POLLINATION ECOLOGY OF *ALTERNANTHERA PARONYCHIOIDES* AND *GOMPHRENA SERRATA* (FAMILY: AMARANTHACEAE; SUB-FAMILY GOMPHRENOIDEAE)

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Alternanthera paronychioides is a perennial herbaceous weed that reproduces by seed and also from perennial root system while *G. serrata* is an annual herbaceous weed and reproduces exclusively by seed. These plants appear during wet season and flower and fruit continually if soil is wet. In both the species, the flowers are hermaphroditic and display auto-selfing by themselves and also by rain drops. *A. paronychioides* is also entomophilous and *G. serrata* is psychophilous. Fruit and seed dispersal is anemo- and hydrochorous in both the species; but *G. serrata* is also myrmecochorous. *A. paronychioides* and *G. serrata* as C_4 species increase photosynthesis in warmer climates and survive well in drier and hot environments. Therefore, these species are useful in the restoration of degraded, damaged and destroyed ecosystems or habitats and support local insects by providing forage.

Keywords: *Alternanthera paronychioides*, *Gomphrena serrata*, entomophily, anemochory, hydrochory, myrmechochory.

INTRODUCTION

The sub-family Gomphrenoideae of Amaranthaceae has 14 genera of which three genera *Alternanthera, Gomphrena* and *Iresine* are represented in South India. This subfamily is further subdivided into two tribes Pseudoplantageae and Gomphreneae of which the former is monogeneric with two representatives in India. Gomphreneae has two sub-tribes, Froelichiinae and Gomphreninae. The former is represented by a single genus, *Alternanthera* in India while the latter has two genera *Gomphrena* and *Iresine* in South India. The genus *Alternanthera* has about 150 low herbaceous species, widely distributed in the American tropics and subtropics, from where many species have spread to several other countries (Tanveer *et al.,* 2013). In South India, six *Alternanthera* species: *A. brasiliana, A. paronychioides, A. philoxeroides, A. pungens, A. sessilis* and *A. tenella* have been reported. *A. paronychioides* is a native of tropical America but it is now naturalized in the United States of America, India, Java and other parts of the Old World

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(Anilkumar, 2006). *Alternanthera* species have been reported to be visited and pollinated by *Ceratina* and *Dialictus* bees (Kubitzki *et al.,* 1994). *Gomphrena* is a large genus of about 100 to 125 species distributed throughout the warm temperate, subtropical and tropical regions of the world, with most of its species centered in American tropics and Pacific Islands. Thirty species of this genus are endemic to Australia (Shu, 2003; Harwood & Palmer, 2011; Shih-huei & Yi-ching, 2012). In this sub-family, *Alternanthera paronychioides* A. St. Hill., and *Gomphrena serrata* L. have not been studied in any part of the world and hence, the present study was contemplated to understand how their floral morphology, floral biology, sexual systems, pollination syndromes, fruiting ecology and seed dispersal modes enable them to grow as weeds to colonize and expand their distribution range and serve as forage sources for local insects that act as pollinators.

MATERIALS AND METHODS

The seasonal annual herbs, *Alternanthera paronychioides* and *Gomphrena serrata* were selected for study during 2014-2016 in Visakhapatnam and its surroundings, Andhra Pradesh, India (17°42'N Latitude and 82°18'E Longitude). The inflorescence type and the number of flowers per inflorescence were noted. Ten inflorescences were tagged prior to commencement of their flowering and followed daily for recording the flowering duration of the inflorescence. Twenty five fresh flowers were used for each plant species to record the floral details such as flower shape, colour, odour, sex, symmetry, floral mechanism, calyx, corolla, stamens and style and stigma and ovule number. Field trips were conducted to record phenological aspects. Ten inflorescences which have not initiated flowering were tagged and followed daily to record the duration of flowering, anthesis schedule and the timing of anther dehiscence. Twenty five fresh flowers were used to record the floral morphological details. Nectar could not be measured and analyzed due to its secretion in minute quantity which was further depleted by thrips during mature bud and flower life. Twenty mature, but un-dehisced anthers were collected from different plants and examined for pollen output as per the protocol described in Dafni *et al*. (2005). The calculation of pollen output per flower and pollen-ovule ratio was done as per the formulas described in Cruden (1977). Ten flowers each from five individuals were used to test stigma receptivity. It was tested with hydrogen peroxide from mature bud stage to flower closure/drop as per Dafni *et al.* (2005). Further, the receptivity was also observed visually whether the stigma is shiny, wet or changing colours or withering. Insects foraging at the flowers were observed from morning to evening on four different days for their mode of approach, landing, probing behavior and contact with the floral sexual organs. Bees, wasps and flies were identified with the representative specimens available with the Department of Environmental Sciences, Andhra University, Visakhapatnam. Butterflies were identified by consulting the books of Kunte (2007). The foraging visits of insects were recorded using 2 x 2 m area of flowering patch for 10 min at each hour for the entire day on four different days and the data was tabulated to record the foraging pattern and the percentage of visits made by them. The pollen/nectar collection behaviour of insects was carefully observed to assess their role in effecting pollination. Ten specimens of each insect species were captured during peak foraging period and brought to the laboratory. Each specimen was washed in ethyl alcohol, stained with aniline-blue on a glass slide and observed under microscope to count the number of pollen grains present. From this, the average number of pollen grains carried by each insect species was calculated to know the pollen carryover efficiency. Inflorescences with 741 buds on *D. muricata* and with 756 buds on *G. serrata* were tagged and followed to record fruit and seed set rate in open-pollinations. Fruit maturation period, the fruit and seed morphological characteristics were recorded to evaluate their adaptations for dispersal by different means. The role of wind, rain, water and ants in fruit and seed dispersal was examined in the field. The aspects of seed germination and establishment of populations were observed briefly in the field.

