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SUCCESSION OF STEPPE AREAS AFTER FIRE IN THE GAP REGION OF TURKEY

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Abstract

To determine the succession after a fire that occured in 1997 in the vicinity of Cekem and Halfeti villages, near Sanliurfa, Turkey work was carried out. The floristic changes in the area were observed during first six years and in the tenth year after the fire. The dominant species of burnt vegetation had a tendency to return towards a state similiar to the existined before fire. Most of the species prior to fire (98.7%) reappeared within the first six years and the vegetation nearly reached the prefire physiognomy. At the end of ten years, no significant differences in term of floristic composition and physiognomy were observed.

Introductıon

There is no significant knowledge about the change of chemical and physical properties of soil, the formation of natural vegetation, and succession on land that is exposed to fire in the Southeastern Anatolia Pr or (GAP). The city of Sanliurfa is in the center of the GAP region (Fig. 1). The nearby villages of Cekem and Dagetegi were studied. These are located near the city of Sanliurfa in southeast Turkey. It comprises 300 hectares. The altitude of the area ranges between 550 and 600 meters.

Fig. 1. Location of study area in Turkey (Sanliurfa).

The climate is cold and rainy in winter; hot and dry in summer. The central part of south-east Turkey belongs to a warm region (mean annual average above 16°C) with a low annual rainfall (below 600 mm). Higher elevations belong to a moderately warm region (mean annual average below 15°C) with a high annual rainfall (above 600 mm) (Fig. 2).

Sanliurfa has characteristically Irano-Turanian flora, with Mediterranean elements also. The natural vegetation of the study area has been under protection since 1973. It has typical steppe plants and communities (Anon. 1995).

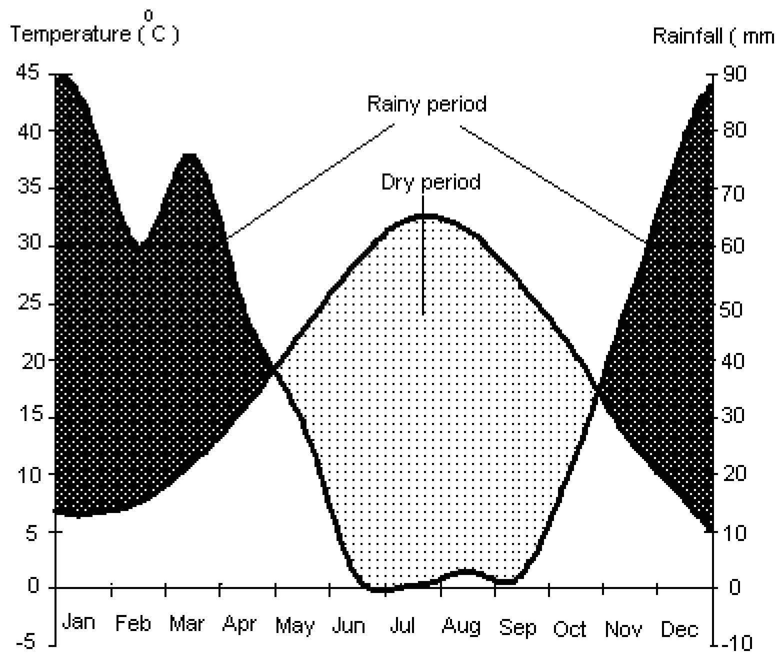

Fig. 2. Climatic diagram of the study area.

