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EVALUATING TWO NON-LINEAR REGRESSION MODELS IN WINTER CEREALS LEAF AREA GROWTH

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ABSTRACT

In the present research, two models evaluated seven winter cereals leaf area variation pattern in 2013/2014/2015 growing season in Iran. Bread wheat, durum wheat, barley include two-rowed barley, six-rowed and hull less barley, oat and triticale were investigated at two nitrogen fertilizer application rates, zero and optimum in a factorial completely randomized block design with four replications. Two logistic and beta models have been fitted to field data. The results showed that leaf area variation pattern has been described very well by both models logistic and beta. According to R^2, RMSE value and models coefficients, Logistic model can be introduced as the suitable model for describing the leaf area pattern variations.

Keywords: Cereals, Growth, Leaf, Modeling, Wheat.

1. INTRODUCTION

Dry matter and leaf area index (LAI) are known as important variables linked to several ecological and environmental driving factors (Demirsoy et al., 2007). Crop leaf area amount strongly depends on plant species, development stage, genetic, environmental conditions and agronomic management practices (Karadavut & Kayiş, 2006).

Crop growth modeling is increasingly used in agricultural research and management and significantly influenced by leaf area traits (Lei & Zhang, 2004). Numerous regression models have been recorded to describe the crops growth patterns that they are valuable method in order to quantitative analysis of cop growth and development (Labbafi et al., 2015).

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Khamis and Ismail (2004) compared fourteen non-linear growth models for tobacco leaf data. They reported that Richards, Inverse power, Transformation and Simple logistic models significantly outperformed parameters of nonlinear models in comparison to the other growth models.

Karadavut et al (2010) evaluated Richards Model, Logistic Model, Weibull Model, MMF Model and Gompertz Models to demonstrating leaf are pattern on five maize cultivars. The coefficient of determination (R^2), sum squares error (SSE), root mean squares error (RMSE) and mean relative error (MRE) were estimated for models fitting performance. The results indicated that Richards, Logistic and Gompertz models are more suitable moleds than other non-linear models to estimate maize leaf growth.

The objective of this study was to collect and evaluate the widely used non-linear regression models linked to winter cereals growth analysis in physiological parameter meanings and select the best model that is fitting on various cereals.

2. METHOD AND MATERIAL

This research was carried out in 2013-2014 and 2014-2015 growing season in Gonbad Kavous region, Iran (37° 15′ N and 45° 46′ E). Seven winter cereals including bread wheat (*Triticum aestivum* L.), durum wheat (*Triticum turgidum* L.), barley (*Hordeum vulgare* L.) include two-rowed barley, six-rowed and hull less barley, oat (*Avena sativa* L.) and triticale (*Triticum wittmak* L.) were investigated at two nitrogen fertilizer application rates, zero and optimum in a factorial completely randomized block design with four replications.

Each plot was 1.5 m * 5.0 m, with 0.20 m distance between rows. plant population was considered 350 plant per m^2 for triticale and wheat and 270 plant per m^2 for barley and oat beads on regional plant population.

At planting time P2O5 was applied at 80 kg ha^{-1} Optimum nitrogen amount was applied 150 kg ha^{-1} for bread wheat and hull less barley, 120 kg ha^{-1} for durum wheat and two rowed barley, 210 kg ha^{-1} for six rowed barley, 240 kg ha^{-1} for triticale and 90 kg ha^{-1} for oat based on the result of soil analysis and the average of recent 10 years yield of each cereals in urea form at three stages: at planting time, tillering and stem elongation.

2.1. Leaf area index (LAI) Twenty plants from each plot were selected by random, during the growing season at intervals of 10–15 days at winter and 7 - 10 days at spring (from tillers emergence to physiological maturity stage). The plants divided into leaves, stems and heads. Leaf area was measured with leaf area meter (Delta- T model device). Logistic and Beta models were fitted to field leaf area data of winter cereals through 2013-2014 and 2014-2015 field data collections as given below (Draper and Smith, 1998):

y=((a*exp((-a)*(x-b))*c))/((1+exp((-a)*(x-b))) ^{2})   (1)

y=lmax*((te-x)/(te-tm)*((x-tb)/(tm-tb))**((tm-tb)/(te-tm))) ^{delta} (2)