RESULTS

Alternanthera paronychioides

Plant and flowering phenology

The plant is a perennial prostrate to erect profusely-branching herb that produces dense stands as a weed in open wet soils, waste lands, road sides and along the stream or canal banks of agricultural fields. Seeds germinate and produce new plants. The plants growing in perpetual wet soils produce new branches from the perennial root system. The plants appear in rainy season. The flowering occurs during August-November with a peak during October in the plants that grow in waste lands and along road sides (Fig. 1a). The plants growing along the streams or canal banks of agricultural fields show flowering and fruiting throughout the year. Inflorescence is a sessile fasciculate globose head and is borne in leaf axils only and the heads are borne on the entire length of plant (Fig. 1b). The globose head borne in each leaf axil consists of 8 ± 2 flowers (Range 3-13) and antheses within a week.

The Flower

The flowers are sessile, small, white, actinomorphic, odorless and bisexual. They are equipped with 1 papery acuminate bract and 2 papery acuminate bracteoles. The tepals are five, free, greenish white, sub-equal, outer 3 tepals oblong-lanceolate, 3-veined in proximal half with barbellate hairs; inner 2 tepals somewhat laterally compressed, 1-veined and apex acute. The stamens are five and alternating with 3-4 toothed pseudo-staminodes with half the length of stamens; the filaments are greenish-white, free but fused at the base forming a cup-like structure enclosing the ovary. The anthers are bisponrangiate, unithecal, introrse, ellipsoid and golden yellow in color. The ovary is globose, compressed, glabrous, unilocular with one pendulous ovule (Fig. 1k). The style is very short and extends into capitate shiny wet stigma that is situated well below the height of anthers.

Floral biology

The flowers are open during 0700–1000 h but most of them open at 0800 h (Fig. 1c-g). The tepals unfold and expose the stamens and stigma following the anthesis. Anthers dehisce during anthesis by longitudinal slits (Fig. 1h). The pollen output is 501.20 ± 45.87 per anther and 2,506 per flower. The pollen- ovule ratio is 2,506:1. The pollen grains are monads, white in color, sticky, spheroidal, dodecahedral, 18.26 ± 3.49 µm in diameter, pantoporate and multiporate (Fig. 1i). The stigma is receptive from anthesis onwards, and ceases by the noon of the following day. The nectar is produced in minute volume around the base of the ovary inside the staminal tube. The tepals close back partially by the evening of the same day or by the noon of 2nd day of anthesis. The bracts, bracteoles and tepals are persistent and remain in their place until seed dispersal occurs while the stamens, style and stigma gradually wither inside as the fruit grows.

The flowers with homogamy facilitate auto-selfing by gravitational pollination (Fig. 1j). Rain drops falling on the flowers splash the dehisced anthers and in effect the pollen drops down and reaches the stigma effecting autogamy.

