Comparison of Distance Indicators and Quadrate Indicators in Determining Dispersion Pattern of *Fritillaria imperialis* L. in Ilam

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Abstract

Crown imperial have been distributed in Zagros regions in Ilam according to soil structure and organic matter. This plant has played an important role in the beautification of the environment, tourist attraction, and the supply of plant essential oils used in the production of medicines. The current research was carried out to evaluate the spatial distribution pattern of *Fritillaria imperialis* in Ilam (Manesht and Ghalarang regions) and to compare distance and quadrate method in 2014. Sampling program was random-systematic just for transects with the length of 100 meters within the extent of 4300 hectares. Distance methods including t^2, Hopkins, Holgate, Johnson and Zimmer and Pielou; and quadrate methods including Taylor, Iwao, Morisita, K and CV were used to determine the spatial distribution pattern of crown imperial. Results showed that the quadrate method (Morisita and CV) and distance method (Holgate and Peilou) evaluated the spatial distribution pattern of crown imperial to be a random pattern. But, the results of quadrate methods (Taylor, Iwao, and K) and distance methods (Hopkins, t2 and Johnson and Zimmer) evaluated a clumped pattern for this species in the study area. It was shown that the distance methods outperformed quadrate methods in accuracy. Also, t2 and Hopkins indexes were the best distance methods to identify the pattern. Iwao and K indexes were the best ones among quadrate methods. Overall, it was revealed that Iwao, K, t^2, and Hopkins had the highest and CV, Morisita, Holgate and Pielou had the lowest accuracy.

Keywords: Clumped, Crown imperial, Hopkins, Morisita, Taylor.

INTRODUCTION

The genus *Fritillaria* L. (Liliaceae) consists of approximately 140 species and is widely distributed in Europe (mostly in the Mediterranean region), Central Asia, China, Japan, and North America (Day *et al.*, 2014; Li *et al.*, 2018). These taxa are mainly in Turkey (Teksen and Aytac, 2011), and the Zagros Mountains of Iran are known as the center of diversity above the species level (Rix, 1997). *Fritillaria* species in Iran are represented by diploid (2n= 24) taxa (Jafari *et al.*, 2014), and this genus is represented by species, all belonging to genus *Fritillaria* (Mozaffarian, 1998).

The medicinal use of *Fritillaria* species is also well established in China, the Himalayas (India, Nepal, and Pakistan), Japan, Korea, and Southeast Asia (Day *et al.*, 2014). In traditional Chinese medicine, the medicinal *Fritillaria* species is called Bulbus *Fritillaria* Cirrhosae (BFC), also known by the Chinese name "Chuan Bei Mu," which has been used as a traditional medicine for thousands of years. BFC was recorded in the traditional Chinese medicine book Shen Nong Ben Cao Jing (The Divine Farmer's Materia Medica Classic), which is one of the earliest classic medical book written in the Eastern Han Dynasty (Wang *et al.*, 2015).

In ecological or demographic studies, pattern is defined as a quantitative description of the horizontal distribution of individuals of a species within a community. This has been widely studied by comparing communities and ecosystems as a means of providing a mechanism to foresee the functional state of the system (Ludwing and Reynolds, 1988). Knowledge about the dispersion pattern of an organism is essential in understanding population biology, resource exploitation, and dynamics of biological control agents (Greig-smith, 1979). It provides a better understanding of the relationship that exists between an organism and its environment which may be helpful in designing efficient sampling programs for population estimates to develop population models (Soemargono *et al.*, 2008). The dispersion of individuals across a population describes their spacing relative to each other. Different species and different populations of the same species can exhibit drastically different dispersion patterns (Fig. 1). Generally, the dispersion can follow one of three basic patterns: random, uniform (evenly spaced or hyper-dispersed), or clumped (Brower and Zar, 1977).
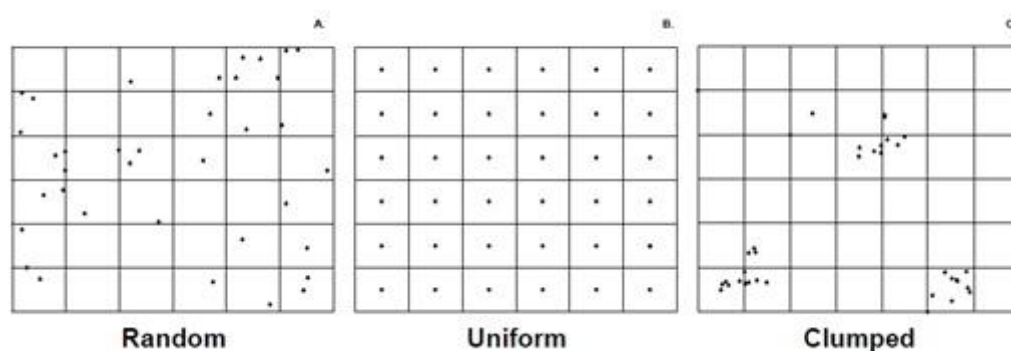

