Identification the Field Bindweed (*Convolvulus arvensis*) Biotypes in Three Areas of Tehran Province

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(Received 11November 2008; returned 11 July 2009; accepted 6 October2009)

ABSTRACT

Morphophysiological variations of field bindweed populations in Tehran province was studied during 2006 and 2007 growing seasons using multivariate analysis methods. To determine the variations, 43 morphological and physiological characters were considered biometrically. The main characters at principal component analysis (PCA) consisted of leaf dry weight, shoot dry weight, and leaf area to identify the biotypes. But, the populations were identified based on allometric variables, particularly root weight ratio. The results suggested that field bindweed ecotypes have been formed while the species adapted to specific geographic locations. Factor analysis based on PCA revealed that twelve factors comprise almost 85% of total variations for field bindweed populations in three locations of Tehran province. Phenological and morphological variabilities among biotypes may explain the survival and adaptability of a population of this weed as a result of environmental and field management changes.

Key words: Field bindweed, ecotype, biotype, principal component analysis.

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INTRODUCTION

Field bindweed (*Convolvulus arvensis* L.) is a serious perennial plant that occurs throughout the temperate regions of the world (Weaver & Riley, 1982). This species is one of the 10 worst weeds in the world and has been reported from more than 54 countries as a weed in 32 different crops (Swan, 1980). Field bindweed is recognized as a noxious weed in cereals and orchards of Iran (Shimi & Termeh, 2004). This weed is found in dry or moderately moist soils and can survive for long drought periods due to extensive root system, but prefers rich and fertile soils (Zouhar, 2004). Species such as field bindweed that inhabit a broad geographic range often include either ecotypes or biotypes (Klingaman & Oliver, 1996). It is self-incompatible and requires insect-pollination for seed set and thus an obligate out-crosser, which may play an important role in maintaining the high degree of phenotypic variation observed in this species (Westwood & Weller, 1997). Numerous examples of intraspecific variation in growth and morphology of weed species have been reported (Degennaro & Weller, 1984). Several morphologically distinct biotypes of field bindweed have been identified and more than one biotype often exists in the same infested area. The morphological variability of this species and the existence of biotypes, ecotypes, or strains are thought to be responsible for differential response of field bindweed to herbicides (Duncan & Weller, 1987). Variation in morphology and herbicide susceptibility of field bindweed has been observed by various researchers (Degennaro & Weller, 1984). Field bindweed grown from seed gathered in three western states of USA had stable differences in leaf and flower characteristics as well as in growth habit (Brown, 1946).

In a review of genetics and evolution of agricultural weeds, Barrett (1988) points out that there has been relatively little experimental work on population biology and evolution of weeds, particularly with respect to the occurrence of genetic differentiation resulting from selection pressures imposed by standard agricultural practices. He further suggests that the transient nature of many weed populations, particularly those subjected to selection pressures from herbicides, can prevent the build-up of large, stable populations capable of maintaining large stores of genetic variation (Barrett, 1988). This is logical when considering variation within a localized geographic area where cultural practices, weed control programs, and environmental factors place similar pressures upon a given population. However, greater genetic variation is most likely to occur across larger geographic expanses (Klingaman & Oliver, 1996).

Morphological parameters are usually used as tools for investigation of diversity and genetic relatedness (Hubner *et al*., 1998). Multivariate statistical techniques are powerful tools for investigating and summarizing underlying trends in complex data structures (Legendre & Legendre, 1998). The term "multivariate" refers to the methods that undertake a simultaneous analysis of several variables or dimensions (Kenkel *et al*., 2002). The aim of this study was preparing an efficient identification for field bindweed populations in Tehran province using multivariate analysis.

MATERIAL AND METHODS

This research was conducted in 2006 and 2007 at Department of Weed Research, Iranian Research Institute of Plant Protection, to identify phenotypic variation and morphological characters in populations of field bindweed. The variations and characters of the populations were quantified and compared in a controlled condition using multivariate analysis as explained below:

Populations Collection and Planting

In September 2006, field bindweed seeds were collected from Karaj, Varamin, and Damavand areas, as the most important agroecological regions in Tehran province. The seeds were stored for 45 days at room temperature (20±2 in paper bags). The seeds were soaked in sulfuric acid 98% (v/v; Merk, Germany) for 35 minutes and washed with distilled water for two minutes.

