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Competitive, stress-tolerant and ruderal based classification of some plant species in an Alpine community of the Giresun Mountains in Turkey

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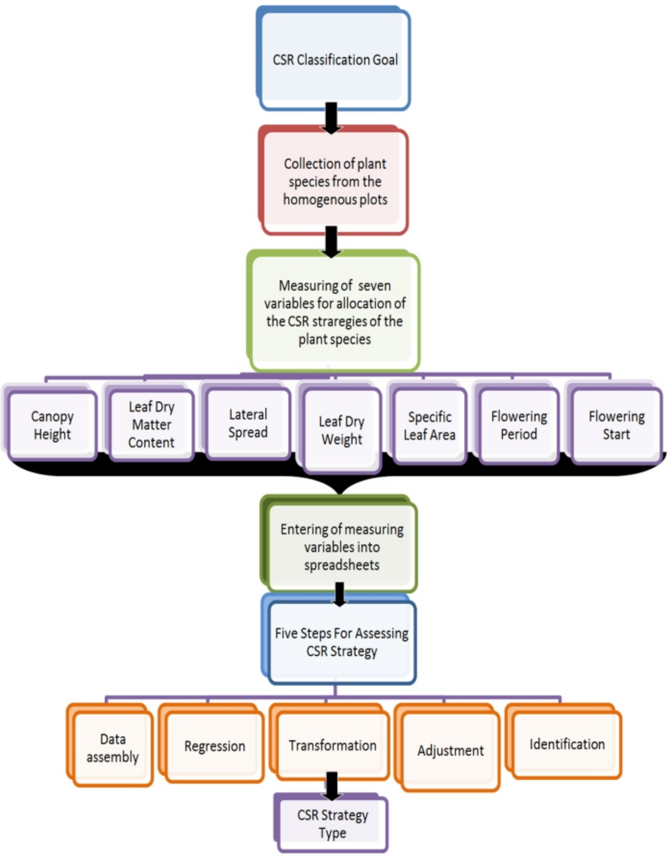
Abstract

Aim: The CSR strategy model classifies plant species based on established strategies in dealing with two groups of external environmental factors, namely stress and disturbance. The main objective of the present study was to analyze established strategies of some characteristic plant species in the alpine belt of the Giresun Mountains in Turkey and to determine any disturbance on plant species present in the study area.

Methodology: Fifty sample plots and ninety plant species were selected from homogenous areas to determine predictor variables for Grime's CSR strategies. Canopy height (CH), dry matter content (LDMC), lateral spreading (LS), dry leaf weight (LDW), specific leaf area (SLA), flowering period (FP) and onset of flowering period (FS) were used to find Grime's strategies for the studied species.

Results: Almost all species present in the study area were allocated into nine different secondary or transient Grime's strategies. Most of these secondary or transient strategies (SC, S/SC, and SC/CSR) have a large proportion stress-tolerator strategy (S). On the other hand, high number of plant species exhibited CR, C/SC, R/CR and C/CR strategies having strong competition and ruderalism extents. CR (competitor-ruderal) was the most common strategy in the study area.

Interpretation: Findings suggested that plant species in the study area were exposed to more than one pressure factor. The presence of a large proportion of ruderalism demonstrates the increasing impact of disturbance (grazing and mowing) on the studied species.



Introduction

Classification of plant species and vegetation according to life-history has a long tradition in plant ecology. This classification is essentially based on the attributes of plant species that gave them the capacity to survive under different geographic, climatic and ecological conditions and is closely linked to plant architecture and physiognomy (Vandvik and Birks, 2002). However, recent studies in plant ecology attempt to classify plant species and communities into the major functional groups that give an opportunity to predict ecosystem responses to recurring fires, grazing, inundation, biological invasions and global climate change (Magdi, 2003; Bond *et al.*, 2005; Diaz *et al.*, 2007; Keith *et al.*, 2007; Zhu *et al.*, 2012; Shryock *et al.*, 2014).