Fig. 1. Common dispersion patterns. A, B, and C represent the spacing of individuals within a population relative to one another. The entire square indicates the entire quadrat, and each small square indicates one sub-quadrat (Ludwing and Reynolds, 1988).

There are various studies on the spatial distribution and population density of different plant species. Comparing the distance-based and quadrate-based methods of spatial pattern in central deserts of Iran are covered with sexual (*Haloxylon* spp.), were investigated that Johnson and Zimmer index, standardized Morisita and dispersion indices showed the clumped pattern for sexual while the other indices showed random pattern. In district II, all indices showed clumped pattern except for Johnson and Zimmer index (Kiani *et al.*, 2013).

Other researchers have evaluated the influence of propagules source and the implication of tree size class on the spatial pattern of *Xylopia brasiliensis* Spreng. The population showed different spatial distribution patterns according to the spatial scale and diameter class. While small trees tended to be aggregated up to around 80 m, the largest individuals were randomly distributed in the area. A plausible explanation for the observed patterns might be the limited seed rain and intra-population competition (Higuchi *et al.*, 2010).

In Kohgiluyeh and Boyer Ahmad province, a plot in Servak forests near Yasuj was chosen as the study site. The 30-ha plot was surveyed by full callipering method and the position of each tree was determined by azimuth and distance measurement to prepare the point map of tree locations. Using Nearest Neighbor index, the spatial pattern was determined as dispersed. Then, two main distance methods, namely T-square sampling and index of dispersion, were compared to figure out the most suitable one in the study site as a method of spatial pattern analysis (Erfanifard *et al.*, 2008).

MATERIALS AND METHODS

The present study was carried out in the Manesht and Ghalarang forest region with a 2,900 ha area located within a protected area in the northeast of Ilam province to the west of Iran in 2016. This region is situated between 46°20′56″ and 46°27′37″ East longitudes and 33°40′20″ and 33°45′20″ North latitudes. This region is limited with the Dalab River from the south, Manesht Mountains from the east, Bankul Mountains from the north, and Sharah Zool Mountains from the west (Fig. 1). The altitude in this region varies from 320 m in the north to 2,650 m in the west. According to available data from the nearest climatic station to the Manesht and Ghalarang woodlands, the mean annual rainfall is 630 mm, the mean maximum annual temperature of the warmest month is 26°C, the mean minimum annual temperature of the coldest month is 8°C, and the average relative humidity of the region is 47%. Surface soil with loamy clay texture is placed on a soil layer with heavy texture of gravel. Soil depth is relatively high and does not exceed one meter. Soil pH of this region is 7.5-8

Fig. 2. Map of the study site in the Manesht and Ghalarang regions (the city of Ilam).

Fritillaria imperialis (also called Ashk-e Maryam) is one of the members of Liliaceae family that grows every year in its endemic region and has a perennial large bulb. Morphologically, it has a thick brown cylindrical stem, bare of leaves under flowers. Located in the lower part of the stem, the spear-like leaves are green, oval and sharp (Fig. 3). A bunch of leaves at the end of the stem grows and 5 to 8 bell-shaped red flowers with curved peduncles appear at the end of leaves. This plant grows widely in Iran, usually in May (Bonyadi *et al.*, 2017).

Fig. 3. *Fritillaria imperialis* in Ghalarang region of Ilam.

In this study, we used distance and quadrate method for investigation of the spatial patterns of *Fritillaria imperialis* where fixed-area sample plots were established and the number of points was counted within each plot. Based on quadrate count data, the sample variance/mean ratio was proposed as an index of dispersion, an index of random, uniform and clumped was developed, and the quadrate sampling method was focused on because of its better results comparing to distance sampling (Musaei Sanjerehei and Basiri., 2007).

