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ORIGINAL PAPER

Application of complex conservation strategy to *Iris atrofusca* of the Northern Negev, Israel

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Abstract We applied the quasi in situ conservation strategy, described in an accompanying paper, to a critically endangered plant species, *Iris atrofusca* from the Northern Negev, Israel. As the first steps of this strategy implementation we performed habitat and demographic observations; creation of two living collections outside the natural populations, but within the same ecological conditions; and relocation experiments. Plants in the living collections got established and showed high reproductive potential. In the relocation experiments, 3 years after introduction of rhizomes, no firm conclusions could be made about factors limiting species distribution at either large or small scale, but microhabitat was important for relocation success. We conclude that complex conservation approach that includes quasi in situ strategy should be useful for an endangered species that is distributed over variable ecological conditions.

Keywords Conservation strategy · Ex situ · In situ · Relocation · Translocation · Local adaptation · *Oncocyclus* irises · Endangered species

Introduction

Iris atrofusca (Fig. 1) Baker is a rhizomatous geophyte that belongs to the section *Oncocyclus* (Siems.) Baker (*Iris*: Iridaceae) characterized by dense clonal growth and conspicuous large flowers that grow individually on a stem (Avishai and Zohary 1980; Sapir et al. 2002). *Oncocyclus* irises grow from the southern parts of the Middle East in Edom (Jordan) and the Negev Desert (Israel), to the high mountains of Transcaucasia in the

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Northeast, spanning semi-arid, Mediterranean, and dry montaneous climates (Avishai and Zohary 1980).

Iris atrofusca grows from the Northern Negev in the South, in ca. 150 mm rain annually, through the eastern slopes of Judean and Samaritan mountains in Israel and the western slopes of Gilead mountains in Jordan, to the Golan heights, where precipitation is ca. 500 mm rain annually. Along the distribution of the species, precipitation is limited to the wet season (November through April), and in the dry season the plants are dormant. Adult plants can be distinguished from juveniles in the field by the compact assemblage of leaf fans, which emerge close to each other from the belowground rhizome. All these leaf fans are genetically identical individuals (ramets) that may become independent plants after fragmentation of the mother rhizome (genet). Due to considerable variation in flower color and other morphological traits across its range, the species is prone to taxonomic mistakes and doubts. For example, Sapir et al. (2002) showed that in many quantitative morphological traits it does not differ from the nearest species neighbors, *I. haynei* and *I. petrana*, and these traits vary clinally with the aridity gradient. However, morphological and genetic analyses indicated that *I. atrofusca* populations of the Northern Negev form a cluster within the general pattern (Arafeh et al. 2002; Sapir et al. 2002), and can be even considered a separate taxon. Historically, these populations were nominated as *Iris loessicola* Kushnir sp. nova (Kushnir 1949) but no species diagnosis was provided by the author. Hereafter, we will use the name *I. atrofusca* in its narrow sense, only for the Northern Negev populations.

Iris atrofusca currently is one of the most threatened species of the *Oncocyclus* group in Israel (Shmida and Pollak 2007). The habitats of *I. atrofusca* in the Northern Negev are vulnerable throughout its distribution. In the last decade, populations of the Northern Negev have been affected mainly by anthropogenic disturbance, which decreased population sizes in general and caused some populations to become extinct. These disturbances included urbanization, infrastructure works, intensive and extensive agriculture, overgrazing, forestry works, and illegal Bedouin settlements. Recently, a plan for expanding the area of Beer Sheva, the main town of the Northern Negev, is threatening the largest and the densest population of *I. atrofusca*, which grows in Goral Hills, north of the town. These issues motivated urgent conservation research and action. Here we present the suite of studies we did under the guidelines we drew in the preceding paper for the quasi in situ conservation approach.

Research area

Iris atrofusca grows in the Northern Negev in two main groups of populations: in Goral Hills (central coordinates: 31°19′N 34°48′E), north of Beer Sheva, and Arad Valley (central coordinates: 31°16′N 35°05′E; see map in Fig. 2).

