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Examination of plant length, dry stem and dry leaf weight of bitter vetch [*Vicia ervilia* (L.) Willd.] with some non-linear growth models

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ABSTRACT

In this study, the aim is to determine the best model for plant length, dry stem and dry leaf weight in different species of bitter vetch by using non-linear growth models. In the study, IFVE 3977-SEL 2802, HAT-14, IFVE 3977-SEL 2802 and Mardin Population bitter vetch species were used as materials. Bertalanffy, Logistic, and Gompertz models were used. At the end of the study, the best models identifying plant length of bitter vetch Logistic in IFVE 3977-SEL 2802 species and Bertalanffy model in IFVE 3351-SEL 2804, HAT-14 and Mardin Population species. Dry stem weight was identified best with Logistic model in IFVE 3977-SEL 2802 and HAT-14 species, Bertalanffy model in IFVE 3351-SEL 2804 and Gompertz model in Mardin population species. Dry leaf weight was identified best with Gompertz model in IFVE 3977-SEL 2802 and Mardin Population, Logistic model in IFVE 3351-SEL 2804 and HAT 14 species.

Key words: Bitter vetch, Growth models, Plant characteristics.

INTRODUCTION

The gene center of bitter vetch [*Vicia ervilia* (L.)Willd.], a type of forage legumes, is grown in the Mediterranean countries (Vavilov, 1949). The bitter vetch, which is an annual plant, has a length of 20-60 centimeters (Soya *et al.,* 2004).

Bitter vetch is generally cultivated for its grains and can be found in every part of Turkey except Northeast Anatolian region (Davis, 1969). Bitter vetch seed is a precious source of concentrate feed and especially used in feeding breeding bulls (Saglamtimur *et al.*, 1998).

Among the landraces collected from different parts of Turkey, plants which have best yield and can be suitable for mechanized agriculture were selected. To that end, Ekiz and Ozkaynak (1984) examined 51 landraces and stated these landraces had great differences in morphological, biological and agricultural characteristics. In the later studies where relatively good plants were chosen (Ekiz, 1988; Ayhan, 1989; Ev and Ekiz, 1994), baselines with better characteristics like plant length, sub-vetch length and seed yield were revealed.

There have been studies on identification of growth in plants by using mathematical models. Some researchers made mathematical modeling in growth in some plants as following: Zur *et al.* (1983) in soy bean; Dwyer and Stewart (1986) and Cerreto and Blackmer (1990) in corn; Joliffe *et al.* (1988) in orchard grass and perennial ryegrass; Mustears (1989) in underground clover; Damgaard *et al.* (2002) in White goosefoot; Zahedi and Jenner (2003) in wheat. Karadavut and Tozluca (2005) stated that above ground fresh and dry weight and underground fresh and dry weight of rye was identified better by Weibull model and underground dry weight was identified better by Richards model. Tezel *et al.* (2005) examined the growth of wheat by using Richards, Logistic, MMF and Gompertz models. Karadavut *et al.* (2010a) stated that dry matter accumulation in corn, silage corn and corn grains, was best identified by Richards model. Karadavut *et al.* (2010b) stated that the growth of corn was identified better by Richards, Logistic and Gompertz models than other non-linear models.

The aim of this study is to model plant length, dry stem and dry leaf weights of 4 types of bitter vetch by using growth models and to compare bitter vetch types.

MATERIALS AND METHODS

This study was conducted in Bingol University Faculty of Agriculture Research and Application field, in 2014 and 2015. Tentative randomized blocks were established 3 times repetitively according to experimental design. Three plants (IFVE 3977-SEL 2802, IFVE 3351-SEL 2804 and HAT-14) of the plant materials which were used in experiment were provided from GAP International Agricultural Research and Training Centre, one plant (Mardin Population) was provided from a farmer who was engaged in agriculture. In bitter vetch genotypes which were examined, plant length, dry stem weight and dry leaf weight were measured on a weekly basis in two years,

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starting approximately a month after October, and measurements were taken for 6 weeks. Measurements were made by collecting three plants from each parcel. Calculations were made over 2 years average of plant length (cm), dry stem weight (g) and dry leaf weight (g) variables' mean values.

In the study, Bertalanffy (Beverton and Holt, 1957), Logistic (Graybill and Iyer, 1994) and Gompertz (Winsor, 1932) models were used to examine plant length, dry stem and dry leaf weight of 4 different species of bitter vetch for weeks. Parameter values of the models were given as Coefficient of Determination (R2), Adjusted Coefficient of Determination (Adj-R2), Mean Square Error (MSE) and Basic Mean Square Error (BMSE).

Statistical analyses were made by using SPSS 22.0 statistical program. During iteration, 1.0 E-8 was used as convergence criterion (Akbas *et al.*, 2001)

RESULTS AND DISCUSSION

Plant length: In the study the plant length of IFVE 3977-SEL 2802, IFVE 3351-SEL 2804,HAT-14 and Mardin Population types of bitter vetch were examined. Measurement values related to plant lengths and standard errors are given in Table 1 and Table 2.

Dry stem weight: Measurement values of the dry stem weight (g) of IFVE 3977-SEL 2802, IFVE 3351-SEL 2804, HAT-14 and Mardin Population types of bitter vetch and standard errors are given in Table 3 and Table 4.

Dry leaf weight: Measurement values of dry stem weight (g) of IFVE 3977-SEL 2802, IFVE 3351-SEL 2804, HAT-14 and Mardin Population types of bitter vetch and standard errors are given in Table 5 and Table 6.

