Rend. Fis. Acc. Lincei (2018) 29:35–41
https://doi.org/10.1007/s12210-017-0655-6

Weed ecology is affected by succession in differently aged gardens of *Citrus sinensis* and *C. reticulata*

Hamid Salehian[1] · **Majid Mohammadzadeh**[1]

Received: 2 June 2017 / Accepted: 16 October 2017 / Published online: 13 November 2017

Abstract The concepts of destruction and rebuilding in the succession play an important role in agro-ecology. Agricultural ecosystems are always affected by tillage, soil preparation, harvest, burning, and arboriculture. A common practice in the northern province of Mazandaran (Iran) is to replace rice (*Oryza sativa* L.) cultivation with Citrus farming. It can be accordingly interesting to investigate the ecology of weed community specifically the dominance and characters during the different stages of succession, using constitutive and physiological aspects. In a 2-year research work, some functional (species composition and stability) and physiological characteristics (relative growth rate, biomass, and N and P uptake) of different weeds in the initial and final stages of secondary succession in Citrus gardens were compared. Three young (*Citrus sinensis* L.) and three old Citrus (*Citrus reticulata* Blanco) gardens (with the average age of 2 and 29 years, respectively), were selected in the suburb of Qaemshahr city (Iran), the centre of Citrus production. In each garden, three main fixed plots (30 m^2), with five subplots (1 m^2) and destructive quadrates in each one, were prepared and used for the experiment (January 2013–August 2014). Weed composition was monthly recorded. The concept of dominance diversity was used to estimate the community consistency. Thirty-three weed species were identified among which the Poaceae and Asteraceae families were the dominant ones. In the young gardens, the number of weed species was twice more than the old ones. *Poa nemoralis* as a perennial and sciophytes species were plentiful in the old gardens. Just in the young gardens, the weed species were moved by pappus. There was a linear and stable regression between weed frequency and dominance in the final sampling. Higher relative growth rate as well as higher N and P uptake was resulted in the young gardens. Seed size and growth rate were correlated in the young gardens, and the smaller seeds resulted in a higher rate of weed survival. Parameters including weed dominance, functional and physiological characteristics, seed size, and the environment may determine weed ecology and survival at different stages of succession in Citrus gardens.

Keywords Citrus (*Citrus sinensis* L.) · *C. reticulata* · Nutrients · Succession · Weed ecology

1 Introduction

Ecologists have recognized two important successions: initial succession, which is the occurrence of ecosystem expansion on the sites that have not been previously occupied by living organisms (such as bare rocks and frozen surfaces); and secondary succession, which happens in the ecosystems, which have been previously occupied by organisms. Tilled fields, clear-cut forests, and burned areas are all exposed to secondary succession (Letcher 2010; Podda et al. 2011; Rezvani et al. 2013).

During the succession, vegetative variations are not coincidental, and spread of vegetation is regularly carried out with the following functional variations (Dölle et al. 2008; Schmid et al. 2017). The early stages in succession include species, which have light seeds (Rockwood 1985), high seed production (Hyatt and Casper 2000), extensive distribution (Samuel and Hart 1994), and rapid growth rate (Lambers et al. 2008). Species with large seeds have longer life period,

✉ Hamid Salehian
hamisalehian@gmail.com

[1] Department of Agronomy, Faculty of Agriculture and Natural Resources, Islamic Azad University, Qaemshahr Branch, Qaemshahr, Iran

meaning they are more competitive and dominant in the final stages of succession (Fenesi et al. 2014). In such stages, perennial weed species replace the annual ones (Corbin and D'Antonio 2004) in a period of one (Brown et al. 1987) to 40 years (Bornkamm 1981). The rate of these events depends on factors such as soil (Dzwonko and Loster 1997; Fanelli and Lucchese 1998), climate (Calvo et al. 2005), weed seed bank (Bekker et al. 2000), and the initial density of perennial weed species (Turner et al. 1998).

