INVENTORY OF SOME INTRODUCED AND INVASIVE PLANT SPECIES IN SOME GOVERNORATES OF THE KINGDOM OF SAUDI ARABIA

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Abstract. This investigation revealed that there are 42 species belonging to fifteen families in eleven governorates of KSA. The highest number (seven) and percentage (20.60%) of introduced species were recorded in Dammam and Riyadh, while, the lowest values were recorded in the regions of Al-Baha, Al-Ghat and Jizan (one and 2.94%). As for Al-Baha a large number of introduced species (nineteen, 46.34%) were recorded, nearly half of the number of species examined, while no invasive species were recorded in Bisha, Dammam, and Tabuk. The life growth of the introduced species ranges from trees to young weeds. Phanerophytes (45%) had the highest proportion of life expectancy for the introduced plants, followed by Therophyte (40%) and Chamaephytes (15%), while the highest percentage (63%) among life ratios of the introduced and invasive plants was recorded for Therophyte, and the percentage of life growth of introduced plants indicates the dominance of herbs among other life forms. Regarding the total growth of life, the highest recorded percentage was in herbs (50%), followed by shrubs (19.05%), trees (16.67%), bush (9.52%) and grass (4.76%). The biological growth of weeds was dominant for the invasive plant species, followed by trees in the introduced species, and shrubs and trees in the introduced and invasive species. These indicate that the annual species and invasive weeds are better adapted to the environmental conditions in the studied areas in KSA.
Keywords: *inventory, plants, biodiversity, introduced, invasive, regions, KSA*

Introduction

Invasive alien species (IAS) are a leading threat causing the mass extinction of native species around the world. In response to this issue, the international community in October 2010 at Nagoya, Japan established several objectives concerning the Convention of Biological Diversity (CBD), with the 9th target focusing on establishing measures to prevent the introduction and incorporation of IAS by 2020 for all signatories (CBD, 2010, 2001). Invasive species are primarily spread by human activities, often unintentionally. Over the past few centuries, the range of plant species colonizing areas outside their native habitats has risen dramatically. (Seebens et al., 2017). Current findings documented in a study by the world bank imply that changing climate leads to the dissemination and thus further intensifies the influence of such

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species. Due to invasive species, more than $1 billion dollars was lost yearly in the US and $1.5 trillion dollars globally (Globalization101, 2020).

In the different ecosystems across KSA only, it has been estimated that the number of alien and naturalized species was 2284 (Thomas, 2011). KSA flora comprises of 48 foreign species, of which 9 species have been identified for the first time by KSA, as well as human intrusion in ecological systems, such as the eviction of naturally grown plants from intensely vegetated areas for road establishment (Kingston and Waldren, 2003). Invasive plants are progressively broadening their existence in various ecosystems, such as roadsides, desolated areas, barren lands, agricultural areas, landfill sites, forest lands, etc., because of the lack of sustainable threats and intensified responsiveness. Competition between invasive and endemic species intensifies for water, sunlight, space and nutrients, and natural ecosystems can be disrupted by dispersing of invasive species. (USDA, 2020). An invader plant is a native or foreign species that have a disruptive impact on the growth and production of commercial plant species, triggering specific management issues, or grows where it is not desired (Le Roux, 1981). Invasive plants are often naturalized species that develop fertile offspring at significant distances from the parent plants, usually in very significant numbers (for clades propagating by seeds and other reproductive structures, the estimated scales are more than a hundred meters in less than 5 decades.; more than 2 m per year for clades distributing by roots, stolons, rhizomes or subterranean stems) accordingly they have the opportunity to disseminate across vast regions (Richardson et al., 2000). These species, independently and sometimes at unprecedented rates, are able to flourish, reproduce and disperse across the landscape (van Wilgen et al., 2001). Invasive species can be found in natural or semi-natural ecosystems and endanger indigenous biodiversity (IUCN, 1999). Invasive species have now become a worldwide challenge to the ecosystem, culture and the economy, endangering biodiversity, altering the balance of ecosystems and growing environmental devastation. (Levine et al., 2003). After ecosystem defragmentation, this is the second-largest factor for loss of biodiversity. (Gaertner et al., 2009). Invasive plants are significant threats to the stability of the ecosystem and biodiversity, where 80% of endangered species extinctions are due to invasions of non-native species worldwide. (Pimentel et al., 2005). Invasive plants could indeed dramatically change biodiversity by replacing the range of native vegetation, insects, and microbial communities with invasive plants, thus obstructing ecosystem infrastructure. By altering the nutrient cycle and soil pH, invasive species alter the ecology of a given ecosystem (Drenovsky et al., 2007), where lowered pH might indeed decrease the availability of nutrients leading to reduced growth of native plants, especially in habitats with poor nutrient availability.

Ecosystem services are the benefits that human derives from ecosystems, like food, fiber and water provision, nutrient cycling, water and air purification (carbon sequestration), as well as erosion prevention, pests, distribution regimes, recreation and tourism (Diaz et al., 2007; Naidoo and Ricketts, 2008). Invasive species frequently have harmful environmental effects on the habitats they enter (Pejchar and Mooney, 2009). Invasive plants severely decrease the crop yields (Pimentel et al., 2000) and values of agricultural lands, causing loss of forages, decreased rangeland productivity and fodder value due to invasion of pastures, in certain circumstances, soil carbon reserves have diminished (Eviner et al., 2010), leading to increased fire incidence, range, and vehemence (Mack et al., 2000), loss of aesthetic elegance in gardens and landscapes as well as the imposition of substantial expenses on the world economy (Vila et al., 2011).

