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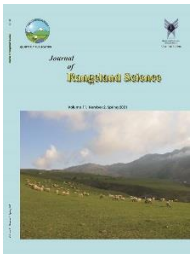

Research and Full Length Article:

Comparison of Different Methods to Estimate Forage Production of Two Shrub Species *Halocnemum strobilaceum* (Pall.) Bieband *Halostachys caspica* C. A. Mey (Case Study: Winter Rangelands of Golestan Province, Iran)

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Abstract. Proper range management needs an accurate and updated method of rangelands production measurement. In range production measurements, selecting an accurate and low-cost method is very important. In the present study, three estimation methods including Adelaide technique, and double sampling using the 20 and 30% of vegetation cover were compared with clipping and weighing method (as control) in two shrub species of *Halocnemum strobilaceum* (Pall.) Bieb and *Halostachys caspica* C. A. Mey (in May 2017). In each vegetation area, two 300m length transects with 100m distance randomly were placed. Data were collected from 15 quadrates 4m^2 along each transect systematically. In each plot, the vegetation cover and yield of two species were estimated and harvested. Data were analyzed regarding variance for each species and means comparison was done using Duncan method. Regression analysis was performed for each method between the estimated and actual clipping rates. The result showed that in *H. strobilaceum*, there were no significant differences between both double sampling with 20% and 30% and control. But higher estimation was obtained by Adelaide method than control. For *H. caspica*, there was no significant difference between both Adelaide and double sampling 30% with control. But the yield estimation of double sampling 20% was significantly higher than control. Also, the regression relationship was well matched to the data. It was concluded that the double sampling method was more suitable for *H. strobilaceum* species due to its symmetrical diameter of the canopy. The Adelaide method was recommended for *H. caspica*, which has separate foliage.

Key words: Forage production, Double sampling, Adelaide technique, *Halocnemum strobilaceum*, *Halostachys caspica*

Introduction

Understanding biomass fluctuations in natural systems is important for managing and conserving biodiversity (Coughenour, 2005; McIntyre *et al.*, 2010; Eldridge *et al.*, 2016; Abdalla *et al.*, 2017). Also, selecting the best method to estimate biomass in ecological, agricultural and forestry researches is important (Boufennara *et al.*, 2019; Fakhar Izadi *et al.*, 2019). The most suitable technique depends on available budget, accuracy required, vegetation composition, and species growth form (Foroughbakhch *et al.*, 2009; Newell and Hayes, 2018). The effective range management requires accurate information on rangeland forage production. Production sampling techniques refer to specific procedures by which shrub parameters may be estimated or measured while sampling strategies are related to the allocation of sample locations at which inventory data are collected. Assessment of specific sampling techniques is divided between techniques that directly measure plant parameters, and parameters that are performed using auxiliary variables and indirect methods. Many techniques have been developed for estimating production such as Adelaide technique, double sampling using cover percent, clipping and weighing method, etc. Finding a method that has superior accuracy, speed and low cost compared to other methods is important. In analysis and assessment of rangeland, there is a time limit and the use of experts. Since for the specific area, there is no available information about the proportion of total biomass as forage, Easdale and Aguiar (2012) suggested estimating using the proportion of forage cover of dominant species in relation to total cover. Although canopy volume estimation has no accurate information regarding shrub production, Foroughbakhch *et al.* (2005) reported that Adelaide and double sampling were the most precise, practical and simplest methods so that they could be considered as the method of choice for measuring the forage biomass of many shrub species. However, the clipped estimates of production are regressed upon visual estimates of canopy volume in a double sampling procedure (Foroughbakhch *et al.*, 2005).

Adelaide method was used in Australia for the first time in 1979. This method was used in Isfahan province, Iran. In this method, the relationship between forage production as an independent variable and some factors including canopy diameter, height, canopy cover, volume, average diameter height as dependent variables to estimate forage production in *Atriplex canescens* and *Haloxylon ammodendron* and efficiency of this method was proven. Their results showed that volume in *A. canescens* and height of *H. ammodendron* were the most effective factors for estimating forage production (Javadi *et al.*, 2011).

