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Impact of alien invasive species on habitats and species richness in Saudi Arabia

Jacob Thomas [a, *], Mohammed A. El-Sheikh [a, c], Ahmed H. Alfarhan [a], Abdulrehman A. Alatar [a], M. Sivadasan [a], Mohammed Basahi [b], Sami Al-Obaid [a], Rajakrishnan R.[a]

[a] Dept. of Botany & Microbiology, College of Science, King Saud University, P.O. Box-2455, Riyadh, 11451, Saudi Arabia
[b] Dept. of Biology, College of Science & Arts, Sajir, Shaqra University, P.O. Box-33, Shaqra, 11961, Saudi Arabia
[c] Botany Department, Faculty of Science, Damanhour University, Damanhour, Egypt

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ABSTRACT

Invasive alien species have distressing impacts on native biota, causing decline or even extinctions of native species, and negatively affecting ecosystems. All major invasions are due to the actions of humans such as deliberate introductions or escapes, and hitchhiking with global trade of species to other continents. Though majority of introductions have only minor impacts to the ecosystem, some of them led to numerous problems. 48 exotic species have been recorded from Saudi Arabia; of which 9 are recorded for the first time from Saudi Arabia. Among these, the species that potentially damaging the biodiversity or altering the ecosystems in general are: *Argemone ochrolecuca, Nicotiana glauca, Opuntia dellenii, Opuntia ficus-indica, Prosopis juliflora* and *Trianthema portulacastrum.* Among these, *P. juliflora* has been observed in lower altitudes with a density of more than 6%/hectare followed by *O. dellenii* and *N. glauca* in areas above 1000 m. Mountains and wadis have the highest values in terms of species richness, cover and exotic species impact. Analysis showed that environmental and diversity variables have high significant variation between habitats. Invasive and other exotic species are correlated positively with altitude and most diversity indices except with species dominance which are correlated negatively.

1. Introduction

Invasion of neophytes is widely regarded as the second largest threat to plant diversity after habitat loss by human interference (Manchester and Bullock, 2000) and this has increased in the past few decades due to economic globalization and liberalization (Pimentel et al., 2001). Invasive species not only threaten the plant diversity centres but also encroach into islands, agriculture lands, woodlands, forests, grasslands and inhabited areas. Past and present vegetation cover, particularly the comparisons among biogeographical and homoclimatic regions are one of the most promising approaches to increase our knowledge and to compare the exotic elements that occur at different regions (Pauchard et al., 2004). Invasions of alien species affect the biodiversity at various levels (Mack, 2000; Davis, 2003) particularly of remote areas and islands where the flora is highly vulnerable. From ancient times, human settlements in widely separated islands and continents paved the way for the entry of alien plants and animals, as native floras and faunas did not satisfy the human needs (Mack, 1999). Over the years, significant progresses have been achieved in accepting and eradicating the alien species from new habitats. However, the degree of impact and the association of invaded plant with the native flora vary from region to region (Coulston, 2001; Hejda et al., 2009). Warm and humid areas are ideal for the invasion of alien plants because it show more rapid seedling emergence compared to native populations (Griffith et al., 2014). Some preliminary account on the impacts of non-native invasive species is available in various countries, but details of many of these assessments or the impact on different segments of a region are largely unknown.

Neophytes have profound impact on both ecosystems and agriculture areas in Saudi Arabia, eliminating or displacing many native species from vegetation rich areas particularly highlands, wadis and meadows. The vegetation of southwestern region,

* Corresponding author.
E-mail address: jathomas@ksu.edu.sa (J. Thomas).

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particularly of some plant diversity hotspots including some of the Red Sea Islands is inundated by the influx of alien plants. However, no data is available about the degree of exotic invasions in Saudi Arabia. The region does have substantial number of floristic and vegetation studies, some of which are confined to certain regions (Abd El–Ghani, 1996; KÖnig, 1986, 1988; Abulfatih et al., 1989) or cover the whole of Saudi Arabia (Migahid, 1988; Chaudhary, 1999–2001, Collenette, 1999) or pertaining to the Pan Arabian flora (Abohassan, 1980; Batanouny, 1984; Abd El-Rahman, 1886; Barth, 2002; Ghazanfar and Fisher, 1998). Although majority of these works contain the names of a few alien species that entered the country several decades ago, none of the works contains a detailed account of the degree of infestations. No historical data is also available about the entry or establishment of these exotic species (Forsskål, 1775; Schweinfurth, 1912; Blatter, 1919–1936; De Marco and Dinelli, 1974). The ways and reasons for the entry of exotic elements into Saudi Arabia are several. Some of the exotic species are assumed to have entered into the country during the past Hajj seasons, while others are brought in by early settlers for food, medicinal, ornamental, and other purposes. Introductions of exotic plants continue even today, and are increasing due to increased international trade and travel or through accidental means. Human disturbance on natural habitats is another reason for the entry of invasive species to a new environment such as the clearance of native plants from densely vegetated areas for the creation of roads (Kingston and Waldren, 2003). This is evident in the case of few exotic elements in the southwestern high ranges where most of these alien plants established along the road sides. Such disturbances not only affect the local species but endangered the whole ecosystem as well. The aim of this research is to provide a first hand knowledge about the degree of infestations by the invasive alien plants in Saudi Arabia. The results will provide valuable information for landscape management and nature conservation. The present study hypothesize that impact of invasive and exotic species increases with altitude and species diversity.