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Invasive plant species have an impact on the diversity of native species, impacting the abundance of water by reducing the flow of water in a system already heavily constrained by water (Mark and Dickinson, 2008), impairing the availability of soil nutrients and increasing the occurrence of many other groups of pests (Mack et al., 2000) as well as disordered morphology of riparian areas of the water bodies, contributing to changes in flood frequency and intensity (Zavaleta, 2000) and increased soil erosion. Comparatively, after a foreign plant has occupied an ecosystem, by altering the light, solar radiation and temperature levels in the infiltrated places, it affects the characteristics of that area. For a variety of animals, the nature and affordability of food, shelter, nesting places sunning sites and rests have changed. Plant invasions have meaningfully undermined innate diversity by plummeting the abundance (by 43.5%), diversity (by 50.7%), and vitality (by 41.7%) of denizen plant species and the appropriateness (by 16.5%) and multiplicity (by 17.5%) of animal species (Vila et al., 2010). Invasive plant species control is a global request to help the offset of damaging consequences and empower the restoration of natural biodiversity (Hulme, 2006) through their exclusion from invaded habitats (Blanchard and Holmes, 2008). Given different biological properties, the issue of alien species control can be identified as the question of how to allocate vital resources among different management efforts (protection, monitoring, and regulation) over space and time, the management target of minimizing the financial and ecological harm incurred by invasive species and the management costs (Büyüktahtakın and Haight, 2018). This present investigation was conducted to discover, identify, and to make an inventory of the introduced and invasive plants in some governorates of the Kingdom of Saudi Arabia (KSA), in addition, warning about them as a threat to the local plant species diversity and flora of KSA.

Materials and methods

Some of the introduced plant species and invasive introduced plant species were restricted during the year 2020 in eleven governorates of the Kingdom, every governorate was given a code from 1-11, respectively (1-Al-Baha, 2- Al Ghat, 3- Bisha, 4- Buraidah, 5- Dammam, 6- Fayfa 7- Jizan, 8- Jeddah, 9- Tabuk, 10- Taif, 11 Riyadh). As shown in *Figure 1*, and the plant species and families to which they belong were defined using the following references (Chaudhary, 1999, 2000, 2001) and the website GBIF (*Table 1*).

Table 1. *The GPS coordinates of eleven governorates in the KSA*

No.	Regions	Latitude	Longitude
1	Al-Baha	20° 16’ 20.1864’’ N	41° 26’ 28.5036’’ E
2	Al Ghat	26° 01’ 21.60” N	44° 57’ 23.39” E
3	Bisha	19° 58’ 34.8672’’ N	42° 35’ 24.6012’’ E
4	Buraidah	26° 21’ 33.2316’’ N	43° 58’ 54.5232’’ E
5	Dammam	26° 23’ 57.3000’’ N	49° 59’ 3.6960’’ E
6	Fayfa	17 16’ 00’’ N	43 06’ 00’’ E
7	Jizan	16° 54’ 34.8588’’ N	42° 34’ 4.4472’’ E
8	Jeddah	21° 32’ 35.9988’’ N	39° 10’ 22.0044’’ E
9	Tabuk	28° 23’ 0.6288’’ N	36° 33’ 58.2876’’ E
10	Taif	21° 16’ 13.01” N	40° 24’ 56.99” E
11	Riyadh	24° 42’ 48.7872’’ N	46° 40’ 31.0656’’ E

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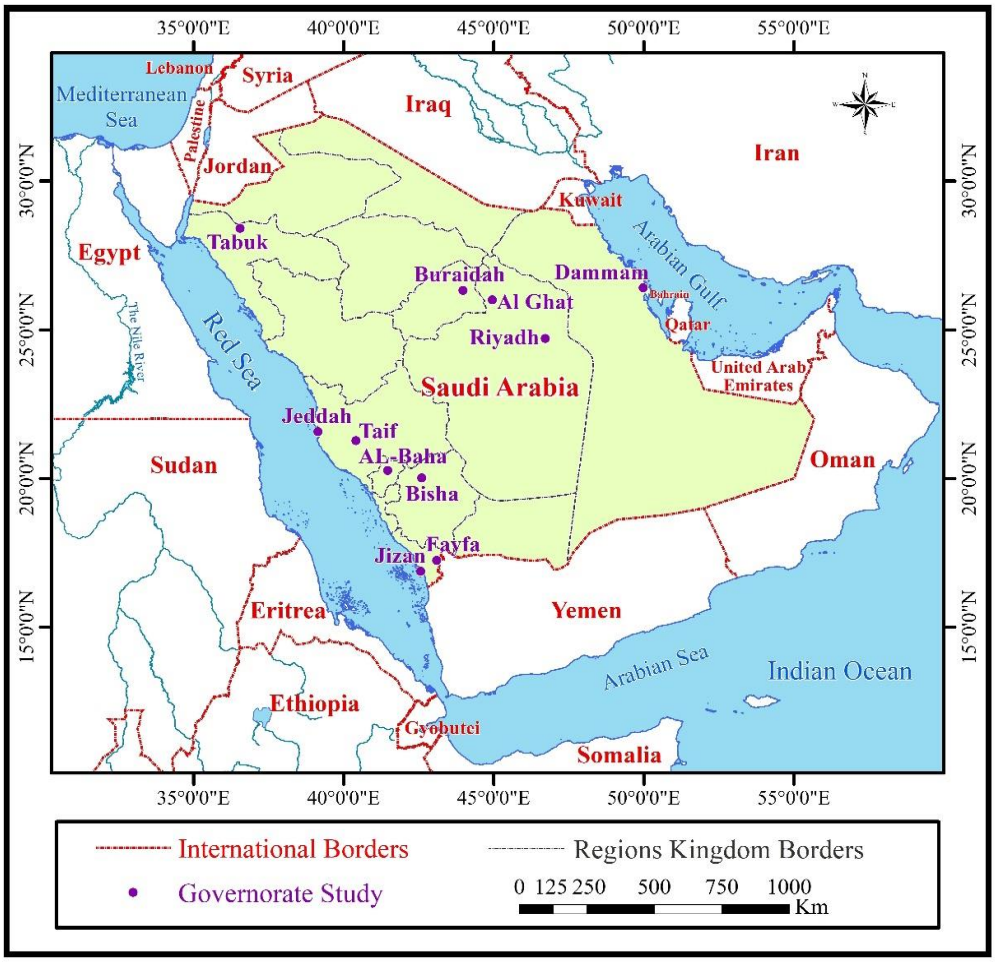