The seeds were planted in pots containing 1:5:5:0.5 (v/v/v/v) mixture of clay, sand, decomposed manure and perlit. The pots were maintained in a greenhouse for 22 weeks under day/night temperatures cycle of 30/18 ±4 ºC and illuminated with 500 lux of supplemental lights to provide a 12-h day length with 45% relative humidity. The plants were irrigated as needed with a nutrient solution containing 200, 100,and 100 ppm N, P, K respectively (Samadani, & Minbashi. 2004).

Morphophysiological Characteristics

For comparing field bindweed populations, based on the principal component analysis (PCA), the studied characters were categorized into three factors. The first factors consisted of shoot number, shoot fresh weight, shoot dry weight, shoot water content, stem dry weight, leaf dry weight, root dry weight, whole plant biomass, collar diameter, leaf number, leaf area. The second factors included of chlorophyll concentration, shoot/root ratio, specific leaf weight, specific leaf area, specific leaf chlorophyll weight, leaf, stem and root weight ratios, length and width of leaf, leaf length/width ratio, length and width of leaf basal lobe, leaf basal lobe length/width ratio, petiole length, leaf tip angle, leaf apex degree, trichome density, leaf color, leaf b coefficient (equation coefficient of leaf area), flower (petal) color, flower diameter, petal nerve color, stigma-anther arrangement, stigma length, anther length, anther color, flower length, calyx (corolla) diameter, pedicel length, total flowering rate, flowering duration, and time to flowering. At the end of flowering (154 days after sowing), 60 plants were randomly collected from each population. Totally, 43 morphological characters were studied biometrically for all regions. The variables were standardized for multivariate statistical analysis.

Statistical Analysis

In order to determine the most variable morphological characters among the populations, factor analysis based on PCA was performed. PCA was performed using the correlation matrix for the traits. All analyses were conducted using SPSS Ver. 13.

RESULTS AND DISCUSSION

Factor analysis based on PCA for the regions, revealed that first twelve factors comprise almost 85% of total variation for field bindweed populations in Tehran province (Table 1). In the first factors with about 20% of total variations in the regions, characters such as leaf and shoot dry weight, leaf area, leaf number, stem dry weight, shoot fresh weight, whole plant dry weight and specific leaf chlorophyll weight (negative), possessed the highest correlation. In the second factors with about 12% of total variations in the regions, characters such as root weight ratio, root dry weight, stem weight ratio (negative), leaf weight ratio (negative), and shoot/root ratio (negative), possessed the highest correlation. Third factors indicated about 9% of total variations (Tables 1 & 2).

Several authors describe variations in botanical characteristics of field bindweed. Degennaro and Weller (1984) identified and characterized 5 biotypes among field bindweed clones collected from a field in Indiana. Consistent variations in leaf morphology, floral characteristics, flowering capacity, phenology, vegetative reproduction potential, and accumulation of shoot and root biomass were found between biotypes when grown in a controlled environment. Whitworth (1964) found that clones of field bindweed which differed in leaf shape and growth vigor also varied in reaction to foliar 2,4-D application. Duncan and Weller (1987) found that five field bindweed biotypes analyzed in their investigation varied in leaf form, root and shoot biomass accumulation, flowering time and rate, corolla size, petal color, stigma-anther arrangement, and response to glyphosate.

The single features showed that there are distinct differences between the examined populations. To get a general impression, all parameters were considered together. These characters showed differences among the samples studied. In addition, leaf dry weight for field bindweed biotypes in PC1 (first principle component), and root weight ratio for field bindweed populations in PC2 (second principle component) were the most important efficient characters in Tehran province for identifying the biotypes and populations (Table 2 & Figure. 1). So, these were selected for biotypes or ecotypes separation. Leaf dry weight in the regions varied from 2.91 to 17.51 g per plant for the different biotypes. Root weight ratio varied from 0.21 to 0.72 for different populations. The plants studied showed a tendency toward different growth among populations (Figure. 2).

