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Research Article

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Evaluation of the radish Vikima cultivar growth stages by regression models in spring planting at Gorgan city.

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ABSTRACT
Growth analysis is considered a valuable method for quantitative assessment of growth, development, and agricultural crop development as well as a powerful method for measuring/estimating long term photosynthesis net assimilation/production. Among growth-related parameters/characteristics, the value of dry matter is considered a determining factor due to higher economic importance. The pattern of dry matter/weight distribution in different plant parts is followed by agricultural crops development stages. Studies of growth and dry matter accumulation in different agricultural crops show that dry matter production is dependent/ related to leaf area index, solar radiation interception during growth stages, and plant utilization of solar radiation. The experiment was carried out in a factorial-RBD design with three replications at research farm of Gorgan Natural Resources and Agricultural Sciences University located at 5 Km to Kordkoy-Gorgan old street. The sown radish cultivar was *Vikima* which is a short-duration variety, market-choice and of small aerial canopy volume. The plot size was 4 m^2 and each compromised of 10 rows. Row to row distance and plant to plant distance were 20 and 5 cm, respectively. 400 seeds were sown in each plot. Generally, with an assessment of the study traits variability, it could be concluded that radish *Vikima* cultivar by 5^{th} leaf emergence, till day 27, produces leaf in an identical sequence. Later on, from day 37 onwards it produces leaves at a high-rate pace and from day 34 the tuber root which increases its diameter, length, and volume uniformly at the same time with the leaf expansion, starts rapidly to increase its fresh and dryness weights. Further, the weight gaining of tuber roots will start from day 34 onwards. In addition, based on found equations, variation of each study trait can be predicted from sowing time till 45 days.
Keywords: Leaf number, Leaf Area, Tuber fresh weight, Tuber dry weight.

INTRODUCTION

Growth analysis is considered a valuable method for quantitative assessment of growth, development, and agricultural crop development as well as a powerful method for measuring/estimating long term photosynthesis net assimilation/production. (Chiariello et al., 1989). The basic concept and physiological applications of growth analysis were introduced in the early 1900s (Blackman, V. H. 1919; Briggs et al., 1920). Later, especially following Watson's classic work in 1947 and 1952, growth analysis was used to quantify plant growth processes in Europe and the Commonwealth countries, and then in the United States and elsewhere (Wallace et al., 1965- Watson, DJ 1947- Watson, DJ 1952).

In the regression method, which is calculated on the variable of leaf area and dry weight or their logarithm, they were given relative to the processing time. Many equations have been proposed to describe sigmoid growth patterns (Zeide, B. 1993). And new equations have been developed (Birch, C. P. D. 1999). Analysis of growth indices to interpret how the reaction plant species react to environmental conditions (Lebaschy et al., 2004). (Kouchaki and Banaeian Avval. 2004) state that leaf area index is important in determining the percentage of sunlight radiation absorbed by each plant and therefore affects plant growth and final dry matter yield. Leaf area index has a decisive effect on the amount of plant radiation absorption through the effect of absorption of sunlight radiation, so that in many plants the maximum leaf area in the canopy, radiation absorption, and subsequent dry matter production will reach the maximum (Liu et al., 2005).

With increasing leaf area index and high absorption of sunlight radiation, high photosynthesis is performed and finally dry matter yield increases (Ghanbari et al., 2013). Among the growth-dependent characteristics, the amount of dry matter is considered a determining factor due to its greater economic importance. The pattern of dry matter distribution between different organs depends on the developmental stages of crops (Koucheki and Hosseini 2008). The study of dry matter growth and accumulation in different crops reveals that dry matter production depends on the leaf area index and the amount of radiation received during the growth period and the efficiency of the plant in converting the intercepted radiation (Yano et al., 2007). In a study, it was reported that the dry weight of a plant depends on the amount of cumulative radiation absorbed during the growing season. On the other hand, the amount of radiation absorbed by the plant depends on the leaf area index and canopy growth. In most plants, when the leaf area index reaches 4 to 5, more than 80% of photosynthetic active radiation is absorbed by the plant (Lebaschy et al., 2004). A study in crops showed that with increasing plant age in the vegetative stage, the dry weight of plant organs and leaf area index increased, but after entering the reproductive stage due to aging and leaf fall, both indices decreased (Alinaghizadeh et al., 2010). In an experiment on pea crop, it was stated that the growth rate of the crop slowed down in the early vegetative stage, but increased rapidly with the onset of flowering and decreased after the formation of 50% of the pods (Alizade et al., 2010).