Calculation of the variance to mean: which in turn would be valuable for $S^2/\bar{X}$. Departure from the random distribution was then ecological, tested by calculating the index of distribution (I_d), as the objectives of the present study were to determine using equation 1 (David and Moore, 1954):

$$(1)\ I_d = (n-1)\frac{s^2}{m}$$

Morisita's coefficient of distribution: The uneven distribution coefficient ($I\sigma$) was calculated through Equation 2 (Morisita, 1962):

$$(2)\ I\delta = N\frac{\sum n_i(n_i-1)}{n(n-1)}$$

where *n*, xi and *N* are the number of sample units, *i* number of individuals in each sample unit and total number of individuals in n samples, respectively.

Taylor power law: This law describes the regression between logarithm of population variance and logarithm of population mean according to Equation 3 (Taylor, 1961):

$$(3)\ \mathrm{Log}\,(S^2) = \mathrm{Log}\,(a) + b\,\mathrm{Log}\,(\bar{X})$$

where S_2 is the population variance, $\bar{X}$ is population mean, *a* is the *y*-intercept and *b* is the slope of regression line.

Iwao's patchiness regression models: Iwao patchiness regression method was applied to quantify the relationship between mean crowding index (*m**) and mean ($\bar{X}$) using Equation 4 (Iwao, 1968):

$$(4)\ m^* = \alpha + \beta\bar{X}$$

where *α* and *β* refer to the tendency to crowding/repulsion and the distribution of population on space, respectively.

***K* index:** This equation can be transformed as Equation 5 (David and Moore, 1954):

$$(5)\ NLn\left(1+\frac{\bar{x}}{\hat{k}}\right)-\sum\left(\frac{A_x}{\hat{k}}\right)=0$$

N is the number of samples, the average population and total abundances observed from the sampling units that are more than one, respectively. Small amounts (less than 8) show the cumulative distribution, and large amounts (greater than 8) show random distribution.

t^2 index: To calculate the index, (X) between the random point (O) to the nearest plant (P) and (Y) distance between plants (P) to the nearest neighbor (Q) are measured so that the angle of over 90 degrees QPQ (Fig. 4). This equation can be written as Equation 6 (Ludweing and Reynolds, 1988):
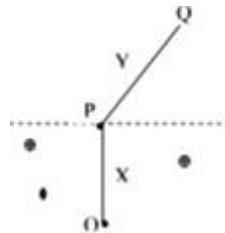

Fig. 4: t^2 index (Mcmurry, 2000)

$$(6)\ C=\frac{\sum_{i=1}^{N}\left[X_i^2/\left(X_i^2+\frac{1}{2}Y_i^2\right)\right]}{N}$$

where *N* is the number of sampling points, X_i is distance to the nearest point of the plant and Y_i is distance from the point to the nearest plant, showing the first plant of its neighbors. $C > 1/2$ indicates clumped pattern (significant at the 5% level is greater than 2.1. $C = 1/2$, Represents a random pattern. $C < 1/2$ showed a uniform pattern (C are 2/1 is significantly smaller than the 5% level).

Pielou index: This indicator also measures the distance between random points based on the nearest sample. It is used for the calculation of Equation 7 (Pielou, 1966).

The index is calculated using accurate mass density (D). A value of 1 for this indicator indicates a random pattern, more than one shows cluster pattern and smaller than 1 indicates a uniform pattern:

$$(7)\ P=\pi D\left(\frac{\sum_{i=1}^{N}x_i}{N}\right)^2$$

Hopkins index: The index is based on a random point to its nearest neighbor (r_i) calculated based on Equation 8 (Hopkins, 1954):

$$(8)\ H=\frac{\sum_{i=1}^{N}(X_i^2)}{\sum_{i=1}^{N}(X_i^2)+\sum_{i=1}^{N}(r_i^2)}$$

If the index value is 0.5, it shows random pattern, H value that is equal to 1 shows clumped pattern, H value that is equal to 0 indicates uniform pattern.

Holgate index: Holgate index is based on measuring distances to the plant so that the distance from any point to the nearest plant (di) is measured and then the second point distance to nearby plants (di') is also expressed by Equation 9 (Holgate, 1965):

$$(9)\ A=\frac{\sum_{i=2}^{N}\frac{d_i^2}{d'_i^2}}{N}$$

d_i is distance to the nearest plant random point, (di') is random point distance to second close plants and N is the number of random points. The random distribution of A = 0, the distribution of cluster A>0 (A is significantly greater than 0 at the 5% level), and the uniform distribution, A significantly smaller than 0 at the 5% level is (A < 0).