Figure 1. *Saudi Arabia map displaying the locations of the plant species being studied*

Statistical analysis

Cluster analysis for introduced and invasive plant species based on Euclidean distances was performed by Ward's method. The Principal Component Analysis (PCA) method explained by Harman (1976) was followed in the extraction of the components for eleven regions based on the presence and absence of introduced and invasive plant species. The percentage variability explained by each component was determined (Harman, 1976; Sharma, 1996). The data were subjected to descriptive statistics and PCA as well as biplot graphical display. Multivariate statistical techniques were executed using a computer software program PAST version 4.03 (Hammer et al., 2020).

Results

Investigation of many governorates in Saudi Arabia (Al-Baha, Al Ghat, Bisha, Buraidah, Dammam, Fayfa, Jizan, Jeddah, Tabuk, Taif, Riyadh,), revealed the presence of forty-two species in the eleven governorates as shown in *Table 2*. These species belong to fifteen families. Amaranthaceae and Asteraceae are the most common families among the investigated families (7 species, each); followed by Fabaceae with 6 species, Aizoaceae with 4 species, and Cactaceae, Solanaceae, and Euphorbiaceae with

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3 species each, followed by Poaceae with 2 species. While Annonaceae, Papaveraceae, Heliotropiaceae, Cucurbitaceae and Verbenaceae, Primulaceae and Potamogetonaceae are represented by 1 species. *Prosopis juliflora* (Sw.) was the most common species, it was recorded in 6 governorates (Al-Baha, Al Ghat, Buraidah, Jizan, Jeddah, Riyadh) of variable ecological conditions (*Table 2*).

Table 2. *List of presence (+) and absence (-) and the number int. and int. & inv. plant species and their families in the studied governorates*

Plant species	Families	Governorates										
		1	2	3	4	5	6	7	8	9	10	11
Acacia ampliceps Maslin	Fabaceae	-	-	-	+	-	-	-	-	-	-	-
Acacia salicina Lindl.	Fabaceae	-	-	-	+	-	-	-	-	-	-	-
Alternanthera pungens Kunth	Amaranthaceae	+	-	-	-	-	-	-	-	-	-	-
Amaranthus albus L.	Amaranthaceae	-	-	-	-	-	-	+		+	+	-
Amaranthus hybridus L.	Amaranthaceae	+	-	-	-	-	-	-	-	+	-	-
Amaranthus spinosus L.	Amaranthaceae	-	-	-	-	-	-	+	-	-	-	-
Annona squamosa L.	Annonaceae	-	-	-	-	-	-	-	-	-	-	+
Argemone ochroleuca Sweet	Papaveraceae	+	-	+	-	-	+	-	-	+	-	+
Atriplex suberecta I. Verd.	Amaranthaceae	-	-	-	-	+	-	-	-	-	-	-
Conyza bonariensis (L.) Cronq.	Asteraceae	-	-	-	-	-	-	-	-	-	-	+
Cylindropuntia rosea (DC.) Backeb.	Cactaceae	+	-	-	-	-	-	-	-	-	-	-
Datura innoxia Mill.	Solanaceae	+	+	-	+	-	-	-	-	+	-	+
Datura stramonium L.	Solanaceae	+	-	-	-	-	-	-	-	-	-	+
Eclipta prostrata L.	Asteraceae	+	-	-	-	-	-	-	-	-	-	-
Euphorbia heterophylla L.	Euphorbiaceae	-	-	-	-	+	-	-	-	-	-	-
Euphorbia maculata L.	Euphorbiaceae	-	-	-	-	-	-	-	-	-	-	-
Euphorbia prostrata Aiton	Euphorbiaceae	-	-	-	-	-	-	-	-	-	+	-
Heliotropium curassavicum L.	Heliotropiaceae	+	-	-	-	+	-	-	-	-	+	+
Imperata cylindrica (L.) P. Beauv.	Poaceae	-	-	-	-	-	-	-	+	-	-	-
Kali turgida (Dumort.) Gutermann	Amaranthaceae	+	-	-	-	-	-	-	-	-	-	-
Lantana camara L.	Verbenaceae	+	-	-	-	-	-	-	-	-	-	+
Leucaena leucocephala (Lam.) de Wit	Fabaceae	-	-	-	-	-	-	-	-	-	+	+
Lysimachia arvensis subsp. Arvensis	Primulaceae	-	+	-	-	-	-	-	-	-	-	-
Momordica balsamina L.	Cucurbitaceae	-	-	-	-	+	-	-	-	-	-	-
Nicotiana glauca Graham	Solanaceae	+	-	+	-	-	+	-	-	-	-	-
Opuntia ficus-indica (L.) Mill.	Cactaceae	+	-	-	-	-	-	-	-	+	-	-
Opuntia stricta (Haw.) Haw.	Cactaceae	+	-	-	-	-	+	-	-	+	-	-
Parkinsonia aculeata L.	Fabaceae	-	-	-	-	-	-	-	-	+	-	-
Phragmites australis (Cav.) Steud.	Poaceae	-	-	-	-	-	-	+	+	-	-	-
Potamogeton perfoliatus L.	Potamogetonaceae	-	-	-	-	-	-	-	-	-	+	-
Prosopis juliflora (Sw.) DC.	Fabaceae	+	+	-	+	-	+	+	-	-	+	-
Prosopis koelziana Burkart	Fabaceae	-	-	-	-	-	-	-	-	-	+	-
Salicornia europaea L.	Amaranthaceae	-	-	-	-	+	-	-	-	-	-	-
Sesuvium portulacastrum L.	Aizoaceae	-	-	-	-	+	-	-	-	-	+	-
Sesuvium sesuvioides (Fenzl) Verdc.	Aizoaceae	-	-	-	-	-	+	-	-	-	-	-
Sesuvium verrucosum Raf.	Aizoaceae	-	-	-	-	+	-	+	-	-	-	-
Tagetes minuta L.	Asteraceae	+	-	-	-	-	-	-	-	-	-	-
Tridax procumbens L.	Asteraceae	+	-	-	-	-	-	-	-	-	-	+
Verbesina encelioides (Cav.) A. Gray	Asteraceae	+	-	-	-	-	-	-	-	+	-	-
Xanthium spinosum L.	Asteraceae	+	-	-	-	-	-	-	-	-	-	-
Xanthium strumarium L.	Asteraceae	+	+	-	-	-	-	-	-	-	-	-
Zaleya pentandra (L.) C. Jeffrey	Aizoaceae	+	-	-	-	-	-	-	-	-	-	-