It has been reported that some plant species behave similarly in their growth strategy in response to the environment and physiological basis of species strategies and related trait attributes is well documented in the literature, especially by Grime's C-S-R model. The term 'strategy' can be defined as a grouping of similar or analogous genetic characteristics that occurs widely among species or population and causes them to exhibit similarities in ecology (Grime, 2002). The CSR strategy model classifies plant species based on established strategies in dealing with two groups of external environmental factors, namely stress and disturbance. Stress factors include sub-optimal temperatures, and shortage of water, light and mineral nutrients and these factors cause restriction of the photosynthetic production of plant species. However, the second group of external factors, namely disturbance, is comprised of factors such as soil erosion, fire, wind-damage, frosting and activities of herbivores, pathogens, man etc. Thus, disturbance factors lead to partial or total destruction of plant biomass. Grime's three-strategy model has defined three primary strategies, such as competitive (C), stress-tolerant (S) and ruderal (R) and four secondary strategies such as competitive-ruderal (CR), competitive stress tolerant (CS), stress-tolerant ruderal (SR) and competitive stress-tolerant ruderal (CSR). In addition to three primary and four secondary strategies, the CSR strategy model also defines twenty-two intermediate or transient strategies and all these strategy types can be ordinated within a triangular space (Hodgson *et al.*, 1999).

Recent studies have shown ambiguous results in relation to apply the CSR model, especially to woody species (Pierce *et al.*, 2013). Navas *et al.* (2010) used revised categories for lateral spread proposed by Grime *et al.,* (2007) to modify CSR classification and include woody species. On the other hand, Cerabolini *et al.* (2010) stated that lateral spread used in CSR classification cannot be assumed as a strict predictor of competitive ability in unproductive habitats by stress tolerators. Even though the CSR model has been criticized by other authors, (Tilman, 1994; Craine, 2005) this theory is considered to be a fundamental functional classification (Hüseyinova *et al.*, 2013) and can be successfully applied to herbaceous vegetation.

In view of the above, the present study aimed to analyze established strategies of some characteristic plant species in the alpine belt of the Giresun Mountains in Turkey and to determine whether there is disturbance impact on the plant species or not in the study area.

Materials and Methods

Study area : The present study was performed in the alpine belt of Giresun Mountains of Giresun Province, in the north-eastern part of Turkey. Giresun mountains are a system of mountains that extend up to the peaks on Karadağ mountain at 3391m in the east and on the Karagöl plateauat 3095m in the west.

The study area is surrounded by high mountains where subalpine *Abies nordmanniana* subsp. *nordmanniana* (Stev.) Spach forests do not develop because of climatic limitations. In the study area the alpine belt extends from 1800 m.a.s.l. (timberline) to 2600 m.a.s.l. upwards on south-facing slopes. These altitudinal boundaries run about 100m lower in the northern part because of being subject to a more maritime climate.

The nearest province to the study area (Shebinkarahisar) has a Mediterranean type climate with 525mm mean annual precipitation (P) and a drought period that prevails in July with 0.5mm precipitation. The mean annual temperature is 11.3°C. Summer rainfall is 37mm. The mean maximum temperature for the hottest month and the mean minimum temperature for the coldest month (m) is 30.3 and -16.1°C, respectively. Index of xericity ($S=PE/ME$) is 1.8. Pluviometric quotient ($Q= 2000P/M + m + 546.4[M-m]$) is 40.7 and the precipitation regime is Sub Mediterranean (Spring, Autumn, Winter, Summer; Sp, Au, Wi, Su).

