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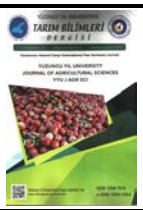

Research Article

Modeling the Effect of Different Medium on Rooting of Northern Highbush Blueberry (*Vaccinium corymbosum* L.) Softwood Cuttings

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Abstract: This study was to develop a mathematical modeling to prediction for the effects of different mediums on degree and percentage of rooting of highbush blueberry (*Vaccinium corymbosum* L.) softwood cuttings. The well fitted estimating equations for the rooting percentage and rooting degree tested were formulized as RP = (95.49533) + (-17.7671 x M)+(1.655312 x M²) + (-24.0961 x CV) and RD = 7.013245 + (-1.29063xM) + (0.119114xM²) + (-1.51642xCV) where RD is rooting degree, RP is rooting percentage, M is mediums, CV is northern highbush blueberry cultivars (Jersey [1] and Berkeley [2]) and M is mediums of the produced equation. Mediums are peat moss (PM) [1], perlite (P) [2], podzolic-brownish soil (BS) [3], podzolic-reddish soil (PR) [4], PM+P [5], PM+BP+PR [6], P+BP+PR [7] and PM+P+BP+PR [8]. All the medium mixed in equal v/v. Here the numerical count put in the angular brackets show the numerical values used for rooting medium and cultivars. Regression analysis over multiply was carried out for the least sum of square (R^2) obtained. R^2 value 0.92 for percentage of rooting and 0.93 for degree of rooting. Standard errors significances found at the p\0.001 level.

Kuzey Orijinli Yüksek Boylu Maviyemiş (*Vaccinium corymbosum* L.) Yumuşak Odun Çeliklerinde Köklenme Üzerine Ortamların Etkisinin Modellenmesi

Makale Bilgileri

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Anahtar kelimeler

Maviyemiş,
Çelik,
Matematik modelleme,
Ortam,
Köklenme.

Öz: Bu çalışma yüksek boylu maviyemişlerin (*Vaccinium corymbosum* L.) yumuşak odun çeliklerinde köklenme oranı ile köklenme derecesi üzerine köklendirme ortamlarının etkilerini tahmin etmek için matematiksel model geliştirmek amacıyla yapılmıştır. Test edilen köklenme oranı ve köklenme derecesini en iyi tahmin eden modeller, RP = (95.49533) + (-17.7671 x M)+(1.655312 x M²) + (-24.0961 x CV) ve RD = 7.013245 + (-1.29063xM) + (0.119114xM²) + (-1.51642xCV) olarak tespit edilmiştir. Buradaki eşitliklerde geçen RD köklenme oranı, RP köklenme derecesi, M ortam iken CV maviyemiş çeşitlerini (Jersey [1] ve Berkeley [2]) ifade etmektedir. Köklendirmede kullanılan ortamlar ise torf (PM) [1], perlit (P) [2], podzolic-kahverengi orman toprağı (BS) [3], podzolic-kırmızımsı orman toprağı (PR) [4], torf+perlit (PM+P) [5], PM+BP+PR [6], P+BP+PR [7] ve PM+P+BP+PR [8] karışımlarından oluşmaktadır. Karışımlar ağırlık/hacim (v/v) olarak eşit şekilde yapılmıştır. Köşeli parantez içinde verilen rakamlar ise eşitliklerde kullanılan çeşit ve ortamların nümerik değerlerini ifade etmektedir. En küçük R2 değeri elde edilinceye kadar çoklu regresyon analizleri yapılarak modeller geliştirilmiştir. Köklenme oranı için R2 0.92, köklenme derecesi için ise R2 0.93 olarak saptanmıştır. Standart hatalar da p\0.001 düzeyinde anlamlı bulunmuştur.

