***INT. J. BIOL. BIOTECH*., 2 (2): 321-327, 2005.**

SEED DISPERSAL PATTERN OF A COMPOSITE WEED *TRIDAX PROCUMBENS* L.

S. S. Shaukat[1], I. A. Siddiqui[1] and A. Zarina[2]

[1]*Department of Botany, University of Karachi, Karachi-75270, Pakistan*
[2]*Department of Botany, Federal Urdu University of Arts, Sciences and Technology, Karachi, Pakistan*

ABSTRACT

The dispersal pattern of a weed *Tridax procumbens* was investigated in an agricultural field. Two seed traps were designed, one to examine the dispersal pattern of isolated individuals and another to study the dispersal distances from a cluster of *T. procumbens* plants. The dispersal curves of both isolated individuals and cluster of plants followed an exponential model. Seeds dispersed in all directions but the movement was primarily in the direction of wind (westerly direction) while the movement was least in the leeward direction. The factors influencing anemochorous dispersal of composite seeds are discussed.

Key words: Seed dispersal, *Tridax procumbens*, Compositae, weed

INTRODUCTION

Dispersal of seeds into suitable habitats is a critical stage of any plant's life history. Because plants are sessile, their seeds must be dispersed by some external agents, such as wind, water or animals (van der Pijl, 1982; Fenner, 1985; Nathan and Muller-Landau, 2000). The dispersal agencies differ considerably with regard to efficiency of seed dispersal. The variation in fruit-removal and dispersal distance presumably result in long-term demographic consequences (Tews *et al*., 2004). Plants are subject to strong selective pressure to invade suitable microhabitats, and such selection can lead to increased dispersal distance (Harper *et al*., 1970; Janzen, 1970; Howe and Smallwood, 1982**).**

Several advantages are associated with the deposition of seeds some distance away from the parent plant. When habitats change with time, dispersal from the parent increases the likelihood for colonization in new sites (Howe and Smallwood, 1982; Wilson and Travest, 2000), lowers seed / seedling mortality by lowering density near the parent plant (Clark and Clark, 1984) and maintains the diversity of plant communities (Christian, 2001; Webb and Peart, 2001). Seeds deposited in the vicinity of parent plant provide a concentrated resource for seed predators and pathogens, while those placed away from the parent are less likely to be found by predators and pathogens (Howe and Smallwood, 1982; Augspurger, 1983). Dispersal also provides the means of release of genetic variability among low-density patches (Comins *et al*., 1980) by promoting migration. In addition, genetic variability may also be induced by dispersal when seeds are carried beyond the maternal neighbourhood thereby increasing the likelihood of genetic exchange with individuals away from the parental source (Price and Waser, 1979).

The distance to which the individual deposits its seeds largely depends on the mode of dispersal. Wing and Tiffney (1987) regarded small, presumably abiotically dispersed seeds to be the primitive dispersal syndrome among angiosperms, although anemochory (wind dispersal) is not restricted Burrows, 1973; Okubo and Levin, 1989; Anderson, 1993). Morphological designs of wind-dispersed diaspores appear to slow their rate of descent and increase their chances of exposure to horizontally blowing or gusts of wind. Horizontal winds spread the diaspores over a broad area and move them away from the parent plant. Consequently, the potential dispersal distance and area are inversely related to the rate of descent. Since the consistency of wind direction also determines the extent of the area over which diaspores are dispersed, most investigations of wind dispersal focus on the dispersal distance rather than the area of dispersal. However, many aspects of seed dispersal and their demographic and genetic consequences still require further investigations (Wilson and Travest, 2000). In particular, knowledge is lacking on seed-dispersal distance, since this requires experimental modifications of seed distributions (see Portnoy and Wilson, 1993). Mathematical models to predict dispersal distances have been developed by Cremer (1977), Okubo and Levin (1989), Greene and Johnson (1989, 1990), Murren and Ellison (1998) and Bullock and Clarke (2000). Some attempts have been made to develop various types of seed traps (Leguizamon *et al*.,1985; Lallana and Elizalde, 1991; Lallana *et al*.,1991; Hill *et al*.,1996; Chaila *et al*., 2000) and to estimate the distance to which seeds are dispersed from an isolated individual (Chaila *et al*., 2000).