Alpine grasslands in the study area is characterized by *Festuca pinifolia* (Hackel ex Boiss.), Bornm. var. *pinifolia, Sibbaldia parviflora* Willd. var. *parviflora, Minuartia umbellulifera* (Boiss.) McNeill subsp. *umbellulifera* var. *umbellulifera, Thymus sipyleus Boiss.*, *Vaccinium myrtillus* L., *Potentilla crantzii* (Crantz) Fritsch and many other species. Cover values of these species ranged from 10 to 50. Plant species in the study area are fragile with its species and population being directly and indirectly influenced by changes in land-use practice, especially abandonment of small-scale agriculture, and fragmentation of habitats. Generally, the study site is exposed to low but frequent disturbance factors. As an important disturbance factor, grazing reduces the dominance of competitive species and by trampling creates germination niches in the bare soil. It, therefore, has a direct effect on the structure and organization of grasslands. Today, many of the pastures in the study area are still in use (i.e. mowing, grazing or both); fallow farmland of pastures can be found in different successional stages. The number of grazing cows and sheep reach 50000 individuals during the year.

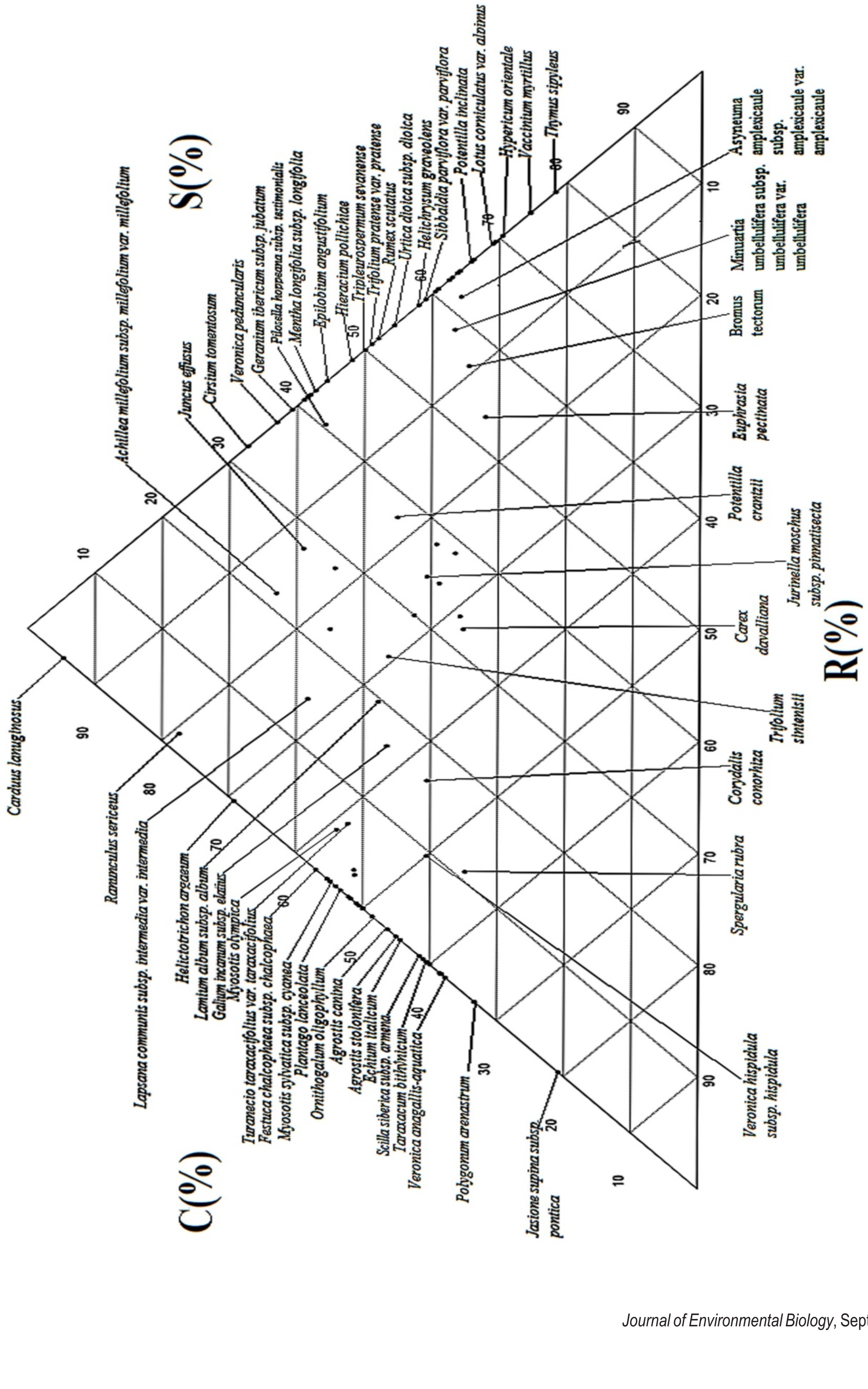


Fig.1: Competitive, stress-tolerant and ruderal (CSR) classification of 90 wild herbaceous species in an Alpine community of the Giresun Mountains in Turkey

Table 1: Definition of the required parameters for allocation of the CSR strategies of plant species (Hodgson *et al.*, 1999)

Variable			Definition
		1	1-49 mm
		2	50-99 mm
		3	100-299 mm
Canopy height	Six-point	4	300-599 mm
	classification	5	600-999 mm
		6	>999 mm
Dry matter content	Mean of percent dry matter content in the largest, fully hydrated, fully expanded leaves (%)		
Flowering Period	Normal duration of flowering period (months)		
		1	First flowering in March or earlier
		2	in April
Flowering start	Six-point	3	in May
	classification	4	in June
		5	in July
		6	in August or later, or before leaves in spring
		1	Plant short lived