Jahnston and zimer index: To calculate this index, distance to the nearest plant each measuring random points using the following equation value was determined using the equation 10 (Mcmurry, 2000):

$$(10)\ I = (N + 1) \frac{\sum_{i=1}^{N}(d_i^2)^2}{\left[\sum_{i=1}^{N} d_i^2\right]^2}$$

d is distance to the random point of nearest plant and N is the number of random points. In random mode I = 2, in the case of cluster I> 2 was significantly greater in the 5% level of 2, and in the random state I<2 significantly at 5% smaller than 2. The evaluation total method Estimated in different ways by Student t- test with software MINITAB (version 13) were compared Distance method with Quadrate method.

RESULTS AND DISCUSSION

According to the results obtained from the Taylor model, the regression communication between log S^2 and log $\overline{X}$ was significant for the two regions of Manesht and Ghalarang (P< 0.01). In 2014, Taylor slope was significantly greater than unity for both regions in Ilam. In this study, b values were 1.13 and 1.21 for the two regions of Manesht and Ghalarang, respectively (Table 1). The Taylor model was obtained as logS^2 = 0.341 + 1.21 log$\overline{X}$ (F = 1204.7, P< 0.05) for the Manesht region and log S^2= 0.255 + 1.13 log $\overline{X}$ (F = 471.5, P< 0.05) for the Ghalarang region.

The results of the Iwao model showed that regression communication between log m^* and log $\overline{X}$ was significant for the two regions of Manesht and Ghalarang (P< 0.01). In 2014, Iwao slope was significantly greater than unity for both regions in Ilam. In this study, β values were 1.34 and 1.21 for the two regions of Manesht and Ghalarang, respectively (Table 1). In other studies, the estimated b Taylor and β Iwao values of these indexes have been ranged from 1.1 to 1.5, for example, for dominant species in the forests of Lian Jiang China (Wei-dong *et al.*, 2001). The Iwao model was obtained as log S^2 = 0.091 + 1.34 log $\overline{X}$ (F = 633.4, P< 0.05) for the Manesht region and log S^2= 0.208 + 1.18 log $\overline{X}$ (F = 106.3, P< 0.05) for the Ghalarang region. Previous studies used the Taylor and Iwao models, That form for the spatial distribution pattern of dominant species in the forests of Lian Jiang China (*Litchi chinensis*, *Elaeocarpus sylvestris* and *Canarium album*) and spatial pattern of sexual *Haloxylon ammodendron* Siahkooh region were clumped. (Wei-dong *et al.*, 2001; Kiani *et al.*, 2013).

The Taylor and Iwao models indicated a clumped distribution of *Fritillaria imperialis* in 2014 (Table 2). This is probably due to niche segregation (Pielou, 1961), habitat heterogeneity (Harms, 2001), reproductive or foraging behavior, differential predation (Janzen, 1970), neighborhood competition (He and Duncan, 2000), and dispersal limitation (Hubbell, 2001). However, the data obtained for *Fritillaria imperialis* fitted better in the Iwao model than in the Taylor model (r²= 0.921, Iwao).

Variance/mean ratio (CV) of *Fritillaria imperialis* was calculated (Table 1). The highest value of distribution indicator was related to the Manesht region (1.08) and the lowest to the Ghalarang region (0.82). The results showed that CV index was significant in the Manesht region (P< 0.01) and non-significant in the Ghalarang region (P> 0.01). In other studies, the estimated values of this index have been ranged from 1.3 to 18.9; for example, the spatial distribution pattern has been reported for five species as *Quercus libani* Oliv. (18.9), *Crataegus pontica* C. Koch (5.05), *Amygdalus scoparia* Spach (1.3), *Quercus persica* Jaub (10.7), and *Quercus* infectoria Oliv. subsp. Boissieri (Reut.) O. Schwarz (8.9) in Kurdestan region (Basiri *et al.*, 2011). Morisita index of *Frit-*

illaria imperialis was calculated (Table 1). The highest distribution indicator was related to the Manesht region (1.08) and the lowest to the Ghalarang region (0.98). The result showed that Morisita index value was non-significant in Manesht and Ghalarang regions (P> 0.01). In other studies, the estimated values of this index have been ranged from 1.1 to 3.4; for example, the spatial distribution pattern has been reported for five species as *Quercus libani* Oliv. (3.4), *Crataegus pontica* C. Koch (1.8), *Amygdalus scoparia* Spach (1.1), *Quercus persica* Jaub (1.5), and *Quercus infectoria* Oliv. subsp. Boissieri (Reut.) O. Schwarz (2.2) in Kurdestan region (Basiri *et al.*, 2011).

