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Original scientific paper

EVALUATION OF DRY MATTER ACCUMULATION IN TRITICALE BY DIFFERENT SIGMOIDAL GROWTH MODELS IN WEST ANATOLIA OF TURKEY

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Monitoring biological growth of field crops is important for planning and timing agricultural practices. In order to assess biological growth pattern of dry matter accumulation in triticale Egeyildizi triticale variety were grown in Çanakkale conditions in 2012-2013 and 2013-2014 growing seasons with continuous plant samplings from seedling emergence until seed maturation. Gompertz, Logistic, Logistic Power and Richards growth models are fitted to actual growth data and their predictions were compared. Results suggested that all sigmoidal growth models successfully explained triticale dry matter accumulation over 98 % R^2 values and low mean square errors, Richards model fitted best for both years with an R^2 value over 99 %. Dry matter accumulation were also investigated as a result of average temperature, precipitation, growth degree days and cumulative growth degree days with stepwise regression. Rresults indicated that average weather temperature had a similar pattern across both growing seasons and had a major influence on dry matter accumulation. Since Richards sigmoidal growth model may be adequately described growth pattern of triticale by generally high R^2 with lower Mean Square Error (MSE) values.
Key words: Dry Matter, Growth Models, Stepwise Regression, Triticale

INTRODUCTION

Triticale (*X Triticosecale Wittm.*) is the newest addition to winter cereals and considered among important cold climate cereals in Turkish agriculture. Despite the facts that how bread wheat and barley is widely grown in Turkey and ability of triticale to yield better than other

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winter cereals in marginal areas with lower water availability, introduction of triticale took relatively longer. First variety (Tatlicak 97) were registered in 1997 in Turkey by Bahri Dagdas International Agricultural Research Institute as a result of breeding efforts of winter – facultative genotypes obtained from European materials and CIMMYT. Triticale breeding efforts in Turkey is reported going back until 1940's, and yielded a slight increase in grain yield in long term (ANONYMOUS, 2015 a), and contributed six triticale cultivars until 2004 (BAGCI *et al.,* 2004), same year when triticale production statistics in Turkey started by Turkish Statistical Institute (TUIK) with 95,000 t nationwide (ANONYMOUS, 2017 a b). More detailed data provided by TUIK suggests that Çanakkale province ranks third after Balıkesir and Denizli by triticale production and mainly aims for green hay production rather than grains, with the average yield of 1,917 kg ha^{-1} (TUIK, 2013). Total triticale production of Turkey reached 125,000 t in 2016, indicating a slow acceleration of its popularity among Turkish farmers. However this increase may seem insignificant, it should be considered that winter cereal growing areas have been decreasing nationwide, mainly due to the increase of irrigation infrastructure in Çanakkale, enabling farmers to shift towards economically more feasible crops such as fruits or vegetables when irrigation became an option (TAYYAR and KAHRIMAN, 2016; ANONYMOUS, 2015 a).

Winter type triticale growth begins with germination in spring but slowly reduces and nearly stops during winter. An exponential growth phase is triggered in early spring when precipitation and overall temperature rises, causing an "awakening" from winter stagnation and rapidly increases plants total biomass, forming an "s" shaped curve. Just like all cold climate cereals, generative growth significantly gains speed with the initiation of heading stage, when vegetative growth is no longer a priority. Hence, the exponential growth phase in triticale is not continuous, it reduces speed in later stages alike many plants, which means overall growth pattern can be represented better with sigmoidal growth models.

MASTRORILLI *et al.* (2000) conducted a study to compare the results of the CERES-Maize model with the results obtained from the field experiment; it was observed that there was a difference of 10% between the observed and simulated values of the amount of dry matter, grain yield and leaf area index in the conditions without water deficit, and it was stated that the model predicted well these conditions. On the other hand; in the case of restricted water application, the observed and simulated values of the CERES-Maize model are 26-46% for leaf area index; 23-29% for dry matter; a difference of 15-23% was determined for grain yield. PANDA *et al.* (2004) reported that values between the measured and estimated values of corn yield, dry matter content and leaf area index were very close to each other. In the same study, model performance was found to be 0.958, 0.966 and 0.972 for grain yield, dry matter and leaf area index, respectively. Low and high air temperature damage on pollination and harvestable yield are considered, as is cold inhibition of biomass production in AquaCrop simulation model (AHUJA *et al.,* 2014).