Generally, seeds of the family Asteraceae (Compositae) bear a feathery strucure (pappus) which acts as a parachute during dispersal. It has been advocated that the primary role of pappus is defense of ovaries from predation (Stuessy and Garver, 1996); latter the role of some pappus types was evolved to achene dispersal (Greene and Johnson, 1990; Anderson, 1993). In addition to these roles of pappus, it has been demonstrated by Wajid and

Shaukat (1993) and Shaukat *et al.* (2004) that the pappus plays a significant role in water absorption since in those achenes where pappus is attached the rate and magnitude of water uptake is much greater compared to those with detached pappus. This capability of water absorption presumably confers added fitness to the plant. For the present investigation, a composite weed *T. procumbens* L. was selected because of reasons mentioned in the 'Materials and Methods' section. Given the importance of dispersal in ecology of weeds, it is surprising that studies of seed dispersal patterns of tropical weeds like *T. procumbens* as well as many other composite weeds has been largely ignored in the old-world tropics.

This study attempts i) to describes the construction of two simple and effective seed traps to measure the extent of dispersal of light airborne diaspores, ii) to assess the pattern of seed dispersal and measure the dispersal distances of achenes of either an isolated plant or for a cluster of individuals of *Tridax procumbens* L., and iii) to fit a statistical model to the seed density / dispersal distance data.

MATERIALS AND METHODS

The experiments were conducted at an experimental field of Crop Disease Research Institute, Karachi University campus, Karachi. *Tridax procumbens* L. (Asteraceae), a herbaceous perennial, occurs as a common weed in the experimental field. *T.procumbens* was selected for the study because it is a common agrestal and ruderal weed in the tropics. It is a South American species that is widely introduced in India and Pakistan. The achene-proper of *T. procumbens* is, generally 2.5-2.7 mm long while the pappus is about 5 mm in length. The achene is turbinate or oblong, silky, and denesely pilose while pappus is composed of several plumose setae (feather-like). When expanded the pappus is voluminous and helps the seed to remain floating for a long period. The pappus surface of *T. procumbens* achenes bears long bristles (Wajid and Shaukat, 1993). Thus, the pappus characteristics of *T. procumbens* make it a good candidate for the seed dispersal study. Two experiments were performed as follows:

Experiment I: In this experiment, isolated plants were chosen, *i.e., T. procumbens* were absent within a radius of at least 2.0 m from the selected individual. An octagonal pattern of strips of adhesive tape was constructed around the selected plant (Fig.**1a**). Wooden sticks were placed at angles of 45°. The wooden sticks were connected with 5 cm wide tape at 5-10, 15-20 and 25-30 cm from the individual plant. The entire setup was replicated five times.

Experiment II: This experiment was concerned with seed dispersal pertaining to patches of *T. procumbens.* Four patches (clusters) of *T. procumbens,* each about 75-90 cm in diameter were deterministically selected in the field. It was assured that there was no other *T. procumbens* plant at least 10 m from the centre of the cluster. Two sectors extending from the centre of each cluster and oriented in east-west direction, were established. Strings were fixed to wooden stakes and adhesive tapes (5 cm wide) were vertically connected to the two strings at 0.5 m intervals (about 2.5 cm from ground surface), up to 6 m from the centre (Fig. **1b**), keeping the sticky side uppermost. Attempts were made to fit a model to the data on seed density in relation to the distance from source. The negative exponential equation (Y=a exp-bx) provided the most appropriate model (Venables and Ripley, 1997).

RESULTS AND DISCUSSION

The diagrammatic seed shadow of isolated individuals of *T. procumbens* (experiment I) is given in Fig. **2.** The seed shadow gives the average values of five replicates. Although the seeds dispersed in all directions, the seed frequency in different compass directions varied greatly. Furthermore, seed frequency also differed considerably among the different octagons. The middle octagon had the highest frequency (48.9%), followed by the first (28.9%) while the outermost exhibited the lowest frequency (22.2%). Thus, in each direction the distribution was unimodal. Highest frequency was found on west (28.9%) and southwest (18.9%) segments of the octagons. Seed frequency was generally low in the eastern direction. The lowest seed frequency was found in the northeast (3.3%), while in the east it was (10%). The variability in the distances that seeds traveled together with directionality of dispersal resulted in a wide range of seed densities within the seed dispersion pattern. The covariance between distance and density within a dispersal pattern will affect both distance-responsive and density-responsive agents of selection (Thiede and Augspurger, 1996). In experiment II the distribution of seed distances was right skewed in both east and west flank of the seed trap although the seed density was much lower in the eastern flank of the seed trap (Fig. **3**). Both these data sets fitted a negative exponential model. The computed exponential equations for east and west sector are given below:

East sector: Y= 522.9 exp-1.368 X SE=±4.069

West sector: Y= 1337 exp-0.899 X SE= ±29.05

Where X is the radial distance form the source, Y is the seed density and SE equals the standard error of the fitted model.