K index of *Fritillaria imperialis* was calculated (Table 1). The highest distribution indicator was obtained for the Manesht region (21.1) and the lowest for the Ghalarang region (10.12). The results showed that Morisita index value was significant in the Manesht and Ghalarang regions (P< 0.01).

Table 1. Quadrate indices observed values of the distribution pattern of the Ghalarang and Manesht regions.

Region	Taylor	Iwao	Morisita	K	CV
Manesht	1.21*	1.34*	1.08	21.1*	1.08*
Ghalarang	1.13*	1.18*	0.98	10.12*	0.82

* The difference is statistically significant at P< 0.05.

Table 2. Distribution patterns obtained in the distribution pattern quadrate indices in the Manesht and Ghalarang regions.

Region	Taylor	Iwao	Morisita	K	CV
Manesht	Clumped	Clumped	Random	Clumped	Clumped
Ghalarang	Clumped	Clumped	Random	Clumped*	Random

The K index of *Fritillaria imperialis* indicated a clumped distribution in both Manesht and Ghalrang regions. But, morisita index value showed that the spatial distribution of *Fritillaria imperialis* was random. Also, the variance/mean ratio (CV) index showed clumped pattern in the Manesht region and random pattern in the Ghalarang region. Previous research has used quantitative indicators (variance/mean ratio, Green index, Morisita index and Morisita standarded index) for five trees species in Kurdestan spatial patterns of tree species in a tropical forest in Arunachal Pradesh, Northeast India. These indicators showed a clumped pattern (Aparajita and Rawat, 2008; Basiri *et al.*, 2011). In this analysis, k index was recognized appropriate for assessing data with clumped pattern. In a study, the spatial distribution pattern was reported for five trees species in the Kurdestan region, and Green index was recognized as to be appropriate for assessing data with clumped pattern (Basiri *et al.*, 2011). Also, dispersion patterns on sagebrush fields of Yazd province showed that the index higher performance Morisita (Musaei-Sanjerehei and Basiri, 2007).

The Hopkins index was evaluated for *Fritillaria imperialis* (Table 3). The highest distribution indicator was related to the Manesht region (1.13) and the lowest to the Ghalarang region (0.93). The results showed that the Hopkins index was significant in Manesht (P< 0.01) but non-significant in the Ghalarang region (P> 0.01). In other studies, the estimated values of this index have been ranged from 0.23 to 0.85 (Vahidi *et al.*, 2017; Vahidinia *et al.*, 2014), For example, the spatial distribution pattern was calculated for *Acantholimon bracteatum* (0.81), *Astragalus gossypinus* (0.66) and *Acanthophyllum mucronatum* (0.85) (Vahidi *et al.*, 2017).

Holgate index of *Fritillaria imperialis* was calculated (Table 3). The highest distribution indicator was related to the Manesht region (-0.23) and the lowest to the Ghalarang region (-0.43). The results showed that Holgate index amount was non-significant in both Manesht and Ghalarang

regions (P> 0.01). In other studies, the estimated values of this index have been ranged from 0.01 to 2.02 (Kiani *et al.*, 2011; Pirouzi *et al.*, 2017). For example, the spatial t distribution pattern was evaluated to be 0.01 for oak species (*Quercus brantii*) (Pirouzi *et al.*, 2017).

The t^2 index of *Fritillaria imperialis* was evaluated (Table 3). The highest distribution indicator was obtained for the Manesht region (1.35) and the lowest for the Ghalarang region (1.21). The results showed that the t2 index was significant in both Manesht and Ghalarang regions (P< 0.01). In other studies, the estimated values of this index have ranged from 0.23 to 1.81 (Musaei-Sanjerehei and Basiri, 2007; Pirouzi *et al.*, 2017). For example, the spatial distribution pattern for *Artemisia sieberi* was calculated as to be 0.01 (Musaei- Sanjerehei and Basiri, 2007).

The Johnston and Zimer index of *Fritillaria imperialis* was calculated (Table 3). The highest distribution indicator was related for the Manesht region (3.43) and the lowest to the Ghalarang region (2.78). The results showed that the Johnston and Zimer index was significant in both Manesht and Ghalarang regions (P< 0.01). In other studies, the estimated values of this index have been in the range of 0.83 to 2.8 (Kiani *et al.*, 2011; Vahidinia *et al.*, 2014). For example, the distribution pattern was evaluated for *Astragalus.gossypinus - Centaurea.aucheri* (1.39), *Centaurea.aucheri- Bromus tectorum* (0.83) and *Festuca.ovina- Bromus.tomentellus* (1.56) (Vahidinia *et al.*, 2014).