Biological diversity, especially endemic plants, has been effected negatively by fires. Fire is one of the most important ecological factors for not only Mediterranean forest ecosystems but also other ecosystem types. Fire has influenced the evolution of the various species of the forests and grasslands, as well as the xeric shrub communities of the Mediterranean climate regions of the world (Ocak *et al.* 2007). Fires occur because of natural reasons, or are caused by humans deliberately, in Mediterranean countries like Turkey, Greece and Spain. Most of the natural vegetation in Mediterranean regions is composed of woodland in various stages of degradation as secondary succession created by the long history of human activities (Le 1974, Naveh 1975, Trabaud 1982, Hadjibiros 2001, Tarrega *et al.* 2001, Turkmen and Düzenli 2005). Similarly, in inner and south-east Anatolia, the steppe vegetation occurs as secondary (anthropogenic) vegetation. Fire, which has continued along the centuries, has an important role in the formation of the steppe areas. Communities and plant species have also been influenced by drought and grazing. Especially in inner Anatolia and south-east Anatolia, fires are set by villagers before harrowing a field to break up stubble. Some of the plants which have resistance to fire by sprouting and seeding can survive after the highly destructive fires (Turkmen and Düzenli 1990). However, fire impact, in association with grazing and cutting, has led to the destruction of many steppe communities.

The main causes of fire are: (1) Unknown origin, negligence, or arson, (2) the Mediterranean type of climate in the region with its long, hot, and dry summers, and (3) accumulation of flammable vegetation and litters (Turkmen *et al*. 2005). The grass-dominated vegetation in the area is highly flammable. In prehistoric times, lighthing and volcanoes certainly played a major role in causing fires (Komarek 1973, Le 1977, Trabaud 1982, Turkmen and Düzenli 2005). However, in Turkey today, most fires are caused by humans. Natural fires are rare, representing at best 1% in Turkey.

Among the plants those occur after the fire, differences and similarities are observed in terms of reproduction and growing (Turkmen and Düzenli 2005). Bulbous, rhizomous and tuberous plants grow first and this is an adaptation to fire (Rodin 1984). Post-fire succession has not been greatly studied in Turkey (Turkmen and Düzenli 2005, Ocak *et al.* 2007), compared to the many reports on this subject carried out internationally, such as in the United States; (Hanes 1970, Keeley 1987, France; Trabaud and Lepart 1981, Trabaud 1982, Israel; Naveh 1975, Greece; Arianoutsou-Faraggitaki 1989, Thanos *et al.* 1989, Troumbis 1992, Böhling and Gerold 1995).

The goal of the present study is to determine the succession after fire and the effects of fire on the floristic composition of the steppe vegetation in the GAP region. Because some of the *Graminea* taxa are endemic in this region, it is important to conserve them; therefore, goal of this study is to determine the migration of these taxa after fire.

Materials and Methods

To analyze the changes in composition and physiognomy of the plant community in this area, ten permanent plots were established; five in the burnt area and five in the adjacent unburnt area. Each plot was 100 square meters (10 m by 10 m) in size. Floristic composition was measured in terms of the number of taxa found on the burnt and unburnt plots on each observation date. All floristic records were made monthly, every year from August 1997 to August 2003, and again in 2007. The Sorenson's similarity equation was used to compare the floristic richness values of burnt and unburnt areas. [Sorenson similarity = 2C/(A + B), where A and B are the richness values of each of the areas in the comparison and C is the number of the common taxa shared by the two areas]. Determination of species is based upon (Davis 1988).

Results and Discussion

The change in floristic composition after fire was different in comparison to the recolonization of other places that had been cleared of plants (e.g., old fields), where the original taxa around the site had a tendency to reestablish themselves. The burnt area permitted the initial invasion of different taxa than the original vegetation, but these were rapidly replaced through the reappearance of species that existed before the fire. These can be seen on Table 1 under column named "5m". (Calvo *et al.* 1992, Trabaud 1981, Espirato-Santo *et al.* 1992) and (Turkmen and Düzenli 2005) also made this same observation. In addition, the extrinsic species (species nonexistent before the fire) continued their existence in the burnt area either vegetatively or generatively, although the vegetative cover had been completely destroyed during the fire. After of them, other essensial plants had migrated to area time by time. These were as follows:

Campanula strigosa, Lactuca undulata, Filago vulgaris, Scandix stellata, Astragalus astereas, Linum pubescens, Cleome ornithopodioides, Thlaspi perfoliatum, Erysimum goniocaulon, Linum nodiflorum, Filago pyramidata, Senecio vernalis, Allium dictyoprasum, Ranunculus arvensis, Geranium rotundifolium, Cruciata articulata and *Adonis annua*.