The two regions differ in aridity. While the Goral Hills area is above the 200 mm isohyet (semi-arid conditions), the Arad Valley is close to or below the 150 mm isohyet (arid conditions) (Shachar 1995; Jaffe 1988). The topography of the Goral Hills area is mostly slopes of shallow hills angle (slope angles up to 20%). The soil is a shallow calcareous lithosol overlying fractured Eocene limestone (Shimshi 1979/80). Depressions between the hills are filled with shallow Aeolian loess soil. Arad Valley, on the other hand, is a relatively flat plain (with wadies and gullies), covered with Quaternary Aeolian loess of considerable depth (>2 m), with some isolated outcrops of calcareous lithosols (Shimshi 1979/80), which mostly form the heads of insulated hills.

Fig. 1 *Iris atrofusca* from the Northern Negev (drawing by Irene Blecher © 2010). Rhizomes are shown at the beginning (left) and the end (right) of a growing season

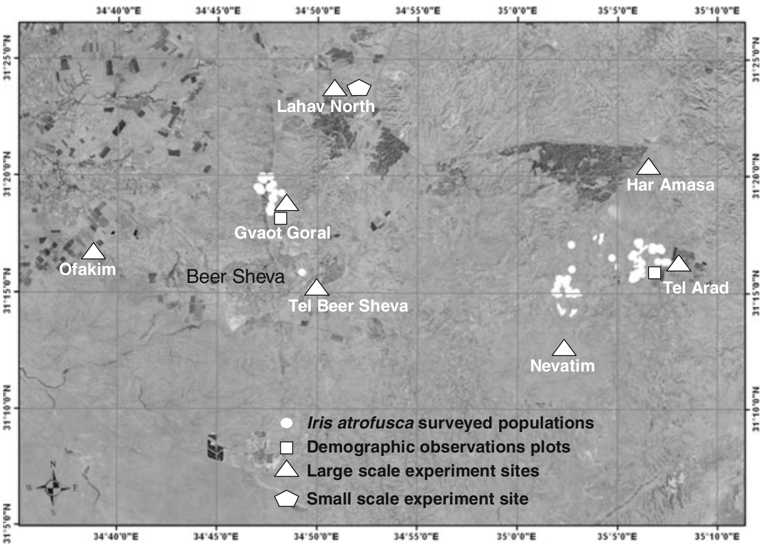

Fig. 2 Map of surveyed populations, experimental relocation sites and populations in which permanent demographic observations plots were established

In the hard and fissured limestone and dolomite with calcareous lithosol of the Goral Hills, some of the rain water penetrates the soil and is accumulated in the fissures and crevices, where it is protected from direct evaporation. The loess soils of the Arad Valley have a different moisture regime, where rain water hardly penetrates over the upper soil layer. This is due to the high moisture holding capacity of the fine-grained loess, comprised mostly of airborne clay, which causes most of this precipitation to be lost by runoffs and direct evaporation from the soil surface (Danin 1988).

Methods

Population demography and germination in the soil seed bank

A field survey based on previous knowledge of the distribution of the species in the Northern Negev was done in 2006 to document the habitat, precise population location and the area of distribution of each population.

To assess in detail population demography in two regions, we established permanent observation plots (see map in Fig. 2) in two representative populations: in Goral Hills ("Gvaot Goral" in Hebrew)—the easternmost population, and in Arad Valley—the population near Tel Arad National Park (designated G-G and T-A, respectively). These populations were chosen for being the densest and with the highest number of plants in each region. Plot sizes were 120 × 6 m (in G-G population) and 60 × 6 m (in T-A population). These long and narrow plots were established in the approximate center of the populations, perpendicular to the hill slope in each population. In March 2006, we counted all individuals within the plots and classified them as either immatures (1st or 2nd year juveniles with a single fan), vegetative (non-flowering, but with >1 fan) adults, or reproductive adults. We marked individually each established clump (= genet) of *I. atrofusca*, measured its diameter and counted the number of leaf-fans (= ramets). We counted number, size, and reproductive status of adults in the plots in the next three seasons. Each year we calculated the average number of fruits per reproducing plant (i.e., a clump comprising >1 ramet), average number of seeds per fruit, and resulting fecundity. Measurements and counting were done when plants started to senesce.