The linear combinations of traits generated from PCA can be used in much the same way as original traits for each experimental unit, with each PC representing a new trait and the PC score its new value (Mercer *et al*., 2002). Each PC explains a fraction of the total variability of the original data with PC1 explaining the most, PC2 explaining as much of the remaining variability as possible, etc (Table 1). A plot of the scores of PC1 and PC2 provided a visual rendering of the relationship between the populations and selection pressures by weed management due to multivariate association. In this study, PC1, in contrast to PC2, could be interpreted as indicator of weed management strategy in field bindweed populations of the regions and were grouped. To evaluate relationship of populations, components contrast mean separation of populations was performed. Field bindweed population of Varamin placed near Damavand groups, but they showed many differences in morphophysiological factors from those of Karaj population (Figure. 3). The most important component was PC2 and the most important character in PC2 was root weight ratio for separation the populations in Tehran province (Figure. 1). Taking all the above observations into consideration, those populations may represent ecotypes of field bindweed for each region. These results suggest that field bindweed has made some locally adapted ecotypes. These ecotypic variations will affect management of field bindweed.

This investigation specified that the most morphological variables and diagnostic features for separating and comparing of populations, are allometric characters such as shoot root ratio, leaf weight ratio, stem weight ratio, and root weight ratio. In this kind of comparisons, environmental factors was eliminated and only individuals were compared. In this point of view, strategy of growth pattern in Karaj field bindweed population relative to other populations was based on development of aboveground (shoot) but in Varamin and considerably in Damavand it was vice versa (Figure. 4).

The result of selection is the movement toward a phenotype having greater fecundity and survival in a given environment. If adaptation is considered to be the enhancement of rates of population increase over time in a given environment, then more adapted weed populations will continually challenge weed control methods over time. Some highly selected populations can be difficult to control. Strong selection pressures promote specific phenotypes in weed populations (Mercer *et al*., 2002). In general, strong selection pressures have been shown to select morphological, phenological, or biochemical traits that increase fitness in that environment (Jordan 1989). The methods of weed control have selected strongly among the weeds, and new appearance biotypes of adapted weeds has required that these methods be replaced or changed (Ghersa *et al*. 1994). However, every successful control of field bindweed requires a long-term management program.

As conclusion, our results indicated that there is a high diversity in the populations of field bindweed in Tehran province. This result leads us to think how to facile management of genetic resources. Moreover, information concerning the geographical and taxonomic distribution of genetic variation provides guidelines for sampling strategies of populations.

Leaf dry weight was the most important variable for effectively detection of biotypes in Tehran province (Table 2, Figures 1 & 2). Because, taking a greatly leaf dry weight is an appropriate strategy for drought stress, and underground competition for water in the semiarid region. Control of field bindweed may be influenced by plant age and environmental conditions, thus it is so difficult when this plant grows in semiarid conditions. Several reasons have been suggested including the increased development of cuticular waxes. This is especially apparent for foliar-applied herbicides, possibly due to lower leaf area, thicker cuticle with higher wax content, slower physiological processes, and smaller leaf/root ratios under semiarid conditions. It has been stated that the plants of field bindweed growing in semiarid conditions may be more resistant to weed control efforts than those growing in moist conditions (Meyer, 1978). Similarly, a laboratory experiment indicated that field bindweed is more resistant to glyphosate action when plants are under drought stress (DallArmellina & Zimdahl, 1989).

This paper explores the differentiation among field bindweed populations collected from three regions in important agroecosystem of Tehran province. The variability in growth and morphology observed in the weed biotypes may explain the survival and adaptability of a field bindweed population under influence of environmental conditions and field management systems. Botanical studies of this nature help to increase the knowledge concerning the variation in growth and biology between differing plants of the same species. Such studies contribute to our ability to predict how an intraspecific weed population might adapt when confronted with changing growing conditions. Understanding weed diversity is also important when considering a weed management strategy.

Table 1. Total variance of eigenvalues explained for 12 components of field bindweed populations in Tehran province.

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.216	23.757	23.757	8.681	20.187	20.187
2	6.975	16.220	39.977	5.351	12.445	32.632
3	3.082	7.167	47.144	3.732	8.678	41.310
4	2.926	6.804	53.948	3.589	8.345	49.656
5	2.325	5.408	59.356	2.439	5.673	55.329
6	2.093	4.867	64.223	2.294	5.336	60.664
7	1.909	4.440	68.663	2.018	4.692	65.357
8	1.727	4.016	72.679	1.904	4.427	69.784
9	1.483	3.450	76.129	1.675	3.896	73.680
10	1.369	3.185	79.314	1.663	3.868	77.548
11	1.170	2.721	82.035	1.531	3.561	81.109
12	1.070	2.488	84.523	1.468	3.414	84.523

Extraction Method: Principal Component Analysis.