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On the other hand, *Table 3* clarified the numbers and percentage of introduced and introduced and invasive plants growing in different governorates. The highest number and percentage of introduced species were recorded in Dammam and Riyadh (7 species with 20.60% each). On the other hand, the lowest number and percentage of introduced plants were recorded in Al-Baha, Al- Ghat, and Jizan, 1 species with 2.94% each. Nonetheless, Jeddah, Buraidah, Tabuk, Taif, and Viva recorded 4, 3, and 2 species with 11.76%, 8.82, and 5.88% respectively.

Table 3. *Number and percentage of the presence of introduced and invasive plant species in some studied governorates*

Plant Species / Governorates	Introduced		Introduced & invasive	
	Number	Percentage %	Number	Percentage %
Al-Baha	1	2. 94	19	46.34
Al Ghat	1	2.94	3	7.31
Bisha	2	5.88	0	0
Buraidah	3	8.82	1	2.44
Dammam	7	20.60	0	0
Fayfa	2	5.88	7	17.07
Jizan	1	2.94	4	9.76
Jeddah	4	11.76	1	2.44
Tabuk	3	8.82	0	0
Taif	3	8.82	5	12.20
Riyadh	7	20.60	1	2.44
Total	34	100	41	100

Concerning, introduced and invasive plants (*Table 3*), in Al-Baha a high number of species and hence percentage (19, 46.34%) was recorded, almost half the number of investigated species. While no invasive species was reported in Bisha, Dammam, and Tabuk. Moreover, it was clarified that the life growth of introduced species ranges from trees to small grass. These include 4-Trees (*A. ampliceps* Maslin, *A. salicina* Lindl., *A. squamosa* L. and *P. aculeata* L. twelve herbs, two bushes, one shrub and two grasses (*P. australis* and *I. cylindrica*) on the other hand, among introduced and invasive plants 3 Trees (*L. leucocephala* (Lam.) de Wit, *O. ficus-indica* (L.) Mill and *O. stricta* (Haw.) Haw, ten herbs, two bushes seven shrubs and no grasses were recorded (*Table 4*). At the level of life form, nine Phanerophytes, eight Therophyte and three Chamaephytes were recorded in introduced plants. While four Phanerophytes, fourteen Therophytes and four Chamaephytes registed in introduced and invasive plants. Moreover, the percentage of life form of introduced plants (*Table 5*) showed that Phanerophytes and Therophyte had the highest percentage (45% and 40%) respectively while Chamaephytes were represented by 15%. Concerning the percentage life form of introduced and invasive plants, it indicated that the highest percentage was recorded in Therophyte among other life forms (63%), while Phanerophytes and Chemophytes shared the same percentage (18%). Percentage of life growth of introduced plants as is represented in *Table 6*, indicated the domination of herbs among other life growth, following the trend: herbs (57.14%) > trees (19.05%) > bush = grass (9.52%, each) and shrub (4.76%). The percentage of life growth of introduced and invasive plants (*Table 7*) followed a

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different trend but also with the domination of herbs. Herbs were recorded in the highest number and no grass was reported. (Herbs (45%) > shrub (32%) > tree (14%) > bush (9%) > grass (0%).) In general, as is represented in *Table 6,* a total of forty-two species were found in the study area as introduced and invasive plants. In form of life form, Therophytes were recorded as the dominant life form, with a percent of more than half the investigated species (52.38%), followed by Phanerophytes (30.95%) and then Chamaephytes (16.67%), (*Table 8*), In terms of a total of life growth, on the other hand, it was showed that the highest number recorded was in herbs 21 species, with a percent of half the number of all studied plants (50%), t followed by shrubs (8, 19.05%), trees (7, 16.67%), bush (4, 9.52%) and grass (2, 4.76) (*Table 8*).