Since the actual age of individual plants of *I. atrofusca* in the field can not be determined, the population structure analysis had to be based on the number of individuals in the different ontogenetic stages of the life cycle that are related to age. During years 2005–2009 we classified the individuals using the following age-stage categories.

(1) Seeds;
(2) Seedlings (individuals developed shortly after germination of seeds, with cotyledons and often with one or two leaves);
(3) Juveniles (individuals with a single leaf fan comprising more than two leaves and having poorly developed root system). A major difference between 1-year and 2–3 year juveniles is in development of root system, where the older juveniles start to develop rhizomes;
(4) Vegetative adults or immatures (non-flowering individuals with more than two leaf fans and fully developed root system with rhizome);
(5) Generative adults (individuals bearing flowers).

Plants of *Oncocyclus* irises are dormant between the end of the vegetating season when leaves dry out (end of spring) and the start of the next winter. Our observations indicate that rhizomes can stay dormant during not only summer, but also during the next fall-to-spring growing season (Volis and Blecher, pers. obs.). This adds another ontogenetic stage for adults during growing season—dormants, which will be verified as more demographic data become available.

To study the pattern of seed germination in the soil over time, we created three experimental permanent soil seed banks in 2005 in Tel Arad National Park and monitored the fate of sown seeds. Seeds had been collected by MB in 2005 from plants in proximity to the plots. The seeds were buried about 3–4 cm below ground level in (1) plastic trays filled with soil from the site of transplanting and containing one seed per cell (221 seeds per tray), and (2) in furrows (100 seeds per furrow, two furrows per site). The introduction had been done in September, before start of the raining season, at three sites: near the top of the hill, at the middle of the slope, and at the hill foot. These three sites differed in the water regime, as runoff water amount is highest at the hill foot and smallest at the top. Similar soil seed banks were established in fall 2006 at Gvaot Goral site. Two trays, each containing 221 locally collected seeds, were buried at the top and the bottom of the hill. The experimental soil seed banks were monitored for germination during 2006–2008.

Effect of rhizome initial size on flowering

Since plant size rather than age determines sexual reproduction in *I. atrofusca*, we studied experimentally an effect of rhizome initial size on probability of flowering. This experiment was conducted during November 2005–April 2006. Large rhizomes, rescued by MB in 2005 from the Goral Hills area north of Beer Sheva (road-building strip for new railroad tracks) that represented a group of (potentially) independent ramets, were cut into pieces that contained only one distinct bud. This experiment aimed at testing the effect of initial rhizome weight on probability of flowering. We also measured several morphological traits to use as potential indicators for probability of flowering. Two-hundred and four rhizomes were individually weighed and planted in 3-liter pots filled with loess soil, one rhizome per pot. Pots were placed 25 cm apart in a nethouse, and watered regularly with 2 l/h drippers, 1 dripper in each pot. In addition to the natural annual rainfall (208 mm), supplementary water equivalent to ca. 95 mm of rainfall were applied throughout the growing season, in order to compensate for the higher evaporation rate from the pots. At first sign of leaf senescence the following measures were taken: length and width of the longest leaf, diameter at the base of the leaf fan, number of ramets, and number of flowers. After complete drying out of aboveground biomass the rhizomes were dug out and weighed.

Creation of quasi in situ living collections

Between 20 and 50 large genets of I. atrofusca, each comprising many ramets, were sampled from four populations from Goral and Arad regions. Populations were chosen based on (1) the threat of habitat destruction—the populations chosen were critically endangered (building works, agriculture activity, etc.) and required immediate relocation; and (2) their representation for the distributional range of *I. atrofusca* in the Northern Negev. The plant rhizomes were planted as two replicates at both Tel Beer Sheva and Tel Arad National Parks (both are important archeological and historical sites, but not complex nature protection territories) that represent ecological conditions similar to those of Goral Hills and Arad Valley areas, respectively. However, because the two population groups (Goral and Arad regions) were found to differ by habitat, demography and morphology (Shimshi 1979/80; Blecher 2007 and this study), we decided that Tel Beer Sheva and Tel

Arad National Parks should harbor populations from their respective regions only. Populations planted outside their region will be relocated to a living collection in their respective region at the next stage of the project. Meanwhile, we are monitoring transplanting success of plants of different origin across the two regions. Proper measures, such as removal of immature fruits, are taken to prevent sexual reproduction and hybridization in the living collections.