Similar distribution for seed distances have been reported for a number of species (Levin and Kirster, 1974; Thiede and Augspurger, 1996). Experimentally, it has been demonstrated that the effectiveness of dispersal depends on the ratio of the size of pappus and the achene proper (which determine the terminal velocity) and the height at which seeds are released (Sheldon and Burrows, 1973). The large pappus of *Tridax procumbens* seeds increases the chances of the seed being transported laterally by wind currents. The directional pattern of dispersal and the long distances some seeds travel (see below) suggest that wind is an effective dispersal agent for *T. procumbens*. The predominant direction of wind in the study area is from east to west. Thus wind plays the major role in the directionality of seed dispersal. However, often there are gusts of whirlwind. Experiment II indicated that the seeds can move up to 4.5 m along the prevailing direction of wind. However, on the leeward side the seeds moved only up to 3.5 m for the seed source.

Efficient wind-dispersal mechanism coupled with high seed production facilitates the relatively rapid and long-distance dispersal of some weedy species (Stallings *et al.*, 1995). Note, however, that since seed crop size could influence dispersal distances or their evenness it does not reflect seed density directly (Sinha and Davidar, 1992). The covariance between distance and density within a dispersal pattern will affect both distance-responsive and density-responsive agents of selection (Thiede and Augspurger, 1996).Often the seeds entangle with each other forming loose bunches while dispersing. Such seed masses were seen on adhesive tapes. The seed clusters falling together at one microsite are expected to result in aggregation of seeds in the soil seed bank. Interestingly, the spatial pattern of *T. procumbens* seeds in soil was found aggregated as indicated by various indices of pattern detection (Shaukat and Siddiqui, 2004). Possible advantages of dispersal include the escape of disproportionate seed loss near the parent due to distance-dependent or density-dependent predation (Wilson and Janzen, 1972; O'Dowd and Hay, 1980; Wright, 1983). Dispersal also determines the spatial relationships among individuals (McCanny and Cavers, 1989), which influences pollination probability and relatedness of pollen donors (Levin and Kirster, 1971; Ehrlich and Gilbert, 1973; Price and Waser, 1979; Augspurger, 1980). In turn, this could play a key role in the determination of genetic structure of populations (Gadgil, 1971; Miyazaki and Isagi, 2000).

