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SPATIO-TEMPORAL EFFECTS ON ASSOCIATION OF PLANT SPECIES IN SOONE VALLEY OF PAKISTAN

IFTIKHAR AHMAD, MUMTAZ HUSSAIN, MUHAMMAD SAJID AQEEL AHMAD* AND MANSOOR HAMEED

Department of Botany,
University of Agriculture, Faisalabad, Pakistan, Pakistan
**Corresponding author: sajidakeel@yahoo.com*

Abstract

Six ecologically diverse study sites viz., Khabeki, Khoora, Dape Sharif, Anga, Knotti Garden and Jallar were selected mainly on the basis of differences in their environmental attributes especially variations in elevation, slope, aspect, altitude, topography, soil composition, habitat, vegetation type and plant community. The available plant species at selected sites were enlisted. The ecological data was recorded during all the four seasons (autumn, winter, spring and summer) using quadrate sampling method. Soil physical and chemical properties of each site had their own impacts on the species association but seasonal effects, which were particularly due to different temperature and rain falls during different seasons of the year, were more pronounced. Most of the herbaceous species were frequent during summer and autumn due to suitable temperature and availability of moisture and nutrients. However during winter sparse vegetation did not show grouping of plants due to severe cold temperature. Availability of different nutrients at different sites and similar ability of some species to absorb these nutrients also had significant effect on association of species. Species sharing similar habitat were mostly associated as moisture loving species were grouped around water springs of Knotti Garden and Dape Sharif. Salt tolerant species were associated at Jaller site. Species which can tolerate both high salinity and pH were associated at Anga and Khoora sites.

Introduction

The Salt Range in the Punjab province of Pakistan is a 175 km thrust between the foot hills of Himalayan Mountains and Indus plains extending from the Jhelum River near Tilla Jogian in the east to the Indus River near Kalabagh in the west (Frisina *et al.*, 2001). Geographically it is located between longitudes 71°00 and 74°00 E and latitudes 32°10 and 33°15 N, covering an area of 10,529 km^2 (Afzal *et al.*, 1999). The vegetation of the Salt range varies with elevation soil type and precipitation. It is predominantly comprised of coarse grasses and scrub plants and has been placed under the division of sub-tropical dry thorny forests. *Acacia modesta* Wall and *Olea ferruginea* Royale have been recorded as the two distinguishing trees of this region (Champion, 1936). However, the vegetation of the entire region is exposed to severe habitat losses resulting in accelerated depletion of natural resources particularly plant diversity (Ahmad & Waseem, 2004).

Soone Valley, lying in the center of the Salt Range is regarded as the heart of Salt Range. It covers an area of 300 km^2, and comprised of many undulating lands, brine lakes, and natural fountains. The highest peak of the Salt Range i.e., Skaser top (1522 m) also exists in the Soone Valley (Afzal *et al.*, 1999). All these aspects impart it a special ecology in the region which is not only well reflected in the variation in the prevailing natural vegetation but also fully exploited by the local people in growing some out of season vegetables i.e., cauliflower and tomato, which earn a good price in the markets of nearby

cities. However, the extensive cultivation of vegetable crops accompanied by low rainfall during the past few years has drastically depleted the aquifer of the valley (Hussain, 2002). As a consequence, the unique wetlands i.e., Khabbeki (a Ramsor site) and Ucchali complex, of the valley are totally dried. Owing to these altered environmental changes and some anthropogenic disturbances i.e., overgrazing, lopping of woods for browsers and logging of woods for fuel and furniture needs, the natural vegetation of the Soone valley is highly threatened and is expected to display much spatio-temporal variation in its composition (Ahmad *et al.*, 2007, Ahmad *et al.*, 2008a & b).

The abundance of different plant species at a site depends on the amount of available soil moisture and mineral contents essential for plant growth and development. The differences in the species composition and their distribution pattern are also controlled by mean annual temperature, annual precipitation and the length of dry season (Skarpe, 1990). Sometimes, a group of species depends on each other and on a specific set of physical conditions for their existence. Different species showing similar distribution pattern along any environmental gradient are said to be associated and constitute the dominant vegetation type (Varghese & Murthy, 2006). Hence the objective of this study was to determine the spatio-temporal variation in the species association in the vegetation of Soone Valley in the Salt Range of Pakistan.