Relocation experiments

Rapid disappearance of *I. atrofusca* populations in the Negev necessitates such means of species conservation as relocation to safe areas protected by law. In order to determine species habitat preferences we installed relocation experiments on two scales, large (tens of kilometers) and small (hundreds of meters), using rhizomes rescued from sites of habitat destruction and immediate threat for the plants, i. e. from populations that currently required relocation.

Large scale relocation experiment

Rhizomes from Arad Valley and Goral Hills were cut to pieces of various sizes, and separated categorically by their size. Two sets of 5 large (above 20 g) and 15 small (5–10 g) rhizomes of *I. atrofusca* of Arad and Goral origin were planted in fall 2006 in seven locations that embraced the whole species range in the Negev and beyond it. The locations were: experimental site near Ofakim, Tel Beer Sheva National Park, Nevatim Base, Lahav North Nature Reserve, Tel Arad National Park, Har Amasa Nature Reserve, Gvaot Goral site (Fig. 3). Rhizomes were planted in the same spatial pattern with regular distances among rhizomes in all sites, and covered with ca. 3 cm soil. In the next 3 years, we recorded number of plants that emerged, flowered and produced fruits.

Small scale relocation experiment

Rhizomes rescued in spring 2006 from Goral Hills region (road-building strip for new railroad tracks) were planted in fall 2006 in sets of 62 rhizomes at 22 microhabitats in Lahav North Nature Reserve (Fig. 3). Each set comprised the following size classes: <5 g (14), 5–10 g (10), 10–20 g (23), 20–30 (10), 30–40 (3) and >40 g (2). As in the large scale experiment, we recorded number of plants that emerged, flowered and produced fruits during the next 3 years.

Results

Habitat and demographic parameters

Observations on plant distribution revealed that the primary species habitat in both geographic regions is hill slopes. A considerable proportion of plants in the Arad Valley (38.3%) grow in wadies, but in the Goral Hills area no population was found in wadis.

The results of the detailed census (monitoring) in two representative populations (Gvaot Goral, G-G, and Tel Arad, T-A) in the years 2006–2009 are the following. The two studied populations differed in average plant density, estimated in spring 2006 (0.88 vs.

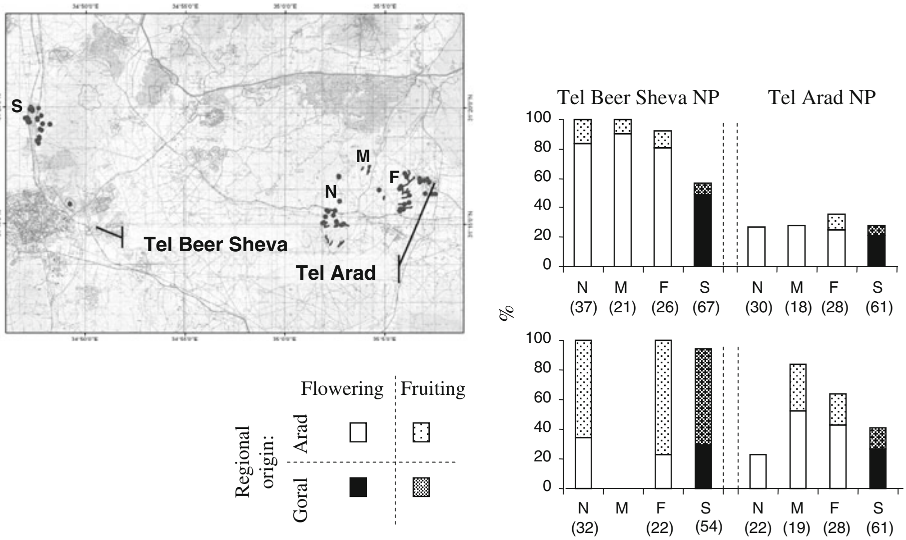

Fig. 3 Population origin, number of genetically distinct individuals (in parentheses), and percentage of flowered and fruited plants two (*top*) and three (*bottom*) years after creation of two quasi in situ living collections in Tel Beer Sheva and Tel Arad National Parks, respectively. The numbers in parentheses do not represent plant survival because rhizomes can remain dormant in the soil for one and more years. Plants of M origin were removed in 2009 from the Tel Beer Sheva NP

