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# The effects of exclosure on plants in the semi-arid rangeland of North Khorasan province, Iran

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**Abstract**

Over the last fifty years, most of the semi-arid rangeland in Iran has been converted to cropland without an equivalent reduction in grazing animals. This shift has led to heavy grazing pressure on rangeland vegetation. The present study has been conducted in Sisab Research Station in the North Khorasan Province to evaluate effects of long-term grazing exclosures on biodiversity of range plants. The study was initiated in May 2008 using three transects within the exclosure and another three transects near exclosure, each with 100m length in the vicinity of exclosure has been established to determine differences in plant composition between areas that have not been grazed in 22 years with neighboring grazed plant communities. The sampling method was randomized systematic one comprised of 10 plots, each of $1m^2$ in area. A total of 53 plant species were identified in the study area with the ungrazed plots containing 18 plants more than the grazed plots. The major species were *Festuca ovina*, *Centurea depressa*, *Stachys turkamanica*, *Stipa barbata*, *Astragalus sp* and *Phelomis cancellata*. Grazing impacts on forbs were more pronounced than for grasses and shrubs. Based on Jaccard's index, there was only a 45% similarity of plant species between the two treatments. Our study led to four generalizations about the current grazing regime and long-term exclosures in the semi-arid rangeland around the study area: (1) exclosures will increase species richness, (2) heavy grazing may have removed some plant species, (3) complete protection from grazing for a prolonged period of time after a long history of grazing disturbance may not lead to an increase in desirable plant species with a concomitant improvement in range condition, and (4) research needs to be conducted to determine how these rangelands can be improved.

*Keywords:* Biodiversity; Exclosure, Grazing; Semi-arid rangelands; North Khorasan province

## 1. Introduction

Iran has 86 million hectares of natural grazing land, 5/5% (5 Mh) of which is located in the north of Khorasan Province (Tavakoli et al, 2006). Over the last years, vast rangelands have been converted to cropland in Iran. The reduction of rangeland has not been linked to an equivalent reduction in grazing animals, thus remaining rangelands are heavily grazed. Iran is endowed with a rich diversity of families, genera, and species (8000 species) of plants (Gahreman, 1999). As a significant source of the world's genetic resources and plant biodiversity, the consequence of increased grazing pressure on Iran plant diversity is of great interest.

Grazing intensity and timing are important factors affecting plant diversity (Laycock, 1967). Excessive and heavy grazing may cause plant mortality, resulting in the loss of some individual

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plant species, through weakening plants and disrupting regeneration. Also encroachment of non-palatable plant species that can persist under heavy grazing can be occurred. Therefore, implementation of sound grazing management is very important for the conservation of individual plant species, plant populations, and ecosystems. In some severely overgrazed areas, destocking may be necessary. However, complete protection from grazing is not a normal condition for range plants, which evolved with grazing animals, both wild and domestic. Under complete protection from grazing, some undesirable changes may occur, such as an excessive litter accumulation that will change the habitat enough to reduce or eliminate many native species in the area (Adler et al, 2004).

In the North Khorasan province, the rangelands contain many grass, forbs, and shrub species. Understanding the effects of grazing and non-grazing on the dynamics of the herbaceous communities of North Khorasan Province is important in formulating rational management plans for both conservation and sustainable animal production. It is well recognized that comparisons between grazed and ungrazed grasslands have been an important tool in determining the effects of grazing (Safford and Harrison, 2001). Additionally, comparison of plant diversity of grazed and ungrazed sites can yield important theoretical insights on the role of herbivory and competition in structuring plant communities (Belsky, 1986).

It has been recognized for many years that grazing animals have an impact on vegetation and vegetation recovery in arid environments can be quite slow (Guo, 2004); however, because ranges have been more heavily and continuously grazed in recent decades in the North Khorasan Province, the opportunities to study ranges that have been ungrazed for a considerable period of time are scarce. A limited number of studies have documented the floristic composition and plant cover of the North Khorasan Province. A few researchers have measured changes in plant cover resulting from grazing exclusion. To date, no research has been conducted comparing vegetation changes in grazed and protected areas for the rangelands of this region.

The objectives of this study were (1) to compare several attributes of range plant diversity in grazed and long-term ungrazed sites, and (2) to determine the effect of grazing on plant species similarity.