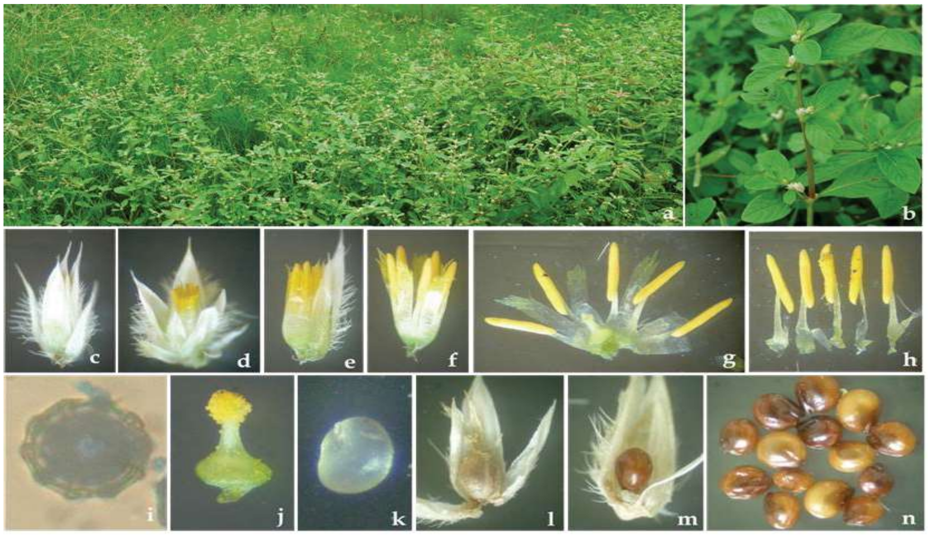

Figure 1. *Alternanthera paronychioides*: a. Flowering patch; b. Twing with flowering inflorescences; c. Mature bud; d. Flower; e. & f. Flower without tepals; g. Relative positions of stamens and stigma; h. Dehisced stamens; i. Pollen grain; j. Gynoecium with stigma coated with pollen; k. Ovule; l. Fruit; m. 1-seeded fruit; n. Mature and dry seeds.

Flower visitors and Pollination

Thrips were found to be using floral buds for breeding and flowers for forage. The flowers were visited by bees, wasps (Hymenoptera), flies (Diptera) and butterflies (Lepidoptera) from 0800 to 1700 h with concentrated activity during forenoon period (Fig. 5, 6). The bees except for *Xylocopa pubescens* collected both nectar and pollen in the same and/or different foraging visits while *X. pubescens*, wasps, flies and butterflies collected nectar only. The bees were *Apis dorsata* (Fig. 2a), *A. cerana*, *A. florea* (Fig. 2b), *Trigona iridipennis* (Fig. 2c) and *Xylocopa pubescens* (Fig. 2d). The wasp was not identified (Fig. 2e). The flies were *Eristalinus arvorum* (Fig. 2f) and *Helophilus* sp. (Fig. 2g). The butterflies were *Phalanta phalantha* (Fig. 2h), *Leptotes plinius* (Fig. 2i), *Zizeeria karsandra* (Fig. 2j), *Zizina otis* (Fig. 2k), *Freyeria trochylus* (Fig. 2l) and *Spindasis vulcanus* (Fig. 2m). Bees except *X. pubescens* were the regular and consistent foragers while all other insects were not consistent foragers. The forage collection behavior resulted in effecting pollination. Bees constituted 53%, wasps 5%, flies 10% and butterflies 32% of total visits made in a day (Fig. 7). All these insect species landed on the globose head inflorescence to probe flowers for the forage; while doing so, they invariably contacted the stamens and stigma with their head and ventral side effecting pollination. Reduced levels of forage, especially nectar due to feeding by thrips increased foraging visits and in effect it promoted pollination rate. The body washings of all insect visitors revealed the presence of pollen to varying extents - bees 64 to 324, the wasp 72.8, flies 11 to 93 and butterflies 16-104 (Table 1).