0.30 plants/m^2 in G-G and T-A, respectively). The clumps at G-G were consistently larger during 4 years than at T-A, while a difference in number of ramets per clump was less pronounced (Table 1). The two populations differed in stage structure, with juveniles comprising 86, 70, 46 and 46% vs. 23, 24, 20 and 16% of established plants (over 4 years) in G-G and T-A populations, respectively. Percentage of flowering adults, average fruit-set and seed-set per reproducing plant over 4 years were higher in G-G than in T-A population (57 ± 10 vs. 32 ± 7%, 1.71 ± 0.29 vs. 0.65 ± 0.25 and 50.3 ± 12.4 vs. 18.3 ± 6.7, respectively).

Germination in the soil seed bank

Low germination rate was observed in the soil seed banks established in 2005 at Tel Arad National Park. During three seasons, 2005–2006, 2006–2007 and 2007–2008 no germination event was recorded in any of the buried trays. In furrows, no germination was

Table 1 Means ± SE for each season for clump size and number of ramets per clump

Season	Clump size (cm)		Ramets per genet	
	G-G	T-A	G-G	T-A
2005–2006	24.0 ± 2.6	19.8 ± 2.4	21.5 ± 3.3	18.6 ± 3.2
2006–2007	23.1 ± 2.6	19.8 ± 2.5	18.3 ± 2.5	15.0 ± 2.5
2007–2008	25.1 ± 2.5	22.6 ± 2.8	18.0 ± 2.3	21.8 ± 2.8
2008–2009	23.9 ± 2.4	18.5 ± 2.2	15.1 ± 1.8	16.0 ± 2.6

G-G Gvaot Goral population, *T-A* Tel Arad population observed in 2005–2006 and 2006–2007, but in 2007–2008 germination fraction was 4, 15 and 12% (hill's top, middle and foot, respectively). At G-G test site, where 2 trays were buried in fall 2006, one seed germinated in the following winter (season 2007–2008). Although some germinated seeds could stay undetected in furrows in 2006–2007, these results suggested strong innate seed dormancy in the first year after dispersal and increase in germination fraction in following years (see also Dorman et al. 2009).

Effect of rhizome initial size on flowering

Sexual reproduction (i.e., production of a flower) in *I. atrofusca* was found to depend on the rhizome weight and two size-related parameters, namely length of the leaves and base diameter (Wald statistics = 30.8, 13.5 and 4.2, $P < 0.0001$, 0.001 and 0.05, respectively). The minimal rhizome weight for flowering appears to be around 2.7–3.0 g, but probability of flowering for such plants is less than 10%. The optimal rhizome weight with reasonably high probability of flowering (>50%) is above 4 g.

Creation of quasi in situ living collections

Two years after planting, survivorship in two living collections was equally high, approximating 100%. Percent of flowering plants was substantially higher in Tel Beer Sheva National Park (NP) than Tel Arad NP, while a difference in percentage of plants that produced mature fruits was less pronounced (Fig. 3). Plants of native geographic origin had no advantage at either location. Three years after planting, plant survival did not change significantly, but some rhizomes stayed dormant. Percent of flowering plants as compared with the previous year did not change at Tel Beer Sheva NP but increased at Tel Arad NP, and number of plants that produced fruits increased at both locations (Tel Beer Sheva NP, flowering $\chi^2_2 = 5.3$, $P > 0.05$ and fruiting $\chi^2_2 = 283$, $P < 0.001$; Tel Arad NP, flowering $\chi^2_3 = 15.5$, $P < 0.01$ and fruiting $\chi^2_3 = 9.2$, $P < 0.05$).