Sigmoidal growth curves have been used to fit biological growth data widely, some of them were specifically created to be used to study growth, like logistic curve in 19^{th} century (KINGSLAND, 1982) and Richards (RICHARDS, 1959) when others were used to explain other events that weren't related to agriculture, like Gompertz equation (GOMPERTZ, 1825; WINSOR, 1932) which were originally used to model human mortality in 1825 (SCHABENBERGER and PIERCE, 2001). Literature of using sigmoidal growth curves to explain biological growth varies greatly by subjects in agriculture, both on animals (AGGREY, 2002; CANAZA-CAYO *et al.*, 2015; SOUZA *et al.,* 2017) and plants, containing many examples. When studying plant growth, many researchers preferred to monitor either plant height (an indicator of plant dry matter accumulation) or plant dry matter increases over time with evenly spaced observations to reach meaningful physiological conclusions (HEADY, 1957; KARADAVUT and OKUR, 2008; PAINE *et al.*, 2012). Although these parameters are relatively simpler to measure, they also can be used to calculate more complex data such as green area index (GAI) and leaf area index (LAI) (ROYO *et al.,* 2004; LABBAFI *et al.,* 2017). The most important climate factors affecting plant development are precipitation and temperature (KAYA and ALADAĞ, 2009). In this context, there is also a difference in plant development if temperature and precipitation are different according to years.

Present study aims to 1) use stepwise regression to evaluate the effects of air temperature and precipitation on dry matter growth of triticale for both years and 2) determine the best fitting sigmoidal growth models to the data of triticale plants dry matter growth over two years to identify best mathematical model to predict actual growth pattern of triticale.

MATERIAL AND METHODS

Material and Field Trials

Field trials were conducted in Çanakkale Onsekiz Mart University Agricultural Experiment Station in Dardanos, Çanakkale in two consecutive growing seasons (2012-2013 and 2013-2014) in the same plot. Egeyildizi triticale variety was used as plant material. Registered by Aegean Agricultural Research Institute in 2005, Egeyildizi were reported having high grain yield, disease resistance, high gluten index, high herbage yield, high silage quality and demonstrated good adaptation to Aegean region of Turkey (FIRAT *et al.,* 2006; TAYYAR and KAHRIMAN, 2016; KAVUT *et al.,* 2012). Field trials were sowed with plot seeder in 7 November 2012 and 30 October 2013 for the first and second years of experiment, respectively.

Soil analysis showed that experimental area had loamy texture with low salinity and were slightly alkaline pH (7.9) with low organic matter (around 1%). Potassium content was found very high (41.3 ppm) and phosphorus and iron concentrations were lower than usual, 2.4 and 3.12 ppm respectively. Study area also contained adequate amounts of Copper (1 ppm), Manganese (2.36 ppm) and Zinc (4.08 ppm).

Triticale plots are conducted with 500 plants m^{-2} density in 6 m^2 plots with 8 rows each year. 0.77 kg ha^{-1} pure N fertilization is applied with two splits, one with sowing (0.27 kg ha^{-1}) and another with the beginning of tillering stage (0.43 kg ha^{-1}) in ammonium nitrate form. Phosphor fertilization is applied in Di ammonium phosphate form along with sowing, at 0.69 kg ha^{-1} P_2O_5. Weed control is maintained by hand.

Triticale plants within plots were continuously sampled with one week intervals beginning from seedling emergence for 28 and 27 weeks in first and second years of experiment, respectively. Each sampling consisted of 5 randomly chosen triticale plants to be collected and segregated into roots, stems, leaves, (spikes also are categorized after ear emergence) each week. Fresh plant material were put in drying oven at 60°C for 48 hours (JONES, 1981), providing enough time for plant samples to reach a constant value, then dry weights are measured in laboratory. Dry weight averages of five samples for one sampling date were used as actual growth data. Since our focus were to evaluate vegetative growth and compare sigmoidal growth models, plant samplings ceased after majority of plants reached ripening “Zadoks 90” (ZADOKS *et al.,* 1974) when vegetative activity of triticale were no longer a consideration.