The flora of the unburnt area (500 m^2) consisted of 82 species and remained nearly consistent (floristically) during ten years after the fire. In the burned area (500 m^2), the presence of plant species changed throughout the observation period as follows: 124 species in the first year, 109 species in the second year, 108 species in the third year, 89 species in the fourth year, 81 species in the fifth year, 80 species in the sixth year, and 79 species in the tenth year (Table 1).

Table 1. Plant species that appeared in the study area (LF: Life form, S = shrub, a^H = annual herb, p^H = perennial herb, b^H= biennial herb, RS = reproductive strategy, V = vegetative, G = generative, VG = both generative and vegetative. Presence of species in terms of time after fire: 6m = first six months, 1 = first year, 2 = second year, 3 = third year, 4 = fourth year, 5 = fifth year, 6 = sixth year, 10 = tenth year, + = recorded, - = not recorded).

Scientific name	Family	LF	RS	5m	1	2	3	4	5	6	10
Capparis ovata ssp. *palaestina*	Capparaceae	S	V	-	+	+	+	+	+	+	+
Allium ampeloprasum	Liliaceae	p^H	VG	+	+	+	+	+	+	+	+
Muscari longipes	″	p^H	G	+	-	+	+	+	+	+	+
Gagea reticulata	″	p^H	G	+	+	+	-	+	+	+	+
Asparagus palaestinus	″	p^H	G	+	+	+	+	+	+	+	+
Linum mucronatum ssp. *orientale*	″	p^H	VG	-	+	+	+	+	+	+	+
Gladiolus atroviolaceus	İridaceae	p^H	VG	+	+	+	+	+	+	+	+
Orchis anatolica	Orchidaceae	p^H	G	-	+	+	+	+	+	+	+
Alcea digitata	Malvaceae	p^H	VG	-	+	+	+	+	+	+	+
Hypericum capitatum var. *capitatum*	Hypericaceae	p^H	VG	-	+	+	+	+	+	+	+
Reseda lutea var. *lutea*	Resedaceae	p^H	VG	-	+	+	+	+	+	+	+
Paliuris spina-christi	Rhamnaceae	S	VG	+	+	+	+	+	+	+	+
Roemeria hybrida ssp. *hybrida*	Papaveraceae	a^H	G	-	-	-	+	+	+	+	+
Papaver rhoeas	″	a^H	G	+	+	+	+	+	+	+	+
Celtis tournefortii	Ulmaceae	p^H	VG	+	+	+	+	+	+	+	+
Phlomis kurdica	Lamiaceae	p^H	VG	+	+	+	+	+	+	+	+
Salvia palaestina	″	p^H	VG	+	+	+	+	+	+	+	+
Salvia bracteata	″	p^H	G	-	+	+	+	+	+	+	+
Phlomis pungens var. *pungens*	″	a^H	G	-	+	+	+	+	+	+	+
Teucrium polium	″	p^H	VG	+	+	+	+	+	+	+	+
Teucrium multicaule	″	p^H	VG	+	+	+	+	+	+	+	+
Helianthemum stipulatum	Cistaceae	p^H	VG	+	+	+	+	+	+	+	+
Rahamnus punctatus var. *punctatus*	Rhamnaceae	S	VG	-	-	-	-	-	+	+	+
Onobrychis gracilis	Fabaceae	p^H	VG	+	+	+	+	+	+	+	+
Prosopis farcta	″	p^H	VG	+	+	+	+	+	+	+	+
Argyrolobium crotalarioides	″	p^H	VG	+	+	+	+	+	+	+	+
Astragalus russelii	″	p^H	VG	+	+	+	+	+	+	-	+
Astragalus ancistrocarpus	″	p^H	VG	+	+	+	+	+	+	+	+
Ononis spinosa ssp. *antiquorum*	″	p^H	VG	+	+	+	+	+	+	+	+
Amygdalus orientalis	Rosaceae	S	VG	+	+	+	+	+	+	+	+
Cretaegus monogyna ssp.*monogyna*	″	S	VG	+	+	+	+	+	+	+	+
Eryngium creticum	Apiaceae	p^H	VG	+	+	+	+	+	+	+	+
Prangos peucedanifolia	″	p^H	VG	-	+	+	+	+	+	+	+
Ducus broteri	″	a^H	V	-	+	+	+	+	+	+	+
Scandix pecten-veneris	″	a^H	G	+	+	+	+	+	-	-	-
Carthamus persicus	Asteraceae	a^H	VG	-	+	+	+	+	+	+	+
Xeranthemum annuum	″	a^H	VG	-	+	+	+	+	+	+	+
Echinops viscosus ssp. *bithynicus*	″	p^H	VG	-	+	+	+	+	+	+	+
Geropogon hybridus	″	a^H	V	-	-	+	+	+	+	+	+
Gundelia tournefortii var. *armata*	″	p^H	G	-	-	+	+	+	+	+	+
Echinops viscosus ssp. *bithynicus*	″	a^H	G	-	-	+	+	+	+	+	+
Achillea wilhelmsii	″	p^H	G	-	-	+	+	+	+	+	+
Sonchus asper ssp. *glaucescens*	″	a^H	G	-	+	+	+	+	+	+	+
Lactuca saligna	″	b^H	VG	+	+	+	-	+	+	+	+
Olea europaea var. *sylvestris*	Oleaceae	S	V	+	+	+	+	+	+	+	+
Echium italicum	Boragınaceae	p^H	VG	+	+	+	+	+	+	+	+
Heliotrophium europaeum	″	a^H	G	-	-	-	-	-	+	+	+