1. Introduction

Blueberries are perennial, long-lived, deciduous, woody shrubs and they been in heath family and in *Vaccinium* genus. This genus shows high diversity and include up to 450 species. Species like blueberry could be found in temperate and boreal regions as well as in tropics at high elevation. Blueberries are shrub like plants. The genus of *Ericaceae* includes many important ornamentals like azalea and rhododendron (Çelik, 2012a). Cultivated blueberries divide in three groups and called highbush, rabbiteye and lowbush. Each group include many cultivars for cultivation. Highbush is the most dominant group in the world. And there are more than a hundred varieties of highbush in cultivation. In addition, some varieties are based on intermediate forms of these groups including the `half high' group (highbush x lowbush). Rabbiteye-highbush intermediates generally have not made good cultivars but have been used extensively in the improvement of highbush blueberries. However, some varieties are intermediate forms of these groups and called half high gained with highbush x lowbush hydrides (Trehane, 2004; Çelik, 2009; Çelik, 2012; Çelik and Ağaoğlu, 2013). Highbush blueberries like cranberry and lingonberry thrive in acid soils and do best in soils with a pH between 4.2 and 5.5 (Çelik, 2012a). Blueberry used in fresh or dried and processed foods such as pie or muffin and mixed in pastries, jam, yogurt or milk. It most commonly used for commercial canning. Small quantity of blueberries also used to make wine, juice products and freeze dried. It was believed that the tea prepared by blueberry leaves was good for urinary infection. Blueberry fruits are good for vitamin C, natural sugars and manganese. It contains relatively high in carbohydrates and soluble solids (Çelik, 2012a).

Turkey has high plant diversity. Many berry and fruit species are grown commercially. In Turkey many local and native fruits and varieties are known for local sale and they are useful for family consumption. Eastern part of Black Sea Region is one of the main gene centers of *Vacciniums*. Several *Vaccinium* species are grown as natively and consumed over hundred years by inhabitants. But tea and hazelnut are the two main commercial crops. Annual rainfall is 831 mm, distributed through the year. This region has 14.5°C annual mean temperature and over 75.0% relative humidity (Çelik, 2009; Çelik, 2012a).

According to the researcher blueberries can be propagated with hardwood and/or softwood cuttings. Many researchers used only hardwood cuttings, as they are easier to handle and are less perishable than softwood cuttings. But, softwood cuttings have rapid multiplication than hardwood ones. Cuttings used for blueberry propagation are usually dig into the pots for a time prior to field planting due to sensitivity of root anchor and the cuttings never transplanted directly to the field (Mainland, 2006; Çelik, 2006a; Çelik, 2006b; Debnath, 2007; Çelik and Ağaoğlu, 2013). On the other hand, several base or mixed mediums could be used to root of the cuttings. Pine bark or pine sawdust, sand, peat-moss, perlite, forest soils with peat-moss, podzolic forest soil with peat-moss and sand are some examples for medium to root the cuttings under controlled conditions (Heiberg and Lunde, 2006; Çelik, 2007). Both rooting medium, cutting time and type, leaves and auxin like rooting hormones affects to root number, rootling quality, degree of rooting and rooting percentage of blueberry cuttings (Mainland, 2006; Depnath, 2007; Çelik and Ateş, 2009; Çelik, 2012; Çelik, 2016; Çelik, 2017).

Mathematical models are common and they explored with computerized and/or simulation techniques (Odabaş et al., 2005; Odabaş, 2007a; Odabaş, 2007b; Odabaş and Mut, 2007; Çelik and Odabaş, 2009; Çelik et al., 2011). It is believed that simulation with basic computer program may be common-aim. Researchers mainly wanted to catch varietal developmental methods depending on the data loaded, or specific-purposes. They also intended to seize a special phenomenon. In models, information that input, range from a few parameters in equations capturing a basic mechanism to hundreds of readings in calibrated descriptive equations of many known plants (species or cultivars). Outputs include standardized numerical numbers may be completed by any images or animations generated by computers (Prusinkiewicz, 2004). There are many investigations focused on development periods of cultivated plants. Plants developed after seed sowing to reproductive phase. After this stage, reproduction and harvest period begins. There is only one mathematical modeling produced for highbush blueberry propagation with cuttings and it included auxins (IBA) and cultivars interactions (Çelik et al., 2009). Plant growth stages had different physiological process and these stages happen in different growing phase. Ambient conditions may effect to rate of dry matter production by plant. Dry matter

partitioning also had strong affection on percentage of rooting and also degree of rooting of any cutting propagated plants (Çırak et al., 2005; Çırak et al., 2007; Odabaş et al., 2005).

