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[Research]

Application of visual surveys to estimate acorn production of Brant`s oak (*Quercus brantii* Lindl.) in northern Zagros Forests of Iran

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ABSTRACT

Acorn production plays a fundamental role in the organization and dynamics of oak forest ecosystems. Regarding acorn importance, visual survey methods have been used to estimate acorn production of oak species throughout the world. In this study, the mast indices of Brant`s oak (*Quercus brantii* Lindl.) were determined in a section of northern Zagros forests, almost 36 ha area, near Baneh, Kurdistan province. Different types of visual surveys (Whitehead, Christisen-Kearby, Modified Graves and Koenig) were used on 120 trees which were selected using stratified random sampling method. In early September, just prior to acorn fall, each tree was investigated using visual surveys. Furthermore, for each tree, acorn density (acorns number/m^2 crown area) was calculated using crown counting to calculate the best regression model in Koenig method. Based on visual estimation indices, fair acorn production of *Q. brantii* was observed. There was a strong (R^2 = 0.73), highly significant (P < 0.001) linear relationship between the Koenig acorn counts (X) and corresponding crown counts. Furthermore, the results of this research confirmed usefulness of the quick visual survey methods to estimate the acorn crop of *Q. brantii*.

Keywords: *Acorn, Baneh, crown count, mast index, Quercus brantii, visual surveys.*

INTRODUCTION

The *Quercus* genus is one of the most widespread oaks in the Northern Hemisphere, and is dominant in many forests and woodlands (Johnson *et al.* 2002; Gea-Izquierdo *et al.* 2006; Cañellas *et al.* 2007). It is the most common genus of the family Fagaceae in forests of Iran, as well (Sabeti 1994). Different species of oaks are distributed in vast areas (about 6 million ha) of Zagros, Arasbaran and Hyrcanian Forests in Iran. *Quercus brantii*, which is the subject of this research, is the most abundant species in Zagros Forests (Jazirehi & Ebrahimi Rostaghi 2003; Panahi *et al.* 2011).

Acorn production plays a fundamental role in the organization, dynamics and sustainability of oak forest ecosystems (Healy *et al*. 1999). The abundance of acorns directly affects the regeneration of oak and the abundance of acorn-consuming species, and indirectly affects the predators and parasites of acorn consumers (Gysel 1957; Johnson 1994; Dey 1995; Elkinton *et al*. 1996; Healy *et al*. 1999; McShea & Healy 2003; Greenberg & Warburton 2007). Because of acorn importance, foresters have attempted to estimate acorn crops for decades. However, direct measures of acorn production are difficult given the height, canopy size, and density of leafy vegetation of oaks (Perry & Thill 1999). The most accurate determination of the number of acorns on a single tree can be made by a complete count before the acorns fall or are heavily utilized by animals. This can be done rather easily on small trees; on large trees, however, complete counts are difficult and time consuming (Gysel, 1956). Sampling methods are particularly challenging for many oak species (Koenig *et al.* 1994a). Ground or quadrat counts are labor intensive and subject to considerable error depending on the interval at which quadrats are checked and the presence of ground predators (Gysel 1956). Traps, which have been used in the majority of studies on acorn production (e. g. Goodrum 1971; Sork *et al*. 1993; Greenberg 2000; Steen *et al.* 2009; Rodríguez-Calcerrada *et al*. 2011) are more convenient yet suffer from at least two disadvantages: (i) because several traps must be placed under each tree and traps must be checked frequently during the acorn fall period, they are labor intensive; (ii) arboreal acorn removal by animals can be appreciable or even complete depending on the size of the acorn crop produced by both the tree being measured and other trees in the area (Christisen & Korschgen 1955). Thus, although traps may offer a viable means of measuring the number of acorns reaching the ground, they may not yield an accurate measure of overall acorn productivity (Koenig *et al*. 1994a).