Table 4. *List of introduced and invasive plant species and their families (type, life form and life growth) in some governorates study*

Plant species	Type	Life form	Life growth
Acacia ampliceps Maslin	Introduced	Phanerophyes	Tree
Acacia salicina Lindl.	Introduced	Phanerophyes	Tree
Alternanthera pungens Kunth	Introduced & Invasive	Therophytes	Herb
Amaranthus albus L.	Introduced & Invasive	Therophytes	Bush
Amaranthus hybridus L.	Introduced & Invasive	Therophytes	Bush
Amaranthus spinosus L.	Introduced	Therophytes	Big weed
Annona squamosa L.	Introduced	Phanerophyes	Tree
Argemone ochroleuca Sweet	Introduced	Therophytes	Herb
Atriplex suberecta I. Verd.	Introduced & Invasive	Therophytes	Shrub
Conyza bonariensis (L.) Cronq.	Introduced	Therophytes	Herb
Cylindropuntia rosea (DC.) Backeb.	Introduced & Invasive	Therophytes	Shrub
Datura innoxia Mill.	Introduced & Invasive	Therophytes	Shrub
Datura stramonium L.	Introduced & Invasive	Therophytes	Shrub
Eclipta prostrata L.	Introduced & Invasive	Chamaephytes	Herb
Euphorbia heterophylla L.	Introduced	Chamaephytes	Herb
Euphorbia maculata L.	Introduced	Chamaephytes	Herb
Euphorbia prostrata Aiton	Introduced	Chamaephytes	Herb
Heliotropium curassavicum L.	Introduced & Invasive	Chamaephytes	Herb
Imperata cylindrica (L.) P. Beauv.	Introduced	Phanerophyes	Grass
Kali turgida (Dumort.) Gutermann	Introduced & Invasive	Therophytes	Herb
Lantana camara L.	Introduced &Invasive	Therophytes	Shrub
Leucaena leucocephala (Lam.) de Wit	Introduced &Invasive	Phanerophyes	Tree
Lysimachia arvensis subsp. Arvensis	Introduced	Therophytes	Bush
Momordica balsamina L.	Introduced	Phanerophyes)	Herb
Nicotiana glauca Graham	Introduced& Invasive	Phanerophyes)	Shrub or small tree
Opuntia ficus-indica (L.) Mill.	Introduced &Invasive	Chamaephytes	Tree
Opuntia stricta (Haw.) Haw.	Introduced &Invasive	Chamaephytes	Tree
Parkinsonia aculeata L.	Introduced	Phanerophyes	Tree
Phragmites australis (Cav.) Steud.	Introduced	Phanerophyes	Grass
Potamogeton perfoliatus L.	Introduced	Phanerophyes	Herb
Prosopis juliflora (Sw.) DC.	Introduced & Invasive	Phanerophytes	Shrub to small tree
Prosopis koelziana Burkart	Introduced	Phanerophytes	Shrub to small tree

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Salicornia europaea L.	Introduced	Therophytes	Herb
Sesuvium portulacastrum L.	Introduced	Therophytes	Herb
Sesuvium sesuvioides (Fenzl) Verdc.	Introduced	Therophytes	Herb
Sesuvium verrucosum Raf.	Introduced	Therophytes	Herb to shrub
Tagetes minuta L.	Introduced & Invasive	Therophytes	Herb
Tridax procumbens L.	Introduced & Invasive	Therophytes	Herb
Verbesina encelioides (Cav.) A. Gray	Introduced &Invasive	Therophytes	Herb
Xanthium spinosum L.	Introduced &Invasive	Therophytes	Herb
Xanthium strumarium L.	Introduced & Invasive	Therophytes	Herb
Zaleya pentandra (L.) C. Jeffrey	Introduced & Invasive	Therophytes	Herb

Table 5. *Each percentage of the presence of introduced and invasive plant species, life form in some governorates of the Kingdom of Saudi Arabia*

Life form / Type	Phanerophytes		Therophyte		Chamaephytes		Total No.	Total P.%
	No.	P.%	No.	P. %	No.	P. %		
Introduced	9	45	8	40	3	15	20	100
Introduced & Invasive	4	18.18	14	63.64	4	18.18	22	100

Table 6. *Each percentage of the presence of introduced and invasive plant species, Life growth in some governorates of the Kingdom of Saudi Arabia*

Life / Growth type	Tree		Herb		Bush		Shrub		Grass		Total No.	Total P.%
	No.	P.%	No.	P.%	No.	P. %	No.	P.%	No.	P.%		
Introduced	4	20	11	55	2	10	1	5	2	10	20	100
Introduced & Invasive	3	13.63	10	45.45	2	9.10	7	31.82	0	0	22	100

Table 7. *Total percentage of the presence of introduced and invasive plant species Life growth in some governorates of the Kingdom of Saudi Arabia*

Life growth	Tree	Herb	Bush	Shrub	Grass	Total
Number	7	21	4	8	2	42
Percentage %	16.67	50	9.52	19.05	4.76	100%