There is no earlier model construction on mediums used to propagate of blueberries with softwood cuttings. In the present study, we have concentrated on the interactions between mediums used for rooting of blueberry cuttings and percentage and degree of rooting. Because of this phenomenon, we focused on to develop new and useful mathematical equations for considering the effects of mediums on rooting and root quality of highbush blueberry.

2. Material and Methods

2.1. Cultivars, cutting preparations, rooting and collecting data

In the present study, Jersey [1] and Berkeley [2] highbush blueberry cultivars had 5 years old bushes were used as plant material. In July, softwood stem cuttings taken from blueberry bushes and they were washed with running water, then they rinsed in a solution of 1% sodium hypochlorite for ten minutes. After sterilization of the surfaces cuttings immediately washed with distillated water for three times. Then softwood cuttings prepared from disinfected cuttings by including 3 nodes and ½ leaves. These leafy softwood cuttings were dipped in 1000 ppm Indole-3-butyric acid (IBA) concentrations for several seconds (Çelik, 2017). After this, leafy softwood cuttings dig in 65mm diameter and 75 mm depth cell trays. In the cells, 4 basic rooting mediums and their mixture were used as rooting media. Basic mediums are peat moss (PM) [1] (Klasmann Art. Nr. 7420.5, EC=10mSs^{-1}, pH=3.5-4.5); small sized agricultural perlite (P) [2], podzolic-brownish soil (BP) [3] (soils from rhododendron forests have 4.25 pH, 0.33% CaCo3, 17.9 kg da^{-1} P2O5, 12.3 kg da^{-1} K2O and 5.52 organic material), podzolic-reddish soil (PR) [4] (soils from grassland have 5.10 pH, 0.50% CaCo3, 0.5 kg da^{-1} P2O5, 4 kg da^{-1} K2O and 3.80 organic material), and the mixture mediums are PM+P [5] in volume of 1:1, PM+BP+PR [6] in volume of 1:1:1, P+BP+PR [7] in volume of 1:1:1 and PM+P+BP+PR [8] in volume of 1:1:1:1. All soil containing mediums kept in 60°C hot water stream within 180 min. for disinfection. Rooting process done under greenhouse with 20±2°C constant temperature. Shade (35%) with net and humidity (85%) also under controlled. After a month and 15 days, cuttings removed and rooting percentage and degree of rooting (1-9 scale, 1=absent and 9=very good) (Çelik, 2017) data collected. The research was managed in a randomized complete block design and three replications (30 cuttings per replication) were used. In this section, the numbers held in the brackets indicated the cultivars and/or mediums for model development.

2.2. Model formation

In the model formation, analysis of multiple regressions applied to obtained results from rooting process of blueberry cultivars by using different mediums. For the best prediction mathematical model of the percentage and degree of rooting, a search was directed with various subsets of arguments, like medium and cultivar.

For the most appropriate of the equations to estimate the percentage of rooting and degree of rooting were stated with the SPSS 12.0 computer package (SPSS, 2017) and formulized as (1) and (2) respectively.

$$RD=(a) + [b \times (M)] - [c \times (M)^2] + [d \times (CV)] \quad (1)$$

$$RP = (a) + [b \times (M)] - [c \times (M)^2] - [d \times (CV)] \quad (2)$$

In the equations, RD is rooting degree, RP is rooting percentage, M is mediums, CV is cultivars, and the coefficients of the developed mathematical models are a, b, c, and d. Cultivars are Jersey [1] and Berkeley [2]. Mediums are peat moss (PM) [1], perlite (P) [2], podzolic-brownish soil (BP) [3], podzolic-reddish soil (PR) [4], PM+P [5], PM+BP+PR [6], P+BP+PR [7] and PM+P+BP+PR [8]. Numbers given in the bracket represents the medium used in equations. In the produced equations, the multiple regression examination was utilized on the data till the least sum of square (R2) obtain.