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Anchuza azurea var. *azurea*	Boragınaceae	p^H	V	-	+	+	+	+	+	+	+
Moltkia coerulea	"	p^H	V	-	+	+	+	+	+	+	+
Verbascum orientale	Scrophulariace	b^H	V	-	+	+	+	+	+	+	+
Scrophularia scariosa	"	b^H	V	-	+	+	+	+	+	+	+
Euphorbia macroclada	Euphorbiaceae	p^H	VG	-	+	+	+	+	+	+	+
Ficus carica ssp. *carica*	Moraceae	S	V	+	+	+	+	+	+	+	+
Geranium tuberosum	Geraniaceae	p^H	G	-	+	+	+	+	+	+	+
Erodium gruinum	"	a^H	G	-	+	+	+	+	+	+	+
Parietaria judacia	Urticaceae	p^H	V	-	+	+	-	+	+	+	+
Sinapis alba	Brassicaceae	a^H	G	-	+	+	+	+	-	-	+
Capsella bursa-pastoris	"	a^H	G	-	+	+	-	-	-	-	+
Isatis lusitanica	"	a^H	G	-	-	-	+	+	-	-	+
Clypeola aspera	"	a^H	G	+	+	+	+	+	-	-	+
Erysimum goniocaulon	"	p^H	VG	-	+	+	+	+	+	+	+
Alyssum meniocoides	"	a^H	G	+	+	+	+	+	-	-	+
Sisymbrium septulatum	"	a^H	G	+	+	+	+	+	-	-	-
Amaranthus sherardiana	Amaranthaceae	a^H	G	-	-	+	+	+	-	-	+
Cynedon dactylon var. *villosus*	Poaceae	p^H	VG	+	+	+	+	+	+	+	+
Poa bulbosa	"	p^H	V	+	+	+	+	+	+	+	+
Avena barbata	"	a^H	VG	-	+	+	+	+	+	+	+
Phalaris paradoca	"	a^H	G	+	+	+	+	+	+	+	+
Lolium rigidum var. *rigidum*	"	a^H	VG	-	+	+	+	+	+	+	+
Aegilops biuncularis	"	a^H	G	-	+	+	+	+	+	+	+
Poa annua	"	a^H	G	-	+	-	+	+	+	+	+
Phleum alpinum	"	a^H	VG	+	+	+	+	+	+	+	+
Briza humilis	"	a^H	VG	+	+	+	+	+	+	+	+
Sorghum halepense var. *multicum*	"	p^H	VG	+	+	+	+	+	+	+	+
Bromus tectorum	"	a^H	VG	+	+	+	+	+	+	+	+
Melica persica	"	p^H	VG	+	+	+	+	+	+	+	+
Gastridium ventricosum	"	a^H	G	-	+	+	-	+	+	+	+
Hordeum spontaneum	"	a^H	VG	+	+	+	+	+	+	+	+
Stipa holosericea	"	p^H	VG	+	+	+	+	+	+	+	+
Phleum exaratum ssp. *exaratum*	"	a^H	G	-	-	-	+	+	+	+	+
Polypogon viridis	"	p^H	VG	+	+	+	+	+	+	-	+
Scabiosa argentea	Dipsacaceae	p^H	VG	-	-	-	+	+	+	+	+
Extrinsic species											
Papaver syriacum	Papaveraceae	a^H	G	-	+	+	+	-	-	-	-
Hypecoum imberbe	"	a^H	G	-	+	+	-	-	-	-	-
Adonis annua	Ranunculaceae	a^H	G	+	+	+	-	+	-	-	-
Delphinium peregrinum	"	a^H	G	-	+	+	+	+	-	-	-
Ranunculus arvensis	"	a^H	G	+	+	+	+	-	-	-	-
Euphorbia taurinensis	"	a^H	G	-	+	+	-	-	-	-	-
Galium verum ssp. *verum*	Rubiaceae	a^H	G	-	+	+	+	-	-	-	-
Cruciata articulata	"	a^H	G	+	+	+	+	-	-	-	-
Ajuga chamaepitys ssp. *laevigata*	Lamiaceae	p^H	G	-	+	+	-	-	-	-	-
Salvia viridis	"	a^H	G	-	+	+	-	+	+	+	-
Geranium rotundifolium	Geraniaceae	a^H	G	+	+	+	+	-	-	-	-
Geranium molle ssp. *molle*	"	a^H	G	-	+	-	+	-	-	-	-
Aegilops triuncialis	Poaceae	a^H	G	-	+	+	+	-	-	-	-
Triticum aestivum	"	a^H	G	-	+	+	-	+	-	-	-
Allium dictyoprasum	Liliaceae	p^H	G	+	+	+	+	+	+	+	+
Scabiosa persica	Dipsacaceae	b^H	G	-	-	+	+	-	-	-	-