MATERIALS AND METHODS

The experiment was carried out in a factorial-RBD design with three replications at the research farm of Gorgan Natural Resources and Agricultural Sciences University located at 5 Km to Kordkoy-Gorgan old street. The sown radish cultivar was *Vikima* which is a short-duration variety, market-choice and of small aerial canopy volume. The plot size was 4 m^2 and each was compromised of 10 rows. Row to row distance and plant to plant distance were 20 and 5 cm, respectively. Totally 400 seeds were sown in each plot. The number of leaves were measured by counting the leaves and the leaf area was measured using the leaf level gauge DELTA T model. Tuber fresh weight, tuber dry weight, leaf fresh weight, leaf dry weights were measured using a digital scale. Root diameter was determined using FX-300 digital caliper. Root length was measured using a ruler. Number of leaves by counting the leaves, leaf area was done using the leaf level gauge of DELTA T model of agriculture group. Tuber fresh weight, tuber dry weight, leaf fresh weight, leaf dry weight were performed using a digital scale. Root diameter was determined using FX-300 digital caliper. root length was measured using a ruler.

Measurement of anthocyanins: Leaf anthocyanin, tuber skin anthocyanin, tuber flesh anthocyanin, anthocyanin was measured by Wenger's (1979) method. Chlorophyll and carotenoids: The amount of chlorophyll and carotenoids was determined by (Barnes, J. D., Balaguer, L., Manrique, E., Elvira, S., A. A. 1992) method.

RESULTS AND DISCUSSION

Generally, with assessment of the trend of leaf number variability over time it was found that the rate of leaf number formation from day 27 till the last measurement (day 45) was significantly slower than the first stage of measurement (tenth day) till day 27 (Figure 1). However, the trend of variability in fresh and dry weight of radish leaves during the growing period indicated that over time, the increase in fresh and dry weight of leaves continued uniformly until day 31 and then with a greater slope (higher speed). The fresh and dry weight of the leaves was increased and remained almost at par during days 41 to 45 (Figures 2 and 3). Leaf area variation was such that the increase in leaf area increased uniformly until day 35, but from day 35 to the end of the measurement (day 45) the leaf area of radish was increased more rapidly (Figure 4). It is predicted that in the radish of Vikima cultivar, after the formation of an average of 5 leaves, the plant's ability is spent more on the development of the formed leaves, and the rate of photosynthesis, absorption, and plant metabolism increase rapidly because the leaf formation process is slowed down from the fifth-leaf stage onwards, but the fresh and dry weights accumulation and leaf area increase more rapidly.

Among the growth-dependent characteristics, the amount of dry matter is considered a determining factor due to its greater economic importance. The pattern of dry matter distribution between different organs depends on the development stages of crops (Koucheki and Hosseini, 2008). The study on dry matter growth and accumulation in different crops has shown that dry matter production depends on the leaf area index and the amount of radiation received during the growth period and the efficiency of the plant is utilizing the intercepted radiation (Yano et al., 2007). In a study, it was reported that the dry weight of a plant depends on the amount of cumulative radiation absorbed during the growing season. On the other hand, the amount of radiation absorbed by the plant depends on the leaf area index and canopy growth. In most plants, when the leaf area index reaches 4 to 5, more than 80% of photosynthetic active radiation is absorbed by the plant (Lebaschy et al., 2004). A study on crops showed that with increasing plant age in the vegetative stage, the dry weight of plant organs and leaf area index increased, but after entering the reproductive stage due to senescence, both indices Decreased (Alinaghizadeh et al., 2010).