These difficulties have caused an interest in alternative sampling methods, particularly visual surveys. Nowadays, these methods are commonly used to estimate acorn crops throughout the world. Visual surveys are much less labor intensive because they can be completed rapidly, require only a single visit to each tree, and require little equipment. Although visual surveys directly do not yield quantitative estimates of acorn production, they provide indices that can be compared among trees, sites, or years (Koenig *et al.* 1994a, b; Koenig et al. 1996; Garrison *et al*. 1998; Perry & Thill 1999; Koenig *et al.* 2002; Pons & Pausas 2012). Various visual survey methods have been used in oak forests. Koenig *et al*. (1994a) used a method whereby observers count acorns in the tree canopy within a given period of time (30 seconds in their case). Most other visual surveys use categorical ranks to evaluate production. The Whitehead method (Whitehead 1969) involves estimating the percentage of a tree's canopy containing mast, the percentage of twigs containing mast, and the average number of nuts per twig to derive a rank of 0 to 10. Other categorical ranking methods use subjective assessments such as "poor," "good," or "bumper" to describe mast production. Graves (1980) used a rating system of 0 (no acorns detected) to 4 (a bumper crop) and Koenig *et al*. (1994a) modified this category to 5 classes. Christisen and Kearby (1984) used a rating system ranging from 1 (few to no acorns) to 9 (a bumper crop).

Acorns of *Q. brantii* have an important role in sexual regeneration. Besides, they have been gathered traditionally by inhabitants and have been used as livestock feed in Zagros forests (Salehi *et al*. 2010). Knowledge of masting and acorn production would facilitate efforts to regenerate oak species, but unfortunately few studies have been carried out in Iran, so far. Yazdanfar (2006) and Panahi et al. (2009) made some efforts to estimate acorn crops for native oaks of Iran. Other studies have focused on acorn biomass (e. g. Fattahi, 1992; Ghorbani, 2005). Furthermore, only Pourhashemi *et al*. (2011) used Koenig visual survey method to estimate the acorn production of Q. infectoria in northern Zagros Forests of Iran. Other researchers have focused on other aspects of Zagros forests (e. g. Arekhi *et al.* 2010; Mahdavi *et al*. 2012). In this study, we will try to present the acorn production indices derived from 3 visual survey methods for *Q. brantii* in a section of northern Zagros Forests to determine the status of this species masting. Furthermore, the Koenig method will be used to present a regression model for easy estimation of acorn production.

MATERIALS AND METHODS

Study area

The study was conducted in 2010 at Halou village, a 36.5 ha natural oak forest located approximately 40 km west of Baneh (36˚5΄53˝ N, 45˚39΄34˝ E), Kurdistan province, Iran (Fig. 1). The mean annual precipitation is 647 mm, and the mean annual temperature is 13.9˚C. All of Zagros native oaks (*Q. brantii, Q. infectoria* and *Q. libani*) are found in the studied site, and *Q. infectoria* is the dominant species. Because of the traditional management of oaks in northern Zagros forests, most of *Q. brantii* trees are in coppice form, but with a single trunk.