Fitting Growth Curves

Gompertz (1), Logistic (2), Logistic Power (3) and Richards (4) growth curves fitted weekly dry weight measurements of triticale variety, Egeyildizi on raw data. Mathematical models of these sigmoidal growth curves are shown in Table 1. Growth curve parameters and predictions were estimated for each model using actual data with Curve Expert v. 1.6 (HYAMS, 2011). Coefficient of determination (R^2), standard error values of each growth curves are used for comparison.

Table 1. Growth Models

Gompertz	$y = ae^{-e^{b-cx}}$	(1)
Logistic	$y = {}^{a}/(1 + be^{-cx})$	(2)
Logistic Power	$y = {}^{a}/(1 + (x/b)^{c})$	(3)
Richards	$y = {}^{a}/(1 + e^{b-cx})^{1/d}$	(4)

Y: dry weights at a measurement, a: asymptotic dry weight, b: growth rate, c: inflection point, d: shape parameter, x: measurement date, e: natural logarithm base.

Stepwise Regression

Since biomass growth of plants are closely associated with weather temperature and precipitation, effects of meteorological conditions of two years on dry matter accumulation of triticale were investigated using Stepwise regression in Minitab 17 (MINITAB 17, STATISTICAL SOFTWARE, 2010). Climate data consisted of daily average temperatures and precipitations were acquired from Turkish State Meteorological Service (TSMS). Daily average temperatures presented as the average of multiple measurements for one day (ANONYMOUS, 2015 b) upon which sum of Growth Degree Days (GDD) values regarding each measurement interval (measurement day and previous 6 days) and cumulative GDD accumulations were calculated (MCMASTER and WILHELM 1997). Daily average temperatures, GDD, cumulative GDD and precipitations are used as predictors for two growing seasons separately when actual dry matter accumulation of triticale were the dependent variable. In order to assess multicollinearity, variance inflation factors are calculated for each variable as the reciprocal of the inverse of coefficient of determination (GRAHAM, 2003).

RESULTS AND DISCUSSION

Average temperature and precipitation data of Çanakkale suggested a warm and temperate climate. It is classified as Mediterranean hot climate (Csa) in Köppen Gauger climate classification as mentioned by PEEL *et al.* (2007). Average temperatures across 2012-2013 and 2013-2014 growing seasons showed a high and positive correlation (0.834). As a result, average temperatures, GDD, cumulative GDD and dry matters of both years were all found highly correlated with each other. Precipitation in first year was mainly congregated before spring, mainly in December (Table 2). In Çanakkale, rain mainly falls in winter with a very little or no direct effect on dry matter accumulation, as seen in first year when there was no significant precipitation recorded after 19 April 2013. Precipitation in second year was considerably lower and showed a different distribution than the first year (Table 3) which also showed poor correlation (Table 5).

Table 2. Dry matter accumulation of triticale plants (DM) and cumulative growth degree days (CumGDD) with average temperature of sampling date (Temp), total precipitation (Prec), growth degree days accumulation (GDD) between two consecutive samplings in 2012-2013 growing season.