The establishment of juvenile plants, bush, and weed under the tree shadow idiomatically is called 'understory' (Leopold and Solozar 2008) that have interference with trees. The interactions between weed growth and tree behaviour have been addressed by different studies (Cantarelli et al. 2006; Rondon 2006; Bonari et al. 2017). For example, Larpkern et al. (2010) have identified specific species of weeds under the trees after tillage. It is preferable that such weeds be controlled at the early stage of growth, or the use of repair trends become difficult. Increased frequency of species is largely controlled by seed production, species growth rate (Chapin et al. 1997), and competitiveness (Tilman 1988).

The chemicals characteristics of soil such as nutrients, salts, and organic matter may cause the appearance of specific weed species (Garnier et al. 2004; Salama et al. 2017). Some research work has shown a correlation between variation of soil nutrients and plant composition (Shaltout et al. 2014; Angiolini et al. 2017). For example, when soil nitrogen and organic matter reduces, bushes are replaced with grasses (Reynolds et al. 1999; Suding et al. 2008).

Unfortunately, important changes in planting patterns in Mazandaran province (Iran) have occurred for various economic reasons, e.g., farming in uplands and rice fields has been changed to Citrus gardens. Such changes will definitely result in the change of weed ecology including dominance and characteristics affecting weed control. How weed ecology may be affected in the Citrus gardens by important parameters, such as succession, is an important question which must be addressed by research work. Accordingly, this study was carried out to determine weed dominance and functional and physiological characteristics (life cycle, seed size, growth rate, and biomass accumulation), affected by succession, in the young and old gardens of *Citrus sinensis* and *C. reticulata.*

2 Materials and methods

In this experiment, three young and three old Citrus gardens were selected as samples of two communities in the early and final stages of secondary succession, respectively. The reason of secondary succession was due to the tillage of the rice fields. Following a destructive deep ploughing (30 cm depth) in the rice fields, farmers transplanted Citrus seedlings. Old gardens in the same region were considered as samples in the climax peak or final succession stages (Blatt et al. 2003) (Table 1).

Three plots (each measuring 30 m^2, 15 m × 2 m), with five subplots (measuring 1 m^2) in each (making the total number of subplots to 15), were selected in each garden. Moreover, destructive sampling was performed in 50 × 50 cm quadrates (Souza et al. 2013). Weed species in the fixed plots were labelled and were identified from the beginning to the end of the experiment (Nov 2013–Aug 2014). Weed seeds were separated and their size was measured in the laboratory after plant maturity and before shedding.

Composition of weed species in the fixed plots was monthly examined (Gregg 1972). In this period, the weeds in the quadrates were randomly sampled, identified, and weighted. The roots were separated and sent to the laboratory to determine dry matter as well as N and P contents according to Olsen et al. (1954) using a spectrophotometer (Jensen 1991). The collected samples at different stages of weed growth were identified in the lab, and their stem and root weights determined (Shimi and Terme 2003).

The index of relative growth rate (RGR) was used for the comparison of dry matter accumulation in young and old gardens (Van Arendank and Porter 1994; James and Drenovsky 2007). Due to the significant differences between the weed population means, least significant difference (LSD) test was used for the determination of significant differences using SAS (2012) ($P = 0.05$) (Dodge 2008).

3 Results and discussion

In the young Citrus gardens, the number of weed species was more (27 species) than the old ones (12 species). The main species belonged to Poaceae and Asteraceae families. In general, 33 weed species were identified in all sites. During the study of the two gardens with different age, Souza et al. (2013) also showed that the number of weed species was more in young gardens. With time, the more stable species of weed species became dominant in the second succession.

Table 1 Characteristics of the experimental Citrus species

Citrus species	Area (ha)	Age at sampling (year)
Citrus sinensis	1	2
Citrus sinensis	2	3
Citrus sinensis	2	1
Citrus reticulata	2	30
Citrus reticulata	4	32
Citrus reticulata	2.5	25

The share of annual weed species was more (77%) in the young gardens, which may be due to the lack of plant cover and high seed production rate. In addition, among annual weeds in the young gardens, the two species of *Senecio arvensis* and *Conyza canadensis*, were found, which had never been found in the old gardens. The above-mentioned species not only can produce plenty of seeds but also their seeds have pappus for dispersion facility, which can also be the explanation for spreading in the young gardens (Monty et al. 2010).