Graphics have three-dimensions pointed out by using "Slidewrite Program" (Çelik and Odabaş, 2009). Equation (3) also used to determine the medium has the most affection for rate of rooting and degree of rooting.

$$M = [-b / (2 \times c)] \quad (3)$$

2.3. Model validation

Multiple linear regression techniques applied to the data for developing the equations. The best version of prediction models determined and below issues considered according to a set of statistics:

- Determination coefficient (R^2)
- Statistical significance of the coefficients,

SPSS, statistical software package program was used in statistical analysis (SPSS, 2013).

3. Results and Discussion

3.1. Rooting percentage (RP)

To the data obtained by the research, actual rooting rate changed to mediums and PM+P [5] gave the lowest (12.79%) rooting percentage while PM [1] medium had the highest (86.56%). After production the models to predicted the mean rooting rate, it was estimated the mean rooting percentage between 7.68% (PM+P [5]) and 73.22% (PM [1]) by using the produced mathematical model equations (Table 1). The maximum actual rooting rate reached to 93.33% and estimated one just up to 81.13%. The second highest actual rooting rate observed from BP [3] as 31.39% but estimated data of BP [3] calculated by the equation is just 17.62%.

Table 1. The mean data, the lowest (min.) and the highest (max.) data for the real and calculated rooting rate for mediums used for rooting of blueberries.

Medium	Real Rooting Rate (%)			Calculated Rooting Rate (%)		
	Mean ±SD	Min.	Max.	Mean ±SD	Min.	Max.
PM* [1]	86.56±7.22	78.90	93.33	73.22±6.98	63.19	81.13
P [2]	16.95±4.72	12.23	21.67	14.44±4.15	6.67	20.00
BP [3]	31.39±5.82	25.57	37.22	17.62±9.33	8.90	33.00
RP [4]	29.45±4.98	24.47	34.43	12.80±11.53	2.72	30.01
PM+P [5]	12.79±6.09	6.7	18.88	7.68±3.86	4.95	13.14
PM+BP+RP [6]	13.63±3.60	10.03	17.23	12.80±6.97	4.95	24.39
P+BP+RP [7]	12.79±3.89	8.90	16.68	11.94±3.98	4.95	18.39
PM+P+BP+RP [8]	20.84±3.02	17.80	23.83	22.70±2.02	18.39	24.39

*PM: Peat moss, P: Perlite, BP: Podzolic-brownish soil, RP: Podzolic-reddish soil. Numbers in the brackets represent the medium and they are used for model construction.

The best fitting equation (4) by using multiple regression analyses to determination of rooting rate (%) for highbush blueberries evaluated. This mathematical model (4) given below showed that there is the most variation for rooting rate explained by medium and cultivar parameters. To the both parameters, the explained variation was 92.42 for mediums used to propagate highbush blueberry by cuttings (Figure 1). Here the SE represent the standard errors it was found significantly at the $p<0.001$ level.

For validation of the developed model equation by using the medium and cultivar which were the selected parameters, we produced the highest coefficient of determination $R^2= 0.9172$ (Figure 2). These coefficient results demonstrated that the equation is acceptable as statistically.

$$RP = (95.49533) + (-17.7671 \times M)+[(1.655312 \times (M)^2]+(-24.0961 \times CV) \quad (4)$$

SE = 3.78*** 1.64*** 0.17*** 1.49***

$R^2= 0.9242$

As it described in the part of methods, it can be feasible to determine the least effective rooting mixture (M) for rate of rooting using the coefficients of b and c independent variables obtained from the

mathematical models. The minimum estimating rooting percentage (7.68%) calculated from Peat moss + Perlite [5] medium and this medium is found the least effective medium.

Figure 3 also indicated that rooting rate was decreasing from number [1] to number [5] medium application. After that, rooting percentage was slightly increasing to the medium numbered 6, 7 and 8. However this increment did not approach to the top level gained by PM [1]. Rooting percentage was the highest on Jersey [1] and rooting rate was the lowest on Berkeley [5] (Figure 3). Literature also stated that rooting rate could be differed by cultivar, environment and several other factors effects to root growth and diameter (Çelik, 2006a; Çelik, 2007; Debnath, 2007; Çelik and Ateş, 2009; Çelik, 2012b; Çelik, 2016; Çelik, 2017).

