agreement with observed and calculated data.

SUMMARY AND CONCLUSION

A ZIFA model with standard cross section was reconstructed. It was based on analytical solution of ZI equations. The model transforms any furrow cross section shape into an equivalent semicircular section. Because of the wide use of Kostiakov-Lewis formula, it was selected for modeling infiltration phenomenon. Standard ZIFA was compared with experimental

Table 1. Geometric parameters needed as input data.

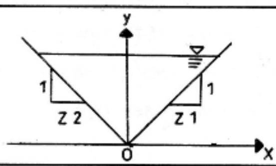
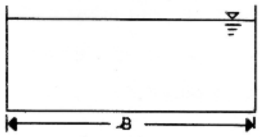
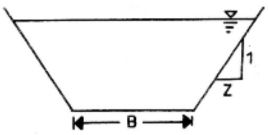
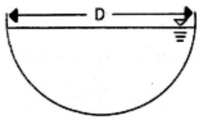
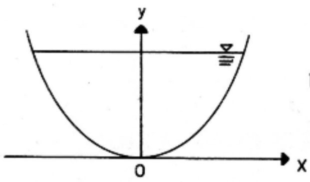
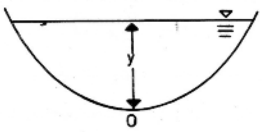
Type of cross sec.	Shape of cross sec.	Parameter	Description
Triangular		Z1,Z2	Left and right side slope
Rectangular		B	Bottom width
Terapezoidal		Z B	Side slope and bottom width
Semi-circular		D	Diameter
Parabolic		b1,b2	Geometric coefficients $Y=b1\ X^2\ X\leq0$ $Y=b2\ X^2\ X\geq0$
General		P1,P2 P3,P4	Geometric coefficients $Y=P1\ A^{P2}$ $R=P3\ A^{P4}$

Table 2. Input data to the model.

Parameter	Unit	First Test†	Second Test§	Third Test¶	Forth Test††	Fifth Test††	Sixth Test††
Q	$l s^{-1}$	2.77	3.94	1.33	0.31	0.21	0.33
L	m	320	350	100	70	70	70
n		0.025	0.02	0.022	0.04	0.04	0.04
So	$m m^{-1}$	0.0025	0.0025	0.001030	0.018	0.018	0.018
K	$m^2 min^{-a}$	0.016	0.013	0.01109	0.00088	0.00057	0.00036
a		0.018	0.024	0.497	0.154	0.427	0.680
fo	$m^2 min^{-1}$	0.0004	0.0005	0.00009	0.00009	0.00008	0.00011
P1		1.13	1.07	1.211	0.898	0.870	0.897
P2		0.75	0.71	0.698	0.605	0.638	0.605
P3		0.79	0.69	0.625	0.435	0.521	0.437
P4		0.74	0.69	0.653	0.576	0.595	0.576

†,§ Simulations refer to the tests 8-2-3 and 3-2-3 at Prinz farm, Colorado, USA [After Oweis (2)]

¶ Simulation refers to the data reported by Fangmeier and Ramsey (1).

†† Field experiments have been conducted at Karkaj Agricultural Research Station of Tabriz University, Tabriz , Iran. [After Sadeghi (3)]

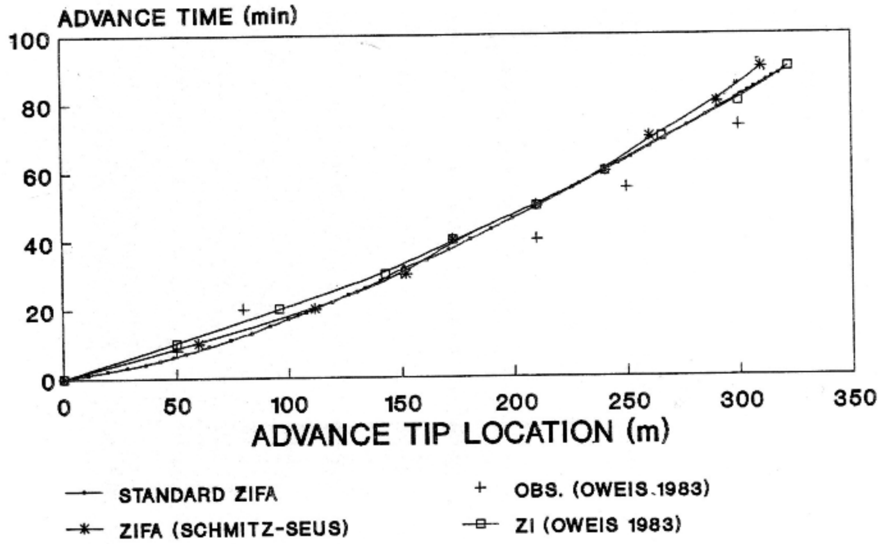


Fig 1. The first test of standard ZIFA.