		2	Compactly tufted about a single axis, no thickened rootstock (in non-graminoids)
		3	Compactly tufted ramets appressed to each other at base (in graminoids)
Lateral spread	Six-point	3	Compactly tufted about a single axis, thickened rootstock present (in non-graminoids)
		4	Shortly creeping, <40 mm between ramets
		5	Creeping, 40-79 mm between ramets
		6	Widely creeping, >79 mm between ramets

Vegetation sampling and ordination of species within CSR space : Fifty sample plots were selected (4x5m) from homogenous areas, and 90 plant species were selected from the plots with the highest cover values to determine predictor variables for Grime's CSR strategies. Species with cover values of less than 5% in these plots were excluded. Taxonomic nomenclature of Davis (1965-1985) and Davis et al. (1988) were referred and Latin names were updated following Güner *et al.* (2000).

Canopy height, leaf dry matter content, lateral spreading, leaf dry weight, specific leaf area, flowering period (FP) and onset of flowering period were used to find Grime's strategies for the studied species. The flowering period parameter was only required for nongraminoids (Table 1).

After determining seven predictor variables (six predictor variables for graminoids) for each species, these variables were entered into spreadsheets and established strategies were assessed by automatic data transformation. The CSR strategy of a specie was assessed in five steps: data assembly, regression, transformation, adjustment and identification of CSR type. Coordinate values ranged from -2.5 to 2.5; data were translated onto a positive axis with the minimum value set as zero. Prior to plotting C, S and R values were then converted into percentages for each species (Hodgson *et al.*, 1999; Çakır *et al.*, 2010).

Results and Discussion

Forty one percent of the studied species belonged to the Euro-Siberian phytogeographical region, 13.3% to the Irano-Turanian phytogeographical region, and 3.3% to the Mediterranean phytogeographical region, while 42.3% of the species were pluriregional or phytogeographically uncertain.