No	Sampling Dates	Temp(°C)	Prec (mm)	GDD (°C)	CumGDD (°C)	DM (g)
1	07/12/2012	6.70	118.90	81.10	81.10	0.225
2	14/12/2012	4.70	60.00	55.50	136.60	0.045
3	21/12/2012	2.70	43.80	39.90	176.50	0.0648
4	28/12/2012	12.30	0.00	59.30	235.80	0.0771
5	04/01/2013	8.20	0.20	59.10	294.90	0.0915
6	11/01/2013	10.00	6.20	31.90	326.80	0.0932
7	18/01/2013	12.30	66.80	72.20	399.00	0.1459
8	25/01/2013	11.80	48.00	91.60	490.60	0.1886
9	01/02/2013	7.90	52.80	37.60	528.20	0.2280
10	08/02/2013	11.30	27.40	89.90	618.10	0.3679
11	15/02/2013	6.00	80.40	58.30	676.40	0.6247
12	22/02/2013	8.50	15.80	41.20	717.60	0.8460
13	01/03/2013	7.10	11.40	63.60	781.20	1.2480
14	08/03/2013	11.40	8.20	63.10	844.30	1.8460
15	15/03/2013	14.50	2.20	100.20	944.50	2.6276
16	22/03/2013	8.30	15.80	41.20	985.70	6.2800
17	29/03/2013	11.20	21.00	73.30	1059.00	10.2970
18	05/04/2013	15.50	10.20	102.10	1161.10	16.3800
19	12/04/2013	15.00	65.40	94.50	1255.60	23.2700
20	19/04/2013	11.40	14.10	92.10	1347.70	28.3600
21	26/04/2013	20.20	0.60	113.00	1460.70	34.2900
22	03/05/2013	18.60	0.00	133.20	1593.90	38.1600
23	10/05/2013	18.50	3.80	133.80	1727.70	40.2600
24	17/05/2013	21.50	1.60	130.20	1857.90	41.3800
25	24/05/2013	20.10	0.20	152.10	2010.00	42.3400
26	31/05/2013	20.70	0.00	142.40	2152.40	42.1900
27	07/06/2013	19.70	11.40	134.10	2286.50	41.1800
28	14/06/2013	22.00	9.10	156.90	2443.40	41.2600

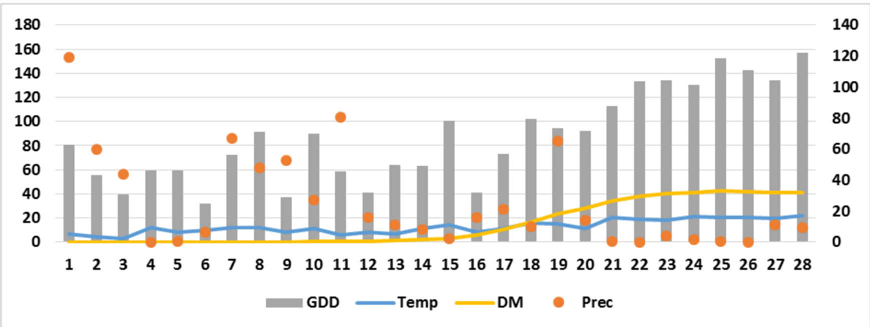

Figure 1. Dry Matter Accumulation of Triticale with GDD, Temperature, and Precipitation in 2012-2013

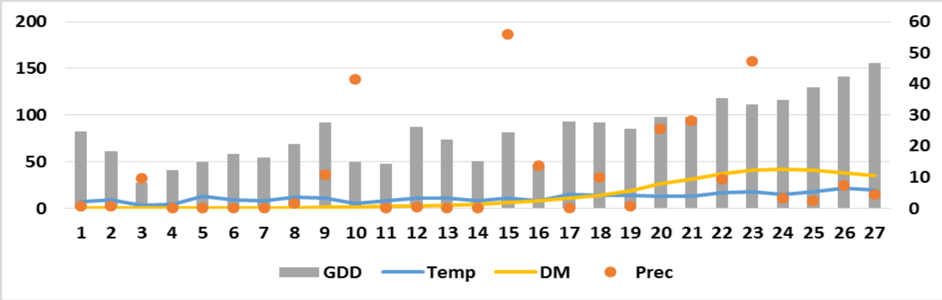

Figure 2. Dry Matter Accumulation of Triticale with GDD, Temperature, and Precipitation in 2013-2014

Table 3. Dry matter accumulation of triticale plants (DM) and cumulative growth degree days (CumGDD) with air temperature of sampling date (Temp), total precipitation (Prec), growth degree days accumulation (GDD) between two consecutive samplings in 2013-2014 growing season.