3. RESULTS AND DISCUSSION

Different cereals vary in phenological events, environmental adaptation and growth vigor. Environment included macro and micro nutrient-limited, moisture-limited temperature, radiation interception and physiological characteristics affect plant growth and development restriction and variation. Results showed that these two models described the variation pattern of leaf are index of winter cereals very well during growing season (Table 1). In order to model evaluation and validation of winter cereals field data, two parameters RMSE and R^2 have been considered in this study as below:

$$RMSE=\sqrt{}\sum \frac{(p-o)2}{n-1} \quad (3)$$

Where P stands for predictable quantity, O is for real observation and n is define as number of observation.   (4)

R^2= 1-SSE/SSG

Where SSE is sum square of error and SSG is total sum square of observation.

Parameters for Logistic and Beta models of leaf growth have been shown in Table 1. Both aforementioned models are significantly fitted the winter cereals data although generally, logistic model gave a reasonable fit based on coefficients and comparison criteria (R^2 and RMSE). Coefficients of determination in Logistic model is higher than beta model with lower RMSE. Besides that, the logistic model shows more reasonable coefficients by the mathematical pattern. In comparison these two models, logistic can be introduced as the suitable model for winter cereals.

Coefficients (a, b and c) of leaf area index equation, Standard error (SE), maximum of leaf area index (LAI_{max}), and coefficients of determination (R^2) of winter cereals by Logistic model have been shown for both years of experiment in table 2. In years, the primarily investigating of combination coefficient and standard error range of LAI model at zero and optimum rates showed that nitrogen application had no significant effect on leaf area index. In the first year leaf area index varied from 6.08 in triticale to 3.28 in hull less barley. In the second year maximum leaf area index obtained in triticale (4.51) and minimum leaf area index related to oat (3.38). High coefficients of determination of winter cereals in table 2 show that leaf expansion pattern has been described very well by logistic model through both years (higher than 0.90). As it can be seen in figure 1, Leaf area index pattern is defined by logistic model in different winter cereals. Expose of the growth curves vary according to the phenotype characteristics and genotype differences to be considered base on environment (Karadavut et al, 2008, Ghadiryan et al, 2011). Selecting suitable growth curves with logical parameters that are able to depict biological and physiological events in growth season is required (Yang and Allay, 2005).

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Table 1. Parameters estimation of logistic and beta models for leaf growth

model	Cereal	Oat	Durum	Bread Wheat	Two Rowed Barley	Hull Less Barley	Six Rowed Barley	Triticale
LOGESTIC	**a± SE**	0.08±0.011	0.08±0.012	0.09± 0.013	0.08±0.016	0.08±0.014	0.09± 0.015	0.08±0.012
	b± SE	121.5± 2.38	117.8± 2.72	116.6± 2.47	113.9± 3.15	115.1± 2.69	117.7 ± 2.59	116.3± 2.43
	c± SE	161.3± 18.30	178.9± 22.74	190.5± 23.79	173.6± 26.77	134.6 ± 18.03	173.7± 23.41	214.6± 25.80
	R^2	0.91	0.88	0.88	0.83	0.87	0.87	0.89
	RMSE	0.66	0.84	0.93	1.03	0.7	0.93	1
BETA	**lmax± SE**	3.31± 0.70	3.67± 0.49	4.16± 0.79	3.58± 0.96	2.90± 0.67	3.94± 0.52	4.50± 0.64
	tb± SE	-1.4E15±1.0E14	46795535 ± 1.0E14	-6.12E14± 4.22 E27	-1.17E13±8.35E24	-7.87E14± 8.56E27	-5.18E14±3.19E27	-2.91E14±8.84E26
	tm± SE	122.6± 5.62	121.7 ± 4.21	118.3± 5.59	115± 6.40	116.6± 7.52	118.8± 6.08	118.4± 5.21
	te± SE	963.1± 7416.1	163.6 ± 71.33	1134.8 ± 11533.9	1208.5± 75024.8	993.5±8712.8	887.9±8260.1	1012.8± 8584.8
	Delta± SE	1286.7± 12055.1	5.14 ± 29.43	2818.8± 32018.8	2754.8± 552250	1482±15528.6	1460.9±18783.1	2152.6±22519.4
	R^2	0.89	0.9	0.89	0.82	0.85	0.86	0.9
	RMSE	0.76	0.84	0.96	1.14	0.79	1.04	1.04