As seen in Table 2, in IFVE 3977-SEL 2802 type of bitter vetch in Bertalanffy model the findings were as follows: R2=94.10, Adj-R2=90.17, MSE=4.599 and

Table 1: Plant length statistics of bitter vetch

	IFVE 3977-SEL 2802	IFVE3351-SEL 2804	HAT-14	Mardin Population
Week	$\bar{X} \pm s_{\bar{x}}$	$\bar{X} \pm s_{\bar{x}}$	$\bar{X} \pm s_{\bar{x}}$	$\bar{X} \pm s_{\bar{x}}$
1	8.150±1.076	9.367±0.638	9.400±0.721	7.550±0.775
2	14.083±1.332	15.000±1.317	13.417±0.898	13.667±0.910
3	22.500±1.565	18.667±0.989	19.833±1.108	16.333±0.709
4	24.000±2.309	22.000±2.049	19.583±1.753	19.583±1.695
5	22.083±2.973	22.667±2.092	17.917±1.791	18.833±2.774
6	25.550±3.498	24.730±3.926	23.637±3.290	22.587±2.992

Table 2: Plant length model parameters of bitter vetch.

IFVE 3977-SEL 2802							
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	25.125	0.330	0.849	94.10	90.17	4.599	3.185
Logistic	24.507	2.292	1.363	95.30	92.17	3.612	2.820
Gompertz	24.922	1.198	0.966	94.40	90.67	4.333	3.090
IFVE 3351-SEL 2804							
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	26.164	0.288	0.507	99.50	99.17	0.287	0.794
Logistic	24.970	1.588	0.789	99.20	98.67	0.419	0.964
Gompertz	25.764	0.998	0.577	99.40	99.00	0.310	0.827
HAT-14							
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	22.978	0.257	0.525	88.00	80.00	5.030	3.327
Logistic	21.882	1.314	0.825	87.50	79.17	5.232	3.393
Gompertz	22.632	0.876	0.596	87.90	79.83	5.078	3.346
Mardin Population							
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	23.211	0.300	0.500	95.80	93.00	1.987	2.094
Logistic	22.108	1.678	0.776	94.90	91.50	2.387	2.291
Gompertz	22.838	1.043	0.569	95.60	92.67	2.084	2.140

A, b, k: Model parameters, (A:Asymptoticlength; b: Integration constant, k: Maturing index, R^2: Determination coefficients, Adj R^2: Adjusted determination coefficients, MSE: Residual Mean of Squares, BMES: Mean of Basic Square Error.

Table 3: Dry straw weight statistics of bitter vetch

	IFVE 3977-SEL 2802	IFVE 3351-SEL 2804	HAT-14	Mardin Population
Week	$\bar{X} \pm s_{\bar{x}}$	$\bar{X} \pm s_{\bar{x}}$	$\bar{X} \pm s_{\bar{x}}$	$\bar{X} \pm s_{\bar{x}}$
1	0.025±0.002	0.027±0.004	0.020±0.005	0.017±0.001
2	0.092±0.009	0.104±0.018	0.145±0.097	0.069±0.008
3	0.328±0.058	0.260±0.040	0.259±0.034	0.202±0.028
4	0.752±0.150	0.423±0.075	0.467±0.149	0.415±0.055
5	0.722±0.213	0.638±0.143	0.483±0.161	0.715±0.513
6	0.937±0.157	0.963±0.370	0.890±0.219	1.227±0.339

Table 4: Model parameters of dry stem weight of bitter vetch.

FVE 3977-SEL 2802							
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	1.024	2.442	0.726	98.10	96.83	0.005	4.233
Logistic	0.894	404.406	1.849	98.80	98.00	0.003	3.353
Gompertz	0.949	23.075	1.066	98.40	97.33	0.004	3.507
IFVE 3351-SEL 2804							
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	7.003	0.936	0.110	99.92	99.87	0.00018	0.993
Logistic	1.375	56.759	0.813	99.70	99.50	0.002	1.858
Gompertz	2.644	5.696	0.288	99.89	99.82	0.00024	0.993
HAT-14							
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	3445.005	0.982	0.008	88.90	81.50	0.017	10.515
Logistic	589.830	104.364	0.451	89.60	82.67	0.016	10.247
Gompertz	9176.424	12.170	0.045	89.50	82.50	0.016	10.111
Mardin Population							
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	10294.210	0.998	0.008	98.70	97.83	0.004	4.377
Logistic	365.243	124.588	0.621	99.18	98.63	0.0028	3.494
Gompertz	5021.337	12.536	0.068	99.20	98.67	0.0027	3.687

Table 5: Dry leaf weight statistics of bitter vetch

	IFVE 3977-SEL 2802	IFVE 3351-SEL 2804	HAT-14	Mardin Population
Week	$\bar{X} \pm s_{\bar{x}}$	$\bar{X} \pm s_{\bar{x}}$	$\bar{X} \pm s_{\bar{x}}$	$\bar{X} \pm s_{\bar{x}}$
1	0.055±0.008	0.226±0.152	0.055±0.014	0.123±0.074
2	0.172±0.012	0.164±0.011	0.089±0.010	0.144±0.053
3	0.393±0.058	0.303±0.033	0.388±0.062	0.303±0.049
4	1.195±0.198	0.662±0.090	0.548±0.134	0.590±0.084
5	1.070±0.180	1.152±0.401	0.595±0.154	1.013±0.210
6	2.043±0.757	0.987±0.365	1.238±1.179	1.300±0.306

BMSE=3.185. Growth rate was 0.849 g. In Logistic model, the findings were as follows: R2=95.30, Adj-R2=92.17, MSE=3.612 and BMSE=2.820. The growth rate was 1.363 g. In Gompertz model, the findings were as follows: R2=94.40, Adj-R2=90.67, MSE=4.333 and BMSE=3.090. The growth was 1.198. When plant lengths in IFVE 3977-SEL 2802 types of bitter vetch were compared; in Logistic model, R2, Adj-R2 values were highest and MSE and BMSE values were the lowest. In IFVE 3977-SEL 2802 types of bitter vetch, plant length was identified best by Logistic model.