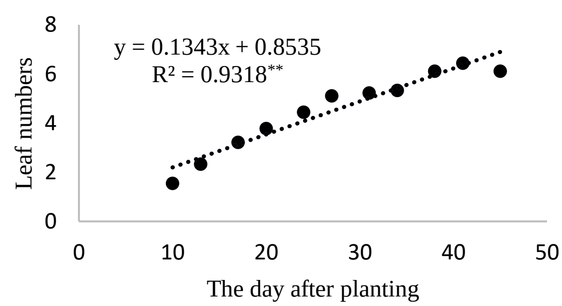

Figure 1. The process of the leaf number variations at different periods

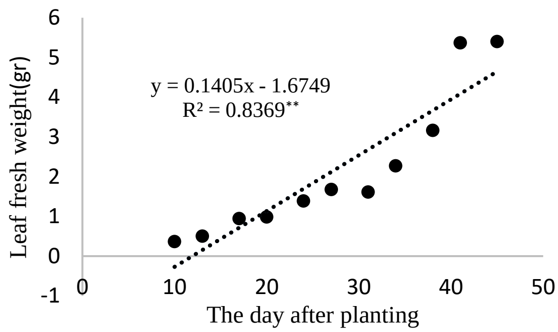

Figure 2. The process of the leaf fresh weight variations at different periods

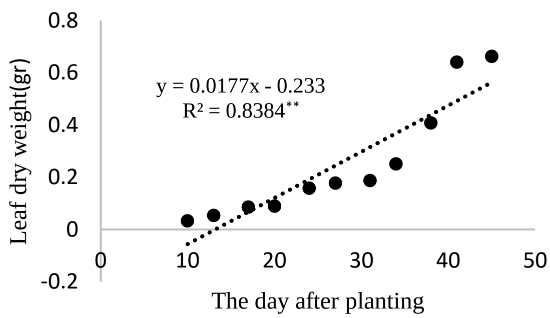

Figure 3. The process of the Leaf dry weight variations at different periods

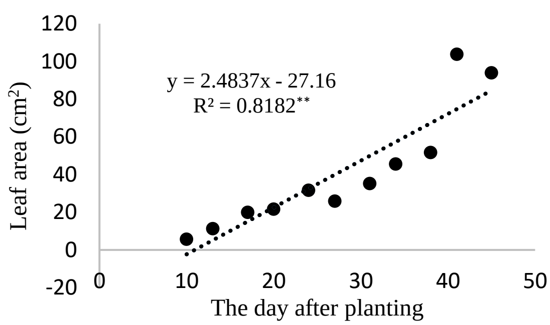

Figure 4. The process of the leaf area variations at different periods

Generally, with an assessment of the trend of quantitative characteristics of radish underground organs over time showed that the increase in volume, diameter, and root length increased from the beginning (day 10) till the last measurement (day 45) with a constant and uniform slope (Figures 5, 6 and 7). However, for the wet and dry weight of tuberous roots from day 34 onwards, the growth process was more rapid (Figures 8 and 9).

Generally, with an assessment of the study traits variability, it could be concluded that radish *Vikima* cultivar by 5th leaf emergence, till day 27, produces leaf in an identical sequence. Later on from day 37 onwards it produces leaves at a high rate pace and from day 34 the tuber root which increases its diameter, length, and volume uniformly at the same time with the leaf expansion, starts rapidly to increase its fresh and dryness weights. Further, the weight gaining of tuber roots will start from day 34 onwards. In addition, based on found equations, variation of each study trait can be predicted from sowing time till 45 days. Also, according to the applied equations, the trend of variability in each of the studied characteristics can be predicted from planting time today 45.

One of the suitable indicators for growth analysis in plant communities is the crop growth rate index (CCR), which indicates the amount of dry matter accumulation in the plant in a specific time unit per unit area of leaf area. The rate of growth in plant communities in each species usually depends on the amount of sunlight received (Kouchaki and Sarmadnia, 2011). Crop growth rate indicates the concept of growth and determines the rate of dry weight production per unit area of land and ultimately shows the interaction between plant and photosynthesis. The shape of the CGR curve in most studies is a quadratic function (Navabpour et al., 2011). In crops, the crop growth rate is highly dependent on net uptake rate and leaf area index (Kouchaki and Sarmadnia, 2011). In an experiment on pea crop, it was stated that the growth rate of the crop slowed down in the early vegetative stage, but increased rapidly with the onset of flowering and decreased after the formation of 50% of the pods (Alizade et al., 2010).