Materials and Methods

The studies were conducted during 2005 and 2006 to determine association pattern of plant species at different sites and seasons. For this purpose, the valley was extensively surveyed and the available species at selected sites were enlisted. Six ecologically diverse study sites viz., Khabeki, Khoora, Dape Sharif, Anga, Knotti Garden and Jallar were selected mainly on the basis of differences in their environmental attributes especially variations in elevation, slope, aspect, altitude, topography, soil composition, habitat, vegetation type and plant community (Tables 1 & 2).

Association of species: The ecological data collected were organized in contingency Tables with 2 plant species appearing binomially distributed (present or absent) in the table to calculate association between them (Hubalek, 1982). A chi-square test was then applied to the tables in order to test the significance of the pair-wise associations (Dice, 1945; Ludwig & Reynolds, 1988).

Results and Discussion

Three tree species were recorded from the Khabeki site viz., *Acacia modesta*, *A. nilotica*, and *Olea ferruginea* along with one large shrub *Ziziphus nummularia. Acacia modesta* has an umbrella-like canopy, and it seems to be restricted the growth of other plant species as it was associated positively with only herbaceous *Solanum nigrum. Acacia nilotica*, on the other hand was associated with a number of species. It was positively associated with a perennial shrub *Justicia adhatoda* in three seasons, but with *Salvia virgata* in autumn, with *Achyranthes aspera* and *Solanum incanum* in winter and spring, with *Solanum nigrum* in spring and with *Peganum harmala* in summer (Table 3). It seems to facilitate the presence of these species as reported by Connell & Slatyer (1977) and Langenheim *et al*., (1984).

Table 1. Geographical aspects of the sites selected in the Soone Valley of the Salt Range.

Sites	Coordinates	Elevation (m)	Slope (%)	Aspect
Khabeki	32.35N and 72.12 E	774	30-35	Western
Khoora	32.23N and 72.11 E	866	40-45	Northern
Dape Sharif	32.30N and 72.04 E	890	35-40	Western
Anga	32.35N and 72.05 E	821	30-35	Northern
Knotti Garden	32.40N and 72.14 E	783	30-35	Northern
Jaller	32.27N and 72.09 E	996	50-60	Eastern

Table 2. Plant community structure of the sites selected in the Soone Valley of the Salt Range.

Sites	Habitat description	Vegetation type	Plant community
Khabeki	Moderate slopes	Dominant large shrubs with grasses	*Justicia adhatoda*
Khoora	Hills with steep slopes	Shrubs herbs and grasses	*Dodonea viscosa*
Dape Sharif	Almost Plain area	Shrubs and grasses	*Dodonea viscosa*
Anga	Hills with steep slopes	Dominant grasses with shrubs	*Acacia modesta*
Knotti Garden	Hills with steep slopes	Mixture of herbs grasses and shrubs	*Justicia adhatoda* and *Acacia fernesiana*
Jaller	Pass through the Hills	Grasses herbs and shrubs along the pass between the hills.	*Acacia modesta* and *Justicia adhatoda*

At Khoora site, vegetation was dominated by shrubby vegetation, with tall shrubs like *Ziziphus nummularia* and *Acacia modesta* and single tree *Olea ferruginea* at scattered places (Table 4). Few dominant species at this site may be due to specific environmental conditions as reported by Clark & Clark (1992). Such habitat requirements for the establishment of few species could potentially have been constrained to specific areas of this site that support those requirements. All shrubby and tree species associated with very few species at this site; however this association varied with the season. *Cynodon dactylon*, however was associated with the maximum number of species, most of them were shrubs like *Ziziphus nummularia*, *Buxus pappilosa*, and *Dodonaea viscosa*. This species dominated the Khoora site among grasses. As mentioned earlier that this species can tolerate a number of environmental stresses and spread over different habitat types (Speranza, 1995), there is a good chance of its association with a number of species.

Dape Sharif showed the maximum species richness and diversity. Among trees, *Ziziphus mauritiana* showed association with the maximum number of species. Only *Z. nummularia* was the large shrubby species that had positive association with *Z. mauritiana,* and that may have been due to the possession of similar habitat conditions (Qaiser & Nazimuddin, 1996). *Acacia nilotica* had positive association with herbs and under-shrubs only except a shrubby *Dodonaea viscosa*. At this site *Cynodon dactylon* was associated with few species only and this association was found only in autumn season. This was an indication of its seasonal spread, which is more in the autumn season. At Dape Sharif, *Prosopis glandulosa* also seemed to facilitate the growth of a number of species as it showed association with mostly herbaceous species along with shrub *Dodonaea viscosa* and tall grass *Saccharum griffithii* (Table 5).