## 2. Materials and methods

The study was carried out in the rangelands of the Sisab Research Station, 35 km east of Bojnord near the Sisaab village range in 2008 (Figure. 1). Prior to the establishment of the Research Station in 1986, the range areas were being grazed heavily and there are no records of tillage for the area. During station establishment, its borders were fenced and some areas have been protected from sheep and goat grazing for 22 years, whereas the village range area has been continuously grazed. Grazing occurs year round with free access and no management practices. Limited rangeland forage in the winter is supplemented by allowing animals to graze stubble after cereal harvest on croplands and by feeding cereal straw, barley grain, and other supplements. Soils are clay-loam, slightly alkaline and low in organic matter. The Sisab Research Station is characterized by its semi-arid climate with 270 mm annual rainfall, cold winters, and dry summers. The major species were *Festuca ovina*, *Centurea depressa*, *Stachys turkamanica*, *Stipa barbata*, *Astragalus spp* and *Phelomis cancellata*.

The rangelands are a typical steppe vegetation type consisting of some perennials (*Festuca ovina*, *Centurea depressa*, *Stachys turkamanica*, *Stipa barbata*,) and annuals (*Boissierra squarrosa*, *Bromus tectorum*, *Taeniatherum crinitum*) grass species and some perennial shrubs (*Astragalus raddie*, *Acantholimon sorchenes*, *Artemisia aucheri*). Other important steppe plant species include *Convolvolus commutatus*, *Cousinia macrocarpa*, *Onobrychis sativa*, *Serratula husskenchtii Boiss* and *Rosa persica*.

A study was initiated in May 2008 using Three transects within the exclosure and another three transects near exclosure in the same vegetation type, each with 100m length has been established to determine differences in plant composition between areas that have not been grazed in 22 years with neighboring grazed plant communities. The sampling method was randomized systematic and each transect comprised of 10 $1m^2$ plots (based on pattern of plants distribution) that had similar soils, slopes, and aspects. (Stohlgren et al, 1998). The plots were sampled at the phenological maturity (peak biomass) during the second week of May.

In the thirty $1m^2$ plots, all plant species were identified, and the canopy cover of each species, percentage of bare ground, and non-plant components (rock and stone) were estimated to the nearest percent. Plant species that could not be identified in the field were collected and identified at the herbarium of the Khorasan Natural Resources and Agricultural Research Center.

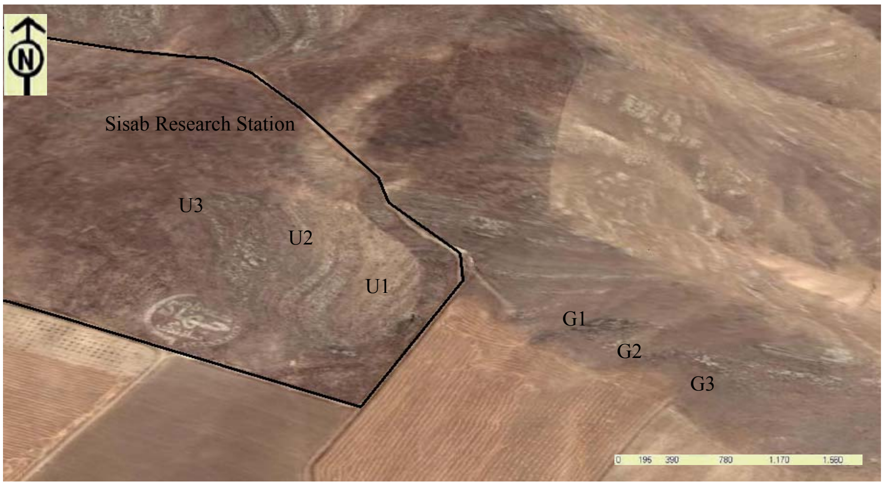


Fig. 1. Aerial photo of the study site; ungrazed sites U1, U2, and U3 are in exclosures, and grazed sites G1, G2, and G3 are in the village range area

Jaccard's coefficient (Krebs, 1989) was used to compare vegetation similarity between ungrazed and grazed plots with data from 1-m2 plot. Jaccard's coefficient (J), which gives equal weight to all plant species, is derived from:

J=A/(A+B+C)