In IFVE 3351-SEL 2804 type, the findings by Bertalanffy model: R2=99.50, Adj-R2=99.17, MSE=0.287, BMSE=0.794 and the growth rate was 0.507. In Logistic

Table 6: Model parameters of dry leaf weight of bitter vetch.

			IFVE 3977-SEL 2802				
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	11064.790	0.984	0.008	98.40	97.33	0.014	4.583
Logistic	142.554	1150.368	0.562	98.78	97.97	0.011	4.004
Gompertz	5693.047	10.949	0.064	98.82	98.03	0.010	4.040
			IFVE 3351-SEL 2804				
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	4.866	0.740	0.129	81.60	69.33	0.054	12.373
Logistic	1.229	24.687	1.067	85.00	75.00	0.044	11.111
Gompertz	2.050	3.405	0.342	82.40	70.67	0.052	12.040
			HAT-14				
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	31230.354	0.990	0.005	93.80	89.67	0.020	8.684
Logistic	110.369	15.110	0.560	95.80	93.00	0.013	7.159
Gompertz	119.588	14.448	0.045	95.50	92.50	0.014	7.622
			Mardin Population				
Parameters	A	b	k	R^2 (%)	Adj R^2	MSE	BMES
Bertalanffy	1522.463	0.968	0.014	96.20	93.67	0.015	6.293
Logistic	2.004	36.138	0.852	97.10	95.17	0.012	5.686
Gompertz	10.275	5.184	0.187	96.50	94.17	0.014	6.337

model: R2=99.20, Adj-R2=98.67, MSE=0.419, BMSE=0.964 and the growth rate was 0.789. In Gompertz model: R2=95.60, Adj-R2=92.67, MSE=2.390, BMSE =2.291 and the growth rate was 0.577. In IFVE 3977-SEL 2802 types of bitter vetch plant length was identified best by Bertalanffy model.

In HAT 14 type, the findings by Bertalanffy model: R2=88.00, Adj-R2=80.00, MSE=5.030, BMSE=3.327 and the growth rate was 0.525. In Logistic model: R2=87.50, Adj-R2=79.17, MSE=5.232, BMSE=3.393 and the growth rate was 0.825. In Gompertz model: R2=87.90, Adj-R2=79.83, MSE=5.078, BMSE =3.346 and the growth rate was 0.596. In HAT 14 types of bitter vetch plant length was identified best by Bertalanffy model.

In Mardin Population type, the findings by Bertalanffy model: R2=95.80, Adj-R2=93.00, MSE=1.987, BMSE=2.094 and the growth rate was 0.500. In Logistic model: R2=94.90, Adj-R2=91.50, MSE=2.387, BMSE=2.291 and the growth rate was 0.776. In Gompertz model: R2=95.60, Adj-R2=92.67, MSE=2.084, BMSE =2.140 and the growth rate was 0.569. In Mardin Population types of bitter vetch plant length was identified best by Bertalanffy model.

In the research, observed values of the plant length of IFVE 3977-SEL 2802, IFVE 3351-SEL 2804, HAT-14 and Mardin Population types and the estimated values that were provided by means of 3 different growth models are given respectively in Figure (Fig) 1, 2, 3 and 4.

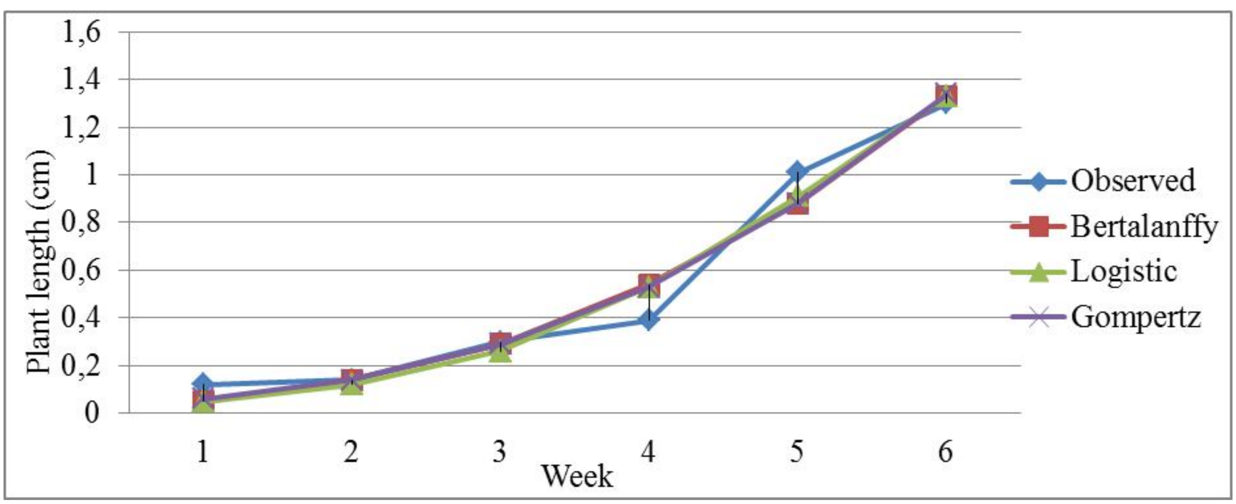

Fig 1: Plant length for IFVE 3977-SEL 2802 cultivar.