The most important factors in the estimation of production are selecting the suitable method. In this sense, the use of non-destructive methods might be a good alternative for evaluating the production of the biomass of wood producing plants. Thus, research works are required to fill this gap and estimate the forage potential of shrubs on shrub land.

Both *H. strobilaceum* and *H. caspica* belongs to the Chenopodiaceae family and is mainly distributed in the Province of Golestan in Northeastern Iran that grows in areas where the groundwater level is high and saline soil. These plants have been used in desert areas as high forage yield with good nutritional properties ((Zhao and Feng, 2001; Sharifirad *et al.*, 2017).

The aim of this study was to compare different methods of estimation of forage production of two species (*H. strobilaceum* and *H. caspica*) in shrub rangelands of Golestan province, Iran.

Materials and Methods

Study area

This research was performed in winter rangelands of Golestan province with the area of 37963 ha (Fig.1) which is located in Northeast of Iran (37º10´ N, 54º2´ E to 37º18´ N, 54º15´ E). The maximum elevation of the study area is -11 m and the minimum elevation is -24 m above sea level (m a.s.l.). Mean annual precipitation of the area is 343.3 mm and mean annual temperature is~ 28.3 ℃. According to DE Martten division, this area is a part of semi-arid regions.

Data collection

The survey of vegetation quantities was initiated in 2017 for one year. Initially, the distribution area of *Halocnemum strobilaceum* and *Halostachys caspica* in two vegetation types (4 ha) was determined by field surveys and topographic maps of the region. Based on the distribution of species and the area studied, four 300m length transects with 100m distance were randomly placed in each vegetation type. The data were collected from 15 quadrates 4m^2 along each transect systematically. Quadrate size was determined for each vegetation type using minimal area method (Cain, 1938). Data were collected in the spring (the last stage of vegetative growth).