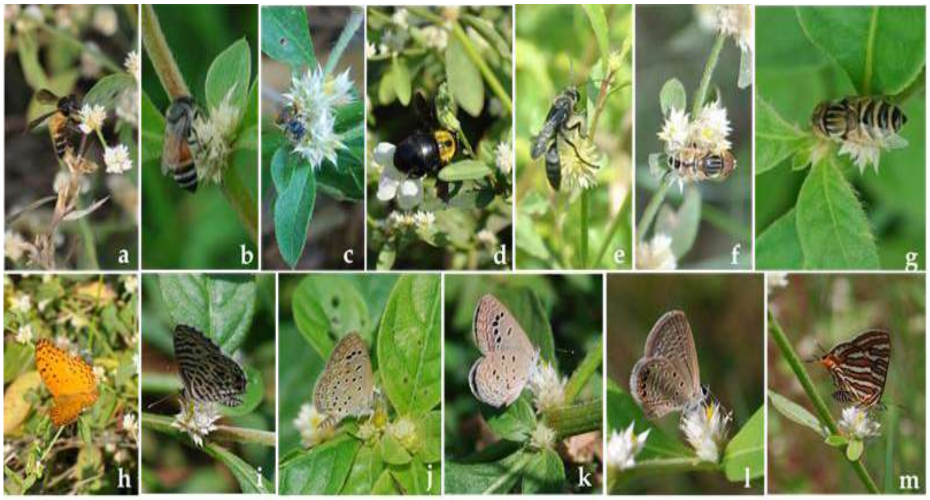

Figure 2. *Alternanthera paronychioides*: a. *Apis dorsata*; b. *Apis florea*; c. *Trigona iridipennis*; d. *Xylocopa pubescens*; e. Wasp (unidentified); f. *Eristalinus arvorum*; g. Helophilus sp.; h. *Phalanta phalantha*; i. *Leptotes plinius*; j. *Zizeeria karsandra*; k. *Zizina otis*; l. *Freyeria trochylus*; m. *Spindasis vulcanus*.

Table 1. Pollen recorded in the body washings of insect foragers on *Alternanthera paronychioides*

Insect species	Sample size (N)	Number of pollen grains		
		Range	Mean	S.D
Apis dorsata	10	96 - 315	208.3	71.85
Apis cerana	10	72 - 264	162.4	52.82
Apis florea	10	125 - 324	229.4	66.92
Trigona iridipennis	10	64 - 252	150.3	60.81
Xylocopa pubescens	10	74 - 208	146.1	37.31
Wasp (Unidentified)	10	46 - 102	72.8	18.06
Eristalinus arvorum	10	25 - 93	59.7	22.58
Helophilus sp.	10	11 - 82	52.2	22.39
Phalanta phalantha	10	16 - 73	45.2	17.93
Leptotes plinius	10	32 - 93	62.3	19.72
Zizeeria karsandra	10	24 - 104	64.7	27.66
Zizina otis	10	19 - 82	55.7	20.44
Freyeria trochylus	10	21 - 94	60.6	22.19
Spindasis vulcanus	10	18 - 86	53.9	21.91

Fruiting ecology and seed dispersal

Fruits mature within 3 weeks. The tepals gradually bulge and cover the growing fertilized ovary; externally the tepals are surrounded by the bract and bracteoles. Natural fruit and seed set is 93.05% . Fruit is an indehiscent membranous, obcordate utricle with a single shiny, brown, discoid somewhat lenticular and vertical seed (Fig. 1-n). The fruited globose heads fall off as single units from the mother plant. Fruits from these heads gradually separate and expose the seeds during rainy season. Globose heads are dispersed by high winds and rain water during rainy season. Therefore, seed dispersal is anemochorous and hydrochorous.

Gomphrena serrata

Plant and flowering phenology

It is an erect annual herbaceous weed. It produces dense stands in open wet soils, road sides and in irrigated agricultural fields (Fig. 3a). The stem produces several prostrate branches and it is densely clothed with appressed white hairs especially when young. Seeds germinate and produce new plants during rainy season. The flowering season varies with the habitat type, it is from August-November plants occurring in open areas and along the roadsides while it is from August to February in agricultural lands and in areas where soil is sufficiently wet. The plants disappear in March. The branches are borne from basal part of the stem and each branch and main stem produces a single inflorescence only. Inflorescence is a terminal, sessile, solitary globose spike with 67.27 ± 9.31 flowers which anthese acropetally over a period of 10 to 12 days (Fig. 3b). The flowers fall off sequentially in acropetal manner. The inflorescence elongates into 3.6 cm when fruiting and is subtended by 2 leafy bracts.