Where A is the number of species found in both grazed and ungrazed sites, B is the number of species found only in the grazed sites, and C is the number of specie found only in the ungrazed sites (Krebs, 1989). Jaccard's coefficient varies from 1 (completely similar species) to 0 (no similar species) and is a good similarity measurement (Stohlgren et al, 1997). It is often expressed in percent as J×100. We also compared species diversity between grazed and ungrazed sites using Shannon's index and Simpson's index as described by Ludwing and Reynolds (1988). Shannon's index (H) for a sample, which is the average degree of uncertainty in predicting what species an individual chosen at random from a sample will be, is defined as

$$H = \sum_{i=1}^{s} (^{ni}/_{n})(\ln {^{ni}/_{n}})$$

Where ni is the cover of the *i*th species of S species in the sample and n is the total cover of all species in the sample. Simpson's index (λ) for a sample, which is the probability that two individuals selected at random will be the same species, is defined as

$$\lambda = \sum_{i=1}^{s} \left( \frac{ni}{n} \right)^2$$

The values from these indices were transformed in a method recommended by Ludwing and Reynolds (1988) and described by Hill (1973), to determine the abundant ($N_1$) and very abundant species ($N_2$). N1 was calculated as

$N_1 = e^H$

and N2 was calculated as

$N_2 = 1/\lambda$

With the values from the above equations, a modified Hill's ratio was then determined as a measure of evenness (Hill, 1973). $E_4$ was calculated as

$E_4 = (1/\lambda)/e^H$

As $E_4$ approaches zero, one species becomes more dominant in the total cover component. Higher values of E indicate a more even division of cover among the species in the sample area.

## 3. Results

There were a total of 53 species in the study area, including 34 forbs, 11 grasses, and 8 shrubs. The majority of these species were perennials (32), although 21 annual species were identified in the study area (appendix).

Based on Jaccard's coefficient, there was a 45% similarity in species composition between ungrazed versus grazed plots, with 24 species in common, and 24 and 5 species only in the ungrazed and grazed plots, respectively.

Table 1. Indices of diversity from percent cover estimates of $1m^2$ plots in the ungrazed (U) and grazed (G) plots at Sisab Research Station in the North Khorasan Province, Iran

| Index | Treatment | Value | P-value |
|---|---|---|---|
| Shannon's index | U | 2.56±0.087 | $0.47^{ns}$ |
| | G | 2.35±0.416 | |
| Simpson's index | U | 0.143±0.008 | $0.667^{ns}$ |
| | G | 0.139±0.009 | |
| $N_1$ | U | 12.93±1.19 | $0.175^{ns}$ |
| | G | 10.48±2.1 | |
| $N_2$ | U | 6.99±0.312 | $0.7^{ns}$ |
| | G | 7.19±0.53 | |
| $E_4$ | U | 0.54±0.08 | $0.11^{ns}$ |
| | G | 0.68±0.06 | |

$^{ns}$ no significant within rows.

There were no significant differences in Shannon's diversity index, diversity ($N_1$, $N_2$), or evenness ($E_4$) between the grazing treatments (Table 1).

Table 2. Percent canopy cover of major plant species at the Sisab Research Station in the North Khorasan Province, Iran in ungrazed (U) and grazed (G) plots

| Plant species | Treatment | cover (%) ± StD) | P-value |
|---|---|---|---|
| *Festuca ovina L.* | U | 16.35±0.53 | $0^{**}$ |
| | G | 7.12±0.48 | |
| *Centaura depressa* | U | 7.74±0.07 | $0.003^{**}$ |
| | G | 0.15±0.01 | |
| *Stachys turcamanica* | U | 3.51±0.78 | $0.139^{ns}$ |
| | G | 2.35±0.25 | |
| *Artemisia aucheri* | U | 0.87±0.032 | $0.011^{*}$ |
| | G | 2.85±0.35 | |
| *Astragalus spp* | U | 1.95±0.15 | $0.001^{**}$ |
| | G | 0.7±0.08 | |
| *Phlomis cancellata* | U | 3.69±0.56 | $0.51^{ns}$ |
| | G | 3.3±0.42 | |
| *Stipa barbata* | U | 2.11±0.42 | $0.001^{**}$ |
| | G | 9.3±0.77 | |

*Significant at $P < 0.05$ and **Significant at $P < 0.01$, $^{ns}$ no significant within rows.