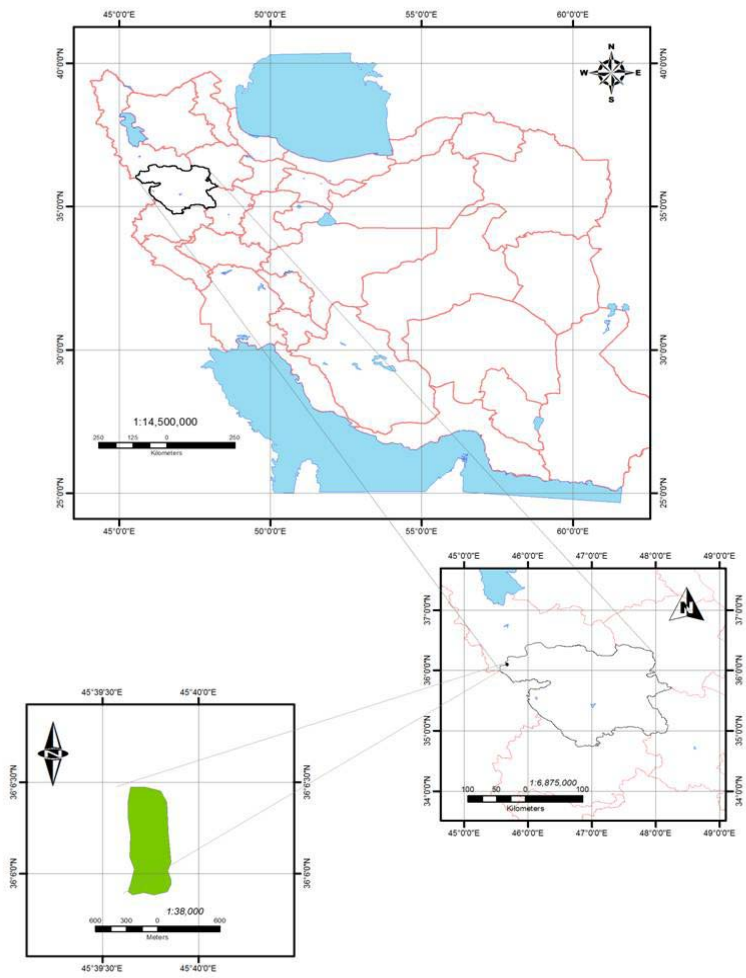

Fig. 1. Map of the experimental site

Sampling procedure

Based on dbh range of *Q. brantii* trees in the studied site, the sample trees were selected using stratified random sampling method. For this purpose, diameter range divided into diameter classes with 5 cm intervals, and then 120 Brant`s oak trees were selected, so that there were at least 2 trees in each diameter class. Trees selected were larger than 15 cm in dbh, dominant in crown position, and had visible acorn production. Furthermore, there was no contact with the crown of adjacent trees. Small and large diameter of crown was measured for each tree to calculate crown area.

Visual surveys methods

Sample trees were surveyed in early September of 2010, just prior to acorn fall. Each tree was surveyed using 4 different visual survey methods. A single observer completed all surveys to eliminate observer biases (Perry & Thill, 1999). We first used the Koenig method on each tree (Koenig *et al*. 1994a). For this survey, the observer randomly selected a portion of the crown and counted all mature acorns seen with the naked eye (because the crowns were close to the ground) during a 15 seconds period. The observer then moved to another side of the tree and counted acorns for an additional 15 seconds period. Both counts were combined, and the total number of acorns counted in 30 seconds was used as the index value. We then evaluated each tree using the Whitehead method (Whitehead 1969). First, the entire tree canopy was scanned, the percent of the crown containing acorns was categorized as 1 of 4 percentage classes (column 1, Table l), and the score for that percentage class was noted. Next, the percent of twigs within the portion of the crown containing acorns was estimated, categorized as 1 of 4 percentage classes (column 3, Tab. l), and the score for twigs was noted. Finally, the average number of acorns on producing twigs was estimated, and the score for that number was noted (column 5, Tab. 1). The overall production index (mast numerical rating) for each tree was derived by summing the scores for each of the three measures (percent of crown, percent of twigs, and average number of nuts; column 7, Tab. 1). This method results in a number between 0 (little or no mast) and 10 (a bumper crop).

Table 1. Classes and corresponding score used to determine Whitehead's mast index

Percent of crown with acorns		Percent of twigs with acorns		Number of acorn/fruiting twig		Mast numerical rating	
Class	Score	Class	Score	No	Score	Sum of scores	Acorn crop quality
<5	0	<5	0	0	0	0-2.49	Poor
6-33	1	6-33	1	1-2	1	2.5-4.49	Fair
34-66	2	34-66	2	3-4	2	4.5-6.49	Medium
67-100	3	67-100	3	5-6	3	6.5-8.49	Good
				>7	4	>8.5	Excellent

Data analysis

To standardize comparisons among different sized trees and simplify for use by foresters, the number of acorns per tree was converted to the number per m2 crown area per tree (acorn density) by dividing the total acorn production of each tree by its crown area. A tree was defined as good producer if it produced ≥ mean of acorn density, moderate if it produced ≥ 60% of mean of acorn density, and poor if it produced < 60% of mean of acorn density (Healy et al. 1999; Greenberg 2000). The acorn density of fruiting trees (excluding non-fruiting individuals) was compared among production classes using ANOVA and Duncan test at the 0.05 probability level. Crown count and Koenig index data were log transformed to reduce the correlation between the mean and variance (Zar 1999). Indices derived using the Koenig method were regressed with crown counts and the best model calculated. Ten percent of data were laid aside in modeling as witness samples (Mohammadi 2006).