The Pileou index of *Fritillaria imperialis* was evaluated (Table 3). The highest distribution indicator was obtained for the Manesht region (0.78) and the lowest for the Ghalarang region (0.91). The results revealed that the Hopkins index was significant in Manesht (P< 0.01) but non-significant in the Ghalarang region (P> 0.01). In other studies, the estimated values of this index have ranged from 0.77 to 1.05 (Kiani *et al.*, 2011; Pirouzi *et al.*, 2017). For example, the spatial distribution pattern was calculated for *Haloxylon ammodenderon* as to be 0.77 (Vahidi *et al.*, 2017).

Table 3. The values of the distribution pattern in the two regions of Manesht and Ghalarang.

Region	Hopkins	Holgate	*t*	Johnston and Zimer	Pielou
Manesht	1.13*	-0.23	1.35*	3.43*	0.78*
Ghalarang	0.93	-0.41	1.21*	2.78*	0.91

* The difference is statistically significant P< 0.05.

The Hopkins index of *Fritillaria imperialis* indicated a clumped distribution in Manesht and random distribution in the Ghalrang region. But, the Holgate index showed that the spatial distribution of *Fritillaria imperialis* was random. The T^2 index revealed a clumped pattern in both Manesht and Ghalarang regions. The Johnston and Zimer index showed that spatial distribution of *Fritillaria imperialis* was clumped. Also, the Hopkins index of *Fritillaria imperialis* indicated a clumped distribution in Manesht and a random distribution in the Ghalarang region (Table 4). Previous research has used distance indicators (t^2, Linear transect, Byte and Ripley) for *Salsola laricina* in Saveh. These indicators showed a random pattern (Entezari *et al.*, 2016). In study, comparing distance-based and quadrate-based methods to identify spatial pattern of sexual *Haloxylon ammodenderon* (Siah-Kooh Region, Yazd province) that used distance methods (Jnohston and Zimmer, Abrhart, Hienz, C, Pielou Hopkinz and Holgate), these indicators showed a clumped pattern (Kiani *et al.*, 2011). In this analysis, the Hopkins and t2 indexes were recognized to be appropriate for assessing data with a clumped pattern. In a study, comparing distance-based and quadrate-based methods to identify spatial pattern of sexual *Haloxylon ammodenderon* (Siah-Kooh Region, Yazd province), the t2 index outperformed the others (Kiani *et al.*, 2011).

Table 4. Distribution patterns obtained in the distribution pattern distance indices in the two regions of Manesht and Ghalarang.

Region	Hopkins	Holgate	t	Johnston and Zimer	Pielou
Manesht	Clumped	Random	Clumped	Clumped	Clumped
Ghalarang	Random	Random	Clumped	Clumped	Random

CONCLUSIONS

Our study indicated that the spatial distribution of *Fritillaria imperialis* in two regions in Ilam (Manesht and Ghalarang) was of clumped pattern. The current research showed the clumped pattern by all indices (Johnson and Zimmer, t^2 and Hopkin) except for Pielou and Holgate indexes, in the Manesht and Ghalarang regions. Overall spatial pattern random in flat areas and clumped in mountain-sides. Also, the t^2 index and Hopkin were the best distance-based indices to identify pattern. In quadrate method, all indices (Taylor, Iwao and *k*) showed clumped pattern except for Pielou and Holgate index. The Iwao method and *k* index was the best one between quadrate-based indices, too. Therefore, these methods should be used to determine the spatial distribution pattern of *Fritillaria imperialis* and pay attention to are better methods to clumped pattern of this species when ornamental plant are retrieve with this species. Dispersion structure in a natural ecosystem can be useful to understand ecological aspects such as competition and the mass deployment, growth, production use of growth models and dynamic modeling mortality provide. Most species usually occur in nature in clumped pattern. The results of this research support this claim. The distance-based approach requires that distances be standardized to avoid scaling problems. Also, distance-based record linkage methods are simple to implement and to operate. Therefore, the results of analysis showed that the distance method was more accurate than the quadrate method. It was suggested that in future studies, the environmental factors affecting the distribution pattern of *Fritillaria imperialis* be checked. Also, investigation should consider soil physical and chemical properties in studying the spatial distribution of reversed crown imperial.

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