Moreover, bulky canopy, plenty of stems, and high leaf area in the old gardens (Mueller et al. 2015) can cause the extension of sciophytes species. This was confirmed by the high frequency of *Poa nemoralis* in the old gardens, which is a perennial and shadow bearing weed (Hawksworth and Bull 2006). Oka (1984) also showed that in the end of a secondary succession, the portion of perennial weed was higher. Increase of perennials weed in the old gardens probably can be related to tillage frequency and soil compaction (Stolcova 2002; Woźniak and Soroka 2015).

In the young gardens, weeds absorbed higher rate of P (Table 2). Hauser and Mekao (2009) carried out an experiment in Cameron forests that were exposed to secondary succession. They found that during the final stages of succession, the biomass of broad-leaf weeds and P uptake in all species reduced. Similarly, Saxena and Ramakrishnan (1984) showed that weed biomass and nutrient uptake decreased in lands, exposed to secondary succession.

The regression analysis between the frequency of weed species and percentage of accumulated dominance in the final sampling (Nov 2014) in both gardens was only significant in the final succession stages (Farahat et al. 2016) (Fig. 1). Linearity of this function in the peak of succession indicates that there was a balance between species and the lack of dominance. This result is confirmed with current supplementary connection instead of competitive linkage among species (Numata 1982). Growth of weed species in the young gardens was more rapid as 22% of them had the highest RGR (12–20 g g^{-1} w^{-1}). Meanwhile, the frequency of this trait was zero in the old gardens. Moreover, the highest rate of abundance in the old gardens belonged to the species, which had the least RGR (0–4 g g^{-1} w^{-1}) (Fig. 2; Table 3). On the whole, the rate of photosynthesis during the early succession stages was more than the next stages of succession (Owens 1996). In the old gardens and during the secondary stages of succession, only the more stable weed species, which are tolerant to the less abundance of soil resources such as nutrients, can survive. This is due to the fact that in the old gardens, the higher growth of Citrus trees makes them more demanding for the soil resources, adversely affecting the growth of weed species.

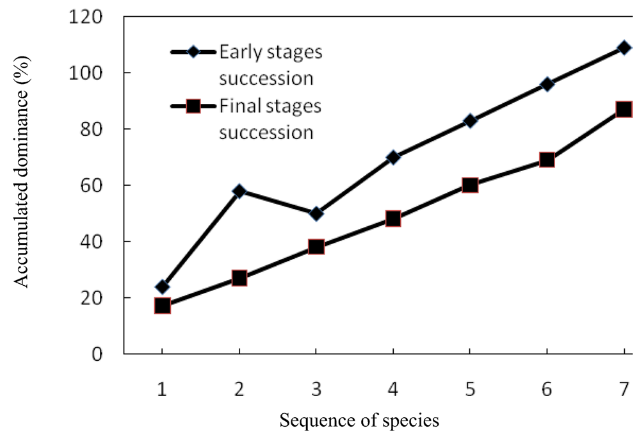

Fig. 1 Accumulated dominance of species in the various stages of succession (July sampling)

Weed species in young gardens had smaller seeds (Fig. 3). It seems that this happened to make transformation simple. The large seeds in the old gardens increased the seed food storage indicating that the weed seedlings can be more competitive in the dense canopy of trees. High food storage in bigger seeds let them to survive in the final succession stages declining plant mortality under the tree canopy (Grime and Jeffrey 1965). The species grown in the unclosed sites (young gardens) can produce numerous seeds. Therefore, due to the high diversity of re-grown weed species, the probability of seed adaptation can be maximal in the destroyed places (Marshall et al. 2002).