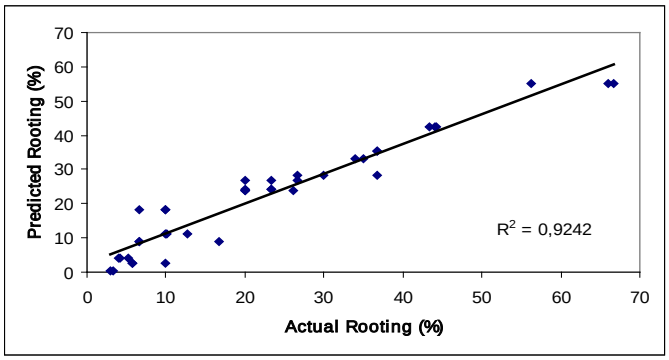

Figure 1. Correlation for actual and predicted rate of rooting gained from mediums used for cutting propagation of blueberry cultivars.

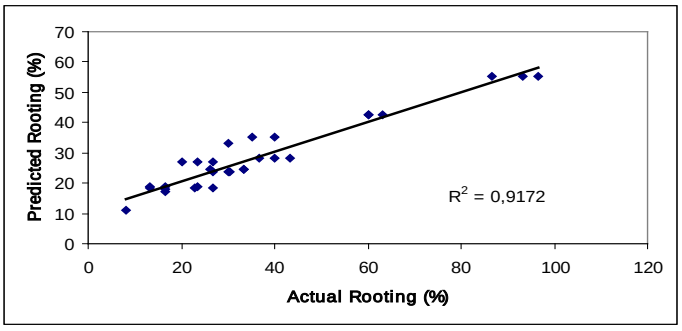

Figure 2. Correlation between real and calculated rate of rooting for mediums after validation.

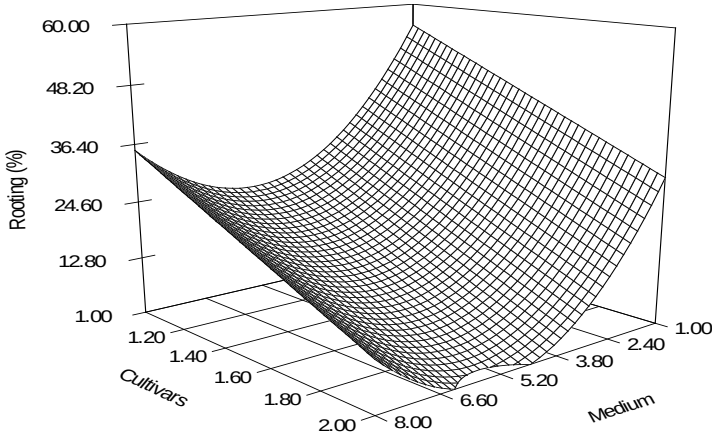

Figure 3. Changes in rooting percentage (%) with different medium and blueberry cultivars.

3.2. Rooting degree (RD)

The rooting degree determines the root growth and development. It was calculated by the root ball and its volume using the scale of 1-9. Here the actual rooting degree calculated by using the 1–9 scales changed to the mediums used for propagate the northern highbush blueberry cultivars by hardwood cuttings and it was between 1.39 (PM+BP+RP [6]) and 5.34 (PM [1]). As shown in the Table 2, calculated rooting degree count up by the produced mathematical equation model was between 1.26 (PM+P [5]) and 3.57 (PM [1]).

To reveal the overall effect of rooting medium and blueberry cultivars on rooting degree, multi-regression analysis was carried out by rooting degree (RD) against mediums and cultivars (CV) the following equation (5) was obtained. It was found that most of the variation (93.31%) in rooting degree was explained by mediums and cultivars. Standard errors are shown (SE) and they are found significant at $p<0.001$ level.

$$RD = 7.013245 + (-1.29063xM) + (0.119114xM^2) + (-1.51642xCV) \quad (5)$$
$$SE = 0.23^{***} \quad 0.096^{***} \quad 0.01^{***} \quad 0.093^{***}$$
$$R^2 = 0.9331$$

Utilizing the equation (5), the sectional effect of medium and cultivar on the degree of rooting of mediums used to propagate highbush blueberry by cuttings was shown in Figure 4.