Results

Diameter at breast height of sample trees had a good range, so there were various crown areas which helped us for a better analysis of acorn production. Descriptive statistics of measured variables are given in Table 3.

Table 3. Descriptive statistics of quantitative variables and acorns

Variable	Mean ± SD	Range (Min-Max)
DBH (cm)	33.3 ± 3	20-72
Height (m)	8.5 ± 0.5	5.1-9.2
Crown area (m^2)	26.1 ± 1.8	7.1-78.5
The number of acorns per tree	370.4 ± 8.9	0-7800
Acorn density	11.3	0-122.7

Low values of sample tree heights (with mean value of 8.5 m) allowed us to scan the crowns with naked eyes easily. Individual trees varied greatly in productivity. The total number of acorns collected per individual tree varied from zero to 7800. Totally, 7 sample trees had no acorn and one tree was an extreme outlier, producing 17.5% of all acorns collected from sample trees (Fig. 2).

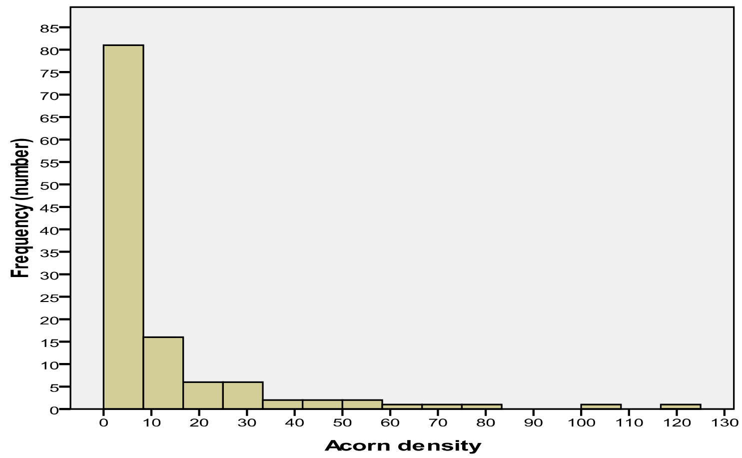

Fig. 2. Distribution of sample trees based on acorn density

Acorn production performance varied among individuals, too. A good producer comprised 23.3% (28 trees) of the sample trees, while a poor producer comprised 65% (78 trees) of the sample trees. There were significant differences among acorn production classes (F = 139.1, P < 0.0001; Fig. 3).

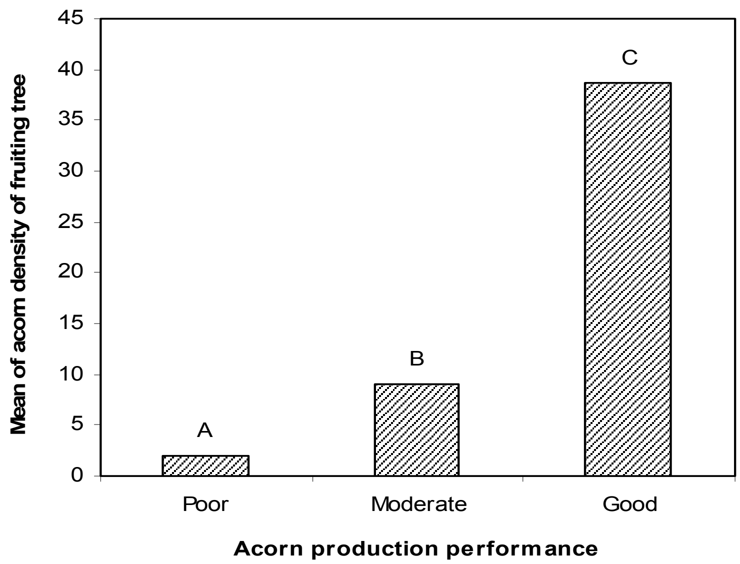

Fig. 3. Mean number of acorns/m^2 crown area produced by fruiting trees of poor, moderate and good producer. Significant differences (P < 0.05) are denoted by different letters among production classes. Acorn data were natural log transformed for ANOVA, but are presented as actual mean.