There were significant differences in N and P uptake in weed roots in young and old gardens (Fig. 4) as the young gardens absorbed more nutrients (Touraine et al. 1994). This can be due to the high potential for growth rate (Fig. 2)

Table 2 Changes in the functional and physiological characteristics of the weeds from the initial to the secondary succession

Weed characteristics	Initial stage	Secondary stage
Life cycle	Mainly annual (23% perennial)	Increased perennial (33% perennial)
Weed dominance	Broad-leaf (74% biomass)	Narrow-leaf (66% biomass)
P concentration (%)	312	267
Total weed biomass (g m^{-2})	7.94	3.83
Annual weed biomass (g m^{-2})	26.1	1.55
Broad-leaf biomass (g m^{-2})	5.35	1.10

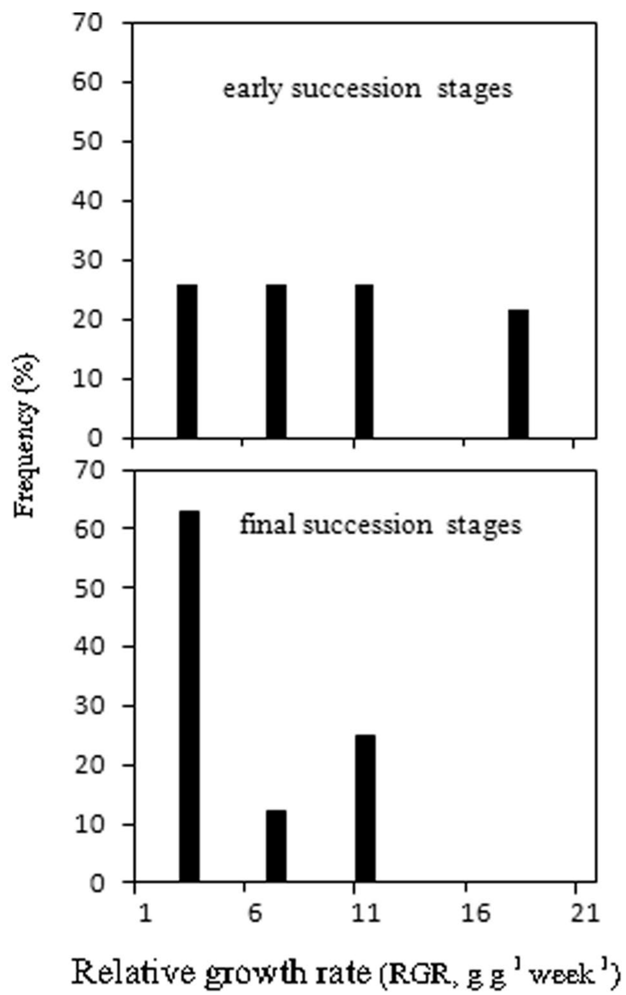

Fig. 2 RGR frequency distribution of species in the initial and final succession

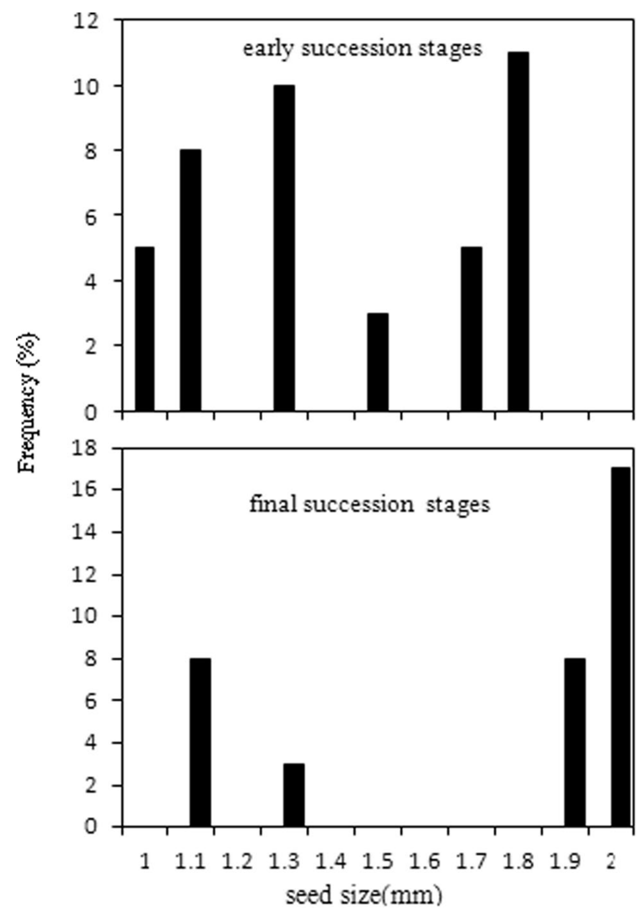

Fig. 3 Distribution of seed size frequency in the initial (n = 62) and final stages (n = 36) of succession