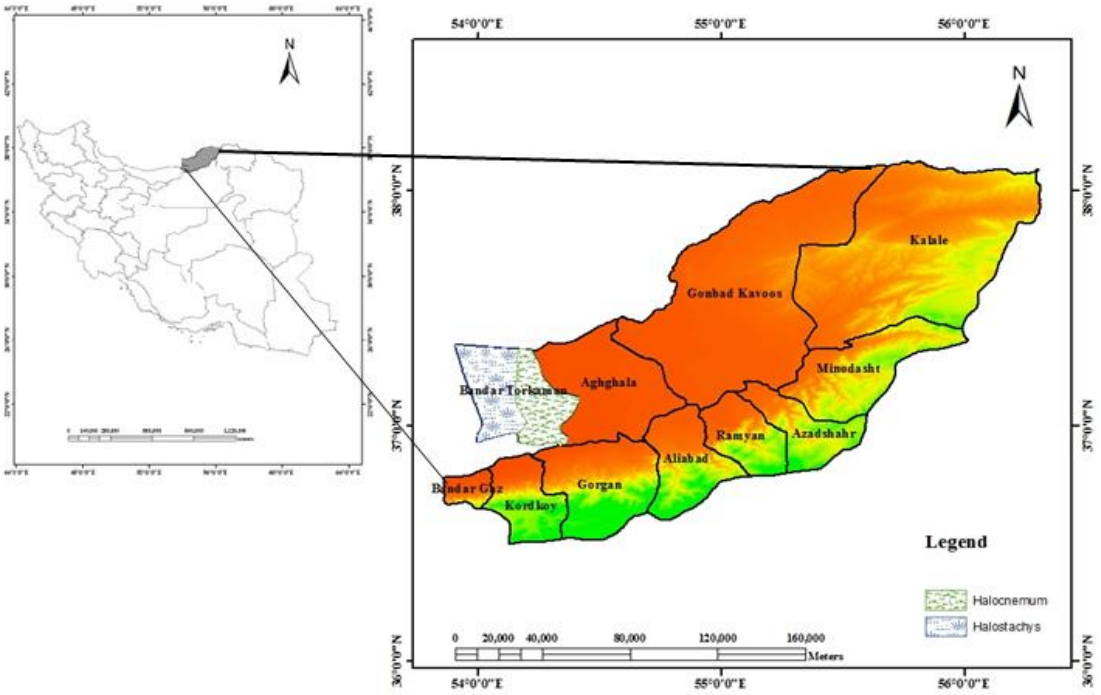

Fig. 1. Location of study area

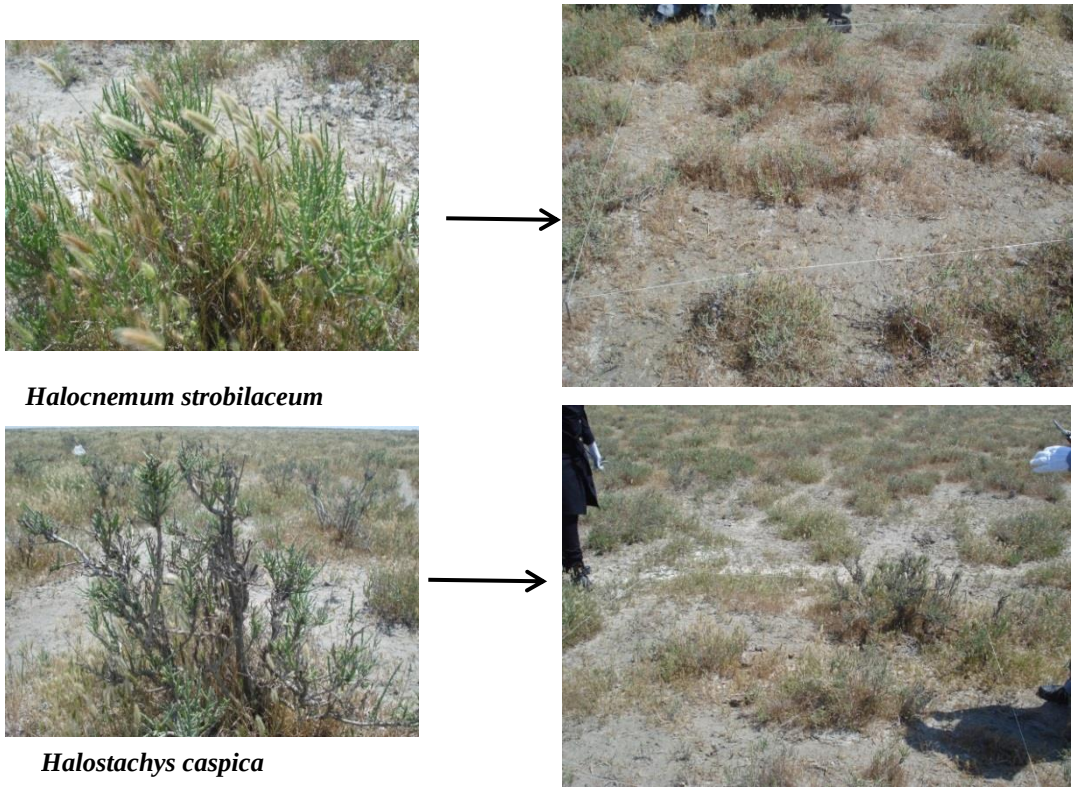

Fig. 2. Pictures of the studied species in type 1 and 2

Clipping and weighing Method

Clipping vegetation to annual growth and then weighing are the most direct and objective ways to measure the brushes biomass (Van Dyne *et al.,* 1963). Measurements of annual forage yield of two species (*Halocnemum strobilaceum* and *Halostachys caspica*) were carried out with plot area and clipping and weighting method. Though "clip-and-weigh" methods are highly accurate, they are very time consuming (Van Dyne *et al.,* 1963). Therefore, in this study, this method was examined as a control treatment to compare with other methods.