The scores and indices of visual survey methods are presented in tables 4 and 5. Although sum of scores in Whitehead method ranges from 0 to 10, we had no trees that scored a 10 and only one tree that scored a 9. Furthermore, 30% of sample trees had a score of zero and were categorized in the poor class (Fig. 4). Whitehead mast index of stand showed poor acorn production of *Q. brantii* in the studied area. A poor acorn crop usually indicates a situation where there are a few acorns early in the fall and none thereafter. There was no sample tree in bumper class of Christisen-Kearby method, too.

Table 4. Mast index of *Q. brantii* by Whitehead method

Number of sample trees	Sum of scores	Mast index	Mast class
120	305	2.54	Fair

Table 5. Mast index of Q. brantii by Christisen-Kearby and modified Graves methods

Visual survey method	Class	Score	Number of tree	Weighted score	Mast index	Mast class
Christisen-Kearby	Few to none	1	32	32	2.86	P+ or F-
	Poor	2	32	64		
	P+ or F-	3	27	81		
	Fair	4	9	36		
	F+ or G-	5	7	35		
	Good	6	1	6		
	G+ or H-	7	7	49		
	Heavy	8	5	40		
	Bumper	9	0	0		
	Sum		120	343		
Modified Graves	None	0	32	0	1.09	Fair
	Poor	1	61	61		
	Fair	2	14	28		
	Good	3	10	30		
	Bumper	4	3	12		
	Sum		120	131		

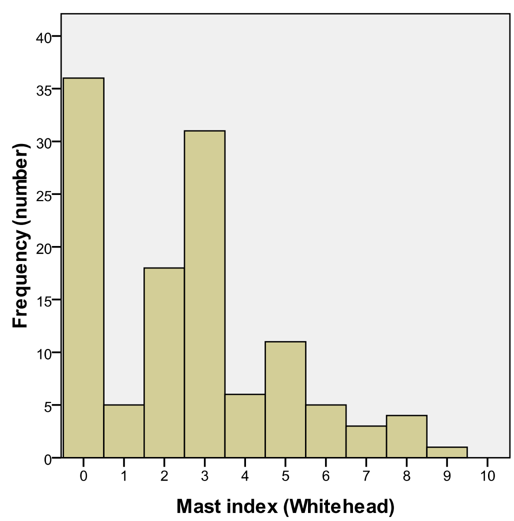

Fig. 4. Distribution of sample trees in Whitehead classes. The x axis is the sum of scores.

Regression of the total number of acorns obtained from crown counts and Koenig counts is graphed in figure 5. There was a strong (R^2 = 0.73), highly significant (F = 206.6, P < 0.001) linear relationship between the Koenig acorn counts (X) and corresponding crown counts as expressed by the following equation: y =1.36x + 1.32, where x = number of acorns counted in 30 seconds and y = crown counts. Confidence limits of crown counts of witness samples showed that the obtained linear model has statistical validity at 0.05 probability level (Table 6).

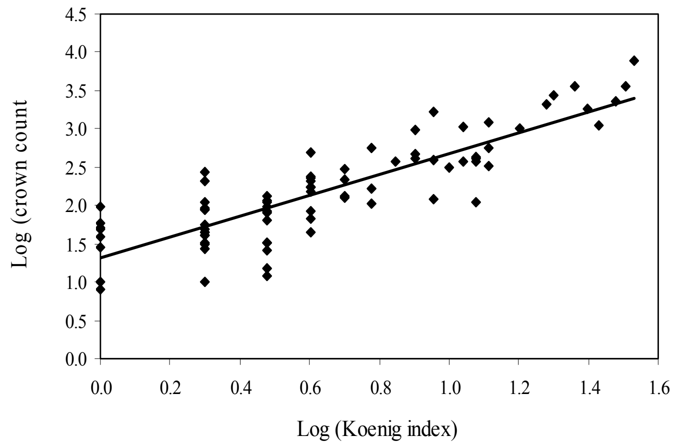

Fig. 5. The relationship between the number of acorns counted on crown and the number counted in Koenig method (Koenig index)