and more demand for nutrients. Van der werf et al. (1992) also showed that *Holcus lanatus* had higher RGR relative to *Carex diandra*, because their rates of N absorption were 2.7 and 0.7 m mol g^{-1} day^{-1}, respectively. There was a strong correlation between N uptake and RGR (Lambers and Poorter 1992; Blank et al. 2015) in both gardens (Fig. 5) and its line slope was significant in both sites. Such correlation means that more metabolic compounds are allocated to the roots and leaf side than the cell wall in the aerial part (Van der werf et al. 1992). Therefore, it can be mentioned that the rapid growth of seedlings in the early succession stages (young gardens) is related to the great potential uptake of N (Table 3) (Salama et al. 2017). In addition to growth activity, root storage allocation causes RGR variation.

Table 3 Weed root N concentration and dry weight in the initial and secondary stages of succession (July sampling)

Initial stage			Secondary stage		
Species	*N* (%)	Root dry weight (g)	Species	*N* (%)	Root dry weight (g)
Conyza canadensis	1.52	0.2	*Setaria glauca*	2.75	0.16
Amaranthus retroflexus	3.25	0.52	*Amaranthus retroflexus*	2.28	0.23
Chenopodium album	2.47	0.36	*Mercurialis annua*	2.18	0.42
			Cyperus esculentus	1.67	0.28
Mean	3.41	0.36		2.22	0.27

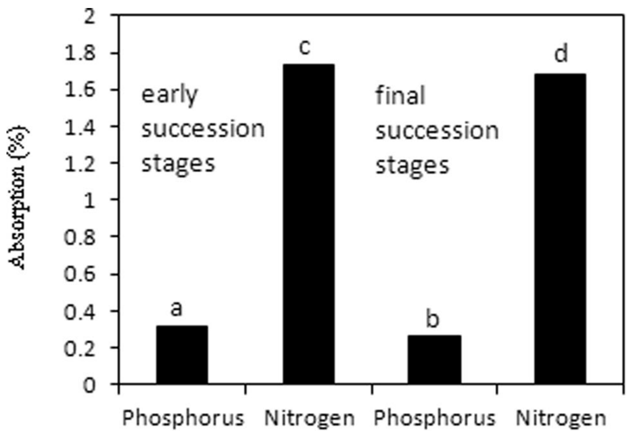

Fig. 4 Phosphorus and nitrogen absorption by weed roots in the initial (n = 29) and final (n = 16) stages of succession. Different letters indicates significant difference at P = 0.05 using LSD

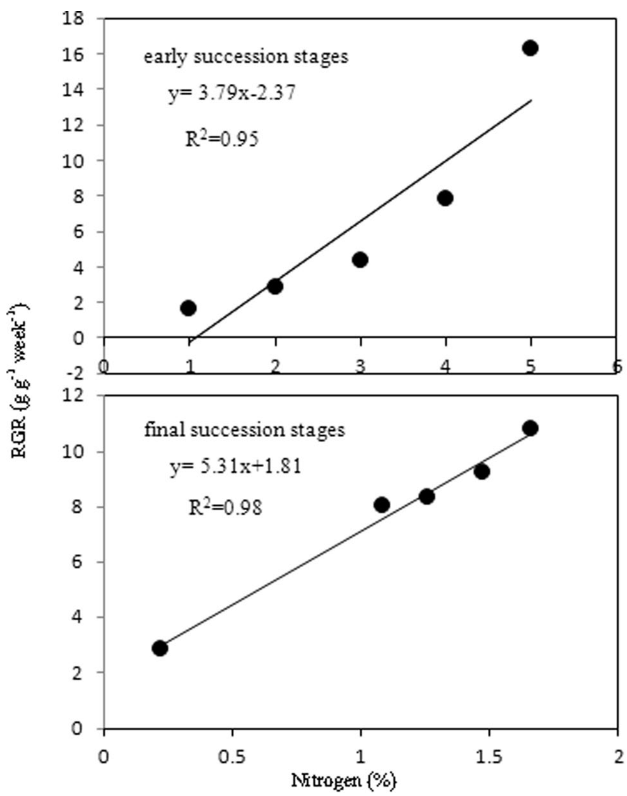

Fig. 5 Correlation between nitrogen absorption and relative growth rate (RGR) in different succession stages