The most abundant species (Table 2) in the study area was *Festuca pinifolia* var. *pinifolia* (cover=50%), that exhibited a plant strategy of CR incorporating substantial competitive and, to a slightly lesser extent, ruderal abilities (C : S : R = 52.1 : 0 : 47.9). The second most abundant species (*Minuartia umbellulifera* subsp. *umbellulifera* var. *umbellulifera*; cover=20%) exhibited a broadly stress-tolerant-competitor (SC) strategy (36.6 : 58.5 : 4.9), and the third most abundant species (*Vaccinium myrtillus*; cover=15%) demonstrated a pure stress-tolerator (S) strategy (25.4 : 74.6 : 0). A few of the studied species (only six species) represented primary established strategies. Two of these species exhibited competitor (C) strategy whereas another four species were allocated into the stress-tolerator (S) strategy. Almost all the species in the study area were allocated to nine different secondary or transient Grime's strategies (CR, SC, S/SC, C/SC, SC/CSR, C/CSR, C/SR, C/CR and R/CR) (Table 2). Some of these secondary or transient strategies (SC, S/SC, SC/CSR) also

Table 2: Plant species, their C (%), S (%), R (%) percentages and CSR strategies collected from the Alpine community of the Giresun Mountains in Turkey

Taxa	Strategy type of the studied species	Percentage C(%)	S(%)	R (%)	Cover (%)	Family	Taxa	Strategy type of the studied species	Percentage C(%)	S(%)	R (%)	Cover (%)	Family
Agrostis canina	CR	46.3	0	53.7	5	Poaceae	*Epilobium angustifolium*	SC	55.6	44.4	0	5	Onagraceae
Phleum alpinum	CR	45.6	0	34.4	10	Poaceae	*Alchemilla orthotricha*	SC	58.1	41.9	0	5	Rosaceae
Agrostis stolonifera	CR	45	0	55	5	Poaceae	*Sibbaldia parviflora* var. *parviflora*	S/SC	41	59	0	10	Rosaceae
Alopecurus pratensis	R/CR	38.3	0	61.7	5	Poaceae	*Taraxacum stevenii*	CR	51.2	2,4	46.4	5	Asteraceae
Dactylis glomerata subsp. *hispanica*	R/CR	38.3	0	61.7	5	Poaceae	*Taraxacum bithynicum*	CR	40.5	0	59.5	5	Asteraceae
Bromus tectorum	S/SC	34.5	56.3	9.2	5	Poaceae	*Taraxacum microcephaloides*	C/CR	55	22.5	22.5	5	Asteraceae
Trisetum flavescens	R/CR	38.5	0	61.5	5	Poaceae	*Lapsana communissubsp. intermedia* var. *intermedia*	C/CR	58.3	14.6	27.1	5	Asteraceae
Calamagrostis arundinacea	CR	54	0	46	5	Poaceae	*Hieracium pollichiae*	SC	51.9	48.1	0	5	Asteraceae
Juncus effusus	C/CSR	59	27.7	13.3	5	Juncaceae	*Pilosella hoppeana* subsp. *testimonialis*	SC	55.8	40.4	3.8	10	Asteraceae
Luzula campestris	SC/CSR	39.2	38	22.8	5	Juncaceae	*Hieracium cyaneum*	CR	50	0	50	5	Asteraceae
Kobresia simpliciuscula subsp. *simpliciuscula*	R/CR	33.3	0	66.7	5	Cyperaceae	*Leontodon crispus* subsp. *asper* var. *Asper*	S/SC	37.5	62.5	0	5	Asteraceae
Carex davalliana	C/SR	35.2	32.4	32.4	5	Cyperaceae	*Jurinella moschus* subsp. *pinnatisecta*	SC	40.6	34.4	25	5	Asteraceae
Elymus repens	CR	50.5	0	49.5	5	Poaceae	*Carduus lanuginosus*	C	94.7	0	5.3	5	Asteraceae
Urtica dioica subsp. *dioica*	SC	45.6	54.4	0	5	Urticaceae	*Cirsium rhizocephalum* subsp. *sinuatum*	CR	51.3	2.8	45.9	5	Asteraceae
Potentilla crantzii	SC	45	37.5	17.5	10	Rosaceae	*Cirsium tomentosum*	C/SC	67.3	32.7	0	5	Asteraceae
Potentilla erecta	S/SC	34.2	65.8	0	5	Rosaceae	*Helichrysum graveolens*	S/SC	42	58	0	10	Asteraceae
Potentilla inclinata	S/SC	33.8	66.2	0	5	Rosaceae	*Tripleurospermum sevanense*	SC	50	50	0	5	Asteraceae