Table 6. Confidence limits of crown counts for witness samples

Witness sample characteristics	Upper limit of y	Lower limit of y
x = 0, y = 1	1.2	0.9
x = 0, y = 1.6*	1.2	0.9
x = 0.6, y = 1.7	2.06	1.65
x = 0.3, y = 1.9*	1.75	1.34
x = 0.8, y = 2.3	2.64	2.25
x = 0.5, y = 1.9	1.93	1.50
x = 0.7, y = 2.4	2.52	2.12
x = 1, y = 2.7	2.85	2.45
x = 1.2, y = 3	3.1	2.6

Note: Values were log-transformed
* The samples which are out of model confidence limits

Discussion

There was a great variability in acorn production from tree to tree as other studies have shown (e.g. Whitehead 1969; Christisen & Kearby 1984; Auchmoody *et al.* 1993; Dey, 1995; Greenberg 2000; Gea-Izquierdo *et al*. 2006). The number of acorn resulted from crown counts of *Q. brantii* showed that the acorn production was poor in the studied site in 2010, which was confirmed by visual indices. Panahi et al. (2009) reported the mean value of 46.5 for acorn density of *Q. brantii* in Zagros collection of National Botanical Garden of Iran, which is highly more than our research (11.3). Years of good acorn production provide more information about the potential of individual trees than did years of poor (Healy et al. 1999). Sharp and Sprague (1967) recommended identifying good acorn producers during good acorn years, but recognizing a good seed crop may take considerable field experience and need to repeat the same research during the following years in the studied area. Greenberg & Parresol (2002) found that acorn density per fruiting tree was positively correlated with the proportion of trees bearing acorns. Thus, good crop years were the result of more trees producing acorns and more acorns per tree. Conversely, poor crop years were the result of fewer trees producing, each with fewer acorns. The results of our research confirmed this matter. The large proportion of poor acorn producers decreased the value of acorn density.

On the other hand, election of estimation method should be based on economy, time, availability of workers, and scientific accuracy required. Total collection method, which was used in this research, is the most accurate one. Nevertheless, it requires the highest effort and, like all collection methods, does not permit estimating acorn yields in advance. Visual surveys are simple methods, and they provide an index to acorn production. With visual counts, acorn production can be categorized on a nominal scale ranging from no production to a bumper crop (Whitehead 1969; Graves 1980; Christisen & Kearby 1984), or acorns can be counted from a subset of the entire tree (Koenig et al. 1994a), but special attention should be devoted to the disadvantages of the visual method. They are biased if the procedures are not standardized and the observers are well trained before the survey (Garrison et al. 1998). Furthermore, various factors can affect an observer's ability to see acorns during visual surveys, especially in tal1 (>18 m) trees (Perry & Thill, 1999). Extreme sun angles, position of the observer in relation to the sun, cloud cover, and canopy leaf density can affect one's ability to accurately see acorns in trees. Acorns can be difficult to count on windy days because of branch and leaf movement, causing errors in counting with the Koenig method, whereas moving leaves reveal acorns that would otherwise not be seen and increases the accuracy of the categorical survey methods. The size of the acorn also affects the accuracy of the visual surveys. Oak species with big nuts are much easier to see than oaks with small acorns. Another shortfall of visual surveys is their susceptibility to observer differences. When more than one observer is used to conduct surveys, it is imperative that all procedures are standardized prior to conducting surveys. Different observers may count acorns at different speeds using the Koenig method or interpret what is considered a twig or branch differently using the Whitehead method. When using categorical surveys with subjective measures such as fair, good, or bumper, all observers should have prior exposure to trees with varying levels of acorn production so they know what constitutes a fair, good, or bumper mast crop. Graves (1980) demonstrated that 3 observers classified 150 trees the same only 73% of the time when using a 6 category classification survey. Thus, variation among observers can be high, especially when numerous category levels are used such as in the Christisen-Kearby method.