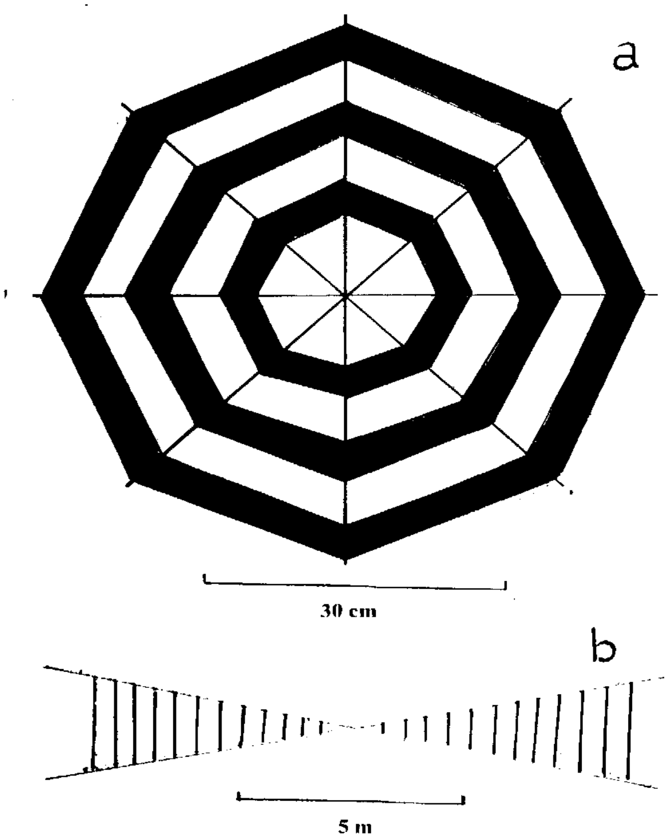

Fig. 1. The two types of sampling design used in the dispersal experiments a) octagonal seed trap used for a single isolated plat of *Tridax procumbens*, b) seed trap used for estimating the dispersal of a cluster of plants of *T. procumbens*.

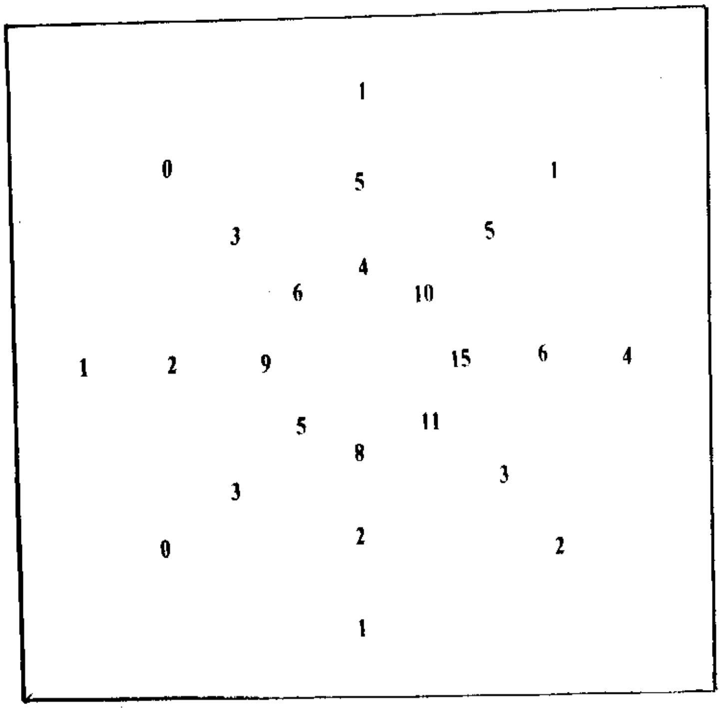

Fig.2. The seed shadow of a single plant of *Tridax procumbens*. Each value is an average of number of seeds caught in the different sectors of seed trap.