Table 3. Association of plant species at Khabeki site during different seasons.

Plant species	Abr.	Autumn	Winter	Spring	Summer
Achyranthes aspera	Aa	Os, Sc, Si	An, Sv	An, Zn	An, Sv
Acacia modesta	Ac		Sn		
Acacia nilotica	An	Ja, Sv	Aa, Si	Aa,Ja, Si, Sn	Aa, Ja,Ph.
Adiantum capillus-veneris	Ac				
Albizia lebbeck	Al				
Alternanthera sessilis	As				
Barleria cristata	Bc				
Boerhavia procumbens	Bp				
Buxus papillosa	Bpa				
Cannabis sativa	Cs				
Capparis deciduas	Cde				
Conyza ambigua	Ca				
Cynodon dactylon	Cd	Dbi, Dv, Pp		Db, Os	Os
Cynoglossum lanceolatum	Cl				
Cyperus rotundus	Cr				
Datura metel	Dm				
Desmostachya bipinnata	Dbi	Cd, Ja			Ja
Diclyptera bupleuroides	Db	Ja, Sc		Ca	Pp
Dodonaea viscosa	Dv	Cd			
Fagonia indica	Fi				
Heliotropium strigosum	Hs				
Justicia adhatoda	Ja	An, Db		Sn	Dbi
M. coromandelianum	Mc	Sn, Zn			Ws
Melilotus indica	Mi				
Mentha longifolia	Ml				
Nerium oleander	No				
Olea ferruginea	Of			Os	
Oxalis corniculata	Os	Aa, Ph, Zn		Cd, Of	Cd, Sc
Parthenium hystorophorus	Pp	Cd, Sv			Dv, Sc, Sn, Sv
Peganum harmala	Ph	Os		Zn	Db
Prosopis glandulosa	Pg				
Prosopis juliflora	Af				
Saccharum griffithii	Sm				
Salvia virgata	Sv	An, Sn, Pp		Sn	Aa, Pp, Sc, Sn
Sida cordifolia	Sc	Aa, Db, Pp		Zn	Pp, Os, Sn, Sv
Solanum incanum	Si	Aa	Aa, An	Aa	
Solanum nigrum	Sn	Mc, Sv	Am, Ja	Aa, Sv, Zn	Pp, Sc, Sv
Solanum surratense	Ss				
Sophora tomentosa	St				
Tecomella undulata	Tu				
Tinospora malabarica	Tm				
Tribulus terrestris	Tt				
Withania coagulans	Wc				
Withania somnifera	Ws				Mc
Ziziphus mauritiana	Zm				
Ziziphus nummularia	Zn	Mc		Aa, Ph, Sc, Sn	

Table 4. Association of plant species at Khoora site during different seasons.

Plant species	Abr.	Autumn	Winter	Spring	Summer
Achyranthes aspera	Aa	Si, St	Am, Zn		Dbi, Os, Sm
Acacia modesta	Ac	Zn	Aa, Cd		Cde
Acacia nilotica	An			Bp, Sv	Os
Adiantum capillus-veneris	Ac				
Albizia lebbeck	Al				
Alternanthera sessilis	As				
Barleria cristata	Bc				
Boerhavia procumbens	Bp	Sc	Cd, Dv, Ja, St	An, Cd	
Buxus papillosa	Bpa	Cd, Pg			
Cannabis sativa	Cs				
Capparis deciduas	Cde				
Conyza ambigua	Ca				
Cynodon dactylon	Cd	Bpa, Dv, Zn	Am, Bp, Dv, Ja,	Bp, Dv, Ph, Zn	Dv, Ja, Si, Tu
Cynoglossum lanceolatum	Cl				
Cyperus rotundus	Cr				
Datura metel	Dm				
Desmostachya bipinnata	Dbi				Ac
Diclyptera bupleuroides	Db				
Dodonaea viscosa	Dv	Cd, Si	Bp, Cd,	Cd, Ja	Ja, Sc, Zn
Fagonia indica	Fi				
Heliotropium strigosum	Hs				
Justicia adhatoda	Ja	Sm	Bp, Cd	Dv	Cd, Dv, Ph
M. coromandelianum	Mc				
Melilotus indica	Mi				
Mentha longifolia	Ml				
Nerium oleander	No				
Olea ferruginea	Of	Pg, Si, Sn	Cd		
Oxalis corniculata	Os				Aa, An.
Parthenium hystorophorus	Pp				
Peganum harmala	Ph			Cd, St	Ja
Prosopis glandulosa	Pg	Bpa,			
Prosopis juliflora	Af				
Saccharum griffithii	Sm		Dv		Aa, Am, Os
Salvia virgata	Sv	Sn		An, Zn	
Sida cordifolia	Sc	Bp, Sn			Dv, St, Tu, Zn
Solanum incanum	Si	Aa, Dv, Of, St			Cd
Solanum nigrum	Sn	Of, Ja, Sc, Sv			
Solanum surratense	Ss				
Sophora tomentosa	St	Aa, Si	Bp	Ph, Tu	Sc, Zn
Tecomella undulata	Tu			St	Cd, Sc
Tinospora malabarica	Tm				
Tribulus terrestris	Tt				
Withania coagulans	Wc				
Withania somnifera	Ws				
Ziziphus mauritiana	Zm				
Ziziphus nummularia	Zn	Am, Cd	Aa	Am,Cd, Sv	Dv, Sc, St