Table 8. *Total percentage of the presence of introduced and invasive plant species life form in some governorates of the Kingdom of Saudi Arabia*

Life form	Phanerophytes	Therophytes	Chamaephytes	Total
Number	13	22	7	42
percentage	30.95%	52.38%	16.67%	100%

Multivariate statistical technique

For the determination of the similarities and differences among introduced and invasive plant species based on the presence and absence of them in some governorates

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of the KSA, cluster analysis with the Ward method was used. According to the cluster analysis, the introduced and invasive plant species were divided into eight clusters (*Fig. 2*). The tree diagram had exhibited the least distances or dissimilarity between the introduced and invasive plant species inside each cluster. While the high distances of these species are found among the eight clusters. Both the first and the seventh clusters consisted of two species. While each of the second, third, and sixth clusters comprised of five types. Each of the fourth and eighth clusters consisted of seven types and the fifth cluster of nine types. *Figure 2* indicates that there are identical or similar species in their presence and absence in the study regions within all eight clusters except for the seventh cluster, for example, the two species *Amaranthus hybridus* and *Opuntia ficus-indica* in the eighth cluster as well as the species *Zaleya pentandra*, *Alternanthera pungens*, *Cylindropuntia rosea*, *Eclipta prostrata*, *Kali turgida*, *Tagetes minuta* and *Xanthium spinosum* in the fifth cluster. On the other hand, the species *Euphorbia maculata* was not observed in any of the studied regions.

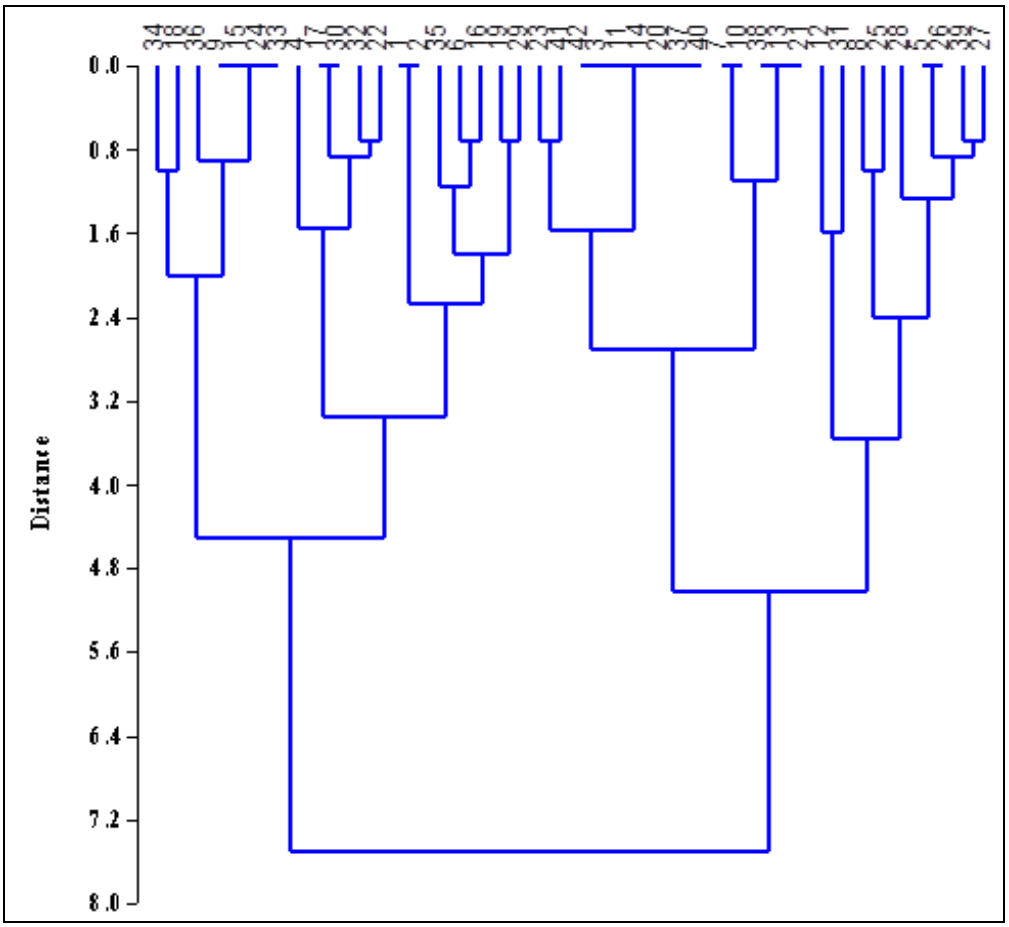

Figure 2. *Tree diagram for introduced and invasive plants species using ward's method. 1: A. ampliceps; 2: A. salicina; 3: A. pungens; 4: A. albus; 5: A. hybridus; 6: A. spinosus; 7: A. squamosa; 8: A. ochroleuca; 9: A. suberecta; 10: C. bonariensis; 11: C. rosea; 12: D. innoxia; 13: D. stramonium; 14: E. prostrata; 15: E. heterophylla; 16: E. maculata; 17: E. prostrata; 18: H. curassavicum; 19: Icylindrica; 20: K. turgida; 21: L. camara; 22: L. leucocephala; 23: L. arvensis; 24: M. balsamina; 25: N. glauca; 26: O. ficus-indica; 27: O. stricta; 28: P. aculeata; 29: P. australis; 30: P. perfoliatus; 31: P. juliflora; 32: P. koelziana; 33: S. europaea; 34: S. portulacastrum; 35: S. sesuvioides; 36: S. verrucosum; 37: T. minuta; 38: T. procumbens; 39: V. encelioides; 40: X. spinosum; 41: X. strumarium; 42: Z. pentandra*