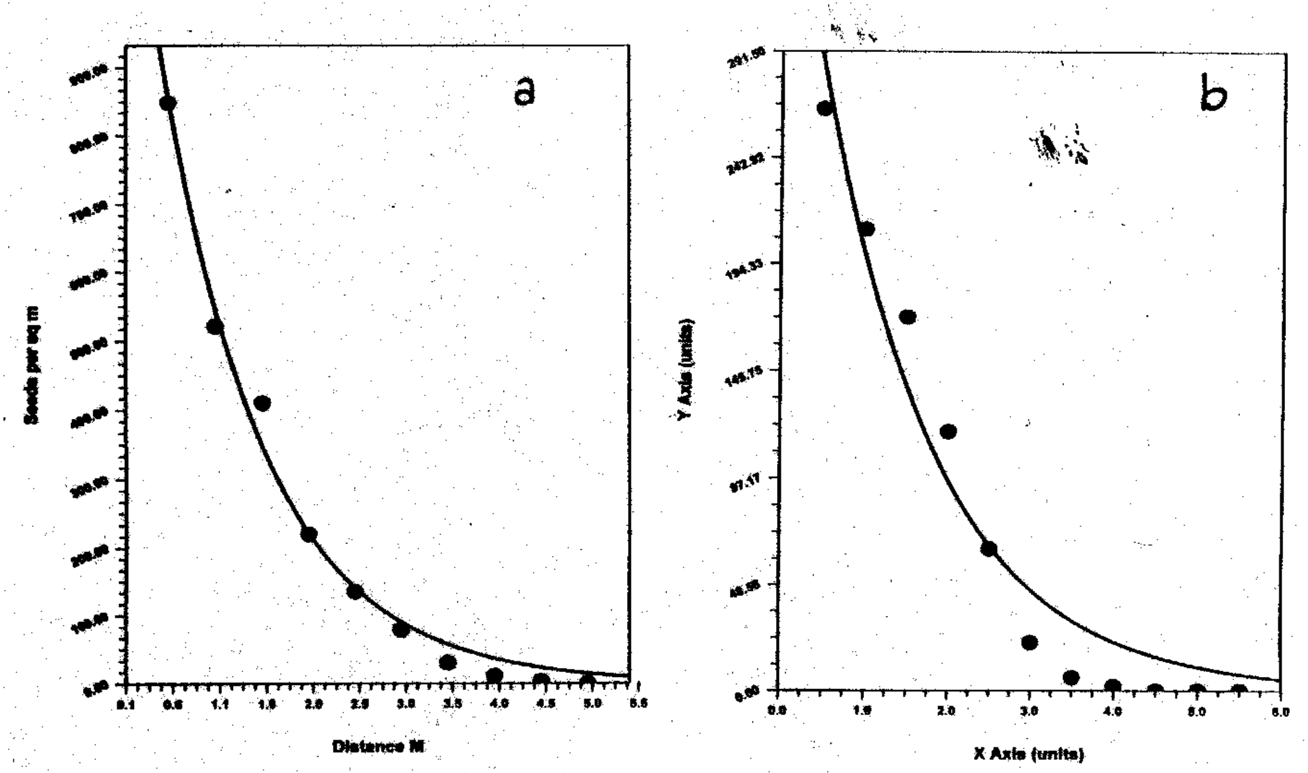

Fig.3. Seed density with increasing distance from centre of cluster of *T. procumbens* plants, a) dispersal curve for west sector, b) dispersal curve for east sector.

There are several morphological characters that may improve the chances of the embryo in a diaspore landing in a safe site for successful germination and establishment. In particular, the plume-like parachute mechanism of the pappus may serve to orientate it during its fall from the parent, thereby increasing the likelihood that it will land in a standing position (pappus upward) and penetrate the soil surface, enter a crack or crevice or get implanted on litter. On the other hand, the diaspore may fall horizontally on the ground so that the pappus remains in contact with the soil and thereby facilitates the seed in the absorption of moisture from the soil.

However, although rarely, the diaspore may land vertically with pappus facing the ground, i.e., ‘fortuitous landing’ (Wajid and Shaukat, 1993). In this landing condition the absorption of water is limited since the achene proper does not remain in contact with the water supplying substrate. Wajid and Shaukat (1993) also found marked reduction in the rate and final germination percentage of *Tridax procumbens* and *Sonchus arvensis* when seeds were vertically placed compared to those placed horizontally. It was conjectured that horizontal landing position provides a condition where water uptake across the seed-substrate interface exceeds the water loss across seed atmosphere interface thereby creating the level of moisture enough to germinate a seed.

The advantage of a dispersal appendage such as pappus should not be underrated. Selection on morphological traits that results in only a small increase in mean dispersal distance should have a substantially greater effect on the area of a parent’s seed distribution. Often the mean dispersal distance has been emphasized (Augspurger, 1986; Carey and Watkinson, 1993). High or extreme values have been reported for wind-dispersed diaspore (Whitmore, 1984). However, the relative importance of mean versus extreme values for successful seedling establishment has not yet been resolved.

REFERENCES

Anderson, M.C. (1993). An analysis of variability in seed settling velocities of several wind-dispersed Asteraceae. *Amer J. Bot*., 79: 1087-10991.

Augspurger, C.K. (1980). Mass-flowering of a tropical shrub (*Hybanthus prunifolius*): influence on pollinator attraction and movement. *Evolution*, 34: 475-488.

Augspurger, C.K. (1983). Seed dispersal of tropical tree, *Platypodium elegans*, and the escape of its seedlings from fungal pathogens. *J. Ecol*., 71: 759-771.

Augspurger, C. K. (1986). Morphology and dispersal potential of wind-dispersed diaspores of neotropical trees. *Amer. J. Bot*., 73:353-363.

Burrows, F.M. (1975a). Calculation of the primary trajectories of dust seeds, spores and pollenin unsteady wind with variable convection. *New Phytol*., 75: 389-403.