Table 2 : (Continued)

Taxa	Strategy type of the studied species	Percentage C(%)	S(%)	R (%)	Cover (%)	Family	Taxa	Strategy type of the studied species	Percentage C(%)	S(%)	R (%)	Cover (%)	Family
Rubus idaeus subsp. *idaeus*	C/SC	59	41	0	5	Rosaceae	*Achillea millefolium subsp. millefolium* var. *millefolium*	C/SC	63	21.7	15.3	5	Asteraceae
Sedum pallidum	CR	40.4	0	59.6	5	Crassulaceae	*Tussilago farfara*	CR	54.8	04	5.2	5	Asteraceae
Phedimus spurius	R/CR	40	0	60	5	Crassulaceae	*Turanecio taraxcifolius* var. *taraxacifolius*	CR	52.2	6.5	41.3	5	Asteraceae
Epilobium gemmascens	S/SC	37	63	0	5	Onagraceae	*Alchemilla orduensis*	SC	58.5	41.5	0	5	Rosaceae
Draba siliquosa	S	25.4	74.6	0	5	Brassicaceae	*Pedicularis caucasica*	SC/CSR	42.5	30	27.5	5	Orobanchaceae
Minuartia umbellulifera subsp. *umbellulifera var. umbellulifera*	SC	36.6	58.5	4.9	20	Caryophyllaceae	*Aster alpinus*	SC/CSR	36.4	38.6	25	5	Asteraceae
Lotus corniculatus var. *alpinus*	S/SC	31	69	0	5	Fabaceae	*Euphrasia pectinata*	SC	32	53	15	5	Orobanchaceae
Melilotus officinalis	C/SC	54.3	28.3	17.4	5	Fabaceae	*Veronica peduncularis*	C/SC	63	37	0	5	Plantaginaceae
Trifolium pratense var. *pratense*	SC	49	51	0	5	Fabaceae	*Veronica anagallis-aquatica*	R/CR				5	Plantaginaceae
Trifolium badium subsp. *rytidosemium* var. *rytidosemium*	S/SC	39.1	60.9	0	5	Fabaceae	*Veronica hispidula* subsp. *hispidula*	CR	40.6	9.4	50	5	Plantaginaceae
Trifolium sintenisii	CR	46.3	24.4	29.3	5	Fabaceae	*Veronica gentianoides* subsp. *gentianoides* var. *alpina*	CR	55.3	0	44.7	5	Plantaginaceae
Geranium ibericum subsp. *jubatum*	C/SC	60.8	39.2	0	5	Geraniaceae	*Echium italicum*	CR	44.4	0	55.6	5	Boraginaceae
Hypericum orientale	S/SC	29.6	70.4	0	5	Hypericaceae	*Myosotis olympica*	CR	53.9	5.1	41	10	Boraginaceae
Chenopodium foliosum	CR	50.9	0	49.1	5	Amaranthaceae	*Myosotis sylvatica* subsp. *cyanea*	CR	54.8	0	45.2	5	Boraginaceae
Rumex scutatus	SC	48	52	0	5	Polygonaceae	*Ranunculus cappadocicus*	S/SC	30.6	69.4	0	5	Ranunculaceae
Polygonum arenastrum	R/CR	33.3	0	66.7	5	Polygonaceae	*Corydalis conorhiza*	CR	40.5	16.2	43.3	5	Papaveraceae
Polygonum setosum subsp. *setosum*	S/SC	39.5	69.5	0	5	Polygonaceae	*Ranunculus ficaria* subsp. *ficariiformis*	R/CR	38.3	0	61.7	5	Ranunculaceae