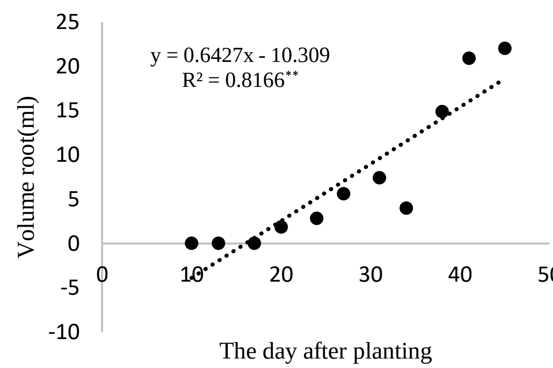

Figure 5. The process of the volume root variations at different periods

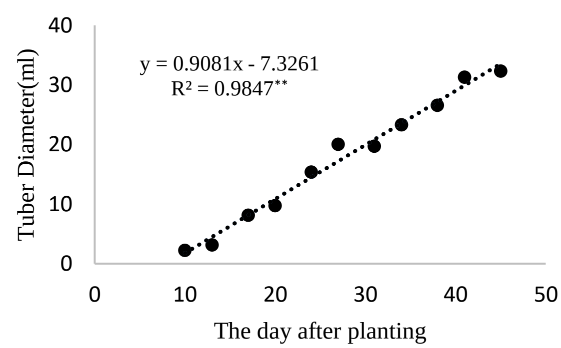

Figure 6. The process of the tuber diameter variations at different periods

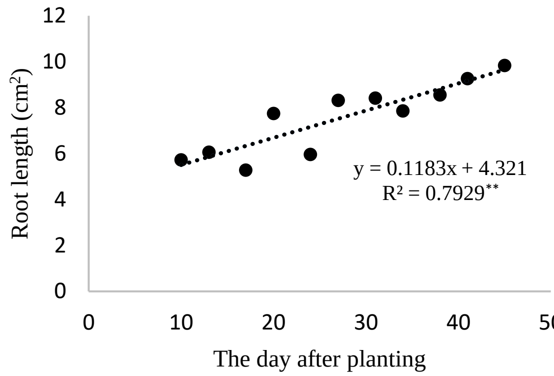

Figure 7. The process of the root length variations at different periods

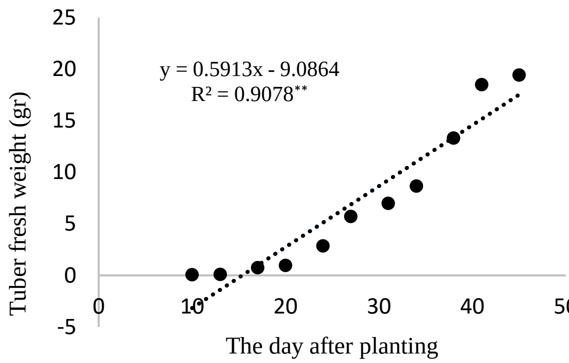

Figure 8. The process of the tuber fresh weight variations at different periods

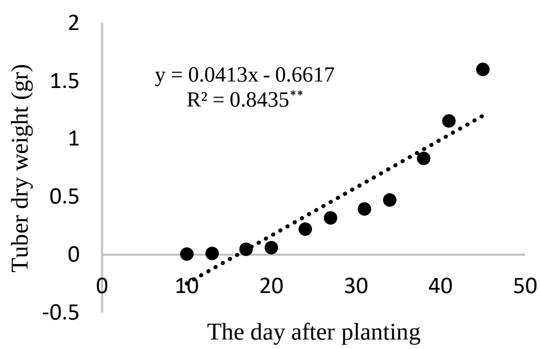

Figure 9. The process of the tuber dry weight variations at different periods

No similar changes were observed in the process of anthocyanin changes in leaves and roots of tubers; So that the anthocyanins in the leaves and roots of the tubers fluctuated a lot. Anthocyanin of tuberous roots increased sharply from day 24 and has since maintained its difference in anthocyanin content with the early stages of growth (Figures 10 and 11).