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Caucalis platycarpus	Apiaceae	a^H	G	+	+	+	-	+	+	-	-
Scandix stellata	″	a^H	G	+	+	-	+	-	-	-	-
Smyrnium cordifolium	″	a^H	G	-	+	-	-	-	-	-	-
Torilis tenella	″	a^H	G	-	+	-	+	-	-	-	-
Trigonella corniculata	Fabaceae	a^H	G	-	+	+	+	-	+	+	-
Astragalus astereas	″	a^H	G	+	+	-	+	-	-	-	-
Trifolium campestre	″	a^H	G	-	+	+	-	-	-	-	-
Vicia narbonensis var. *narbonensis*	″	a^H	G	-	+	-	-	-	-	-	-
Vicia ervilia	″	a^H	G	-	+	+	-	+	-	-	-
Vicia aintabensis	″	a^H	G	-	+	+	+	-	-	-	-
Linum nodiflorum	Linaceae	a^H	G	+	+	-	+	-	-	-	-
Alyssum strictum	Brassicaceae	a^H	G	-	+	+	-	-	-	-	-
Malcolmia crenulata	Brassicaceae	a^H	G	-	+	+	-	+	+	+	-
Erysimum goniocaulon	Brassicaceae	a^H	G	+	+	-	+	-	-	-	-
Fumaria parviflora	Papaveraceae	a^H	G	-	-	+	+	-	-	-	-
Alyssum aureum	Brassicaceae	a^H	G	-	+	-	+	-	-	-	-
Clypeola aspera	″	a^H	G	-	+	-	+	-	-	-	-
Arabis verna	″	a^H	G	-	+	+	-	-	-	-	-
Iberis acutiloba	″	a^H	G	-	-	+	+	+	-	-	-
Thlaspi perfoliatum	″	a^H	G	+	+	-	-	-	-	-	-
Neslia apiculata	″	a^H	G	-	+	-	+	-	-	-	-
Cleome ornithopodioides	Capparaceae	a^H	G	+	+	-	-	-	-	-	-
Scleranthus annuus ssp. *annuus*	Illecebraceae	a^H	G	-	+	-	-	-	-	-	-
Linum pubescens	Linaceae	a^H	G	+	+	-	-	-	-	-	-
Cichorium glandulosum	Asteraceae	b^H	G	-	+	-	-	-	-	-	-
Senecio vernalis	″	a^H	G	+	+	+	+	-	+	-	-
Anthemis arvensis	″	a^H	G	-	+	+	-	+	-	-	-
Filago vulgaris	″	a^H	G	+	+	-	-	-	-	-	-
Geropogon hybridus	″	a^H	G	-	+	-	+	-	-	-	-
Lactuca undulata	″	b^H	G	+	+	+	-	-	-	-	-
Carlina lanata	″	a^H	G	-	+	+	+	-	-	-	-
Filago pyramidata	″	a^H	G	+	+	+	-	-	-	-	-
Anagallis arvensis var. *arvensis*	Primulaceae	a^H	G	-	+	-	+	-	-	-	-
Campanula strigosa	Campanulaceae	a^H	G	+	+	+	-	-	-	-	-