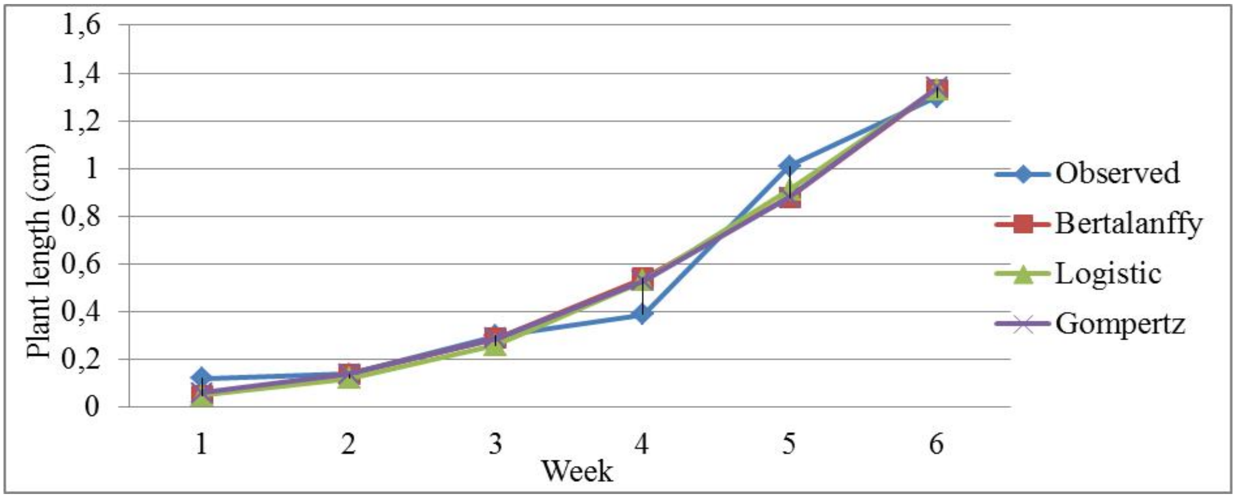

Fig 2: Plant length for IFVE 3351-SEL 2804 cultivar.

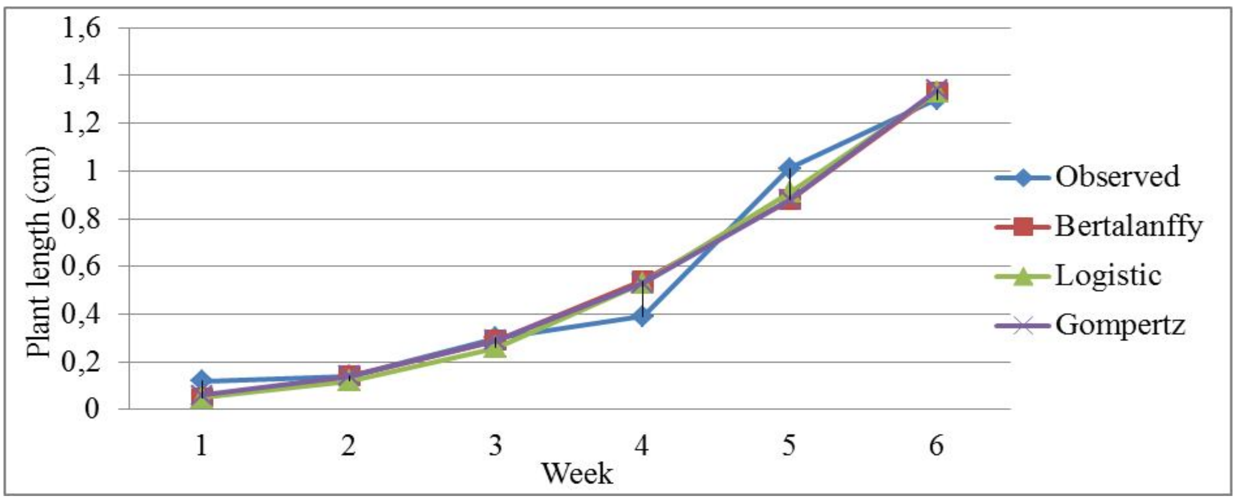

Fig 3: Plant length for HAT-14cultivar.

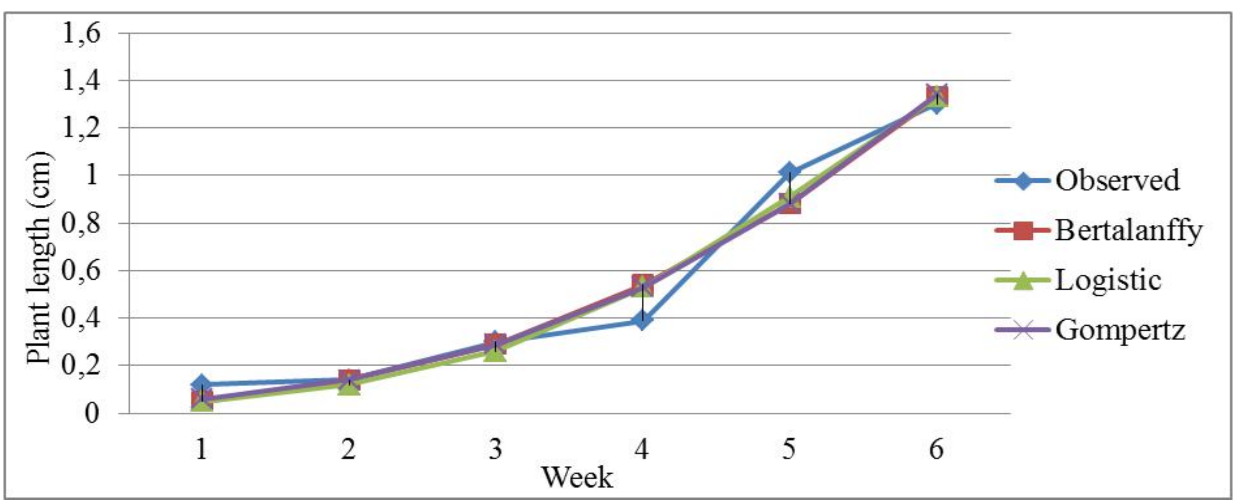

Fig 4: Plant length for Mardin population cultivar.