Table 5. Association of plant species at Dape Sharif site during different seasons.

Plant species	Abr.	Autumn	Winter	Spring	Summer
Achyranthes aspera	Aa	Cs, Db, Pg, Sv	An, Dv, Zn	Db, Tu,, Zm, Zn	Af, Db, Of, St, Zn
Acacia modesta	Ac	Zn	Zn		Db, Sn
Acacia nilotica	An	Dm, Hs, Ws	Aa,	Ph, Sc, St	Dv, Sv
Adiantum capillus-veneris	Ac			Os	
Albizia lebbeck	Al				
Alternanthera sessilis	As				
Barleria cristata	Bc	Cd, Db, Of		Cs, Db, Dm, Ph, Si, Sv	
Boerhavia procumbens	Bp	Dm, Hs, Sn, St, Zm			
Buxus papillosa	Bpa				
Cannabis sativa	Cs	Aa, Sv	Db, No	Bc, Db, Os, Sn	Os
Capparis deciduas	Cde				
Conyza ambigua	Ca	Cd, Db, Sn			Af, Tu
Cynodon dactylon	Cd	Af, Bc, Ca, Sn			
Cynoglossum lanceolatum	Cl	Hs, Ja, Pg, St, Sv, Zm			
Cyperus rotundus	Cr				
Datura metel	Dm	An, Bp, Zm	Aa, Zn	Bc	Ws, Zn
Desmostachya bipinnata	Dbi	Sm		No	
Diclyptera bupleuroides	Db	Aa, Bc, Ca, Zm	Cs, No	As, Bc, Cs, Os, Tu	Aa, Am, Sn, Zn
Dodonaea viscosa	Dv	Hs, St, Sv	Aa, Zm, Zn	Zn	Ss, Sv, Zn
Fagonia indica	Fi				
Heliotropium strigosum	Hs	Cn, Bp, Cy, Dv, Si, St			
Justicia adhatoda	Ja	Cy, Sv		No	Of, Ph
Malvastrum coromandelianum	Mc				
Melilotus indica	Mi				
Mentha longifolia	Ml				
Nerium oleander	No		Cs, Db	Db, Ja	
Olea ferruginea	Of	Bc	Dv		Aa, Ja, St
Oxalis corniculata	Os				
Parthenium hystorophorus	Pp				
Peganum harmala	Ph			An, Bc, Zn, Zm	Ja, Sc, Zn

Table 5. (Cont'd.).