Burrows, F.M. (1975b). Wind-borne seed and fruit movement. *New Phytol*., 75: 405-418.

Carey, P.D. and A.R. Watkinson (1993). The dispersal and fates of seeds of the winter annual grass *Vulpia ciliata*. *J. Ecol*. 81:, 759-776.

Chaila, S. M.T Sorber and O.B. Avila (2000). Dissemination of seeds of *Eryngium paniculatu*m from isolated plants. II. Relationships between distance of seed traps and gathering capacity. *Pak. J. Bot*., 32: 283-288.

Christian, C.E. (2001). Consequences of a biological invasion reveal the importance of mutualism for plant communities. *Nature*, 413: 635-638.

Clark, D.A. and D.B. Clark (1984). Spacing dynamics of a tropical rain forest tree: evaluation of Janzen-Connell model. *Amer. Nat*., 124:769-788.

Comins, H.N., W.D. Hamilton and R.M. May (1980). Evolutionary stable dispersal strategies. *J. Theor.Biol*., 82: 205-230.

Cremer, K.W. (1977). Distance of seed dispersal in eucalyptus estimated from seed weight. *Aust. J. Forest. Res.*, 7: 225-228.

Ehrlich, P.R. and L.E. Gilbert (1973). Population structure and dynamics of the tropical butterfly *Heliconius ethilla. Biotropica*, 5: 69-82.

Fenner, M. (1985). *Seed Ecology*. Chapman & Hall, London.

Gadgil, M. (1971). Dispersal: population consequences and evolution. *Ecology*, 52: 253-260.

Greene, D.F. and E.A. Johnson (1989). A model of wind dispersal for winged and plumed seeds. *Ecology*, 70: 339-347.

Greene, D.F. and E.A. Johnson (1990). The aerodynamics of plumed seeds. *Funct. Ecol.*, 4: 117-126.

Harper, J.L., P.H. Lovell and K.G. Moore. (1970). The shapes and sizes of seeds. *Ann. Rev. Ecol. Syst.*, 1:327-356.

Hill, R.I., A.H. Gourlay, W.G. Lee and J.B. Wilson (1996). Dispersal of seeds under isolated gorse plants and the impact of seed feeding insects. *Proc. 49th New Zealand Pl. Pr. Conf.* 1-5.

Howe, H.F. and J. Smallwood (1982). Ecology of dispersal. *Ann. Rev. Ecol. Syst*., 13:201-228.

Janzen, D.H. (1970). Herbivores and the number of tree species in tropical forests. *Amer. Nat.,* 104:501-528.

Lallana, V.H. and J.H.I. Elizalde (1991). *Eryngium paniculatum* Cav. et Dom ex Delaroche (Caraguata). II Diseminacion y factores que la afectan. Reunion Argentina sobre la Maleza y su Control. *ASAM* 1: 83-90.

Lallana, V.H., J.H.I. Elizalde and L.R. Zimerman (1991). Cuantificacion de la caida natural de frutos de *E. paniculatum* Cav. et Dom ex Delaroche (Caraguata) en un campo no pastoreado. XII Reunion Argentina sobre la Maleza y su Control. *ASAM* 1: 91-96.

Leguizamon, E.S., E. Brovelli, L. Allieri and L. Giuggia (1985). Dinamica poblacional de sorge de alepo (*Sorghum helepense* Pers.) en la secuencia trigo-soja. *IDIA* 44: 437-440.

Levin, D.A. and H.W. Kerster (1974). Gene flow in seed plants. In: *Evolutionary biology, vol. 7* (T. Dobzhansky, M.K. Hecht and W.C. Steere eds.), Plenum Press, New York. pp.139-220.

McCanny, S.J. and P.B. Cavers (1989). Parental effects on spatial patterns of plants: a contingency table approach. *Ecology,* 70: 368-378.

Miyazaki, Y. and Y. Isagi (2000). Pollen flow and and the interpopulation genetic structure of *Heloniopsis orientalis* on the forest floor as determined using microsatellite markers. *Theor. Appl. Genet.,* 101:718-723.

Murren, C.J. and A.M. Ellison (1998). Seed dispersal characteristics of *Brassavola nodosa* (Orchidaceae). *Amer. J. Bot.,* 85:675-680.