The percent canopy cover of the major plant species, measured at the $1m^2$ scale, is given in Table 2. Only plant species that were sufficiently abundant could be analyzed. The cover of *Phlomis cancellata* was similar in both grazing treatments, with 3.69% in ungrazed and 3.3% in grazed plots ($P > 0.05$). Similarly, *Stachys turcamanica* cover did not differ with 3.51% in the ungrazed and 2.35% in the grazed plots ($P > 0.05$). The cover of *Centaura depressa* was significantly different ($P < 0.01$) between the grazing treatments, with 7.74% in the ungrazed and 0.15% in the grazed plots. The shrub species, *Astragalus spp* had a greater ($P < 0.01$) plant canopy cover in the ungrazed plots (1.95%), whereas *Artemisia aucheri* had more ($P < 0.05$) canopy cover in the grazed plots (2.85%). As a perennial grass, *Stipa barbata* had a greater canopy cover in the grazed plots (9.3%) compared to ungrazed plots (2.11%) ($P<0.01$). Similarly, *Festuca ovina L.* cover was significantly different ($P < 0.01$) between the grazing treatments, with 16.35% in the ungrazed and 7.12% in the grazed plots.

There were differences in total cover between the treatments of plant categories and life forms when analyzed by canopy cover (Table 3). The cover of the perennial species was significantly different ($P < 0.05$) between the grazing treatments with 46.2% in the ungrazed compared to 34.6% in the grazed plots. In comparing plant categories, the forbs in ungrazed plots had twice as much cover (27.8%) as did the grazed plots (14.6%). The grass crown cover was the same in the ungrazed (19.8%) and grazed plots (17.3%). Shrub species had similar cover between the treatments. Total plant cover was significantly greater (P < 0.01) in the ungrazed (51.6%) than in the grazed (36.1%) plots. For the life forms, there were two different groups, the annual and perennials. Most of the annual species were forbs and their total cover appeared to be greater in the ungrazed (5.33%) than in the grazed 1.66%) plots.

Table 3. Percent canopy cover of plant categories at the Sisab Research Station in the North Khorasan Province, Iran in ungrazed (U) and grazed (G) plots

| Plant species | Treatment | cover (%) ± StD) | P-value |
|---|---|---|---|
| *Total cover* | U | 51.67±5.2 | 0.02 * |
| | G | 36.1±3.08 | |
| *Forbs* | U | 27.83±2.57 | 0.008 ** |
| | G | 14.63±2.58 | |
| *Grasses* | U | 19.8±1.28 | 0.28 ns |
| | G | 17.3±2.69 | |
| *Shrubs* | U | 4.56±0.32 | 0.54 ns |
| | G | 4.33±0.5 | |
| *Annuals* | U | 5.33±0.49 | 0.007 ** |
| | G | 1.66±0.27 | |
| *Perennials* | U | 46.2±1.11 | 0.023 * |
| | G | 34.63±2.89 | |

*Significant at P < 0.05 and **Significant at P < 0.01, ns no significant within rows.

## 4. Discussion and conclusion

The basic assumption made in this study was that if all other variables influencing vegetation were the same on both sides of the fence, then any difference must result from grazing. Although this is a small case study, we perceive it to be an important measure of vegetation change in North Khorasan Province rangelands.

Grazing can influence the structure and organization of plant communities in different ways (Noy-Meir et al, 1989). Sternberg and others (2000) explained that grazing caused two kinds of effects: a direct effect that occurs through the selective and differential removal of plant tissue or species, and an indirect effect that occurs on botanical composition and species diversity when selective grazing on dominant species reduces their vigor and presence, thus favoring the spread of less competitive but more tolerant species.

There is an expectation that many of the plant species specific to the ungrazed areas would be more palatable. However, most of the forbs were noxious and some were poisonous. The two annual grasses that appeared (*Boisseria squarrosa*, *Taeinatherum crinitum*) are invaders, one perennial grass (*Bromus tomentellus Boiss*) is considered to be a decreaser, and the other (*Avena sativa*) is an increaser. Except for *Astragalus glucacanthus* and *Rosa persica* with a spiny stature, the other shrubs (*Artemisia sp*, *Ephedra sp*) are all grazed by sheep and goats.