No	Sampling Dates	Temp(˚C)	Prec (mm)	GDD (˚C)	CumGDD (˚C)	DM (g)
1	29/11/2013	7.50	0.80	82.20	82.20	0.058
2	06/12/2013	9.10	0.80	61.60	143.80	0.062
3	13/12/2013	3.00	9.70	27.60	171.40	0.078
4	20/12/2013	4.10	0.20	40.90	212.30	0.112
5	27/12/2013	13.10	0.00	49.10	261.40	0.156
6	03/01/2014	8.80	0.20	58.00	319.40	0.156
7	10/01/2014	7.70	0.00	54.10	373.50	0.265
8	17/01/2014	11.90	1.60	69.30	442.80	0.330
9	24/01/2014	11.30	10.80	91.90	534.70	0.844
10	31/01/2014	5.30	41.60	49.80	584.50	1.212
11	07/02/2014	7.80	0.00	48.00	632.50	1.822
12	14/02/2014	11.30	0.40	87.00	719.50	2.187
13	21/02/2014	11.40	0.00	74.10	793.60	2.841
14	28/02/2014	8.00	0.00	50.40	844.00	3.783
15	07/03/2014	10.60	56.00	81.60	925.60	6.071
16	14/03/2014	8.10	13.60	46.70	972.30	8.305
17	21/03/2014	14.80	0.00	93.00	1065.30	10.811
18	28/03/2014	13.90	10.00	91.90	1157.20	13.538
19	04/04/2014	13.60	0.80	85.70	1242.90	18.544
20	11/04/2014	12.50	25.60	97.60	1340.50	26.016
21	18/04/2014	12.90	28.20	98.00	1438.50	31.586
22	25/04/2014	16.90	9.40	117.80	1556.30	37.000
23	02/05/2014	17.40	47.40	111.70	1668.00	40.596
24	09/05/2014	15.00	3.20	116.30	1784.30	41.440
25	16/05/2014	17.90	2.40	129.50	1913.80	40.390
26	23/05/2014	21.90	7.40	140.80	2054.60	37.633
27	30/05/2014	19.70	4.40	156.10	2210.70	34.776

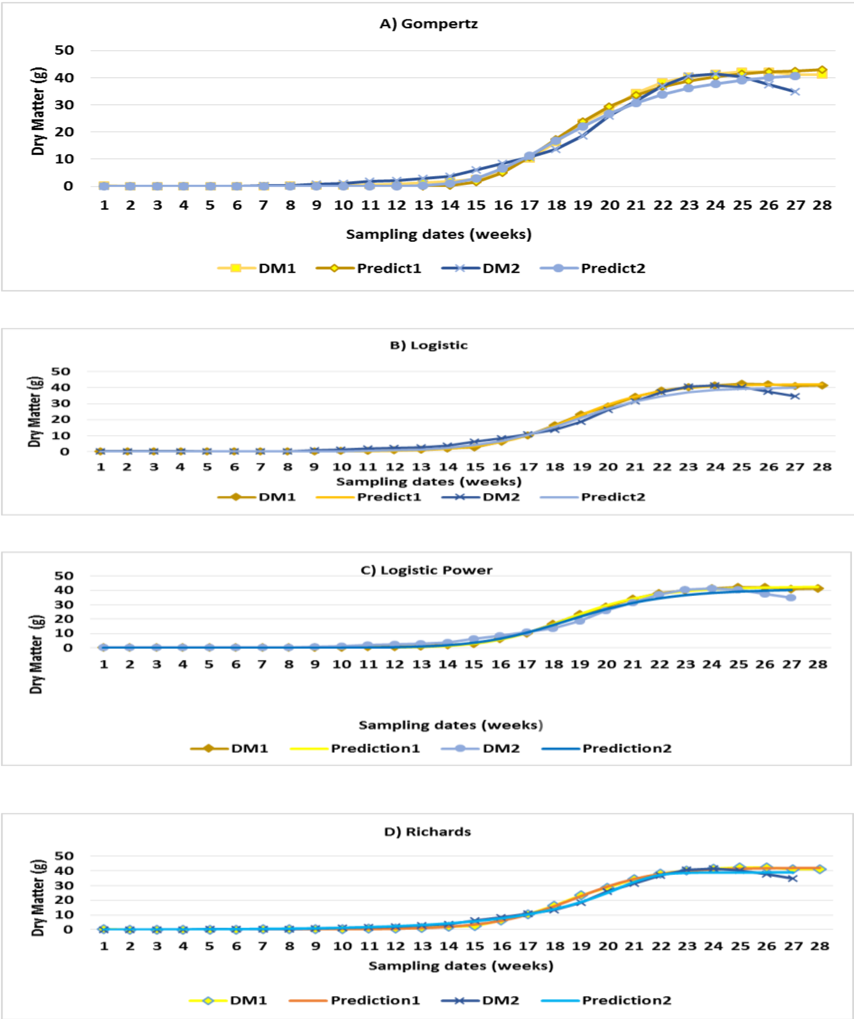

Figure 3. Dry matter accumulation and different curve models through 1st and 2nd years