As seen in Table 4, in IFVE 3977-SEL 2802 type of bitter vetch in Bertalanffy model the findings were as follows: R2=98.10, Adj-R2=96.83, MSE=0.005 and BMSE=4.233. The growth rate was 0.726 g. In Logistic model the findings were as follows: R2=98.80, Adj-R2=98.00, MSE=0.003 and BMSE=3.353. The growth rate was 1.849 g. In Gompertz model, the findings were as follows: R2=98.40, Adj-R2=97.33, MSE=0.004 and BMSE=3.507. The growth rate was 1.066 g. Amongst the growth models concerning dry stem weight in IFVE 3977-SEL 2802 types of bitter vetch, the best model was Logistic model. In these types of bitter vetch, the one which identified dry stem weight the least was Bertalanffy model.

In IFVE 3351-SEL 2804 type, in Bertalanffy model the findings were as follows: R2=99.92,Adj-R2=99.87, MSE=0.00018, BMSE=0.993 and the growth rate was 0.110. In Logistic model, the findings were R2=99.70, Adj-R2=99.50, MSE=0.002, BMSE=1.858 and the growth rate was 0.813. In Gompertz model, the findings were R2=99.89, Adj-R2=99.82, MSE=0.00024, BMSE=0.993 and the growth rate was 0.288. The best model for dry stem weight in IFVE 3351-SEL 2804 type of bitter vetch was Bertalanffy model while Logistic model was the worst.

In HAT-14 type, in Bertalanffy model, the findings were R2=88.90, Adj-R2=81.50, MSE=0.017, BMSE= 10.515 and the growth rate was 0.008. In Logistic model, the findings were R2=89.60, Adj-R2=82.67, MSE=0.016, BMSE=10.247 and the growth rate was 0.451. In Gompertz model, the findings were R2=89.50, Adj-R2=82.50, MSE=0.016, BMSE=10.111 and the growth rate 0.045. The best model which identified dry stem weight in HAT-14 type of bitter vetch was Logistic model; the worst model was Bertalanffy model.

In Mardin Population type, in Bertalanffy model, the findings were R2=98.70, Adj-R2=97.83, MSE=0.004, BMSE=4.377 and the growth rate was 0.008. In Logistic model, the findings were R2=99.18, Adj-R2=98.63, MSE=0.0028, BMSE=3.494 and the growth rate was 0.621. In Gompertz model, the findings were R2=99.20, Adj-R2=98.67, MSE=0.0027, BMSE=3.687 and the growth rate was 0.068. In Mardin population type of bitter vetch the best model which identified dry stem weight was Gompertz models and Bertalanffy model identified dry stem weight the least. Logistic model was the second best model to identify dry stem weight.

Observed values of dry stem weight in IFVE 3977-SEL 2802, IFVE 3351-SEL 2804, HAT-14 and Mardin Population types and the estimated values that were provided by means of 3 different growth models are given respectively in Fig 5, 6, 7 and 8.

In IFVE 3977-SEL 2802 type, R2 (%) values for Bertalanffy, Logistic and Gompertz models were respectively 98.40, 98.78 and 98.82. According to the same models, Adj-R2 values were respectively 97.33, 97.97 and 98.03; and MSE values were respectively 0.014, 0.011 and 0.0107. BMSE values were respectively 4.583, 4.004 and 4.040. In IFVE 3977-SEL 2802 type, dry leaf weight was identified best by Gompertz model.

In IFVE 3351-SEL 2804 type, R2 (%) values for Bertalanffy, Logistic and Gompertz models were respectively 81.60, 85.00 and 82.40. According to the same models, Adj-R2 values were respectively 69.33, 75.00 and 70.67. MSE values were respectively 0.054, 0.044 and 0.052. BMSE values were respectively 12.373, 11.111 and 12.040. In IFVE 3977-SEL 2804 type dry leaf weight was identified best by Logistic model.

In HAT-14 type, R2 (%) values for Bertalanffy, Logistic and Gompertz models were respectively 93.80, 95.80 and 95.50. According to the same models Adj-R2 values were respectively 89.67, 93.00 and 92.50. MSE values

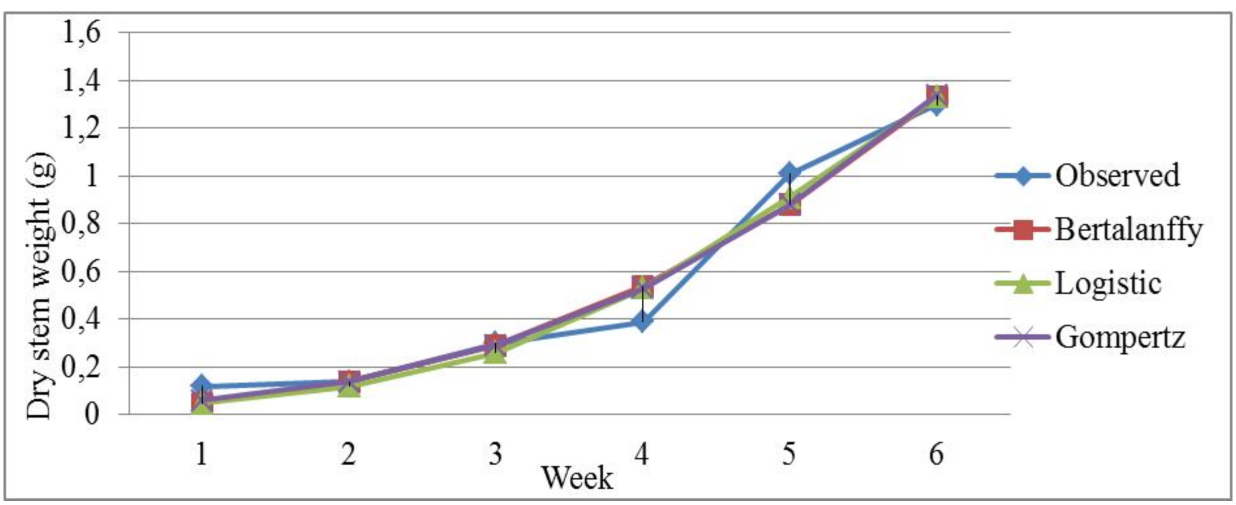

Fig 5: Dry stem weight (g) for IFVE 3977-SEL 2802 cultivar.