The cessation of grazing for 22 years has resulted in increased species richness compared to the grazed plots. However, after 22 years of protection from grazing and only a 45% similarity of species, one would wonder if the plant communities are even comparable. Life history and morphology of dominant plant species are important attributes in the responses of the community to grazing intensity and timing (McIntyre et al, 1995; Lavorel et al, 1997). The general hypothesis is that the sensitivity of plant communities to grazing depends on the frequency and strength of adaptations helping plants avoid or tolerate grazing animals (McIntyre and Lavorel 2001). Adaptation to aridity, such as small stature, canopy meristems, and drought-deciduous leaves, also proves advantageous in preventing or recovering from grazing (Coughenour, 1985). Adler and others (2004) specified two separate hypotheses: first the main control on the development of grazing-resistance traits is the evolutionary history of grazing and environmental factors related to aridity, and, second, because grazing resistance traits mediate plant-herbivore interactions, such traits are the direct determinants of ecosystem response to grazing.

The cessation of grazing can increase the cover and frequency of shrubs (Aghajanloo and mousavi, 2007; Jalilvand et al, 2007). However, there are some conflicting results: Huges (1980, 1983) found higher shrub frequency on grazed sites in desert shrub communities in Arizona, and Akbarzadeh et al (2007) found no significant increase in shrub cover after 24 years of protection from grazing. In this research we found similar result with last research (Table 3).

Grazing resulted in a stronger selective pressure against forbs rather than for grass and shrub species. Grasses and shrubs were less affected and appeared to be more resilient to grazing pressure. Though the effect of overgrazing on soil erosion is not measured in this study, the considerable reduction in the plant cover of the grazed sites has exposed the soil to water and wind erosion (Moghadam, 2001).

Our results indicate that a more species-rich plant community can be developed with the complete exclusion of grazing for 22 years after a long history of grazing disturbance. However, long protection from grazing did not lead to an increase in the amount of desirable range plants species.

Our study reveals the importance of considering plant adaptation to grazing when planning restoration projects. This study led to four generalizations about current grazing regime and long-term exclosures in the rangeland around the study area:

1. Exclosures will increase species richness.
2. Heavy grazing may have removed some plant species from the vegetation community.
3. Complete protection from grazing for a lengthy period of time after a long history of grazing disturbance may not lead to an increase in desirable plant species, with a concomitant improvement in range condition.
4. Research needs to be conducted to determine how these rangelands can be improved.

In conclusion, these grazing exclosures have provided important insights on vegetation patterns that mere comparisons of grazed sites would have never generated.

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Appendix 1- Species list, Family, functional groups (forb, grass, shrub) and life forms (annual, perennial) in which the species occurred of plants identified in the study area

| | Scientific name | Family | Palatability | Functional groups | Life forms | % Cover | |
|---|---|---|---|---|---|---|---|
| | | | | | | Grazed | Ungrazed |
| 1 | *Bunium sylindicum* | *Apiaceae* | III | F | A | - | 0.63 |
| 2 | *Ferula sp* | | III | F | P | - | 0.09 |
| 3 | *Scandix pecten* | *Apiaceae* | III | F | A | - | 0.05 |
| 4 | *Serratula husskenchtii Boiss* | *Asteraceae* | III | F | A | 0.22 | 3.3 |
| 5 | *Centaura virgata Lam.* | *Asteraceae* | III | F | P | - | 0.14 |
| 6 | *Centaura depressa* | *Asteraceae* | III | F | P | 0.15 | 7.74 |
| 7 | *Cousinia assyriaca* | *Asteraceae* | III | F | P | 3.4 | 2.1 |
| 8 | *Artemisia sp* | *Asteraceae* | II | S | P | - | 0.43 |
| 9 | *Artemisia aucheri* | *Asteraceae* | III | S | P | 2.85 | 0.87 |
| 10 | *Lappula sp* | *Boraginaceae* | III | F | A | 0.15 | - |
| 11 | *Dianthus orientalis* | *Caryophillaceae* | II | F | P | 0.3 | 0.39 |
| 12 | *Convolvulus commutatus* | *Convolvulaceae* | II | F | P | 0.25 | 0.3 |
| 13 | *Convolvulus pseudocantabrica* | *Convolvulaceae* | II | F | P | 1.62 | 1 |
| 14 | *Isatis raphanifolia Boiss.* | *Cruciferae* | III | F | A | - | 0.03 |
| 15 | *Eruca sativa* | *Cruciferae* | II | F | A | 0.02 | - |
| 16 | *Alyssum bracteatum* | *Cruciferae* | III | F | A | 0.39 | 0.06 |
| 17 | *Alyssum daycarupm* | *Cruciferae* | III | F | A | 0.03 | 0.015 |
| 18 | *Scabiosa rotata* | *Dipsaceae* | III | F | A | - | 0.03 |
| 19 | *Ephedra* | *Ephedraceae* | III | S | P | - | 0.75 |
| 20 | *Euphorbia bungei* | *Euphorbiaceae* | III | F | P | - | 0.015 |