In the present study, root volume was considered as a dependent variable, and number of leaves, fresh and dry weight and leaf area, diameter, length, fresh and dry weight of tuberous roots, and anthocyanin of leaves and tuberous roots were considered as independent variables.

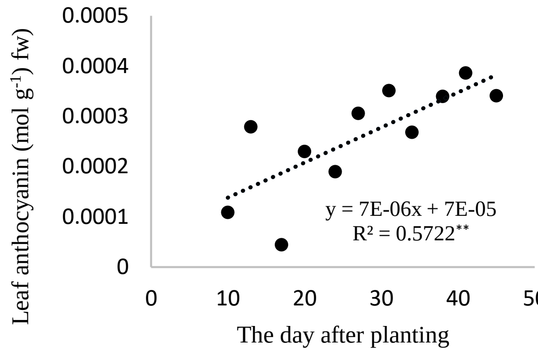

Figure 10. The process of the leaf anthocyanin variations at different periods

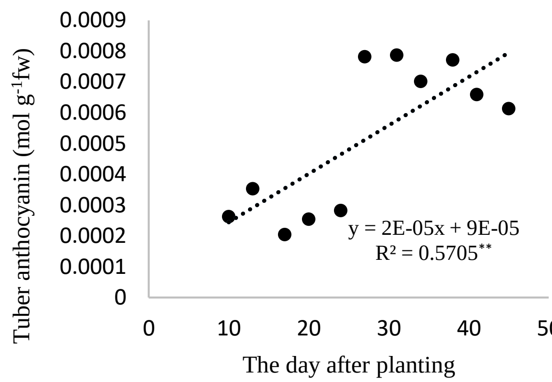

Figure 11. The process of the tuber anthocyanin variations at different periods

Table1. Data depiction concerning analyzed traits by linear regression

CV	RMSE	R^2	Source of changes
9/84	0/44	0/93**	number of leaves
35/19	0/76	0/84**	Leaf fresh weight
38/12	0/09	0/84**	Leaf dry weight
35/31	14/33	0/82**	Leaf area
51/63	3/73	0/81**	Volume root
7/93	1/38	0/98**	Tuber diameter
9/81	0/74	0/79**	Root length
32/76	0/89	0/91**	Tuber fresh weight
46/77	0/22	0/84**	Tuber dry weight
28/55	0/0001	0/57**	Leaf anthocyanin
32/37	0/0002	0/57**	Tuber anthocyanin

** Significant at P<0.01

The results of stepwise regression showed that in the first stage, leaf dry weight with a coefficient of determination of 0.96 was the first-factor affecting tuber root volume. In the second stage, fresh leaf weight entered the equation and increased the coefficient of explanation to 0.97, and in the third stage, root length entered the equation as the third factor affecting root volume and the coefficient of explanation reached 0.98 (Table 2).

Root size:

In the present study, root volume was considered as a dependent variable, and number of leaves, fresh and dry weight and leaf area, diameter, length, fresh and dry weight of tuberous roots, and anthocyanin of leaves and tuberous roots were considered as independent variables. The results of stepwise regression showed that in the first stage, leaf dry weight with a coefficient of determination of 0.96 was the first-factor affecting tuber root volume. In the second stage, fresh leaf weight entered the equation and increased the coefficient of explanation to 0.97, and in the third stage, root length entered the equation as the third factor affecting root volume and the coefficient of explanation reached 0.98 (Table 2).

Therefore, according to the results of stepwise regression analysis for the root volume of radishes of Vikima cultivar, the equation Y = -6.40 + 92.73X1 - 7.83X2 + 0.98X3 can be suggested which is used to predict the root volume with an explanation coefficient of 0.98. In this equation, Y represents the volume of tuberous roots, X1 represents the dry weight of the leaves, X2 represents the fresh weight of the leaves and X3 represents the length of the roots.