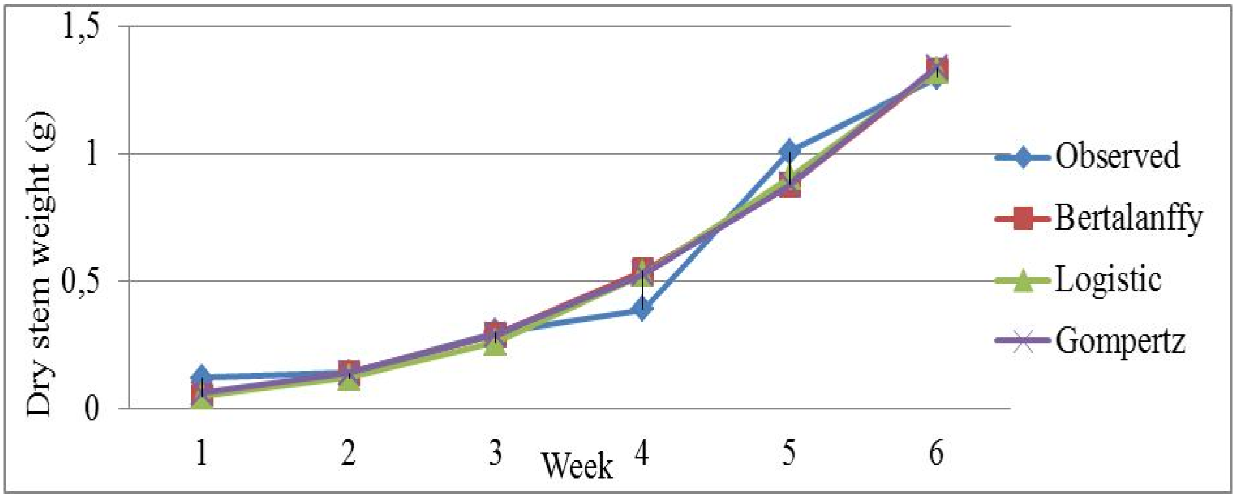

Fig 6: Dry stem weight (g) for IFVE 3351-SEL 2804 cultivar.

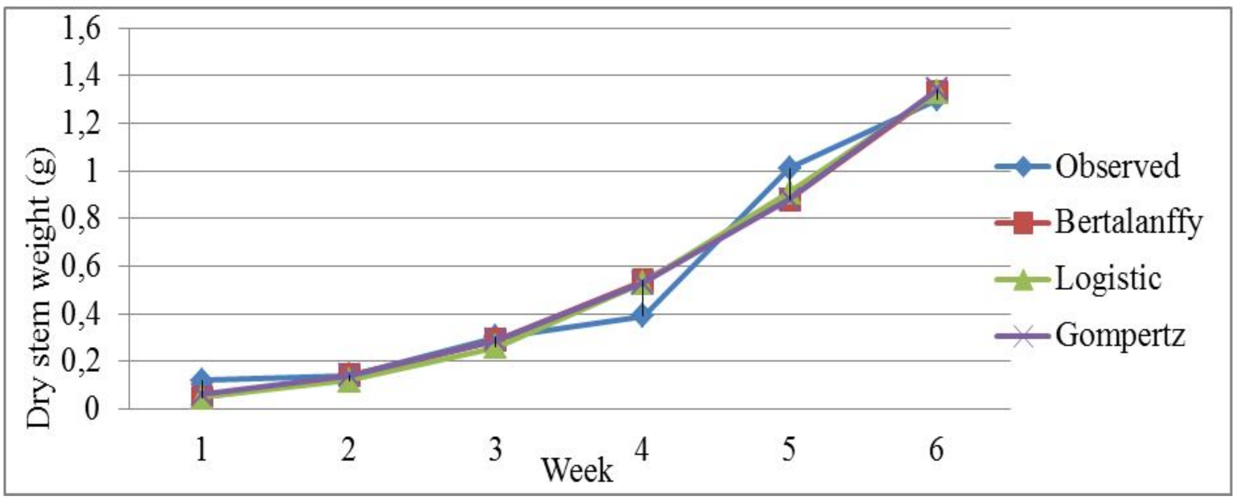

Fig 7: Dry stem weight (g) for HAT-14cultivar.