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Principal component analysis (PCA)

PCA is a multivariate statistical approach that reduces the complex data by turning the number of interrelated variables into a smaller number of variables called principal components. Hence, it has been used to understand the relationship among the eleven studied regions based on the presence and absence of introduced and invasive plant species in these regions. The first five main PCAs extracted had larger eigenvalues than one (Eigenvalue > 1) which contributed to 69.36% of the accumulative variation of the original variables (*Table 9*). While the other PCAs extracted had eigenvalues less than one (Eigenvalue < 1). The results demonstrated that the PCA1 and PCA contributed to 35.95% of the total variability with Al-Baha, Bisha, Jizan, and Taif regions in the PCA1 and with AlGhat, Buraidah, and Jeddah regions in the PCA2. The first two PCAs had principally featured the eleven regions in various groups; consequently, PCA1 and PCA2 were harnessed to construct a biplot (*Fig. 3*).

Table 9. *PCA results for eleven regions based on presence and absence of introduced and invasive plant species*

Regions	PCA1	PCA2	PCA3	PCA4	PCA5
Al-Baha	0.47	-0.11	-0.20	-0.17	-0.06
Al Ghat	0.19	0.54	-0.28	-0.03	-0.05
Bisha	0.42	-0.18	0.42	0.27	0.11
Buraidah	0.15	0.56	-0.24	0.01	-0.02
Dammam	-0.33	-0.14	0.00	0.45	-0.29
Fayfa	0.20	-0.16	-0.33	0.17	0.75
Jizan	0.44	0.12	0.42	0.30	-0.07
Jeddah	-0.14	0.47	0.41	0.03	0.07
Tabuk	-0.19	0.11	0.44	-0.47	0.43
Taif	0.34	0.02	0.06	-0.12	-0.26
Riyadh	-0.16	0.25	-0.03	0.58	0.26
Eigen value	2.24	1.72	1.47	1.19	1.02
Explained variance	20.33	15.62	13.32	10.85	9.24
Cumulative variance	20.33	35.95	49.27	60.12	69.36

The relationships among different eleven regions based on the presence and absence of introduced and invasive plant species are graphically displayed in a biplot of PCA1 and PCA2 (*Fig. 3*). A highly positive correlation was found between L3 and L6, L7 and L8, L2 and L4 as well as L1 and L3. The positive and low association between all possible pairs of the regions 1;2;3;4;6;9 were observed. Also, the low positive correlations were recorded for the L7 region with 2, 4, and 10 as well as for the L11 region with 1 and 3. On the other hand, the other relationships were either very low or negative between the regions under study. This could be due to the existence of a relationship between these invasive species and the environmental conditions of these areas, especially the local species.

Discussion

Out of 13000 vascular plant species, 4% of plants are outside their original range in the world (Van Kleunen et al., 2015). The two American continents are considered to be

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the main habitat for all the basic invasive species found in the Kingdom of Saudi Arabia. During the past decade, the urbanization in KSA has led to the introduction of many invasive, exotic, and harmful plant species (Al-Harthi et al., 2019).

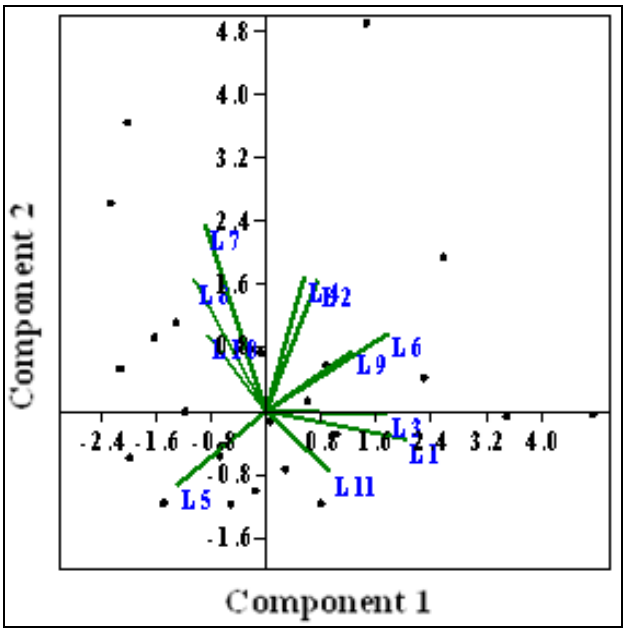

Figure 3. *Biplot graph on the basis of the first two principal component axes of eleven regions according to the presence and absence of introduced and invasive plants species. L1: Al-Baha; L2: Al Ghat; L3: Bisha; L4: Buraidah; L5: Dammam; L6: Fayfa; L7: Jizan; L8: Jeddah; L9: Tabuk; L10: Taif; L11: Riyadh*