The best fitting equation (5) by using multiple regression analyses to determination of rooting degree (1-9) for highbush blueberries evaluated. This mathematical model (5) given up showed that there is the most variation for rooting degree explained by medium and cultivar parameters. To the both parameters, the explained variation was 93.31% for mediums used to propagate highbush blueberry by cuttings (Figure 4). Here the SE represent the standard errors it was found significantly at the $p<0.001$ level.

For validation of the developed model equation by using the medium and cultivar which were the selected parameters, we produced the highest coefficient of determination 91.32% (Figure 5). These coefficient results demonstrated that the equation is acceptable as statistically.

For determine to the least effective mediums of rooting degree by using the “b” and “c” independent variables coefficients achieved from the equation (2). The medium of PM+P [5] (1.26 over 9) gave minimum rooting rate and it was the least effective medium according to the calculation data by equation, on the other hand the PM medium gave the maximum mean rooting degree (3.57 over 9). Rooting degree was decreasing till the PM+P [5] medium application. After that, a small increasing rooting degree resulted in other mediums but those were lower than PM [1]. As a result, PM [1] medium application gave the highest rooting degree. PM+BP+RP mixed medium application gave the lowest degree of rooting calculated over 1-9 scale (Figure 6). According to the researcher findings, rooting degree could be differed to cultivar, environment and several other factors effects to root growth and diameter (Çelik, 2006a; Çelik, 2007; Debnath, 2007; Çelik and Ateş, 2009; Çelik, 2012b; Çelik, 2016; Çelik, 2017).

Table 2. Means, the lowest (min.) and the highest (max.) values for the real and estimated rooting degree of medium used for rooting of blueberry cultivars.

Medium	Real Rooting Degree (1-9)			Calculated Rooting Degree (1-9)		
	Mean ±SD	Min	Max	Mean ±SD	Min	Max
PM [1]	5.34±0.34	5.00	5.67	3.57±0.75	2.81	4.33
P [2]	1.58±0.14	1.44	1.71	2.63±0.76	1.88	3.39
BP [3]	2.40±0.26	2.14	2.66	1.94±0.76	1.18	2.70
RP [4]	2.38±0.20	2.18	2.58	1.48±0.76	0.72	2.24
PM+P [5]	1.42±0.15	1.27	1.56	1.26±0.76	0.51	2.02
PM+BP+RP [6]	1.39±0.12	1.27	1.50	1.28±0.76	0.52	2.04
P+BP+RP [7]	1.43±0.07	1.36	1.50	1.37±0.68	0.78	2.30
PM+P+BP+RP [8]	1.62±0.07	1.55	1.68	1.87±0.68	1.28	2.80

*PM: Peat moss, P: Perlite, BP: Podzolic-brownish soil, RP: Podzolic-reddish soil. Numbers in the brackets represent the medium and they are used for model construction

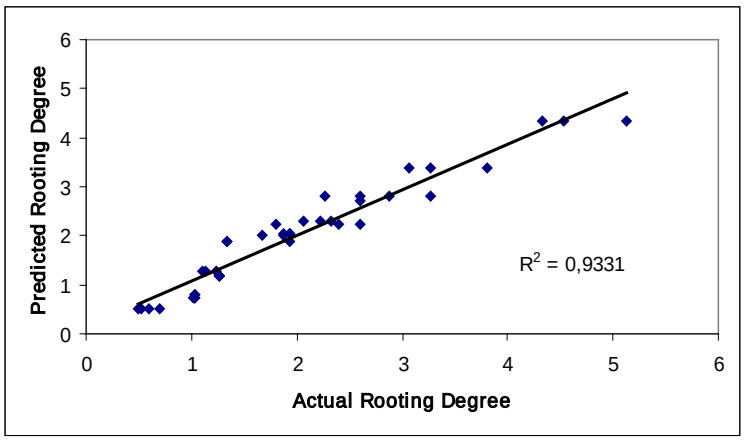

Figure 4. Correlation for actual and predicted degree of rooting gained from mediums used for cutting propagation blueberry cultivars.