Adelaide Method

The method includes the selecting of a branch from each species which is taken from outside of the study area. This branch is called the reference unit (Andrew *et al.,* 1979; Andrew *et al.,* 1981 and Cabral and West, 1986). It should represent the form and foliar density of the branches for each species. Then, using this reference unit, the number of branch units for each sampled shrub was estimated. The shrub was harvested at the end of the measurement period to determine its leaf biomass. Then, the regression equation which fits the relationship between leaf dry matter and the number of units was chosen to predict the leaf biomass as forage on site for other individual shrubs of the same species (Froughbakhch *et al.*, 2005).

Double-Sampling Method

Although the harvesting method is highly accurate, it is also very time and labor consuming. Therefore, harvest techniques are usually combined with indirect estimation techniques in methods known as "double sampling". In contrast, the estimation method is more rapid but not as accurate. By combining the harvest and estimation methods, the Double-Sampling Method can reduce the time that it takes to sample and is still fairly accurate. This procedure basically requires that the observer estimates the weight of several

plots and then clips a few more plots to determine the accuracy of estimations. It can be much more efficient than direct sampling of the primary variable if the secondary variable can be measured quickly and it is highly correlated with the primary variable (Reid *et al.*, 1990). The formulas for data analysis and sample size estimation are much more complex than those of other methods.

Statistical Analyses

In this research, production estimation methods were considered as treatments in two species *(H. strobilaceum* and *H. caspica).* The collected data were analyzed using SPSS version19 software. First, One-way ANOVA was conducted to test the differences between the three methods (double sampling,20% and 30%, and Adelaide method) compared to the clipping method (control treatment) and means comparison was made using Duncan method. Regression analysis was performed for each of the methods between the estimated and actual clipping rates.

Results

The collected data were analyzed in relation to variance for determining the best method for estimating the plant production in Golestan winter rangeland with *H. strobilaceum* and *H. caspica* leading to a special result that comes in following. The VIF (variance inflation factor) were less than 5, and as a result, the independent variables did not have multicollinearity. The regression analysis between the estimated yield and clipping and weighing rates (kg/ha) is shown in (Equation 1 to 6 (Table 1)). The result of regression analysis showed significant relationships between estimation values and actual yields for all of the three methods in both species P <0.01). Also, results showed that the Adelaide method produced the best fit for *H. caspica* (R^2 =0.91). The double sampling method (20%) had the highest precision in the case of *H. strobilaceum* (R^2 = 0.91) and double sampling (30%) in the case of *H. caspica* (R^2 =0.95) (Table 1).

Table1. Regression equations of three estimation methods

Regression between Methods	*Halocnemum strobilaceum*			*Halostachys caspica*		
	Regression equations	R^2	Sig.	Regression equation	R^2	Sig.
Adelaide vs. clipping/weighing	$W_{H.s}$ =7.44m+14.27	0.57	0.008	$W_{H.c} = 7.8m + 14.1$	0.91	0.00
DSM (20%) vs. clipping/weighing	$W_{H.s}$ =2.78m+24.1	0.91	0.001	$W_{H.c} = 1.3m + 7.5$	0.88	0.00
DSM (30%) vs. clipping/weighing	$W_{H.s}$ =3.0m+18.7	0.89	0.002	$W_{H.c} = 2.5m + 4.5$	0.95	0.00

DSM = Double Sampling Method, W=Estimated value m=actual estimation in different methods

Results of ANOVA analysis are presented in (Table 2, Fig 3). The comparisons among the means of treatments (different methods) for *H. strobilaceum* are shown (Fig 3). Results showed that average values of double sampling (20% and 30%) had no significant differences with control (clipping method) (p>0.05) and the average value of Adelaide method showed a significant difference with control (p< 0.05).