2. Materials and methods

2.1. Study area

Saudi Arabia contains a variety of ecosystems, ranging from high altitude mountains (Jabals) (up to 3050 m asl), valleys (wadis), meadows (Raudhas), salt pans (Sabkhas), lava areas (Harrats), deep sands (Nafud) and drainage canals. Winters are generally cool with occasional frost in the mountains of northwestern region. Summer months are hot with temperatures sometimes reaching above 50 °C. Rainfall is unpredictable and erratic in most parts of the country and mainly falling in winter and spring (100–150 mm) with exceptions in southwestern region where the region receives heavy rains (>600 mm) between September and November. Humidities are low in the interiors (15-20%-central Najd) and high along the coastal zones (55–75%).

Over 1000 stands from 10 major habitats in four regions in Saudi Arabia were surveyed to have a preliminary observation on the impact of invasive species (Fig. 1). Cover value of vascular plants was recorded from 50 × 50 m^2 quadrats belonging to infested localities across the Kingdom. For the convenience of data collection and subsequent analysis, the study area was first divided into 4 major sectors, such as southwestern & southern regions, northern & northwestern regions, central region and eastern region; each of which is then divided into various habitats. These major habitats includes mountains, wadis, raudhas, sandy deserts, gravel and open plains, sabkhas, islands and agriculture areas. While selecting each stand, care was taken to guarantee a reasonable degree of physiographic and physiognomic similarity of both habitat and vegetation (Lovett-Doust et al., 2009). General selection of stands includes: 1). presence of invasive species in the stands and 2) areas close to invasive species' presence. In the case of mountainous regions in the southwestern part, apart from the presence of invasive species, stands were selected from an area along transect from lower elevation to higher elevation covering various landforms such as slopes, plateau, gullies, plains, etc., while in the case of central, eastern and northern regions, locations with high species diversity and abundance were taken as main measures. In addition, stands containing rare, endangered or endemic species were deliberately selected to include all floristic associations of such species in the survey.

The sampling process was carried out during early and middle spring season when most species were expected to be in flowering and fruiting stage. For every quadrate/stand species composition was determined and readings of individual abundance were taken from all stands. Data from 109 stands belonging to farms (Wheat, barley, date palm, fig, mango, banana, sorghum, coffee, tomato, chilli, brinjal (egg plant), ladies finger, okra, cucumber, squash, etc.) of major agriculture centres in the Kingdom, particularly the southwestern regions and central regions were also recorded. All species present in the quadrats were identified and their cover values (%) were recorded. From the surveyed areas, invasive and exotic species in Saudi Arabia have been identified and given a score based on the degree of infestions. Species with high degree impact were given high score (5), while the medium and low impact species have given medium (score-3) and low (score-1) respectively. Some of the species with insignificant representations except rare/endangered species were omitted from analysis as the species with insignificant cover value have little influence on the analysis and do not determine the vegetation structure (Legendre and Legendre, 1998). Classification of different plant communities have been accomplished by carrying out TWINSPAN analysis (Hill, 1979). Identification of the specimens was carried out with help of standard Floras and illustrated guides such as Chaudhary (1999–2001), Collenette (1999) or new reports on flora (Thomas et al., 2014). The sampling approach had two main objectives, first to see the impacts of invasive species in each habitat in general and secondly to see the impact of invasive species in affected communities.

2.2. Statistical analysis

The analysis of variance (ANOVA-one way), was used to identify statistically significant differences in habitats over the altitude, invasive and exotic plant impact levels and six species diversity indices. Significant differences between means among the ten habitats were identified using the least significant difference at $P < 0.05$. Correlations between altitude, invasive, exotic species impact levels and diversity indices parameters were evaluated using the Pearson's correlation coefficient *r*. The relationship between altitude, invasive, exotic and diversity indices content and habitat was examined with a linear regression. All statistical analyses were executed using SPSS 15.0 software (SPSS, 2006).

3. Results

661 species in 415 genera belonging to 98 families have been recorded from the affected plant communities of 10 major habitats belonging to four major sectors. Asteraceae and Poaceae are the largest families with 79 and 67 species respectively, followed by Leguminosae (51 spp.), Chenopodiaceae (29 spp.), Asclepiadaceae (20 spp.) and Zygophyllaceae (20 spp.). Floristic data from quadrates of infested areas were analysed and species accounts and the degree of impact on various vegetation units were prepared