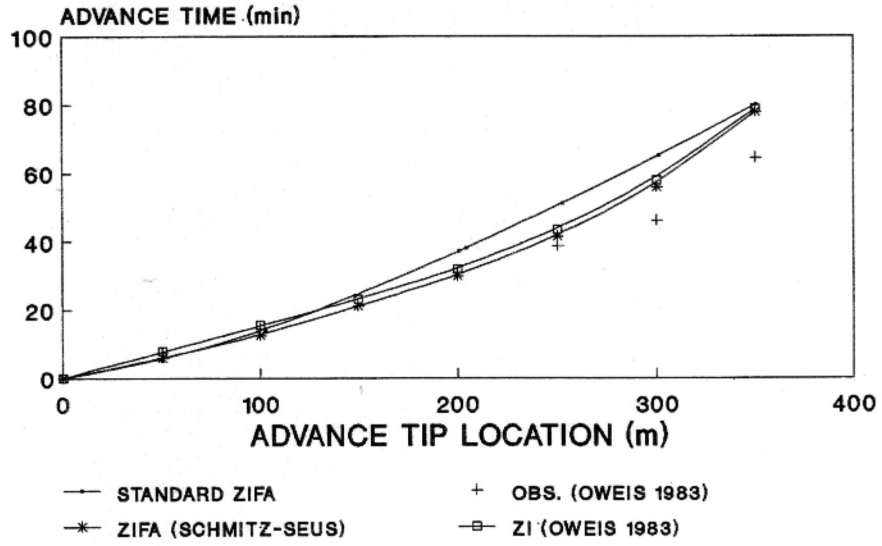


Fig 2. The second test of standard ZIFA.

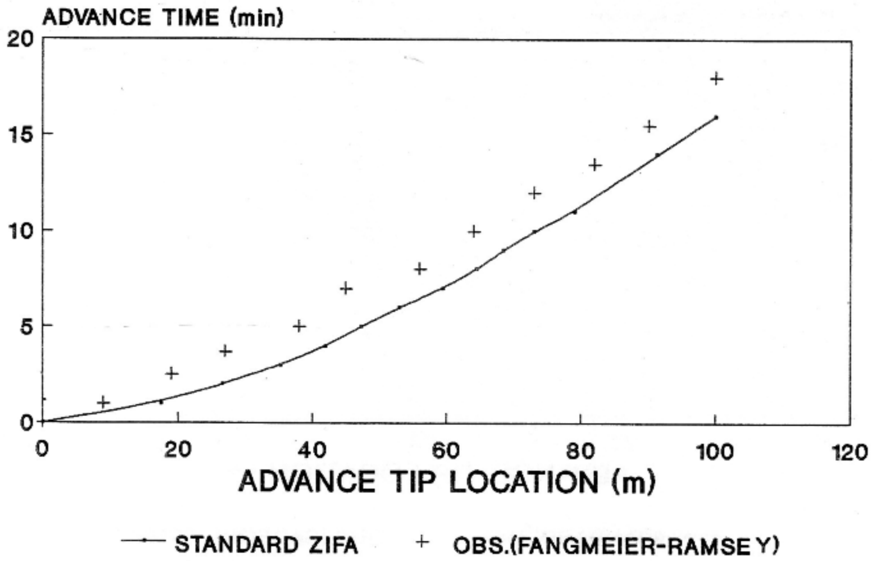


Fig 3. The third test of standard ZIFA.