Table 2. Root volume stepwise regression analysis (dependent variable) in comparison with other studied traits from sowing time till harvest.

Sum of squares (SS)	Coefficient of determination (R^2)	Standard error	Estimating factor	root lenght X_3	Leaf fresh weight X_2	Leaf dry weight X_1	Adjective entered the equation		Stage
656/59	0/96	2/36	-1/79	-	-	36/14	X_1	Leaf dry weight	1
17/9	0/97	4/14	-0/55	-	-6/90	90/90	X_2	Leaf fresh weight	2
7/44	0/98	0/46	-6/40	0/98	-7/83	92/73	X_3	root lenght	3

$$Y= -6.40 + 92.73X_1 - 7.83X_2 + 0.98X_3$$

Root diameter:

At the present study, root diameter was considered as a dependent variable, a number of leaves, leaf fresh and dry weights, leaf area, root volume, root length, fresh and dry weight of tuberous roots, anthocyanin of leaves, and tuberous roots were considered as independent variables. The results of stepwise regression showed that in the first stage, the number of leaves with a coefficient of determination of 0.95 was the first factor affecting the root diameter of tubers. In the second stage, the fresh weight of tuberous roots entered the equation and increased the coefficient of determination to 0.99, and in the third stage, the root volume entered the equation as the third factor affecting the root diameter and the coefficient of explanation reached 0.99 (Table 3).

Table 3. Root diameter stepwise regression analysis (dependent variable) in comparison with other studied traits from sowing time till harvest.

Sum of squares) SS(	Coefficient of determination) R^2(	Standard error	Estimating factor	number of leaf X_3	Tuber fresh weight X_2	number of leaf X_1	Adjective entered the equation		Stage
1069/93	0/95	0/50	-11/48	-	-	6/40	X_1	number of leaf	1
47/98	0/99	0/10	-5/07	-	0/61	4/03	X_2	Tuber fresh weight	2
3/84	0/99	0/19	-4/63	-0/37	1/07	3/81	X_3	root volume	3

$$Y= -4.63 + 3.81X_1 + 1.07X_2 - 0.37X_3$$

Therefore, according to the results of stepwise regression analysis for the root diameter of radishes of Vikima cultivar, the equation Y = -4.63 + 3.81X1 + 1.07X2 - 0.37X3 can be suggested which is used to predict the root diameter with a coefficient of 0.99 determination. In this equation, Y represents the diameter of tuberous roots, X1 represents the number of leaves, X2 represents the fresh weight of tuberous roots and X3 represents the volume of roots.

Root length:

At the present study, root volume was considered as a dependent variable, a number of leaves, leaf fresh and dry weights, leaf area, root diameter, root length, fresh and dry weight of tuberous roots, anthocyanin of leaves, and tuberous roots were considered as independent variables. The results of stepwise regression showed that in the first stage, the number of leaves with a coefficient of determination of 0.78 was the first-factor affecting root length. In the second stage, the fresh weight of tuberous roots entered the equation and the coefficient of the determination reached 0.88 (Table 4).

Therefore, according to the results of stepwise regression analysis for the length of radish tubers of Vikima cultivar, the equation Y = 4.43 + 0.08X1 + 6949.60X2 can be suggested that is used to predict the root length of tubers with a coefficient of determination of 0. 88. In this equation, Y represents the root length of the tubers, X1 represents the number of leaves, and X2 represents the fresh weight of the tubers.

Table 4. Root length stepwise regression analysis (dependent variable) in comparison with other studied traits from sowing time till harvest.