4 Conclusion

Weed ecology, specifically dominance and characteristics, at the initial and secondary stages of succession in the young and old Citrus gardens, was investigated using different functional and physiological characteristics. The composition of weeds and their response to the environmental parameters, including N and P nutrients, was significantly different in the young and old gardens. This experiment showed that the weed species in the young gardens were more competitive, and the higher RGR was related to the higher rate of compound translocations to the roots and high seed production. In the old gardens, perennial sciophytes species had more frequency and used much storage for maintenance process, which leads to the rise of higher stability. Parameters including weed dominance, functional and physiological characteristics, seed size, and the environment may determine weed ecology and survival at different stages of succession in Citrus gardens. Such findings can be used for a more efficient use of weed controlling strategies by determining the composition of weeds and their interactions with Citrus trees. Future research work may determine how other ecological and environmental parameters, rather than the ones investigated in this study, may affect weed ecology in differently aged Citrus gardens.

References

Angiolini C, Bonari G, Landi M (2017) Focal plant species and soil factors in Mediterranean coastal dunes: an undisclosed liaison? Estuar Coast Shelf Sci. doi:10.1016/j.ecss.2017.06.001 **(in press)**

Bekker RM, Verweij GL, Bakker JP, Fresco LFM (2000) Soil seed bank dynamics in hayfield succession. Ecology 88:594–607

Blank RR, Morgan T, Allen F (2015) Suppression of annual *Bromus tectorum* by perennial *Agropyron cristatum*: roles of soil nitrogen availability and biological soil space. AoB Plants 7:plv006

Blatt SE, Janmaat JA, Harmsen R (2003) Quantifying secondary succession: a method for all sites? Community Ecol 4:141–156

Bonari G, Acosta AT, Angiolini C (2017) Mediterranean coastal pine forest stands: understorey distinctiveness or not? Forest Ecol Manag 391:19–28

Bornkamm R (1981) Rates of change in vegetation during secondary succession. Vegetation dynamics in grasslands, health lands and Mediterranean ligneous formations. Springer, Dordrecht, pp 213–220

Brown VK, Hendrix SD, Dingle H (1987) Plants and insects in early old—field succession: comparison of on English site and on American site Biol. J Linn Soc 31:59–74

Calvo L, Tarrega R, Luis E, Valbuena L, Marcos E (2005) Recovery after experimental cutting and burning in three shrub communities with different dominant species. Plant Ecol 180:175–185

Cantarelli EB, Machado SLO, Costa EC, Pezzutti R (2006) Effect of weed management on the initial development of *Pinus taeda* in low flatlands of Argentina. Rev Arvore 30:711–718

Chapin FS, Walker BH, Hobbs RJ, Hooper DU, Lawton JH, Sala OE, Tilman D (1997) Biotic control over the functioning of ecosystems. Science 277:500–504

Corbin JD, D'Antonio CM (2004) Competition between native perennial and exotic annual grasses. Implications for an historical invasion. Ecology 85:1273–1283

Dodge Y (2008) The concise encyclopedia of statistics. Springer, New York

Dölle M, Bernhardt-Römermann M, Parth A, Schmidt W (2008) Changes in life history trait composition during undisturbed old-field succession. Flora Morphol Distrib Funct Ecol Plants 203:508–522