Plant species	Abr.	Autumn	Winter	Spring	Summer
Prosopis glandulosa	Pg	Aa, Cy, Dv, Si, Sm, St,		Aa, Dv,Sm	Dv,Sm,Ws
Prosopis juliflora	Af	Cd			Aa, Ca, St, Zn
Saccharum griffithii	Sm	Db, Pg			
Salvia virgata	Sv	Aa, Cs, Cy, Dv, Ja, Pg, St		Bc, Sc, Sn, St	An, Dv, Tu, Ws
Sida cordifolia	Sc				
Solanum incanum	Si	Hs, Pg, St, Zm	Zn	Bc, Ss, Tt, Zm, Zn	St
Solanum nigrum	Sn	Bp, Ca, Cd	Cs, Db, Sv, Zm, Zn	Am, Db, Zm	
Solanum surratense	Ss				
Sophora tomentosa	St	Bp, Cy, Dv, Hs, Of, Si, Sv		Of, Sv, Zn	Aa,, Of, Si
Tecomella undulata	Tu			Aa	Ca, , Sv
Tinospora malabarica	Tm				
Tribulus terrestris	Tt				
Withania coagulans	Wc				
Withania somnifera	Ws	An			Dm, Pg, Sv
Ziziphus mauritiana	Zm	Bp, Cy, Db, Dm, Si, St,	Aa, Dv,Zn	Aa, Ph, Si,Zn	Zn
Ziziphus nummularia	Zn	Ph	Aa, Dm, Dv, Si	Aa, Ph, Si, Sn, St	Aa, Af, Db, Dm, Ph

At Anga site, *Ziziphus nummularia* showed association with the maximum number of species among tall shrubs or trees. It was associated with tree/shrub species like *Acacia modesta*, *Olea ferruginea* and *Dodonaea viscosa*, and grass species as *Cynodon dactylon*. Among shrubs, *Dodonaea viscosa* was associated with a number of species; most of them were herbaceous species and single tree *Acacia modesta*. Among grasses, *Cynodon dactylon* was associated with the maximum number of species, but this association was weak in spring season, and this may be due to its suppressed growth due to severe winters (Table 6).

Knotti Garden had very specific type of vegetation. Tree species at this site were growing in isolated patches and only *Acacia modesta* showed some association with shrubby *Prosopis glandulosa*. However, there were some herbaceous and grass species found to be associated with tree species. *Justicia adhatoda* was associated with a number of species, particularly in autumn season, including three large shrubs/trees (*Prosopis juliflora, P. glandulosa* and *Olea ferruginea*) and two small shrubby species (*Nerium oleander* and *Cannabis sativa*). *Cynodon dactylon*, however, the most dominant perennial grass of the area and was found associated with a number of species in all the seasons (Table 7). As this species is adaptable and tolerant to a variety of habitat types and environmental stresses (Holmgren & Holmgren, 1977; Gleason & Cronquist, 1991; Speranza, 1995), therefore its distributional pattern seems to be not dependent on a particular soil condition (Bell, 2000; Hubbell, 2001).

Table 6. Association of plant species at Anga site during different seasons.

Plant species	Abr.	Autumn	Winter	Spring	Summer
Achyranthes aspera	Aa			Zn	
Acacia modesta	Am	Sn	Cd, Of,Zn	Ja, Zn	Dv,Ja, Zn
Acacia nilotica	An				
Adiantum capillus-veneris	Ac				
Albizia lebbeck	Al				
Alternanthera sessilis	As	Si			
Barleria cristata	Bc				
Boerhavia procumbens	Bp			Si, Zn	
Buxus papillosa	Bpa				
Cannabis sativa	Cs				
Capparis deciduas	Cde				
Conyza ambigua	Ca				
Cynodon dactylon	Cd	Mc, Mi, Ph, Sv, Ws	Am, Dv, Ja, Sv		Dv, Ja, Os, Sm
Cynoglossum lanceolatum	Cl				
Cyperus rotundus	Cr				
Datura metel	Dm		Dv		Ja
Desmostachya bipinnata	Dbi				
Diclyptera bupleuroides	Db				
Dodonaea viscosa	Dv	Ja, Ph, Zn	Cd, Dm, Sm, Zn		Cd, Ja, Ph, Sv, Ws
Fagonia indica	Fi				
Heliotropium strigosum	Hs				
Justicia adhatoda	Ja	Dv	Cd	Am, Of, Ph, Ws	Cd, Dm, Zn
Malvastrum coromandelianum	Mc	Cd, Mi			
Melilotus indica	Mi	Cd, Mc			Ph
Mentha longifolia	Ml				
Nerium oleander	No				
Olea ferruginea	Of		Zn,	Ja, Zn	Zn
Oxalis corniculata	Os			Ph, Zn	Cd
Parthenium hystorophorus	Pp				
Peganum harmala	Ph	Cd, Dv, Pg		Ja, Os, Sn, Sv, Ws	DV, Mi, Sn
Prosopis glandulosa	Pg	Dv, Ph, Sv, Ws			
Prosopis juliflora	Af				
Saccharum griffithii	Sm		Dv		Cd
Salvia virgata	Sv	Cd, Pg, Sn, Zn	Cd	Ph	Dv, Ws
Sida cordifolia	Sc				
Solanum incanum	Si	As		Bp, Zn	
Solanum nigrum	Sn	Am, Sv		Ph, Zn	Ph
Solanum surratense	Ss				
Sophora tomentosa	St				
Tecomella undulata	Tu				
Tinospora malabarica	Tm				
Tribulus terrestris	Tt				
Withania coagulans	Wc				
Withania somnifera	Ws	Cd, Pg		Ja, Ph	Dv, Sv
Ziziphus mauritiana	Zm				
Ziziphus nummularia	Zn	Dv, Sv, Of, Cd	Am, Dv, Of	Aa, Am, Bp, Cd, Dv, Of, Os, Si, Sn	Am, Ja, Of