Appendix - Continued

| | Scientific name | Family | Palatability | Functional groups | Life forms | % Cover | |
|---|---|---|---|---|---|---|---|
| | | | | | | Grazed | Ungrazed |
| 21 | *Onobrychis radiata* | *Fabaceae* | II | F | P | - | 0.81 |
| 22 | *Astragalus raddei* | *Fabaceae* | II | F | P | 0.18 | 0.6 |
| 23 | *Glycyrrhiza glabra* | *Fabaceae* | III | F | P | 0.05 | 0.1 |
| 24 | *Astragalus glucacanthus* | *Fabaceae* | III | S | P | - | 0.7 |
| 25 | *Astragalus sp* | *Fabaceae* | III | S | P | 0.7 | 1.95 |
| 26 | *Iris persica* | *Iridaceae* | III | S | P | 0.1 | - |
| 27 | *Lagochilus cabulicus Benth.* | *Labiatae* | III | F | A | - | 0.45 |
| 28 | *Eremostachys pulvinaris* | *Labiatae* | III | F | P | - | 0.1 |
| 29 | *Proveskia abrotaoides* | *Labiatae* | III | F | P | - | 0.84 |
| 30 | *Stachys lavandulifolia Vahl* | *Labiatae* | III | F | P | - | 0.075 |
| 31 | *Salvia limbata C.A.Mey.* | *Labiatae* | III | F | P | 0.12 | - |
| 32 | *Phlomis cancellata* | *Labiatae* | III | F | P | 3.33 | 3.69 |
| 33 | *Stachys turcamanica* | *Labiatae* | III | F | P | 2.35 | 3.51 |
| 34 | *Allium stamineum* | *Liliaceae* | III | F | A | - | 0.07 |
| 35 | *Tulipa micheliana* | *Liliaceae* | III | F | P | - | 0.06 |
| 36 | *Linium marshallianum* | *Linaceae* | III | F | A | 0.04 | 0.15 |
| 37 | *Acantholimon sorchenes Rech.f.* | *Plumbaginaceae* | III | S | P | 0.49 | - |
| 38 | *Avena sativa* | *Poaceae* | II | G | A | - | 0.015 |
| 39 | *Taeinatherum crinitum* | *Poaceae* | III | G | A | - | 0.66 |
| 40 | *Aegilops cylindrica Host* | *Poaceae* | III | G | A | 0.4 | 0.006 |
| 41 | *Boisseria squarrosa* | *Poaceae* | III | G | A | 0.06 | 0.015 |
| 42 | *Bromus danthonia* | *Poaceae* | III | G | A | 0.07 | 0.05 |
| 43 | *Bromus tectorum L.* | *Poaceae* | III | G | A | 0.15 | 0.05 |
| 44 | *Eremopyrum confusum Melderis* | *Poaceae* | III | G | A | 0.13 | 0.015 |
| 45 | *Bromus tomentellus Boiss .* | *Poaceae* | I | G | P | - | 0.05 |
| 46 | *Poa bulbosa L.* | *Poaceae* | III | G | P | - | 0.39 |
| 47 | *Festuca ovina L.* | *Poaceae* | I | G | P | 7.12 | 16.35 |
| 48 | *Stipa barbata* | *Poaceae* | III | G | P | 9.3 | 2.11 |
| 49 | *Rosa persica* | *Rosaceae* | III | S | P | - | 0.045 |
| 50 | *Galium verum L.* | *Rubiaceae* | III | F | A | - | 0.001 |
| 51 | *Asperula gilanica Trin.* | *Rubiaceae* | III | F | P | 2 | 0.45 |
| 52 | *Linaria sp* | *Scrophulariaceae* | III | F | A | - | 0.057 |
| 53 | *Hyosyamnus niger* | *Solanaceae* | III | F | P | 0.04 | 0.36 |

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