Dry matter accumulation of Egeyildizi on both seasons was highly correlated (0.988) which may be due to the influence of average temperature rather than precipitation regimes. Dry matter accumulations also reached a rapid growth phase after 22 March 2012 (16th sampling) in the first year and 21 March 2013 (17th sampling) in the second year (Table 2 and 3, Figure 1, 2 and 3) roughly corresponding to another rapid increase in GDD values. Even though average temperatures of exact sampling dates didn’t reflect this increase clearly, GDD values had a better correspondence by including average temperatures for every day between two sampling dates and the actual sampling day. Association in timing of rapid increase in dry matter and GDD’s in both years indicates a positive relation between weather temperature and dry matter accumulation in triticale. Although precipitation didn’t show any association with neither as a pattern, but it there were continuous rainfall in first year (Table 2) and considerable amount of rainfall recorded 15^{th} and 16^{th} sampling dates in second year (Table 3), prior to rapid growth phase of dry matter.

Evaluation of the Growth Data

According to the results of stepwise regression, GDD and Cum GDD provided a close estimate for dry matter accumulation in the first year with an R^2 of 90.35%. Even though CumGDD and GDD were highly correlated candidates, data did show high multicollinearity due to sum of variance inflation factors of both candidates weren’t exceeding 10 (GRAHAM 2003; DORMAN *et al.*, 2013). CumGDD alone were the main variable driving dry matter accumulation in second year, with a slightly lower R^2 of 87.24%. Noticeably, actual data of average temperatures and precipitation were absent in both equations (Table 4 and 5).

Table 4. Correlations of average temperature (Temp), growth degree days (GDD), cumulative growth degree days (CumGDD) and precipitation (Prec) and p values of both experiment seasons (year 1 and year 2).

	DM1	Temp1	GDD1	Cum GDD1	Prec1	Dm2	Temp2	GDD2	Cum GDD2
Temp1	0.856**								
GDD1	0.866**	0.880**							
CumGDD1	0.933**	0.855**	0.831**						
Prec1	-0.438*	-0.535*	-0.323	-0.526					
DM2	*0.988***	*0.850***	*0.846***	*0.935***	*-0.459**				
Temp2	0.818**	0.834**	0.755**	0.844**	-0.441*	0.802**			
GDD2	0.877**	0.801**	0.773**	0.901**	-0.339	0.854**	0.927**		
CumGDD2	0.931**	0.850**	0.821**	0.999**	-0.520	0.937**	0.845**	0.904**	
Prec2	0.153	0.136	0.089	0.181	-0.061	0.212	0.013	0.106	0.192

Table 5. Relations and statistics of the stepwise analysis

	Equation	R^2
Year 1	DM = -15.32 + 0.1435 GDD + 0.01723 CumGDD	*90.35%*
	VIF (GDD) = 3.94	
	VIF (CumGDD) = 3.94	
	P<0.01	
Year 2	DM = -8.91 + 0.02363 CumGDD	*87.24%*
	VIF (CumGDD) = 1.00	
	P<0.01	

DM: Dry Matter, GDD: Growth Degree Days, CumGDD: Cumulative Growth Degree Days, VIF: Variance inflation factor

Table 6. Dry matter accumulation and predictions with Gompertz, Logistic, Logistic Power and Richards growth models in 2012-2013 season