Dzwonko Z, Loster S (1997) Effects of dominant trees and anthropogenic disturbances on species richness and floristic composition of secondary communities in southern Poland. J Appl Ecol 34:861–870
Fanelli G, Lucchese F (1998) The status of *Brometalia rubenti-tectorum* communities from the Mediterranean area in different syntaxonomical schemes. Rend Fis Acc Lincei 9:241–255
Farahat EA, Galal TM, El-Midany MM, Hassan LM (2016) Phenology, biomass and reproductive characteristics of *Calotropis procera* (Aiton) WT Aiton in South Cairo, Egypt. Rend Fis Acc Lincei 27:197–204
Fenesi A, Albert ÁJ, Ruprecht E (2014) Fine-tuned ability to predict future competitive environment in Ambrosia artemisiifolia seeds. Weed Res 54:58–69
Garnier E, Cortez J, Billès G, Navas ML, Roumet C, Debussche M, Laurent G, Blanchard A, Aubry D, Bellmann A, Neill C (2004) Plant functional markers capture ecosystem properties during secondary succession. Ecology 85:2630–2637
Gregg WP Jr (1972) Ecology of the annual grass *Setaria lutescens* on oldfields of the Pennsylvania Piedmont. Proc Acad Nat Sci Philadelphia 124:135–196
Grime JP, Jeffrey DW (1965) Seedling establishment in vertical gradients of sunlight. J Ecol 53:621–642
Hauser S, Mekao C (2009) Biomass production and nutrient uptake of *Chromolaena odorata* as compared with other weeds in a burned and a mulched secondary forest clearing planted to plantain (*Musa* spp). Weed Res 49:193–200
Hawksworth DL, Bull AT (eds) (2006) Forest diversity and management. Springer, Dordrecht, p 549
Hyatt LA, Casper BB (2000) Seed bank formation during early secondary succession in a temperate deciduous forest. J Ecol 88:516–527
James JJ, Drenovsky RE (2007) A basis for relative growth rate differences between native and invasive forb seedlings. Rangeland Ecol Manag 60:395–400
Jensen ES (1991) Evaluation of automated- analysis of 15-N and total N in plant material and soil. Plant Soil 133:83–92
Lambers H, Poorter H (1992) Inherent variations in growth rate between higher plants: a search for physiological causes and ecological conservancies. Adv Ecol Res 22:187–261
Lambers H, Chapin FS, Pons TL (2008) Plant physiological ecology, 2nd edn. Springer, New York, p 605
Larpkern P, Moe SR, Totland Ø (2010) Bamboo dominance reduces tree regeneration in a disturbed tropical forest. Oecologia 165:161–168
Leopold AC, Solozar J (2008) Understory species richness during restoration of wet tropical forest in Costa Rica. Ecol Restor 26:22–26
Letcher SG (2010) Phylogenetic structure of angiosperm communities during tropical forest succession. Proc R Soc Lond B Biol Sci 277:97–104
Marshall EJP, Baudry J, Burel F, Joenje W, Gerowitt B, Paoletti MG, Thomas G, Kleijn D, Le Coeur D, Moonen C (2002) Field boundary habitats for wildlife, crop, and environmental protection. In: Ryszkowski L (ed) Landscape ecology in agroecosystems management. CRC Press, Boca Raton, pp 219–247
Monty A, Maurice S, Mahy G (2010) Phenotypic traits variation among native diploid, native tetraploid and invasive tetraploid *Senecio inaequidens* DC. (Asteraceae). Biotechnol Agron Soc Environ 14:627–632
Mueller KE, Hobbie SE, Chorover J, Reich PB, Eisenhauer N, Castellano MJ, Chadwick OA, Dobies T, Hale CM, Jagodziński AM, Kałucka I (2015) Effects of litter traits, soil biota, and soil chemistry on soil carbon stocks at a common garden with 14 tree species. Biogeochemistry 123:313–327
Numata M (1982) Experimental studies on the early stages of secondary succession. Plant Ecol 48:141–149
Oka HI (1984) Secondary succession of weed communities in lowland habitats of Taiwan in relation to the introduction of wild-rice (*Oryza perennis*) populations. Plant Ecol 56:177–187
Olsen SR, Cole CV, Watanabe FS, Dean LA (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA. Circ, pp 939–943