Table 2. Coefficient (a, b and c) of leaf area index equation. Standard error (SE), maximum of leaf area index (LAI_{max}), days to maximum of leaf area index (Tmax), and coefficients of determination (R^2) by Logistic model

2013/2014						
cereal	**Nitrogen**	**a±SE**	**b±SE**	**c±SE**	**LAI_{max}**	**R^2**
Oat	-	0.09±0.009	121.8±1.55	184.5±14.80	3.68	0.97
Durum Wheat	-	0.086±0.07	117.7±1.37	199.1±13.55	4.27	0.98
Bread Wheat	-	0.094±0.007	117.5±.10	232.7±14.14	5.47	0.98
Two Rowed Barley	-	0.10±0.005	118.6±0.87	216.6±10.37	5.41	0.99
Hull Less Barley	-	0.09±0.008	117.3±1.25	145.9±10.04	3.28	0.98
Six Rowed Barley	-	0.09±0.007	118.4±0.99	185.1±10.92	4.16	0.98
Triticale	-	0.10±0.008	116.6±1.38	243.4±18.25	6.08	0.98
		2014/2015				
Oat	-	0.078±0.015	118.5±4	145.8±24.88	2.84	0.93
Durum Wheat	-	0.082±0.014	114±3.25	178.8±25.67	3.65	0.94
Bread Wheat	-	0.0851±0.017	117.7±3.89	143.6±25.63	3.06	0.93
Two Rowed Barley	-	0.083±0.01	109.3±1.92	164.3±14.77	3.41	0.97
Hull Less Barley	-	0.0802±0.014	110±2.93	168.4±22.31	3.38	0.95
Six Rowed Barley	-	0.0870±0.014	113.8±2.95	200.2±27.43	4.35	0.95
Triticale	-	0.0841±0.015	115±3.37	214.5±32.59	4.51	0.94

CONCLUSION

LAI prediction and determination in various plants is affected by environmental factors, genetic and physiological parameters. In the present study leaf area variation pattern has been described very well by both models Logistic and Beta. Non-linear investigation of plant growth in mathematic method might contribute a technique for estimating economic information of plant growth mechanism.

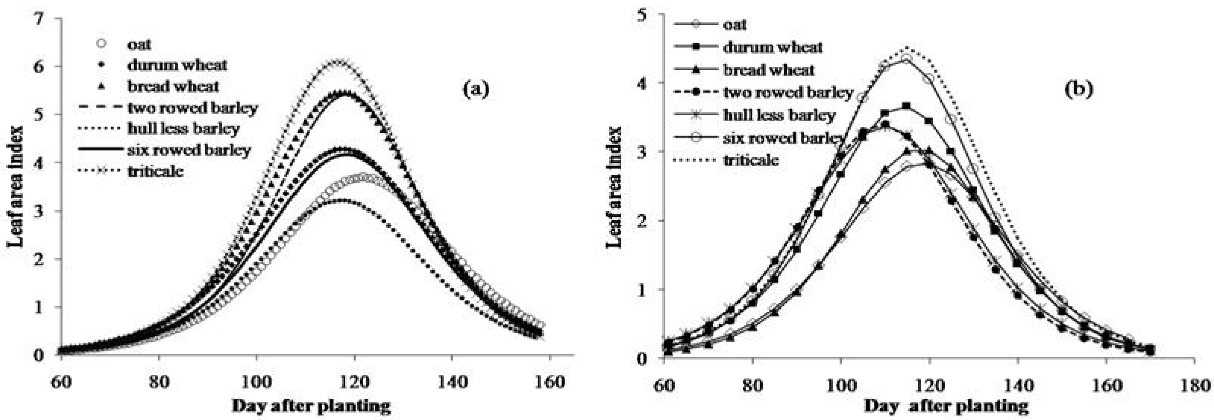

Fig 1 Variations of leaf area index pattern in logistic model during the crop cycle of winter cereals in 2013/2014 (a) and 2014/2015 (b) .

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