Year 1			Predictions		
Week	DM	Gompertz	Logistic	Logistic Power	Richards
1	0.225	0.00001	0.00038	0.00000	0.00078
2	0.045	0.00001	0.00073	0.00000	0.00143
3	0.0648	0.00001	0.00141	0.00000	0.00261
4	0.0771	0.00001	0.00272	0.00000	0.00478
5	0.0915	0.00001	0.00523	0.00001	0.00876
6	0.0932	0.00001	0.01006	0.00005	0.01603
7	0.1459	0.00001	0.01937	0.00033	0.02935
8	0.1886	0.00001	0.03726	0.00163	0.05373
9	0.2280	0.00001	0.07166	0.00669	0.09832
10	0.3679	0.00001	0.13772	0.02359	0.17985
11	0.6247	0.00001	0.26430	0.07372	0.32869
12	0.8460	0.00034	0.50582	0.20822	0.59970
13	1.2480	0.02010	0.96297	0.53856	1.09047
14	1.8460	0.28675	1.81531	1.28449	1.96980
15	2.6276	1.63042	3.36066	2.82462	3.51322
16	6.2800	5.07945	6.02548	5.67921	6.11903
17	10.2970	10.67821	10.24654	10.28004	10.22178
18	16.3800	17.35722	16.10941	16.48844	15.97622
19	23.2700	23.84672	22.92365	23.32168	22.79555
20	28.3600	29.35113	29.38007	29.48077	29.36643
21	34.2900	33.62009	34.41587	34.19258	34.50937
22	38.1600	36.74163	37.78004	37.41127	37.90238
23	40.2600	38.93769	39.80128	39.46867	39.89165
24	41.3800	40.44405	40.93916	40.74185	40.97729
25	42.3400	41.46034	41.55637	41.52116	41.54655
26	42.1900	42.13860	41.88443	41.99886	41.83878
27	41.1800	42.58806	42.05692	42.29407	41.98715
28	41.2600	42.88452	42.14709	42.47862	42.06207

Table 7. Dry matter accumulation and predictions with Gompertz, Logistic, Logistic Power and Richards growth models in 2013-2014 season

Year 2	DM			Predictions	
		Gompertz	Logistic	Logistic Power	Richards
1	0.058	0.00000	0.00154	0.00000	0.09121
2	0.062	0.00000	0.00273	0.00000	0.12264
3	0.078	0.00000	0.00482	0.00000	0.16489
4	0.112	0.00000	0.00854	0.00000	0.22170
5	0.156	0.00000	0.01510	0.00004	0.29808
6	0.156	0.00000	0.02672	0.00026	0.40079

7	0.265	0.00000	0.04726	0.00131	0.53887
8	0.330	0.00000	0.08356	0.00531	0.72454
9	0.844	0.00000	0.14763	0.01821	0.97417
10	1.212	0.00001	0.26052	0.05481	1.30981
11	1.822	0.00083	0.45876	0.14827	1.76110
12	2.187	0.02070	0.80483	0.36660	2.36787
13	2.841	0.19877	1.40278	0.83746	3.18370
14	3.783	0.97534	2.41790	1.77653	4.28062
15	6.071	2.98501	4.09063	3.49767	5.75547
16	8.305	6.55493	6.71619	6.35249	7.73846
17	10.811	11.39737	10.53845	10.54183	10.40451
18	13.538	16.81688	15.53414	15.85455	13.98759
19	18.544	22.10796	21.21784	21.59899	18.78983
20	26.016	26.79749	26.74813	26.92443	25.09725
21	31.586	30.67930	31.36819	31.26231	32.36373
22	37.000	33.74123	34.76099	34.47543	37.30503
23	40.596	36.07571	37.02386	36.71350	38.67683
24	41.440	37.81346	38.43783	38.21903	38.89334
25	40.390	39.08539	39.28565	39.21546	38.92304
26	37.633	40.00538	39.78148	39.87206	38.92703
27	34.776	40.66527	40.06724	40.30595	38.92756

Growth Model Comparison

Standard errors of growth curves were 0.455 and 0.457 (in Logistic and Richards models respectively) in first year and 1.916 and 1.222 (in Logistic and Richards models respectively) in second year, also Richards model had highest R^2 for both experiment years (0.999 and 0.994). Standard error of Logistic power (0.584 in first and 2.154 in second years) and Gompertz (0.909 in first and 2.494 in second years) were relatively higher. Highest standard errors of both years were acquired by Gompertz model, also in accordance with its lower R^2 indicating its limitations of explaining dry weight growth of triticale (Table 8).