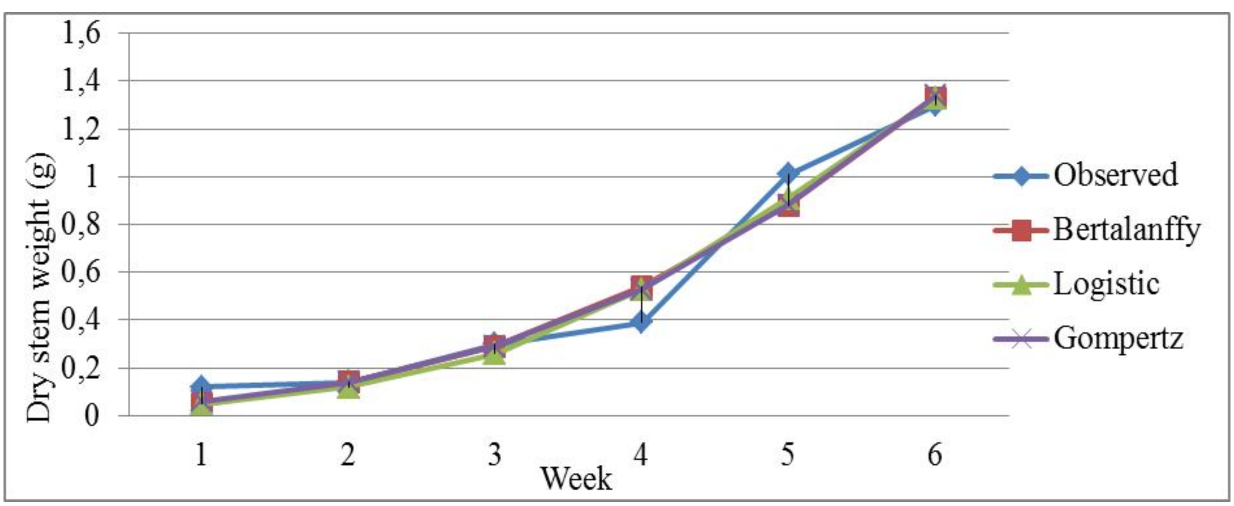

Fig 8: Dry stem weight (g) for Mardin population cultivar.

were respectively 0.020, 0.013 and 0.034. BMSE values were respectively 8.684, 7.159 and 7.622. In Hat-14 type, dry leaf weight was identified best by Logistic model.

In Mardin Population type, R2 (%) values for Bertalanffy, Logistic and Gompertz models were respectively 98.70, 99.18 and 99.20. According to the same models Adj-R2 values were respectively 97.83, 98.63 and 98.67. MSE values were respectively 0.004, 0.0028 and 0.0027. BMSE values were respectively 4.377, 3.494 and 3.687. In Mardin Population type, dry leaf weight was identified best by Gompertz model.

Observed values of dry leaf weight in IFVE 3977-SEL 2802, IFVE 3351-SEL 2804, HAT-14 and Mardin Population types and graphics of the estimated values that were provided by means of 3 different growth models were given respectively in Fig. 9,10, 11 and 12.Gregorczyk (1994), identified leaf area (cm2) growth in corn with Richards model and he found R2=0.995. Tezel *et al.* (2005) studied on jointed goatgrass' effects on growth in wheat by applying multiple herbicides, and stated that growth in Daðdaþ-94 type of wheat was modeled better by Logistic model. Karadavut et al. (2010b) found the highest R2 values for relative growth rates in silage corn types with the help of Weibull model. Karadavut *et al.* (2010c) examined growth models related to leaf length in corn in a comparative way. Profen 1550 type of corn leaf length was identified better by Gompertz model; Monton, Ranchero, TTM 81-19 and 35 P 12 types of corn leaf length was identified better by Richards model.

In all types, models were generally compatible with each other in terms of plant characteristics. When they were compared with each other in terms of model determination criteria, it was seen that these criteria values between the model which identified best and the model which identified least were so close to each other. Generally, it was seen that plant length, dry stem and dry leaf weight in bitter vetch were identified by different growth models according to types.

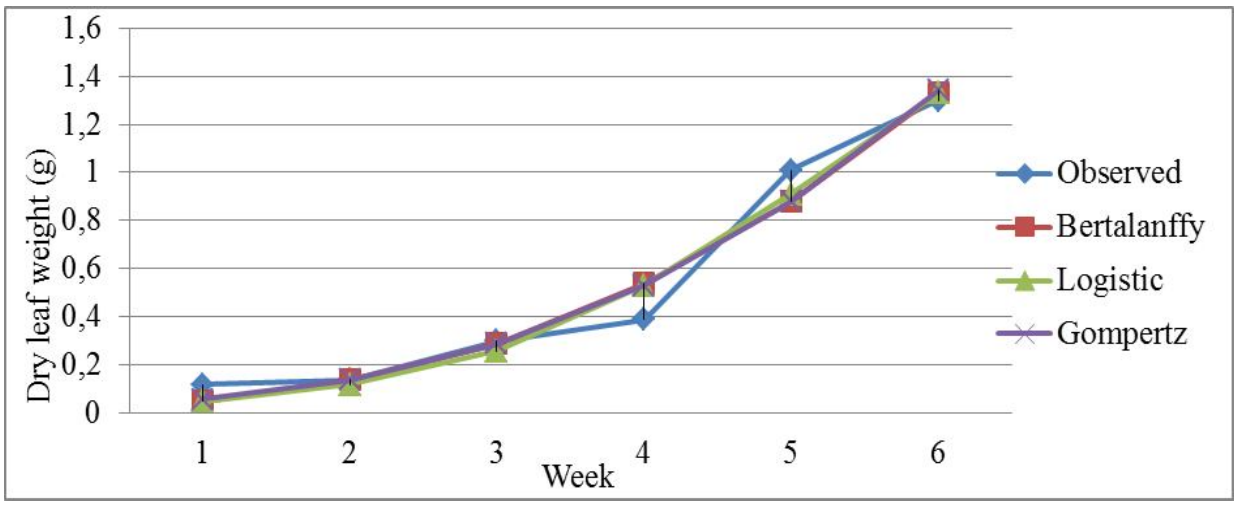

Fig 9: Measured and estimated values of dry leaf weight of IFVE 3977-SEL 2802species.