The four visual survey methods differed only slightly in their difficulty and accuracy. The modified Graves and Christisen-Kearby methods were the simplest to perform and took the least amount of time to complete, whereas the Whitehead and Koenig methods took slightly longer. The Koenig method is probably less affected by observer biases than the other methods. No relative knowledge of acorn production (e.g., poor, average, or bumper) is required, making it less subjective than other methods. Furthermore, there are no ambiguous terms such as "branch" or "twig" with this method. Thus, we preferred the Koenig method over the other visual survey methods.

In this research, a strong, highly significant linear relationship was found between the Koenig acorn counts and corresponding crown counts. This result is similar to what Pourhashemi et al. (2011) found in the same site for *Q. infectoria*. Koenig et al. (1994a), Garrison et al. (1998) and Perry & Thill (1999) found same results in American oaks, as well. Compared to our results, Koenig et al. (1994a) and Perry & Thill (1999) reported greater R^2 values for blue oak ($R^2 = 0.82$) and white oak ($R^2 = 0.76$), whereas Koenig et al. (1994a), Garrison et al. (1998) and Pourhashemi et al. (2011) presented lower R^2 values for valley oak ($R^2 = 0.63$), California black oak ($R^2 = 0.41$) and gall oak ($R^2 = 0.69$), respectively. These data suggest the Koenig method is highly effective in predicting acorn densities. The proposed model can be simply used in a long period (at least 15 years) to obtain useful information about masting behavior of *Q. brantii* such as mast fluctuations (cycles), variation among individuals, variation within and among years and identification of good acorn producer. Finally, we propose to repeat the same research in other sites and on other native oak species of Iran to complete our results.

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کاربرد روش‌های برآورد چشمی بذر برای گونۀ برودار در جنگل‌های زاگرس شمالی

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چکیده

بذردهی نقش اساسی در پویایی اکوسیستم‌های جنگلی بلوط دارد. با توجه به اهمیت بذر درجنگل‌های بلوط، مدتهاست که در سرتاسر دنیا از روش‌های مختلف چشمی برای برآورد میزان بذردهی بلوطها استفاده می‌شود. در این پژوهش سعی شد با استفاده از روش‌های مختلف چشمی، شاخص‌های بذردهی گونۀ برودار (*Quercus brantii* .Lindl) در بخشی از جنگل‌های زاگرس شمالی برآورد شوند. منطقۀ موردمطالعه با مساحت حدود ۳۶ هکتار در اطراف شهرستان بانه، در استان کردستان قرار دارد. چهار روش برآورد چشمی شامل روش‌های Whitehead، Christisen-Kearby، تعدیل‌شدۀ Graves و Koenig درمورد ۱۲۰ درخت نمونه که با روش نمونه‌برداری طبقه‌ای تصادفی انتخاب شده بودند، اجرا شد. شمار بذر درختان نمونه در نیمۀ اول شهریور با استفاده از روش‌های چشمی برآورد شد. همچنین شمار واقعی بذر درختان نمونه با استفاده از روش شمارش تاجی مشخص شد و برای تعیین مدل رگرسیونی در روش Koenig، تراکم بذر (شمار بذر در واحد سطح تاج) نیز محاسبه شد. مقدار شاخص-های بدست‌آمده از روش‌های مختلف چشمی بیانگر بذردهی ضعیف گونۀ برودار در منطقۀ موردمطالعه بود. مدل خطی بدست‌آمده از روش Koenig نیز همبستگی بسیار خوبی (r2=۰/۷۳) را بین شمار بذر برآوردشده با روش Koenig (x) و شمار واقعی بذر درخت (y) نشان داد. درمجموع نتایج این پژوهش سرعت و دقت قابل‌توجه روش-های برآورد چشمی بذر بلوط‌ها را برای گونۀ برودار در منطقۀ موردمطالعه نشان داد.

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