Table 7. Association of plant species at Knotti Garden site during different seasons.

Plant species	Abr.	Autumn	Winter	Spring	Summer
Achyranthes aspera	Aa				
Acacia modesta	Ac	Sv,Pg	Bp,Pg	Pg	Db
Acacia nilotica	An				
A. capillus-veneris	Ac	Dm, Dbi	Cs, No	Cd, Db	Cd
Albizia lebbeck	Al				
Alternanthera sessilis	As				
Barleria cristata	Bc				
Boerhavia procumbens	Bp	Ja, Si	Am, Cd	Dv	Dv, Si, Sn
Buxus papillosa	Bpa				
Cannabis sativa	Cs	Ja, Os	Ac, No		
Capparis deciduas	Cde				
Conyza ambigua	Ca			Db	Dbi, Sc
Cynodon dactylon	Cd	Sn, Tm, Ws	Bp, Db, Dv, Ja, Of, Pj	Ac	Ac, Ja, Sn
C. lanceolatum	Cl				
Cyperus rotundus	Cr				
Datura metel	Dm	Ac			Cs, Sc
Desmostachya bipinnata	Dbi	Ac, Tm			Cs, Dv, Sc, Sn
Diclyptera bupleuroides	Db	Ja, Ml	Cd, Tm	Ac, Ca, Os	Am, Ws
Dodonaea viscosa	Dv		Cd	Bp, Ja, Of	Bp, Dbi, Ph, Sn
Fagonia indica	Fi				
Heliotropium strigosum	Hs				
Justicia adhatoda	Ja	Bp, Cs, Db, No, Oc, Of, Pj, Pg	Ca,Of	Dv,Pg, Ph,Of,	Cd,Of,Pg
M. coromandelianum	Mc				
Melilotus indica	Mi				
Mentha longifolia	Ml	Db			
Nerium oleander	No	Ja, Ws	Ac, Cs, Tm		
Olea ferruginea	Of	Ja	Cd,	Dv,Ja	Ja
Oxalis corniculata	Oc	Cs, Ja, Pg, Sv		Cs, Db, Ph	
P. hystorophorus	Ph				
Peganum harmala	Pha			Ja, Os	Dv
Prosopis glandulosa	Pg	Ja, Os, Sv	Cd, Si		
Prosopis juliflora	Pj	Ja			Sc
Saccharum griffithii	Sm				
Salvia virgata	Sv	Am, Os, Pg, Sn		Ws	
Sida cordifolia	Sc				Ca, Cs, Dm, Pj
Solanum incanum	Si	Bp	Pg		Bp, Ws
Solanum nigrum	Sn	Cd, Sv			Bp, Cd, Dbi
Solanum surratense	Ss				
Sophora tomentosa	St				
Tecomella undulata	Tu				
Tinospora malabarica	Tm	Cd, Dbi	Db, No		
Tribulus terrestris	Tt				
Withania coagulans	Wc				
Withania somnifera	Ws	Cd, No		Sv	Db, Dbi, Dv
Ziziphus mauritiana	Zm				
Ziziphus nummularia	Zn				

Vegetation diversity and species richness was the minimum at Jallar among all the study sites. However, there was strong association among most of the species (Table 8). According to Connell & Slatyer (1977) and Langenheim *et al.,* (1984) non-competitive species may actually be facilitated by the presence of other species, therefore, this may have resulted in a strong association of a number of species at this site. Among tall shrubs and trees *Ziziphus nummularia* was associated with a number of species, more frequently with shrubby species like *Justicia adhatoda* and *Dodonaea viscosa*. Shrubby species (*Dodonaea viscosa* and *Justicia adhatoda*) showed positive association mainly with herbs and grasses, the most important among them was *Cynodon dactylon*. Among grasses, *Cynodon dactylon* was associated with the maximum number of species, and this association was relatively weaker only in the summer season.