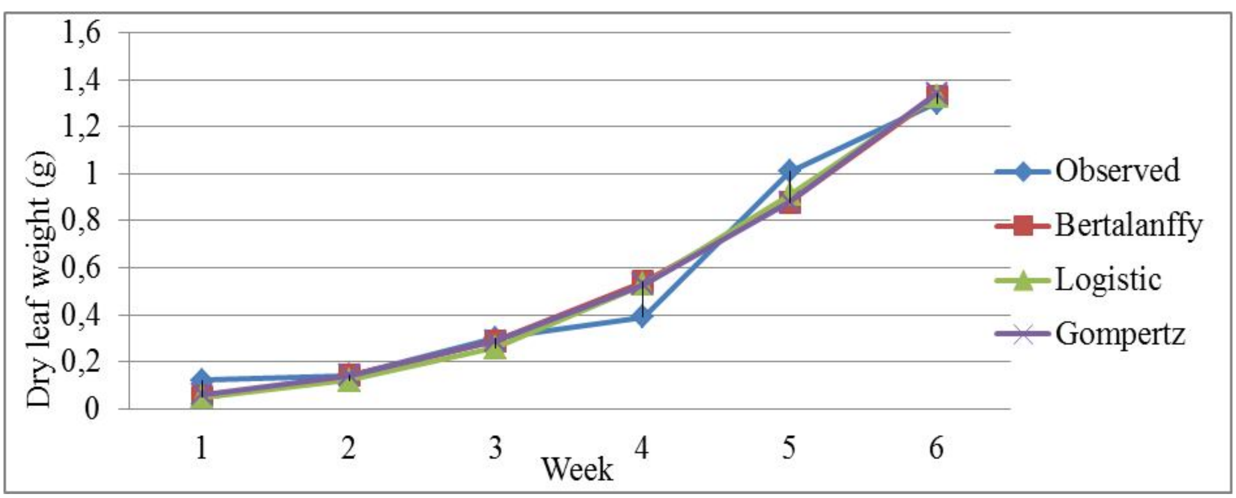

Fig 10: Measured and estimated values of dry leaf weight of IFVE 3351-SEL 2804 species.

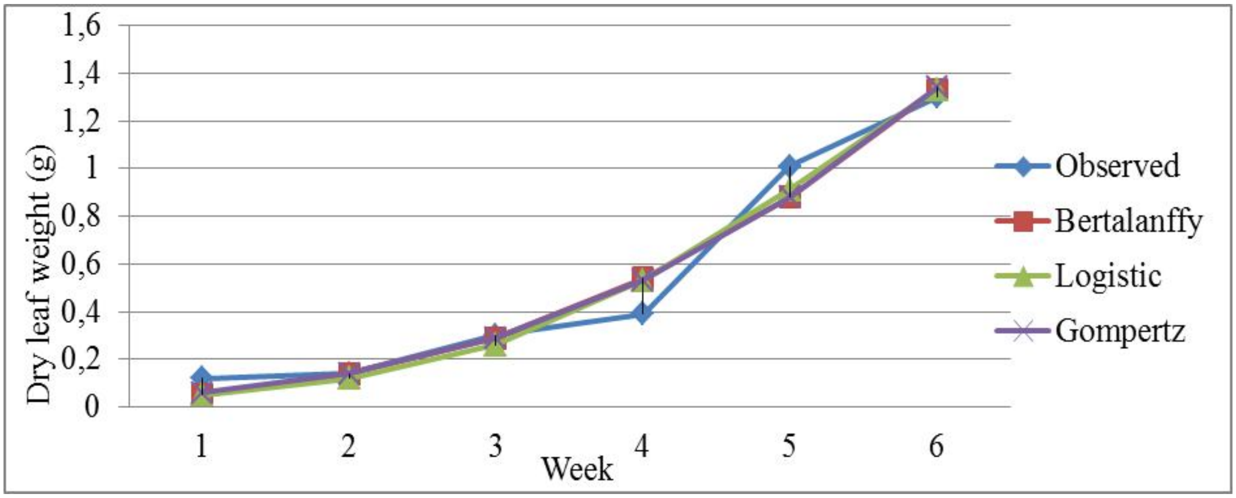

Fig 11: Measured and estimated values of dry leaf weight of HAT-14species.

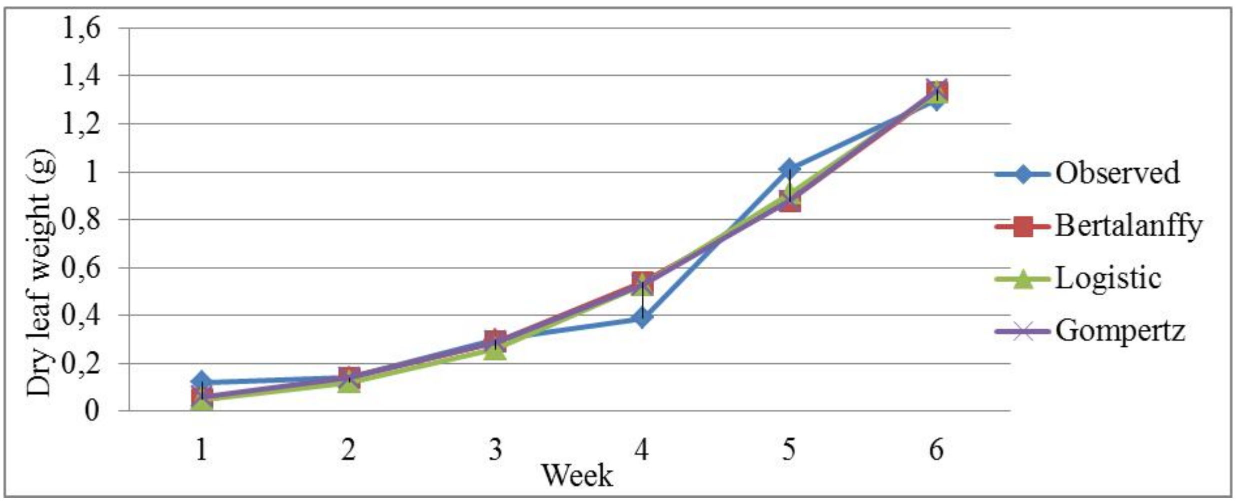

Fig 12: Measured and estimated values of dry leaf weight of Mardin population

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