Table 2: (Continued)

Taxa	Strategy type of the studied species	Percentage C(%)	S(%)	R (%)	Cover (%)	Family	Taxa	Strategy type of the studied species	Percentage C(%)	S(%)	R (%)	Cover (%)	Family
Silene italica	CR	51.8	0	48.2	5	Caryophyllaceae	Vaccinium myrtillus	S	25.4	74.6	0	15	Ericaceae
Spergularia rubra	CR	34.8	10.9	54.3	5	Caryophyllaceae	*Gagea glacialis*	CR	50	0	50	5	Liliaceae
Stellaria media	SC/CSR	35.7	33.3	31	5	Caryophyllaceae	*Colchicum szovitsii* subsp. *szovitsii*	CR	41	0	59	5	Colchicaceae
Asyneuma amplexicaule subsp. *amplexicaule* var. *amplexicaule*	S/SC	35.7	61.9	2.4	5	Campanulaceae	*Lamium album* subsp. *album*	CR	47.8	19.6	32.6	5	Lamiaceae
Capsella bursa-pastoris	S	25.4	74.6	0	5	Brassicaceae	*Thymus sipyleus*	S	21.7	78.3	0	10	Lamiaceae
Gentianella ciliata subsp. *blepharophora*	SC/CSR	38.8	34.7	26.5	5	Gentianaceae	*Mentha longifolia* subsp. *longifolia*	C/SC	57.3	42.7	0	5	Lamiaceae
Jasione supina subsp. *pontica*	R/CR	20.8	0	79.2	5	Campanulaceae	*Plantago lanceolata*	CR	53.3	0	46.7	5	Plantaginaceae
Muscari armeniacum	SC	39.6	60.4	0	5	Asparagaceae	*Galium verumsubsp. verum*	S/SC	35.9	64.1	0	5	Rubiaceae
Ornithogalum oligophyllum	CR	48.6	0	51.4	5	Asparagaceae	*Galium incanum* subsp. *elatius*	CR	46.5	16.3	37.2	5	Rubiaceae
Scilla siberica subsp. *armena*	CR	41.5	0	58.5	5	Asparagaceae	*Ranunculus sericeus*	C	77.4	1.9	20.7	5	Ranunculaceae
Helictotrichon argaeum	C/CR	69.2	0	30.8	5	Poaceae	*Festuca pinifolia* var. *pinifolia*	*CR*	*52.1*	*0*	*47.9*	*50*	*Poaceae*

C-competitor; S-stress-tolerator; R-ruderal; CR-competitive-ruderal; SC-stress-tolerant competitor; SR-stress-tolerant ruderal; CSR-"C-S-R" strategist.

have a large proportion stress-tolerator strategy (S). Notably, these plant species and species that exhibited pure stress-tolerator strategy (S) realistically reflect their ecologies. As it is known, is that low temperature the dominant environmental stress in alpine belts and the growth of vascular plants is constrained due to short summer period. Additionally, plants in alpine regions are subject to other stress factors such as strong winds and intense solar radiation peculiar to high altitudes (Grime, 2002). Therefore, these plant species, particularly slower-growing perennials with tough leaves and low SLA values, were grouped together in the S corner of the triangle (Fig. 1). There were large numbers of species that displayed SC strategy in the study area (Table 2). Species representing the stress-tolerant/competitor strategy were robust perennials of the sites with at least one maximum or minimum environmental factor. They differed from C-strategists in their capacity for lateral vegetative spread by means of rhizomes or expanding tussocks, lower maximum potential relative growth rates, longer life-span of leaves and shoot phenology that exhibits an entire reconciliation between that of the competitor and stress-tolerator (Grime, 2002; Zelnik and Čarni, 2008).