Nathan, R. and H.C. Muller-Landau (2000). Spatial pattern of seed dispersal, determinants and cosequences of recruitment. *TREE* 15:278-285.

O'Dowd, D.J. and M.E. Hay (1980). Mutualism between harvester ants and a desert ephemeral: seed escape from rodents. *Ecology,* 61: 531-540.

Okubo, A. and S.A. Levin (1989). A theoretical framework for data analysis of wind dispersal of seeds and pollen. *Ecology* 70:329-338.

Pijl, L. van der (1982). *Principles of Dispersal in Higher Plants*. 3rd. ed. Springer-Verlag, Berlin.

Portnoy, S. and M.F. Wilson (1993). Seed dispersal curves: behaviour of the tail of the distribution. *Evolut. Ecol*. 7:25-44.

Price, M.V. and N.M. Waser (1979). Pollen dispersal and optimal outcrossing in *Delphenium nelsoni*. *Nature* 277: 294-297.

Sheldon, J.C. and F.M. Burrows (1973). The dispersal effectiveness of the achene-pappus units of selected Compositae in steady winds with convection. *New Phytol*. 72:665-675.

Shaukat, S.S. and I.A. Siddiqui (2004). Spatial pattern analysis of seeds of an arable soil seed bank and its relationship with above-ground vegetation in an arid region. *J. Arid Environ*. 57: 311-327.

Shaukat, S.S., I.A. Siddiqui, Z. Ali and S. Sikander (2004). Fecundity and factors regulating germination of *Vernonia cinerascens* and *V. cinerea*. *Int. J. Biol. Biotech*. 1: 279-291.

Sinha, A. and P. Davidar (1992). Seed dispersal ecology of a wind dispersed rain forest tree in the Western Ghats, India. Biotropica 24: 519-526.

Stallings,G.P., D.C. Thill, C.A. Mallory_Smith and L.W. Lass (1995). Plant movement and seed dispersal of Russian thistle (*Salsola iberica*). *Weed Sci.* 43:63-69.

Stuessy, T.F. and D. Garver (1996). The defensive role of pappus in heads of Compositae.In: *Compositae: Biology and utilization.* Vol.2, (D.J. Hind & P.D.S. Caligari eds.) Royl Botanical. pp.93-104.
Gardens, Kew, UK

Tews, J., K. Moloney and F. Jeltsch (2004). Modeling seed dispersal in a variable environment: a case study of the fleshy fruited savanna shrub *Grewia flava*. *Ecol. Model*. 175:65-76.

Thiede, D.A. and C.K. Augspurger (1996). Intraspecific variation in seed dispersion of *Lepidium campestre* (Brassicaceae). *Amer. J. Bot.,* 83: 856-866.

Venables, D.L. and B.D. Ripley (1997). *Modern applied statistics with S-PLUS*. Springer, New York.

Wajid, A. and S.S. Shaukat (1993). Effects of seed dispersal unit and the position of seed relative to substrate on germination of three composites. *Pak. J. Bot*., 25:118-126.

Webb, C.O. and D.R. Peart (2001). High seed dispersal rates in faunally-intact tropical rain forest: theoretical and conservation implications. *Ecol. Lett*., 4: 491-499.

Whitmore, T.C. (1984). *Tropical rain forests of the Far East*. Oxford Univ. Press, Oxford.

Wilson, M.F. (1983). *Plant reproductive ecology*. Wiley, New York, NY.

Wilson, D.E. and D.H. Janzen (1972). Predation of *Scheelea* palm seeds by bruchid beetles: seed density and distance from the parent palm. *Ecology* 53:954-959.

Wilson, M. and A. Travest (2000). The ecology of seed dispersal. In: *Seeds: the ecology of regeneration in plant communities*. (M.J. Fenner ed.). *CAB International*, 85-110.

Wing, S.L. and B.H. Tiffney (1987). Interactions of angiosperms and herbivorous tetrapods through time. In: *The origin of angiosperms and their biological consequences*, (E.M. Friis, W.G. Chaloner and P.Q. Crane eds.). pp.203-224. Cambridge Univ. Press, Cambridge.

Wright, S.U. (1983). The dispersion of eggs by a bruchid beetle among *Scheelea* palm seeds and the effect of distance to the parent palm. *Ecology,* 64: 1016-1021.

(*Accepted for publication March 2005*)