Large scale relocation experiment

In the first year after introduction, high survivorship was observed at all locations (Fig. 4). The highest number of reproducing plants was observed at Ofakim and Lahav North sites (Fig. 4). At Har Amasa, plant aboveground biomass was browsed by grazing livestock, thus, assessment of reproduction was not possible. Two years after introduction, variation in plant performance among the locations started to appear (Fig. 4) but mostly as a differential mortality of plants introduced as small rhizomes at Ofakim and Lahav North. Grazing at Har Amasa again prevented assessment of plant reproduction. In the third year, great increase in number of reproducing plants was observed at all locations for both small and large rhizomes.

At the Lahav North Reserve reproduction of plants was consistently high during the 3 years of observations. At the Ofakim site reproduction was high the first year but dropped dramatically the second year after planting.

Small scale relocation experiment

The number of plants observed at the 22 microsites in Lahav North Nature Reserve one year after introduction ranged from 25 to 52 out of 62 introduced with no significant

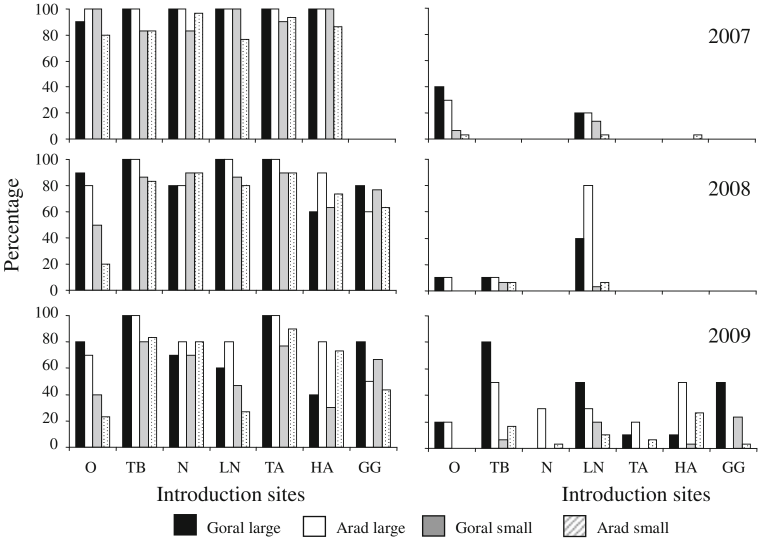

Fig. 4 Survival (*left*) and reproduction (*right*) of *I. atrofusca* planted in 2006. Ten large (>20 g) and 30 small (5–10 g) rhizomes of Goral and Arad origin were introduced at each introduction site. Abbreviations: *O* Ofakim, *TB* Tel Beer Sheva, *N* Nevatim, *LN* Lahav North, *TA* Tel Arad, *HA* Har Amasa, *GG* Gvaot Goral. The data for GG in 2007 are missing

difference between microsites (G-test, $G_{21} = 9.2$, $P > 0.05$). The microsites did not differ also for number of plants that set fruits ($G_{21} = 32.4$, $P > 0.05$), but differed for number of flowering plants ($G_{21} = 36.8$, $P < 0.05$).

Two years after introduction, the range of observed plants per microsite was between 33 and 53, generally higher than the previous year's records. This indicates that some plants were not counted in the first year census, perhaps due to rhizome dormancy. As in the first year, no microsite difference was observed for plant survival ($G_{21} = 20.0$, $P > 0.05$), but number of reproducing plants was significantly different among microsites ($G_{21} = 74.2$, $P < 0.001$; Fig. 5). As opposed to the first year, no flowers set fruit at any microsite in the second year. All the flowers were consumed by grasshoppers and caterpillars, indicating the important role of biotic interactions at the Lahav North Nature Reserve.

Three years after introduction, microsite differences in plant performance became clearly visible ($G_{21} = 148$, 161 and 134, $P < 0.001$ for number of observed, flowering and fruiting plants, respectively) and number of observed plants per microsite ranging from 2 to 58 (Fig. 5).