Sum of squares (SS)	Coefficient of determinatio (R^2) n	Standard error	Estimating factor	X_2 Tuber fresh weight	X_1 number of leaf	Adjective entered the equation		Stage
18/47	0/78	0/02	5/32	-	0/13	X_1	number of leaf	1
2/47	0/88	2641/61	4/43	6949/60	0/08	X_2	Tuber fresh weight	2

$$Y= 4.43 + 0.08X_1 + 6949.60X_2$$

Tuberous Fresh weight:

In the present study, the fresh weight of tuberous roots was considered as a dependent variable, number of leaves, leaf fresh and dry weights, leaf area, root volume, root length, dry weight of tuberous roots, anthocyanin of leaves, and tuberous roots were considered as independent variables. The results of stepwise regression showed that in the first stage, leaf dry weight with a coefficient of determination of 0.97 was the first factor affecting the fresh weight of tuberous roots. In the second stage, anthocyanin of tuberous roots entered the equation and increased the coefficient of determination to 0.99 (Table 5).

Table 5. Tuberous Fresh weight stepwise regression analysis (dependent variable) in comparison with other studied traits from sowing time till harvest.

Sum of squares (SS)	Coefficient of determination (R^2)	Standard error	Estimating factor	X_2 Tuber anthocyanin	X_1 Laef dry weight	Adjective entered the equation		Stage
504/89	0/97	1/78	-0/85	-	31/69	X_1	Leaf dry weight	1
12/51	0/99	768/88	-2/89	5568/39	28/34	X_2	Tuber anthocyanin	2

$$Y= -2.89 + 28.34X_1 + 5568.39X_2$$

Therefore, according to the results of stepwise regression analysis for the fresh weight of radish root of Vikima cultivar, the equation Y = -2.89 + 28.34X1 + 5568.39X2 can be suggested which is used to predict the fresh weight of root of tuber with a coefficient of determination of 0.99. In this equation, Y represents the fresh weight of the tuberous roots, X1 represents the dry weight of the leaves, and X2 represents the anthocyanin of the tuberous roots.

Tuber Dry weight:

At the present study, the dry weight of tuberous roots was considered as a dependent variable, a number of leaves, leaf fresh weight, leaf area, root diameter, root volume, root length, fresh weight of tuberous roots, anthocyanin of leaves, and tuberous roots were considered as independent variables. The results of stepwise regression showed that in the first stage, leaf dry weight with a coefficient of determination of 0.97 was the first factor affecting the dry weight of tuberous roots. In the second stage, the leaf area entered the equation and increased the coefficient of explanation to 0.98 (Table 6).

Therefore, according to the results of stepwise regression analysis for the dry weight of radish tuberous roots of Vikima cultivar, the equation Y = -0.05 + 3.56X1 - 0.009X2 can be suggested that is used to predict the dry weight of tuberous roots with an explanation coefficient of 0.98. In this equation, Y represents the dry weight of tuberous roots, X1 represents the dry weight of the leaf, and X2 represents the leaf area.

Table 6. Tuber Dry weight stepwise regression analysis (dependent variable) in comparison with other studied traits from sowing time till harvest.

Sum of squares (SS)	Coefficient of determination (R^2)	Standard error	Estimating factor	Laef area X_2	Laef dry weight X_1	Adjective entered the equation		Stage
2/64	0/97	0/14	-0/105	-	2/29	X_1	Leaf dry weight	1
0/03	0/98	0/005	-0/05	-0/009	3/56	X_2	Laef area	2

$$Y = -0.05 + 3.56X_1 - 0.009X_2$$

CONCLUSION

Generally, with an assessment of the study traits variability, it could be concluded that radish *Vikima* cultivar by 5^{th} leaf emergence, till day 27, produces leaf in an identical sequence. Later on from day 37 onwards, it produces leaves at a high rate pace and from day 34 the tuber root which increases its diameter, length and volume uniformly at the same time with the leaf expansion, starts rapidly to increase its fresh and dry weights. Further, the weight gaining of tuber roots will start from day 34 onwards. In addition, based on found equations, variation of each study trait can be predicted from sowing time till 45 days.

It is predicted that in the radish of Vikima cultivar, after the formation of an average of 5 leaves, the plant's ability is spent more on the development of the formed leaves, and the rate of photosynthesis, absorption, and plant metabolism increa rapidly because the leaf formation process is slowed down from the fifth-leaf stage onwards, but the fresh and dry weights accumulation and leaf area increase more rapidly.

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