Table 2. The main principal components of morphophysiological characters considered for identification of field bindweed populations in Tehran province.

Variables	Component					
	1	2	3	4	5	6
Shoot Number	.374	.089	.107	.028	.032	-.106
Shoot Fresh Weight	.877	.078	.079	.029	.053	.078
Shoot Dry Weight	.950	.052	.122	.147	.116	.114
Shoot Water Contant	-.199	.018	-.089	-.185	-.106	-.093
Stem Dry Weight	.916	.096	.102	.209	.109	.118
Leaf Dry Weight	.951	.001	.138	.074	.119	.106
Root Dry Weight	.648	.706	.091	.053	.041	.072
Whole Plant Dry Weight – Biomass	.820	.503	.111	.095	.074	.094
Collar (Crown) Diameter	.313	.211	-.275	-.139	.011	-.027
Leaf Number	.938	-.089	.026	-.065	.049	-.001
Leaf Area	.943	-.037	.101	-.201	.107	.101
Chlorophyll Concentration	.156	.035	-.254	.484	.103	-.030
Shoot Root Ratio	.023	-.930	-.026	-.115	-.045	-.036
Specific Leaf Weight	-.020	.060	.117	.926	.044	.009
Specific Leaf Area	.060	-.156	-.118	-.908	-.031	-.018
Specific Leaf Chlorophyll Weight	-.837	-.003	-.186	.234	-.017	-.137
Leaf Weight Ratio	-.076	-.943	-.026	-.178	-.003	-.060
Stem Weight Ratio	-.048	-.944	-.067	.106	.009	-.004
Root Weight Ratio	.066	.988	.047	.052	-.002	.036
Leaf Length	.474	.048	.622	.063	.119	.096
Leaf Width	.147	.076	.715	-.079	.187	.257
Leaf Length Width Ratio	.177	-.049	-.251	.116	-.100	-.142
Basal Lobe Length	.201	.065	.765	.122	.166	.182
Basal Lobe Width	-.008	-.020	.017	.060	-.075	.004
Basal Lobe Length Width Ratio	-.062	.120	.326	.155	.062	.058
Petiole Length	.431	.201	.495	-.048	.034	-.024
Leaf Tip Angle, Leaf Apex Degree	.133	.046	-.011	.089	-.051	.061
Trichome Density	.078	-.354	-.102	-.098	.302	-.025
Leaf Colour	.130	.076	-.165	.449	.081	.113
b Coefficient Leaf	-.387	-.048	-.769	-.123	-.159	-.116
Flower (Petal) Colour	.118	.249	.016	.161	-.083	-.084
Flower Diameter	.171	.037	.082	.105	-.041	.796
Petal Nerve Color	.106	.046	-.090	-.037	.027	-.061
Stigma - Anther arrangement	-.035	-.186	.055	.141	.016	-.019
Stigma Length	.093	.003	.029	-.062	-.062	.659
Anther Length	.023	-.083	-.034	-.002	.109	-.020
Anther Colour	.010	-.039	.008	-.048	.039	.158
Flower Length	.251	.054	.170	-.033	.074	.743
Calyx Diameter	.112	.019	.034	.216	.009	.166
Pedicel Length	.074	.179	.284	.044	.000	.460
Total Flowering Rate	.161	-.021	.155	.035	.798	.052
Flowering Time	.152	.038	.082	.124	.933	.012
Time to Flowering	-.102	-.031	-.106	.021	-.885	.090