Also, results of comparisons among the means of treatments (different methods) for *H. caspica* are shown in (Table 2, Fig 4). Results showed that average values of double sampling (30%) had no significant differences with the control (p>0.05); the average of double sampling (20%) had significant differences and Adelaide method showed no significant difference with control (p>0.05).

Table 2. The comparison of treatments means (three methods) with control treatment (clipping method) fortwo species under study

Sources	DF	MS	
		H. strobilaceum	*H. caspic*
Between groups	3	50866.81**	183.97**
Within groups	20	161.575	30.989
CV%		31.48	11.2

**=significant at 1% probability level.

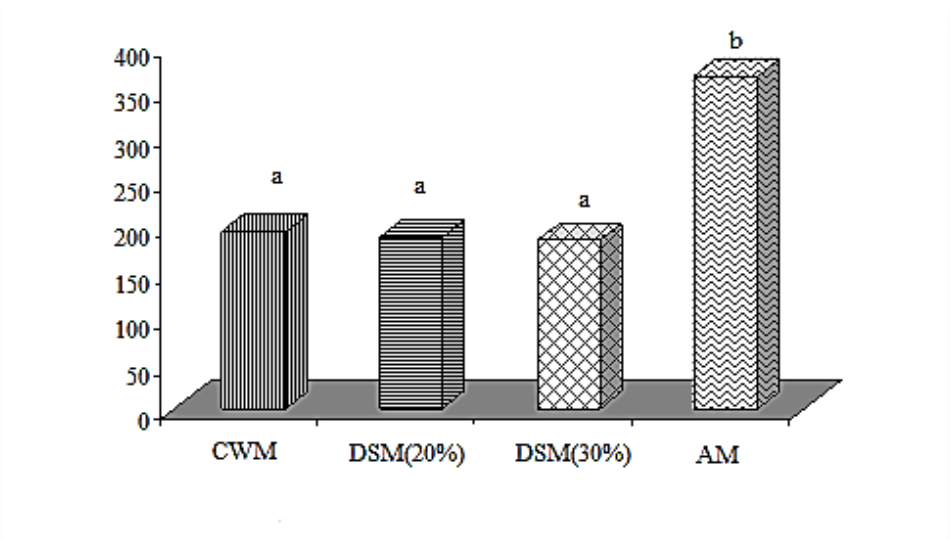

Fig. 3. Comparison between means of different methods for *H. strobilaceum*
CWM: Clipping and Weighing Method; DSM: Double-Sampling Method;
AM: Adelaide Method. Dissimilar letters indicate significant differences, (Duncan test, P < 0.05).

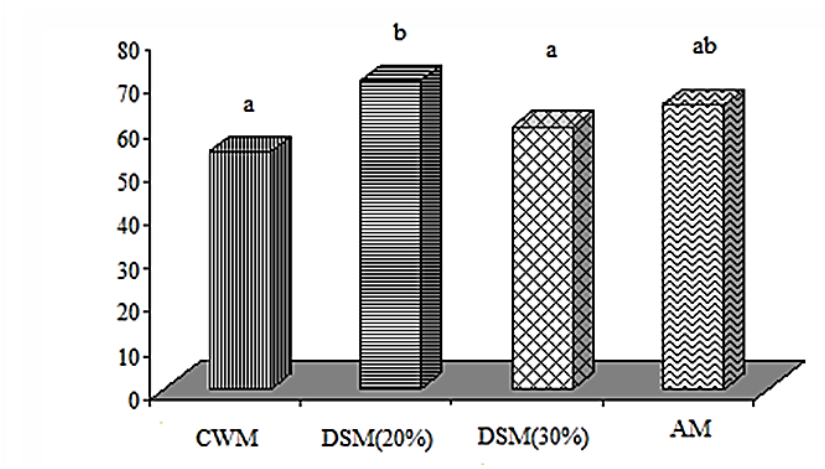

Fig. 4. Comparison between means of different methods for *H. caspica*
CWM: Clipping and Weighing Method; DSM: Double-Sampling Method;
AM: Adelaide Method. Dissimilar letters indicate significant differences, (Duncan test, P < 0.05).