Discussion

Distribution in the Negev and population demography

The observed differences in stage structure (i.e. the frequency of life-cycle stages) between the two populations (Gvaot Goral and Tel Arad) corresponded to two types of demographic behavior, the "invasive" or "dynamic" (G-G) and "normal" or "stable" (T-A) (Rabotnov 1969, 1985; Oostermeijer et al. 1994). The former is characterized by a higher proportion of immature plants relative to adults, while in the latter the adults predominate. These two

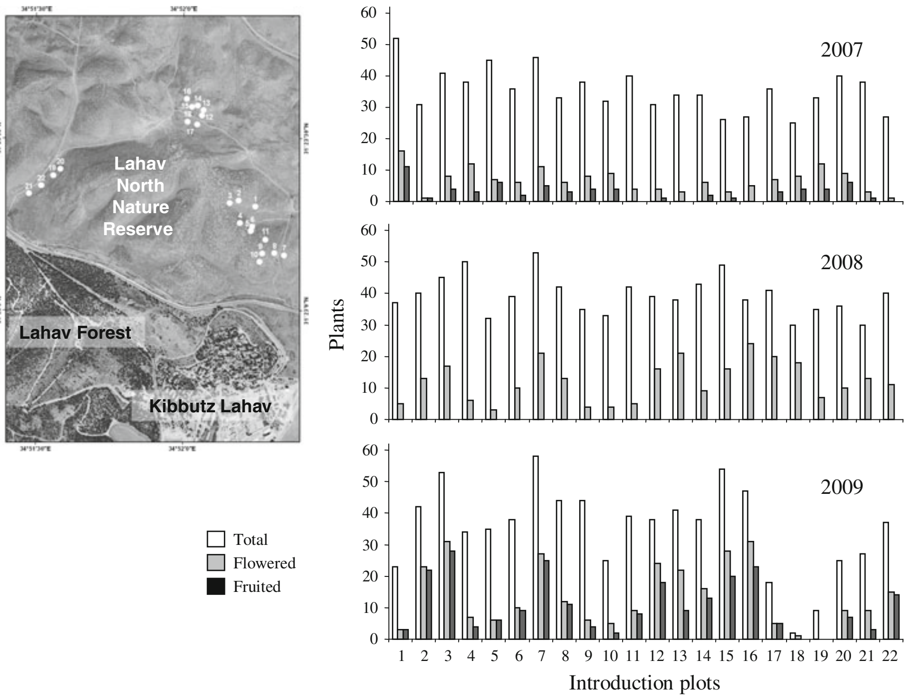

Fig. 5 The map with introduction plots and survival and reproduction of the introduced *I. atrofusca* plants at Lahav North Reserve. Sixty two rhizomes of Goral Hills origin with equal representation of different size classes were introduced at each plot

population types are usually associated with different succession stages of the local vegetation community, but in the two studied *I. atrofusca* populations no difference was apparent with respect to the succession stage. One major difference between the two population locations was in aridity, and the observed difference in proportion of immature plants appeared to be due to higher survival of seedlings (survival of juveniles does not differ) at the less xeric Gvaot Goral site. Nonetheless, it is too early to draw conclusions about the long-term dynamics of these two populations. The latter requires multi-year census coupled with records of annual rainfall and assessment of grazing pressure.

The two groups are separated by ca. 20 km from each other so there can be hardly any gene flow between them. Different environmental conditions (soil, rainfall) and anthropogenic impact (intensive grazing vs. agriculture) may have caused differential selective responses in the two regions. Therefore, a conservation strategy for *I. atrofusca* must be based on the assumption that ecologically important variation exists within *I. atrofusca* in the Negev and a regional criteria (Goral Hills vs. Arad Valley range subdivision) is a first approximation of this variation. This assumption has several implications for ex and in situ conservation of this species.

Implications for ex situ conservation

If plants in two regions are adapted to different environmental conditions, sampling and maintenance of living collections must be done for each region separately. Mixing of plants having different adaptive requirements must be prevented. If, due to logistical limitations, plants are maintained in the same location, measures must be taken to prevent spontaneous hybridization (e.g. removal of fruits before seed dispersal). On the other hand, interbreeding of plants originating in different populations within the same region is important in order to decrease risk of inbreeding depression and mate limitation. The negative effects of the latter were detected in fragmented populations of *I. bismarckiana*, another species of the section *Oncocyclus* (Segal et al. 2007).