The community corresponding to steppe area coppices went through five phases in terms of changes in the floristic richness after the fire. In the first phase, during the first two months, there was no vegetative resprouting. In the second phase, during the following four years, there was a rapid decrease of taxa. In the third phase, during the fifth and sixth years after the fire, there was a slow decrease of taxa. In the fourth phase, the number of taxa was stable through tenth year (Fig. 3). In the last phase, the shrubs reached adult size and maturity.

Of the species present before the fire, 96.3% reappeared in the three years after the fire (Table 2). The return toward a metastable state was quite rapid. It is known that some steppe ecosystems evolved with fire and that most plant species developed fire-adaptive mechanisms. These mechanisms could be associated with the strategies of persistence after a fire (e.g., species those regenerated well or disseminated numerous seeds after fire).

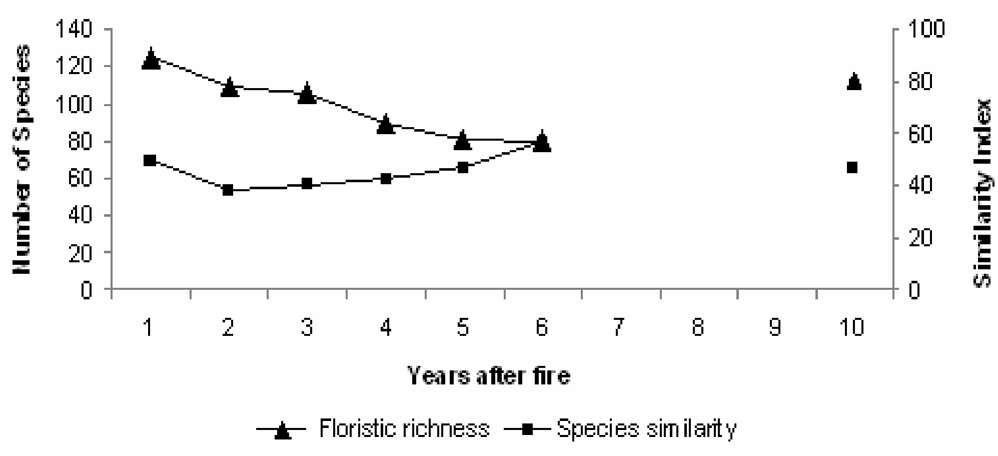

Fig. 3. Development and smilarity of floristic composition of burnt area after the fire.