Discussion

The semiarid rangelands of Golestan western presented differences in the forage production methods in both ecological regions. In general, the species variation in forage production (Fig 2) was the main difference between the two ecological regions. The output of this research showed that the double sampling method is suitable for two studied species. In addition, for *H. caspica*, no significant difference was observed between the Adelaide method and the clipping method. This can be due to the separate foliage of the plant, which is easily calculated by the number of branches. These results are consistent with previous studies

(Flombaum and Sala, 2007; Foroughbakhch *et al.,* 2009; Gholami *et al.,* 2012; Tarhouni *et al.,* 2016) who confirmed using of Adelaide and dimensional analysis for shrub biomass that are non-destructive and faster compared to the harvest technique. Louhaichi *et al.* (2018) found a positive correlation between vegetation cover and DM biomass for seven shrub species: *Atriplex leucoclada* (Moq.) Boiss., *A. halimus* L., *A. lentiformis* (Torr.) S. Watson, *A. canescens* (Pursh) Nutt. A. *nummularia* Lindl., *Salsola vermiculata* L. and *Haloxylon aphyllum* (C.A. Meyer) Bunge. Also, Karl *et al.* (2020) approved the use of field estimates for understanding the impact of livestock use on riparian woody vegetation and pointed out that cloud techniques using unmanned aerial systems generally underestimate canopy volume compared with the field technique. But Gholinejad *et al.* (2012) found that double sampling method has an error for production measurement in mountain region with the predominance of *Astragalus* species (In Kurdistan Province, Iran). The reason for its incompatibility can be the presence of grasses and forbs in these rangelands.

The means comparison of *H. strobilaceum* using Duncan test showed that mean value of Adelaide method was higher than the control ($p < 0.05$). Therefore, this method has no accuracy for measuring the forage production for *H. strobilaceum* and it is not recommended for this species. According to obtained results, canopy cover of *H. strobilaceum* was in agreement with Double-sampling method. In fact, the morphology of the species is heterogeneous (Foroughbakhch *et al.,* 2005).

Adelaide and Double-Sampling (30%) methods showed the closest relationship with clipping method for shrub of *H. caspica*. These results are in agreement with Sanchez and Febles (1999) and Foroughbakhch *et al.* (2009) in order to determine the most accurate estimating procedure studied five nondestructive allometric methods for shrub species. They found the highest value of the coefficient of determination for Adelaide and dimensional methods compared to other estimation methods. Many scientists such as Arzani (1994), Sadeghinia *et al.,* (2003), Salem and Papachristou (2005) and Tarhouni *et al.* (2016) emphasized this point that Adelaide and Double-Sampling methods can be used to estimate forage production for shrub and woody species.

In *H. strobilaceum* vegetative form and foliage had dense volume and it has little free space between its leaves and foliage (Hosseini *et al.,* 2007). It means that Adelaide method in *H. strobilaceum* has variations of the production with cutting and weighing method rather than *H. caspica*. Therefore, the dense form of the plant caused variations of the production. In contrast, there was more free space between leaves and foliage in *H. caspica* and its leaves were not very compact unlike *H. strobilaceum* in which growth begins almost near the ground so that the stem of *H. caspica* is above the ground surface and branches and its leaves are at the top of the plant. Because of these properties, Adelaide method probably indicates higher correlation with cutting and weighing method. In this regard, considering different species easily measured morphological parameters leads to better estimation.

The results of the correlation coefficient analysis between the predicted and the measured yield confirmed that for *H. strobilaceum* double sampling method is more correlated with clipping method. This result agreed with those of Melgoza and Fierro (1980) who confirmed that one of the best parameters for quantifying biomass is canopy projection and coverage. In *H. caspica* this correlation was also relatively high for Adelaide method. These results are in agreement with Sanchez and Febles (1999) and Foroughbakhch *et al.* (2009) who reported that the highest value of the coefficient of

determination on woody shrub species was obtained with double sampling and Adelaide methods compared to other estimation methods.