In our study, plants from four populations of *I. atrofusca* in the Negev were planted at two National Parks (archeological sites with patches of natural habitats), creating two duplicates of the same living collection. After careful study of region-specific differences in environmental conditions, anthropogenic effects and population demography, we conclude that we should divide our collection based on regions. In spite of the initial proximal planting of plants from two regions, no spontaneous hybridization occurred during 2 years of collection maintenance because of precautions, such as removal of immature fruits.

High percentage of flowering plants at Tel Beer Sheva NP in both 2008 and 2009, and at Tel Arad NP in 2009 indicates high potential seed productivity in the living collection. Low percentage of plants that set fruits in 2008 appears to have been due to pollinator limitation. High fruit set was observed in the next year at both locations indicating inter-year variation in pollinator activity.

The next step in applying quasi in situ conservation, after removal and re-planting populations representing Goral Hills and Arad Valley areas into the region-specific locations of Tel Beer Sheva NP and Tel Arad NP, respectively, is to use plants in the living collections for seed propagation. In case of low fruit set due to limited availability of natural pollinators (*Eucera* bees; Sapir et al. 2005), randomly applied artificial pollination should be performed. Seeds, collected in the living collections, can be stored for 1 year to reduce strong innate dormancy, and germinated in mass (Dorman et al. 2009). Young plants with rhizomes exceeding 4 g can be used for in situ actions, which should be performed with plants of proper regional origin.

Implications for in situ conservation

Rapid destruction of *I. atrofusca* natural environment in the Northern Negev due to heavy and rapidly increasing anthropogenic impact on one hand, and lack of a nature reserve that contains any population of *I. atrofusca* in the Negev, on the other, leaves very limited options for conservation of this species. Designation of new protected areas in the Northern Negev is very problematic because of economic, demographic and political issues. There is virtually no viable alternative to relocation, i.e. introduction of the species into seemingly suitable protected areas with no past history of its existence. At the same time the choice of such areas for *I. atrofusca* in the Negev is also limited.

It is still too early to draw firm conclusions from our relocation experiments, started in 2006, about factors limiting species distribution at either large or small scale, but microhabitat is clearly important for relocation success. Importance of microhabitat was evident not only in the small scale relocation experiment, but was also indicated by zero reproduction during the first 2 years after introduction at two experimental sites established in close proximity to the natural populations, Gvaot Goral and Tel Arad. In both cases experimental location was established on an adjacent hill slope. Although reproduction greatly improved in the third year at G-G, it was still low at T-A.

In the small scale relocation experiment, relocation success at each microhabitat had a significant association with some characteristics of vegetation composition, but not with soil properties (Volis et al. unpublished). Thus, other environmental factors and interactions of *I. atrofusca* with other plant and animal species probably will determine species success at the introduction site. Because of among-year fluctuations, more years are needed for reliable conclusions, but some general considerations about choice of relocation material can be offered even at this stage. Using regional subdivision as a guideline for successful relocation, creation of a new population within Goral Hills or Arad Valley region should be done using material from the same region. If the new population location is outside these two regions, possible options include material of single regional origin (either Goral or Arad) or a mix of two. Hybridization of two ecotypes may result in a disruption of co-adapted gene complexes, high genetic load and low average fitness of plants in the new population. As a result, relocation success may be low. On the other hand, it is impossible to decide which of two plant origins suits better without relocation experiments. Therefore, experimental planting should precede relocation planting for conservation purposes.

Overall, we conclude that the quasi in situ approach is useful for an endangered plant species that is distributed over complex and variable ecological conditions. This approach has a number of advantages over ex situ conservation strategy, such as lower cost and higher capacity, but most importantly it allows the proper use of ecological information, is safe against the effects of inbreeding/outbreeding depression and maladaptive hybridization, and is ultimately directed toward in situ actions such as relocation.

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