According to the results mentioned above, all growth curves adequately described growth pattern of triticale by generally high R^2 with lower Mean Square Error (MSE) values. Sigmoidal growth curves often reported as fitting the biological growth data inseparably, a good example can be seen in AGGREY (2002)'s findings, such that Richards and Gompertz curves explaining chicken growth with equal power. Richards curve had the best fit with highest R^2 and lowest MSE in both years, but closely followed by Logistic, Logistic Power and Gompertz which also adequately described biological growth of triticale. A previous study of KARADAVUT (2009) compared several growth curves on three different triticale cultivars grown in irrigated conditions and reached the conclusion of Richards and Weibull models explained the dry weight growth best. Accordingly, Richards growth curve was used successfully to model snap beans (LIETH and REYNOLDS, 1986) and dry matter growth of silage and seed corns (KARADAVUT *et al.*, 2010).

Table 8. Curve fitting statistics of dry matter accumulation

First Year	Gompertz	Logistic	Logistic Power	Richards
R^2	0.997590	0.999395	0.999004	0.999414
Standard error	0.909221	0.455509	0.584460	0.457505
RSE (S)	0.837276	0.438355	0.542338	0.436032
a	43.450137	42.245021	42.821186	42.137889
b	7.613450	213469.580171	18.717980	13.106024
c	0.427779	0.654853	-11.969319	0.689068
d				1.139416
Second Year	**Gompertz**	**Logistic**	**Logistic Power**	**Richards**
R^2	0.988680	0.986714	0.983210	0.994816
Standard error	2.494210	1.916111	2.154038	1.222687
RSE (S)	2.37665	1.84026	2.04959	1.16297
a	42.272721	40.444716	41.232371	38.927647
b	6.298435	46461.634179	18.827560	46.151789
c	0.354470	0.570785	-10.465384	2.011102
d				6.793040

CONCLUSION

We have taken the following messages from the current work.

1) Meteorological data suggests that there were little variation among two consecutive years in terms of overall temperature patterns, a high correlation can be seen between average temperatures, GDD's and Cumulative GDD's of both seasons. Cumulative GDD plays an important role in dry matter accumulation and may be used as a main indicator to explain in season growth patterns. This conclusion excludes the soil factor completely, because plant samples in our study were acquired from the same plot in both years.

2) Even though there weren't enough evidence in our study to evaluate how plant growth is affected by different precipitation regimes, it is apparent in both years that increase of weather temperature exceeding 10°C in daily average in mid-March may have triggered rapid biological growth in both years, probably with an interaction of precipitation and other climate and soil factors that remains unclear.

3) It was concluded that Richards sigmoidal growth model may be adequately described growth pattern of triticale by generally high R^2 with lower Mean Square Error (MSE) values.

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OCENA ACUMULACIJE SUVE MATERIJE KOD TRITIKALEA RAZLIČITIM MODELIMA SIGMOIDALNOG RASTA U ZAPADNOJ ANADOLIJI U TURSKOJ

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Izvod

Praćenje biološkog rasta poljskih useva je važno za planiranje i raspored primene agrotehničkih mera. U cilju procene biološkog rasta i načina akumulacije suve materije kod tritikalea, gajena je sorta Egeiildizi u uslovima Canakkale u periodu 2012-2013 i 2013-2014, sa neprekidnim uzorkovanjem biljaka, od pojave klijanaca do sazrevanja semena. Gompertz, Logistic, Logistic Power i Richards modeli rasta su prilagođeni stvarnim podacima o rastu i upoređena su njihovi predviđanja. Rezultati ukazuju da su svi modeli sigmoidnog rasta uspešno objasnili akumulaciju suve materije tritikalea iznad 98% R^2 vrednosti i niske srednje kvadratne greške, dok je Richards-ov model najbolji za obe godine sa vrednostima R^2 preko 99%. Akumulacija suve materije takođe je istraživana kao rezultat prosečne temperature, padavina, dana stepena rasta i kumulativnih dana stepena rasta sa stepenom regresije. Rezultati ukazuju da je prosečna temperatura bila slična tokom oba vegetacione sezone i da je imala najveći uticaj na akumulaciju suve materije. Zbog toga, Richards-ov model sigmoidnog rasta može biti adekvatan obrazac za opis na rast tritikalea sa generalno visokim R^2 i nižim vrednostima srednje kvadratne greške (MSE).

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