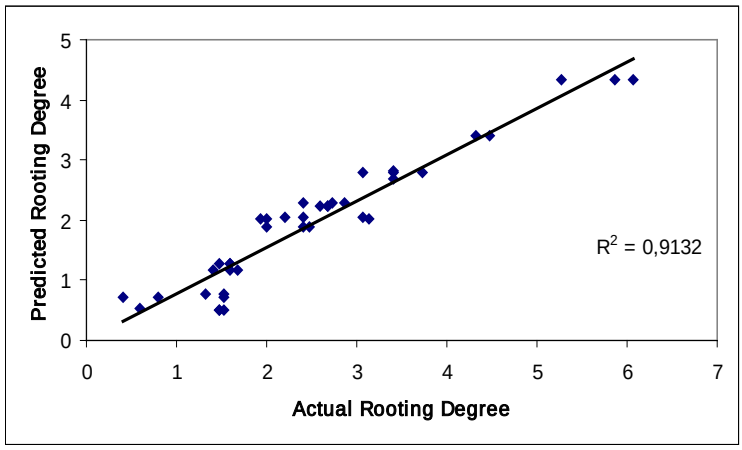

Figure 5. After verification, the correlation between real and calculated rooting degree for medium used for propagation of blueberry cultivars.

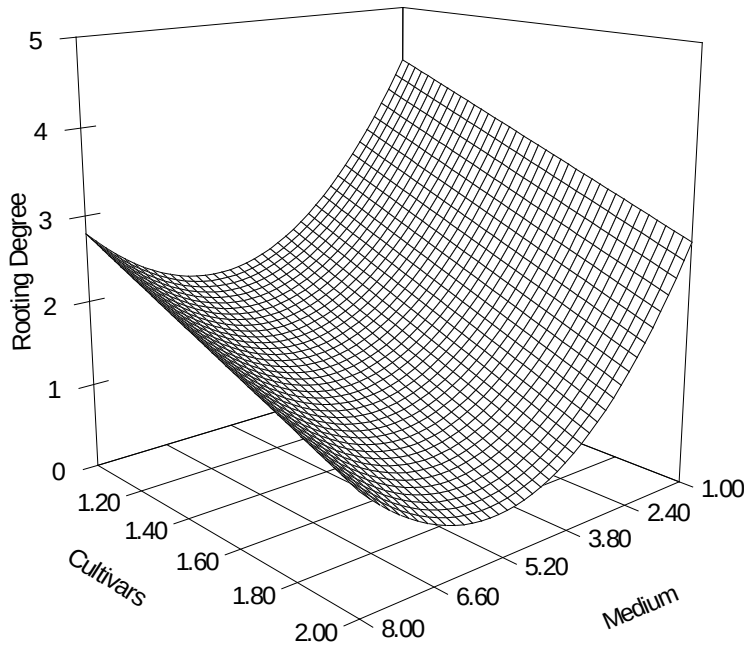

Figure 6. Changes in rooting degree with different mediums and blueberry cultivars.

4. Conclusion

As a result of the present study, produced models for determining the effect of different mediums applications on both rooting percentage (R^2=0.92) and rooting degree (R^2=0.93) of the northern highbush blueberry were found acceptable as statistically. Validations of the produced model for rate of rooting and degree of rooting (R^2=0.91) also backing up to our results. The best rooting percentage was found PM medium as 86.56 and 73.22% actually and predicted, respectively. BP is the second medium had positive effect on rooting of blueberry cuttings but not good as PM as. The highest rooting degree was also determined on PM medium as 5.34 and 3.57 actually and predicted, respectively. BP, P and or RP medium fallowed it. The developed models for rate of rooting and degree of rooting were found simple equations. These equations could be use by researcher on propagation blueberry by cuttings and they prefer which medium ere proper and/or fit for the cultivars. So, the produced models in this research could be utilize confidently by highbush blueberry researchers for the cultivars used in this work. However, different equations could be improved for other blueberry cultivars and species both used in this study and others been in *Vaccinium* genus.

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