Conclusion

The results of the study showed that the method of measuring the cover is almost correct, accurate and fast because there is a direct relationship between production and cover. One of the disadvantages of this method is that in all shrubs, the surface of the canopy cannot be assumed in a circular shape and also, it is difficult to measure the diameter of plants in rangelands where livestock have been grazed because of the change in the shape of the canopy. In addition, the Adelaide method is suitable for species with open foliage. We recommended that for each plant species in different ecological habitats, an appropriate method based on the plant morphology and foliage density should be applied in order to determine the forage production more simply, practically and reliably. It was concluded that the double sampling method was more suitable for *H. strobilaceum* species due to its symmetrical diameter of the canopy. The Adelaide method was recommended for *H. caspica*, which has separate foliage

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مقایسه روش‌های برآورد تولید در دو گونه بوته‌ای *Halocnemum strobilaceum* (Pall.)Bieb و *Halostachys caspica* C. A. Mey (مطالعه موردی: مراتع قشلاقی استان گلستان)

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چکیده. یکی از ضروریات مدیریت صحیح مرتع، داشتن اطلاعات دقیق و به‌هنگام از تولید مراتع است. در اندازه‌گیری‌های مرتع، روشی که از نظر دقت، سرعت و هزینه نمونه‌برداری نسبت به سایر روش‌ها ارجحیت داشته باشد، از اهمیت بالایی برخوردار است. در تحقیق حاضر، سه روش برآورد تولید مرتع: روش‌های آدلاید، نمونه‌گیری مضاعف با استفاده از ۲۰ و ۳۰ درصد تاج پوشش با روش قطع و توزین (به عنوان تیمار شاهد) در دو گونه بوته‌ای *Halocnemum strobilaceum* و *Halostachys caspica* (اردیبهشت ۱۳۹۶) مقایسه شد. در هر تیپ گیاهی، ۲ ترانسکت ۳۰۰ متری با فاصله ۱۰۰ متر از یکدیگر به صورت تصادفی قرار داده شد. داده‌ها از ۱۵ پلات ۴ مترمربعی به صورت سیستماتیک، در امتداد ترانسکت‌ها جمع‌آوری گردید. در هر یک از این پلات‌ها، پوشش گیاهی و تولید دو گونه برآورد و برداشت شد. داده‌های جمع‌آوری شده از نظر واریانس آنالیز گردید و مقایسه میانگین آنها توسط آزمون دانکن انجام شد. آنالیز رگرسیون نیز برای هرکدام از روش-ها بین مقدار برآورد شده و قطع و توزین شده، انجام گرفت. نتایج نشان داد که در گونه *H. strobilaceum* روش نمونه‌برداری مضاعف (۲۰ و ۳۰ درصد) با تولید واقعی (شاهد) تفاوت معنی‌داری نداشت، ولی برآورد تولید بیشتر در روش آدلاید، با اختلاف معنی‌داری بیشتر از تولید واقعی بدست آمد. در گونه *H. caspica*، تفاوت معنی‌داری بین روش تخمین با ۳۰ درصد و آدلاید با تولید واقعی وجود نداشت، اما برآورد تولید با ۲۰ درصد پوشش به‌طور معنی‌داری بیشتر از روش کنترل (تولید واقعی) بود. همچنین، رابطه رگرسیون به خوبی با داده‌ها مطابقت داشت. در پایان نتیجه‌گیری شد که روش اندازه‌گیری مضاعف برای گونه *H. strobilaceum* به دلیل متقارن بودن قطر تاج پوشش مناسب‌تر است و روش آدلاید برای بوته‌ای‌هایی مانند *H. caspica* که دارای شاخ و برگ مجزایی هستند، توصیه می‌گردد.

کلمات کلیدی: تولید مرتع، روش نمونه‌گیری مضاعف، روش آدلاید، *Halocnemum strobilaceum*، *Halostachys caspica*