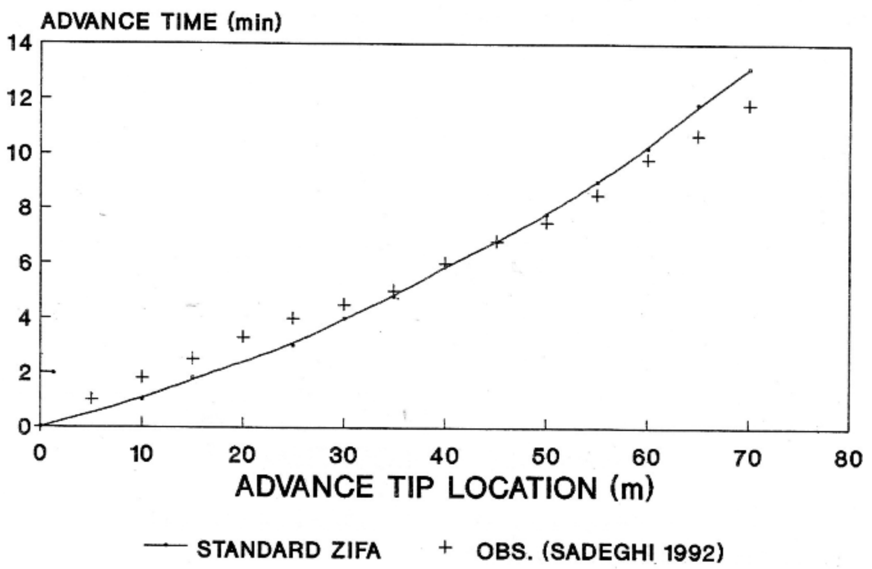


Fig 4. The fourth test of standard ZIFA.

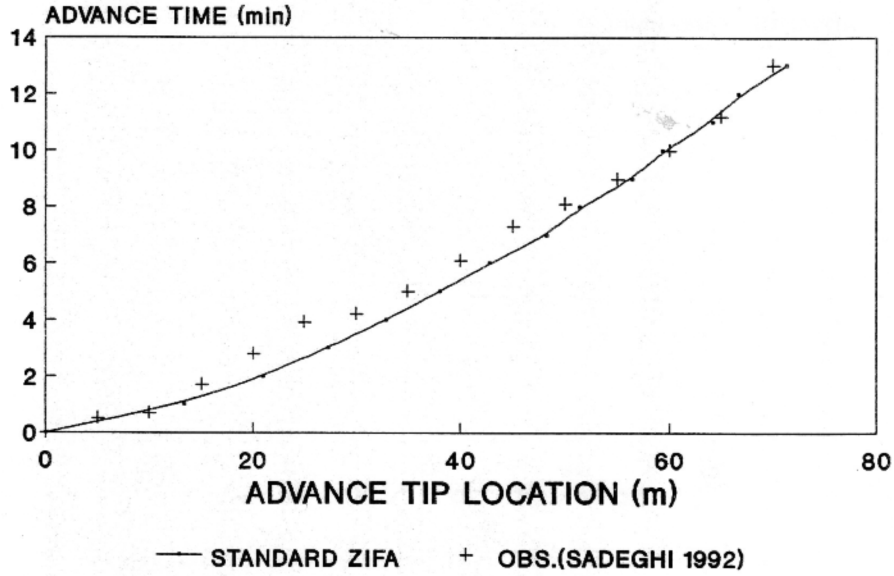


Fig 5. The fifth test of standard ZIFA.

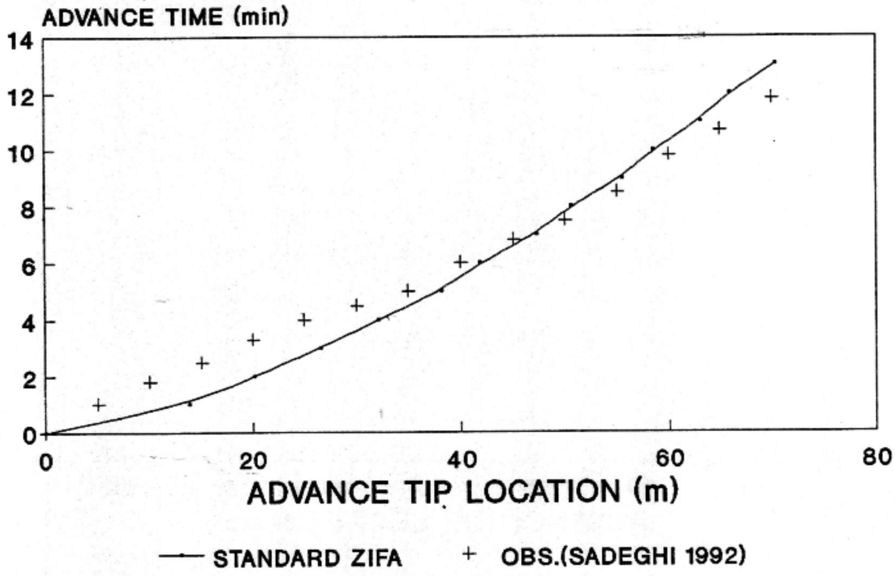


Fig 6. The sixth test of standard ZIFA.

and calculated data of numerical ZI of Oweis (2) and Schmitz-Seus' analytical ZIFA (4). In all comparisons standard ZIFA shows good agreement with observations and mentioned models.

By the help of standard ZIFA, one can predict and simulate the advance phase in furrow with any cross section with good accuracy in very short time.

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