Table 2. Appearance proportions of resident and extrinsic species, and the floristic similarity (Sorenson similarity index, SSI) between burnt and unburnt areas after fire.

Time after fire	Burnt sites				SSI
	No. resident spp.	%	No. extrinsic spp.	%	
5 months	41	50.9	18	36	42.5
1 year	30	36.5	29	58	60.7
2 "	5	6.4	3	6	66.3
3 "	4	4.8	0	0	80.4
4 "	2	1.4	0	0	90.8
5 "	0	0	0	0	93.6
6 "	0	0	0	0	93.7
10 "	0	0	0	0	96.4
Total	82	100	50	100	

Many herbaceous resprouters possessing subterranean structures (rhizomes, stolons, bulbs, or tubers), such as *Poa bulbosa, Asparagus palaestinus, Allium ampeloprasum, Cynedon dactylon* var. *villosus, Sorghum halepense* var. *muticum, Gladiolus atroviolaceus, Gagea reticulata*, and *Gladiolus atroviolaceus*, regenerated easily in the first year after the fire. These results agreed with Turkmen and Duzenli 1990, Daubenmire 1968. The subterranean woody resprouters (*Capparis ovata* ssp. *palaestina, Olea europaea* var. *sylvestris, Ficus carica* ssp. *carica, Paliuris spina-christi, Amydalus orientalis, Celtis tournefortii*) dominated the previous situation in the fifth year.

Sprouting of perennials after fire depends upon the survival of buds having vascular connections with the subterranean organs. Subterranean organs are protected from fire by the soil, which is a good isolator and conducts little of the heat produced by burning vegetation (Packmann 1971, Aston and Gill 1976, Mooney and Dunn 1971) found that nearly 50% of small woody shrubs in California and Chile resprouted after a fire (Kruger 1977) suggested that approximately

65% of South African fynbos species behaved in the same manner (Naveh 1975) in Israel and (Trabaud and Lepart 1980) in southern France found that nearly all the woody species of these regions resprouted after a fire within three to five years.

The successive observations during six years and in the tenth year show that the reappearance of the taxa those were frequent before the fire progressively dominated the floristic composition of the vegetation. Among extrinsic species, the most prolific families were Brassicaceae, Poaceae, Asteraceae, and Liliaceae. We observed that, species of these families were more abundant in the first three years after the fire than in the pre-fire stage. Later (in the fifth year), they increased to pre-fire levels. Some of them had stolens, bulbs etc. which were not affected fire under soil, or some of had light seeds which dispersed with wind easily. So, in the first month, these plants could grow easily in the burnt area.

The study area is located within Sanliurfa large plateau and is not isolated geographically. That, geographical isolation is not the kind of impact has become a facilitator of spreading out of populations. The non-biological factors such as wind, rain and the biological factors such as animal and human have improved and accelerated the spreading of plants. Thus the original populations migrated and spreaded out easily within a short period.

The inorganic substances in the soil remaining after the fire mission has been used as fertilizer. This was also a positive factor in the development and spreading of populations. The climatic parameters of region are favorable during the vegetative period of plants.

As a result, homogeneity of the climate and geographical structure, easy dissemination of seeds provided the recovery of original flora in a short period of time. There was no real succession in the burnt steppe area, where different communities appeared, but rather a progression; i.e., the reconstitution of the former plant community. Present author believes this is a widespread phenomenon in the south-east Anatolia steppe vegetation.

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