On the other hand, quite a higher number of plant species exhibited competitor-ruderal (CR), competitor/stress-tolerant-competitor (C/SC), ruderal/competitor-ruderal (R/CR) and competitor/competitor-ruderal (C/CR) strategies having strong competition and ruderalism extents. Especially, competitor-ruderals were amongst the most frequent species (e.g., F. pinifolia var. *pinifolia, Phleum alpinum*) and subordinate geophytes such as *Ornithogalum oligophyllum, Scilla siberica* subsp. *armena*, *Gagea glacialis* and *Colchicum szovitsii subsp*. szovitsii. These subordinate geophytes have a complementary effect on the properties of ecosystems with dominant species and temporally exploit relatively unfavorable microhabitats making a minor contribution to the biomass of grasslands (Grime, 1998; Grime, 2006). This functional type occurred under two selective pressures, competition and disturbance. Grime (2002) defined competitor-ruderals as occurring in habitats in which dominance of the vegetation by competitors is prevented by a moderate intensity of disturbance. Paušič and Čarni (2012) pointed out that with agricultural land use change (abandonment), the ecological strategies of both plant species and the whole community change. Since traditional land management (e.g. grazing by cattle and sheep) prevails at moderate intensity in the study area, plant strategies shifted from S, SC, S/SC and SC/CSR towards CR, C/CR, R/CR and C/SR. The proportions of ruderalism reflect the degree of disturbance prevailing on different sites. Pierce *et al.* (2007) also stated that increased disturbance intensity encouraged both functional and species diversity, especially of ruderals and lesser co-dominance whereas dominant stress-tolerating graminoids were suppressed. the present findings were consistent with these results. Species representing the S and SR strategies are also able to persist well concurrently on managed sites (Huhta and Rautio, 1998).

The presence of ruderals and CR strategists in the study area confirms that disturbance strongly influences niche segregation; faster-growing ruderals and competitive-ruderals necessarily require a local abundance of nutrients and are well-adapted to propagate genes before ephemeral nutrient patches become exhausted due to their rapid inherent development and competition of the life-cycle (Pierce *et al.*, 2007). Similar results were obtained by Hüseyinova et al. (2013). Guleryuz et al. (2010) also pointed out that in the alpine tundra, plant species have an important control on the soil N turnover, affecting the structure of the plant community and ecosystem function.

The results of the present study were compared with the reports of Grime *et al.* (2007) in the inland areas of Britain. Functional strategy types of only a few plant species *(Agrostis stolonifera, Tussilago farfara, Lamium album* subsp. *album)* were found similar to those obtained from the same species distributed in Europe, while lot of differences in strategy types of species were also found. For example, the deciduous shrub *Vaccinium myrtillus* L., which is a characteristic species in the alpine belt, displayed pure S-strategy in the study area, whereas Grime *et al.* (1998) classified this species as an SC-strategist. Also, roadside species Capsella bursa-pastoris (L.) Medik exhibited S-strategy in the present study, while Grime *et al.* (1998) found that *C. bursa-pastoris* displayed an R type strategy. These differences may be explained by habitat characteristics of the study area including altitude, soil structure, location, climate, light conditions, nutrient availability and intensity of disturbance factors. In fact, alpine belt plants are exposed to severe stress factors such as low temperature, strong wind, dryness, UV radiation, and short growing periods due to high altitudes. Thus, under these conditions the functional strategy of a species may change within CSR space. Similar results were reported by Hunt *et al.* (2004), Çakır *et al.* (2010), Kılınç *et al.* (2010), and Hüseyinova et al. (2013). Therefore, it is difficult to state that one species exhibits same strategy in all the habitats.

This study tried to classify competitive, stress-tolerant and ruderal strategies of some alpine belt plant species which lead to a change in the ecological strategies of plant species. This study suggested that, using easily-measured plant traits and standard vegetation methods might be useful on ecology and conservation efforts of alpine plant species in Turkey.

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