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

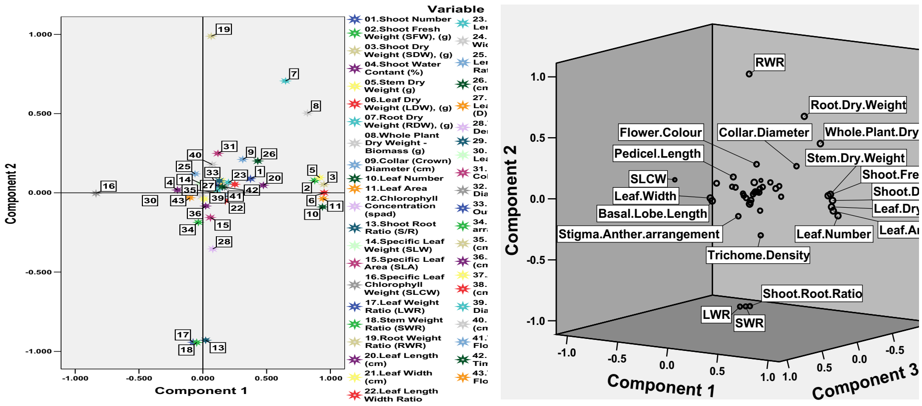
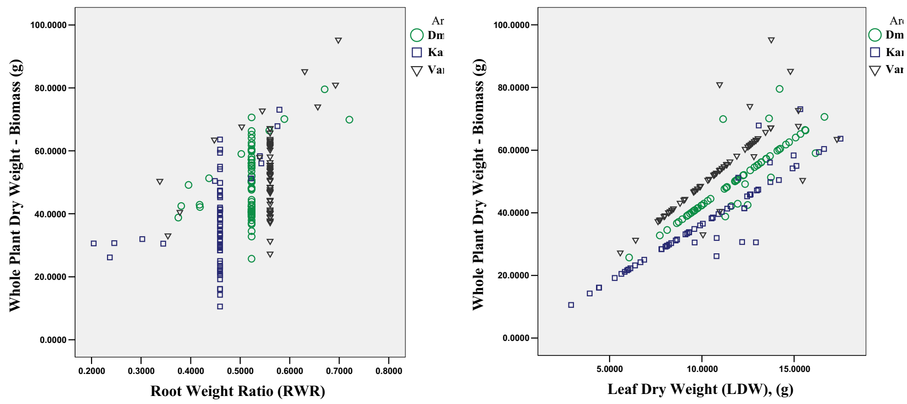


Figure 1. Component plots in rotated space by PC1, PC2 and PC3 for morphophysiological characters of field bindweed populations in Tehran province.



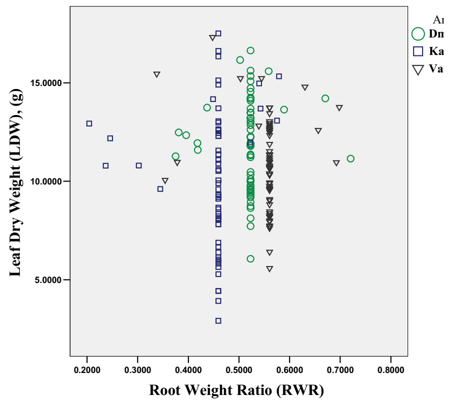


Figure 2. Scattergrams of field bindweed on the basis of leaf dry weight under most important variable in PC1 for biotypes detection, and root weight ratio under most important variable in PC2 for detection of the populations in three areas of Tehran province.