The governorates under study differed in the number and percentage of invasive plants, due to the difference in climate and soil, in addition to the fact that these plants found an appropriate habitat for growth in these areas. Plant growth changes with altering resource availability, the effect of plants on soil properties and soil feedbacks (Wang et al., 2020). Perhaps the success of these invasive plants in these areas is due to the assumption unavailability of the natural enemy (Keane and Crawley, 2002), contains new weapons (Callaway and Aschehoug, 2000), the evolution of increased competitiveness (Blossey and Notzold, 1995), plant-soil feedback (Klironomos, 2002) and resource availability (Wang et al., 2020), or the presence of some different mechanisms enhancing the invasion of alien plants (Qin et al., 2013). The environment and diversity variables showed a difference among habitats in the Kingdom of Saudi Arabia and environmental changes, as drought, heat, and an increase in CO_2 and nitrogen can lead to a change in soil and plant growth (Pugnaire et al., 2019), which leads to the spread of invasive plants in these areas. The results showed that the highest percentage of invasive plants was found in Al-Baha region, which confirms the high invasion of these plants in this region. Invasive plant species menace local biodiversity, but whether alien species can competitively replace local species is still in dispute (Catford, 2018). Huang et al. (2016) reported that invasive species may not outperform native plants under resource limitation. There are several methods of controlling invasive species that have been adopted in countries with experience in this field, such as mechanical control, prescribed burning and chemical control (Berhanu and Tesfaye,

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2006). Chemical control is not recommended to preserve the environment from pollution despite its proven effectiveness and success.

The invasive species *P. juliflora* is generally found in the northwest, north, eastern and central regions of KSA, especially disturbed sites, or amongst secondary plants predominated by some other shrubs. (Thomas et al., 2010). The invasive species *P. juliflora* is spreading rapidly and compete with natural vegetation in the KSA due to rapid growth, resistance to drought, and ability to reproduce and spread successfully under drought conditions, in addition to the loss of the ecosystem to its natural immunity to resistance against such invasive species (Rogers, 2000; Berhanu and Tesfaye, 2006). Consequently, this species is considered very dangerous and has a negative impact on the biological diversity of the Kingdom of Saudi Arabia (Shiferaw et al., 2004). As explained by Thomas et al. (2010), that the invasive species *P. juliflora* has invaded most of the localities in inland sites in the Saudi Jazan region, which will have harmful effects on the local plants in this region. Harding and Bate (1991) reported that Invasive *Prosopis* species are spreading rapidly in arid regions as well as in areas of high rainfall and groundwater in South Africa. Invasive *P. juliflora* trees form dense thickets that are difficult to penetrate and not use the land for various agricultural practices (Harding and Bate, 1991), as well as interfere with mustering and injure livestock in Saudi Arabia (Thomas et al., 2016) and Africa (Berhanu and Tesfaye, 2006). Invasive plant species have been reported to have faster growth rates than native plant species (Ramula et al., 2008). Some plant species are rare in their native regions, but highly invasive in other regions, such as *Acacia baileyana*, *Eucalyptus globulus*, *Impatiens parviflora* and *Centaurea solstitialis* (Catford, 2018). As a result of the multiple introductions of invasive plant species, genetically more diverse invasive species can arise and become more widespread (Oduor et al., 2015). Thus, the environmental adjustment of the introduced plant species can be indorsed by different introductions (Oduor et al., 2016). The different methods of reproduction play an important role in preserving certain genetic groups and thus the continuation of the natural hybridization process (Rebman and Pinkava, 2001), among these methods are sexual (self-fertility) and vegetative reproduction as well as the adventive embryo that led to the spread of invasive species in the kingdom, especially *Opuntia ficus-indica* and *Opuntia stricta* species. From these data, three types of life forms (Therophyte, Chamaephytes, and Phanerophytes) were identified for the invasive plant species in the KSA. The Phanerophytes life form recorded the highest percentage of the introduced types, followed by Therophyte and Chamaephytes. While, Therophyte life form was registered with the highest percentage of the introduced and invasive plants, followed by Phanerophytes and Chamaephytes equally. The results also showed that the life growth of herbs life was dominant for the invasive plant species, followed by trees in the introduced types, and shrubs and trees in the introduced and invasive types. These results indicate that the annual (Therophyte) and herb invasive species adapt better to the environmental conditions in the studied regions of the KSA. Perhaps the reason for the spread of invasive annual species is due to the method of propagation by seed or vegetative growth. The life form of wild species was adequately adapted from annual species through the study system by Nelis (2012). Under abiotic stress conditions, both grass and perennial invasive species adapt and have higher growth and spread rates (Nelis, 2012), and in regions with poor soils, thin grasses are more common and widespread than other plant species (Grime, 2001). Invasive plant species are frequently characterized by evolving adaptations in their exotic areas, and this adaptation appears

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after 20 years (Oduor et al., 2016). Nelis (2012) explained that the botanical characteristics of the life form may explain the differences in the processes underlying the dynamics of the plant populations, and the rate of growth and immigration of plant populations can be predicted by the life form. Thomas et al. (2016) reported that except for the species dominance which negatively correlated, invasive and alien species positively correlated with altitude and most of the indices of diversity in regions. A correlation was found between invasive species and several local species in the KSA, but these correlations are not fixed in all cases.

Conclusion

It was many ways in which these plants were introduced to the KSA, such as the seasons of Hajj, or for food, or medicinal purposes, decorations, etc., as well as the increase in international trade and travel, through occasional means, or human disturbances in natural habitats such as removal of native plants from heavily cultivated areas for road constructions, which is an agent change and a threat to local biodiversity, the environment, society, the economy, and the ecosystem. Therefore, in the future, laws must be established to limit the introduction and use of these plants and be under the supervision of the Ministry of Agriculture, and the community should be encouraged to use local plants. In addition to working on early detection and monitoring of new and emerging invasive plant species they can also be resisted by mechanical, biological, or chemical methods, especially before flowering and fruiting stages.

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