Owens MK (1996) The role and canopy-level gas exchange in the replacement of *Quercus virginiana* (Fagacena) by *Juniperus ashei* (Cupressa) in semiarid Savannas. Am J Bot 83:617–623
Podda L, Fraga i Arguimbau P, Mascia F, MayoralGarcía-Berlanga O, Bacchetta G (2011) Comparison of the invasive alien flora in continental islands: Sardinia (Italy) and Balearic Islands (Spain). Rend Fis Acc Lincei 22:31–45
Reynolds JF, Virginia RA, Kemp PR, De Soyza AG, Tremmel DC (1999) Impact of drought on desert shrubs: effects of seasonality and degree of resource island development. Ecol Monogr 69:69–106
Rezvani P, Nasiri Mahallati M, Koochaki AR, Beheshti AR (2013) Agroecology. Mashhad University Press, Mashhad, Iran, p 460 (**Translated in Persian**)
Rockwood LL (1985) Seed weight as a function of life form, elevation and life zone in neotropical forests. Biotropica 17:32–39
Rondon EV (2006) Biomass study of *Tectona grandis* L. under different spacing conditions in the north Mato Grosso State. Rev Arvore 30:337–341
Salama FM, Abd El-Ghani MM, El-Tayeh NA, Amro A, Abdrabbu HS (2017) Correlations between soil variables and weed communities in major crops of the desert reclaimed lands in southern Egypt. Rend Fis Acc Lincei 28:363–378
Samuel MJ, Hart RH (1994) Sixty-one years of secondary succession on rangelands of the Wyoming high plains. J Range Manag 47:184–191
SAS (2012) Proc GLM procedure. SAS Institute; (Version 9.4). North Carolina, USA
Saxena KG, Ramakrishnan PS (1984) Growth and patterns of resource allocation in *Eupatorium odoratum* L. in the secondary successions environments following slash and burn agriculture. Weed Res 24:127–134
Schmid BC, Poschlod P, Prentice HC (2017) The contribution of successional grasslands to the conservation of semi-natural grasslands species—a landscape perspective. Biol Conserv 206:112–119
Shaltout KH, Galal TM, El-Komi TM (2014) Biomass, nutrients and nutritive value of *Persicaria salicifolia* Willd. in the water courses of Nile Delta, Egypt. Rend Fis Acc Lincei 25:167–179
Shimi P, Terme F (2003) Iranian weeds. Iranian Research Institute of Plant Protection, Tehran, Iran
Souza AD, Silva PSL, Oliverira OF, Dantas LM, Morais PLD (2013) Weeds under the canopies of tree species submitted to different planting densities and inter cropping. Planta Daninha 31:29–37
Stolcova J (2002) Secondary succession on an early abandoned field: vegetation composition and production of biomass. Plant Prod Sci 38:1–60
Suding KN, Lavorel S, Chapin FS, Cornelissen JH, Diaz S, Garnier E, Goldberg D, Hooper DU, Jackson ST, Navas ML (2008) Scaling environmental change through the community-level: a trait-based response-and-effect framework for plants. Glob Change Biol 14:1125–1140
Tilman D (1988) Plant strategies and the dynamics and structure of plant communities. Princeton University Press, Princeton
Touraine B, Clarkson DT, Muller B (1994) Regulation of nitrate uptake at the whole plant level. In: Roy J, Gamier E (eds) A whole-plant perspective on carbon–nitrogen Interactions. SPB Academic, The Hague, pp 11–30

Turner MG, Baker WL, Peterson CJ, Peet RK (1998) Factors influencing succession: lessons from large, infrequent natural disturbances. Ecosystems 1:511–523

Van Arendank JJCM, Porter H (1994) The chemical composition and anatomical structure of leaves of grass species differing in relative growth rate. Plant Cell Environ 17:963–970

Van der werf A, Welschen R, Lambers H (1992) Respiratory losses increase with decreasing inherent growth rate of a species and with decreasing nitrate supply: a search for explanations for these observations. In: Lambers H, van der Plas LHW (eds) Molecular, biochemical and physiological aspects of plant respiration. SPB Academic Publishing, The Hague, pp 421–432

Woźniak A, Soroka M (2015) Biodiversity of weeds in pea cultivated in various tillage system. Romanian Agric Res 32:231–237