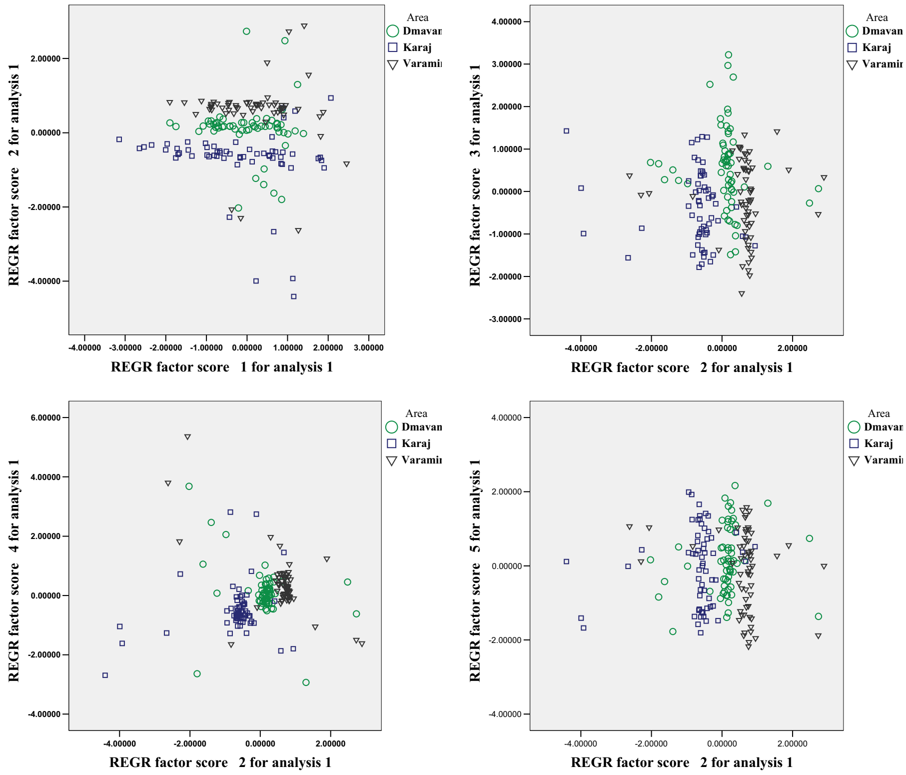


Figure 3. Scattergrams regression of field bindweed populations by two principal components in Tehran province.

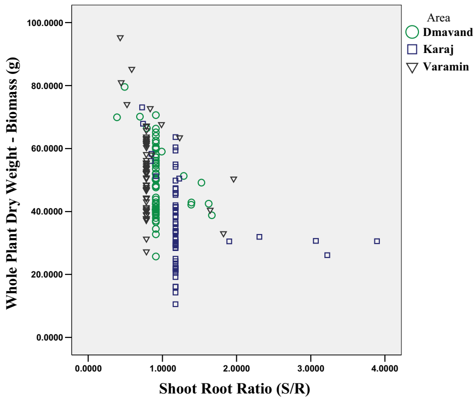


Figure 4. Comparison strategy of different populations by Shoot root ratio (S/R) in Tehran province.

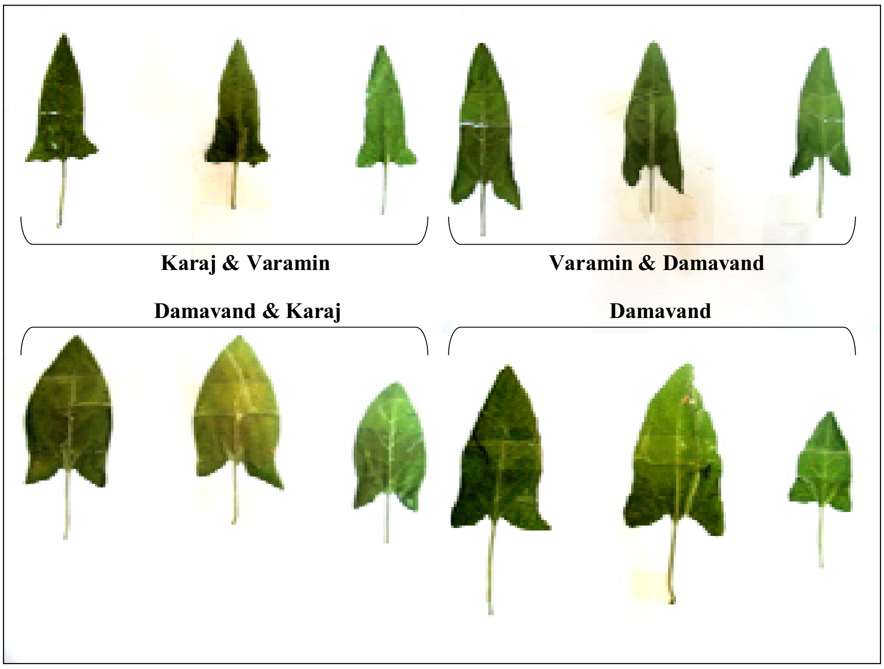


Figure 5. Some leaf shape variations among field bindweed biotypes in Varamin, Damavand and Karaj populations.

ACKNOWLEDGMENTS

We Thank Nazanin Amirian for her useful assistance, comments and hard work.

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