Table 8. Association of plant species at Jallar site during different seasons.

Plant species	Abr.	Autumn	Winter	Spring	Summer
Achyranthes aspera	Aa				
Acacia modesta	Am	Ph	Cd, Ja	Cd, Ja, Ph	Dv, Ph
Acacia nilotica	An				
Adiantum capillus-veneris	Ac				
Albizia lebbeck	Al				
Alternanthera sessilis	As	Dv, Ja, Ph, Sv, Ss			Cd, Ph, Wa
Barleria cristata	Bc				
Boerhavia procumbens	Bp				
Buxus papillosa	Bpa				
Cannabis sativa	Cs				
Capparis deciduas	Cde				
Conyza ambigua	Ca				
Cynodon dactylon	Cd	Dv, Fi, Ja, Of, Si, Sm, Ss, Sv	Am, Dv, Ja, Of, Sm	Am, Dv, Ja, Of, Ph, Si, Ss, Sv, Ws	As, Ja, Sm
Cynoglossum lanceolatum	Cl				
Cyperus rotundus	Cr				
Datura metel	Dm				
Desmostachya bipinnata	Dbi				
Diclyptera bupleuroides	Db				
Dodonaea viscosa	Dv	As, Cd, Of, Ph, Zn	Cd, Sn,Zn	Cd, Ja, Ph, Si, Sv	Ja, Ph
Fagonia indica	Fi	Cd, Ph, Sv	Ss	Ja	
Heliotropium strigosum	Hs				
Justicia adhatoda	Ja	As, Cd,	Am, Cd	Am, Cd, Dv,	Am, Cd, Dv, Oc, Ph
Malvastrum coromandelianum	Mc				
Melilotus indica	Mi				
Mentha longifolia	Ml				
Nerium oleander	No				
Olea ferruginea	Of	Am, Cd, Dv, Sv	Am, Cd,	Am, Cd, Ph	Am
Oxalis corniculata	Oc	Cd, Ph			Ja
Parthenium hystorophorus	Pp				
Peganum harmala	Ph	Am, As, Dv, Fi, Os, Sn	Zn	Am, Cd, Dv, Of, Sv	Am, As, Dv, Ja

Table 8. (Cont'd.).

Plant species	Abr.	Autumn	Winter	Spring	Summer
Prosopis glandulosa	Pg			Dv, Ja, Si	
Prosopis juliflora	Af				
Saccharum griffithii	Sm		Cd		
Salvia virgata	Sv	As, Cd, Of, Pi, Zn		Cd, Dv, Ph, Si	
Sida cordifolia	Sc				
Solanum incanum	Si	Cd, Zn		Cd, Dv, Pg, Sv	Sg
Solanum nigrum	Sn				
Solanum surratense	Ss	Ph, Zn	Fi	Cd	Sm
Sophora tomentosa	St				
Tecomella undulata	Tu				
Tinospora malabarica	Tm				
Tribulus terrestris	Tt				
Withania coagulans	Wc				
Withania somnifera	Ws			Cd	
Ziziphus mauritiana	Zm				
Ziziphus nummularia	Zn	Dv,Ja, Ph, Sv, Si, Sn	Dv,Ja, Ph	Cd,Ja	

Soil physical and chemical properties of each site had their own impacts on the species association but seasonal effects, which are particularly due to different temperature and rain falls during different seasons of the year, are more pronounced in Soone Valley. Most of the herbaceous species are frequent during summer and autumn due to suitable temperature and availability of moisture. Therefore these are grouped together or associated due to availability of moisture and nutrients in different parts of Soone Valley. However during winter sparse vegetation do not show grouping of plants due to severe cold temperature. These effects mostly extend up to early spring. Availability of different nutrients at different sites and similar ability of some species to absorb these nutrients also cause association of species. Species sharing similar habitat are mostly associated as moisture loving species are grouped around water springs of Knotti Garden and Dape Sharif where as salt tolerant species clustered at Jaller site. Species which can tolerate both high salinity and pH are associated at Anga and Khoora sites.

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