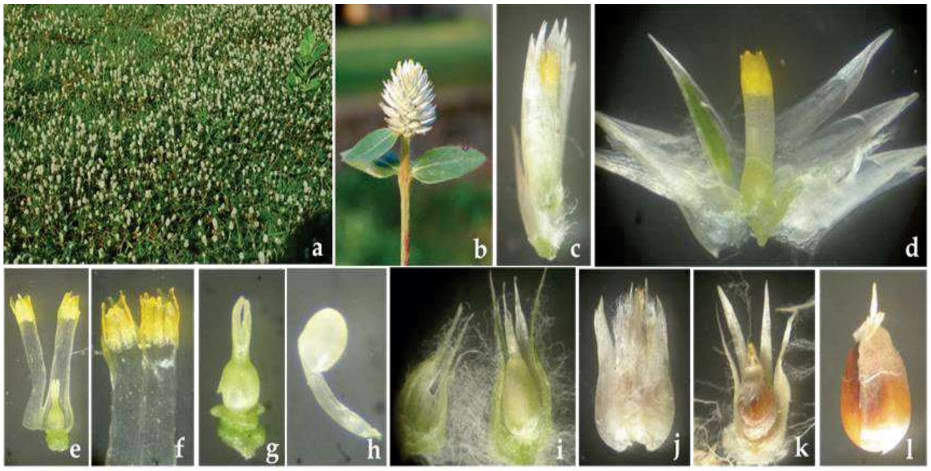

Figure 3. Gomphrena serrata: a. Flowering patch; b. Inflorescence; c. Mature bud; d. Flower; e. Position of stamens and stigma; f. Dehisced anthers; g. stigmas; h. Ovule; i. Mature fruit; j. & k. Ripen and dry fruits covered with thick mass of silky hairs; l. Seed.

The Flower

The flowers are snow-white with pinikish tinge, sessile, small, compressed, ovate-lanceolate, actinomorphic, odorless and bisexual. Each flower has 1 bract and 2 bracteoles; the bract is deltoid-ovate, glabrous while the bracteoles have irregularly dentate crest. The tepals are five, lanceolate, free, white; the outer 2 are fleshy, woolly on the back at base while the inner 3 are papery, woolly at base. The stamens are five and fused to form staminal tube with 5-lobes at the apex. The anthers are positioned between incisions of the lobes; they are dithecous, introrse, glabrous and yellow in color. The ovary is globose, glabrous, greenish-white and uni-locular with a pendulous ovule (Fig. 3h). The style and stigmas are together and greenish-white; the stigmas are 2, linear, equal in length, slender, glabrous and diverge slightly (Fig. 3g). The ovary, style and stigma are seated inside the staminal tube and the distance between the terminal part of the stigmas and the basal part of the anthers is 2.5 mm.

Floral biology

The flowers are open during 0700–1600 h but most of them open during 0700-1000 h (Fig. 3c,d). The stamens are positioned far above the height of the stigmas during and after anthesis (Fig. 3e). During anthesis, anthers dehisce by longitudinal slits (Fig. 3f) and stigma becomes receptive which ceases by the evening of the same day. The pollen output is 213.2 ± 17.93 per anther and 1,066 per flower. The pollen – ovule ratio is 1,066: 1. The pollen grains are monads, yellow in color, spheroidal, 18.26 ± 3.49 µm in diameter, pantoporate, multiporate, dry and fall as single grains. The nectar is produced in minute volume around the base of the ovary within the staminal tube. The tepals close back completely by the evening of the same day. The bract, bracteoles, tepals, style and stigma are persistent and remain in their place until seed dispersal while the stamens gradually wither inside as the fruit grows.

The flowers with homogamy facilitate auto-selfing by gravitational pollination. Rain drops falling on the flowers splash the dehisced anthers and in effect the pollen drops down and reaches the stigma effecting autogamy. The test involving just bagged mature buds for three weeks indicate 70% fruit and seed set confirming auto-selfing.

Flower visitors and Pollination

Thrips were found to be using floral buds for breeding and flowers for forage. The flowers were visited exclusively by lycaenid butterflies (Lepidoptera), *Castalius rosimon* (Fig. 3a), *Leptotes plinius* (Fig. 3b), *Zizula hylax* (Fig. 3c), *Zizeeria karsandra* (Fig.3d), *Zizina otis* (Fig. 3e), *Freyeria trochylus* (Fig. 3f), *Chilades laius* (Fig. 3g), *Euchrysops cnejus* (Fig. 3h) and *Azanus jesous* (Fig. 3i) for nectar from 0900 to 1700 h with more foraging activity during 1000-1200 h (Fig. 8). All these butterflies were regular foragers. They landed on the inflorescence to probe the flowers for the forage; while doing so, they invariably contacted the stamens and stigmas with their head/proboscis effecting pollination. The body washings of all butterflies revealed the presence of pollen to varying extents for each species; the mean pollen recovered varied from 44.6 to 61.7 (Table 2) and hence proved their role in pollination.

Table 2. Pollen recorded in the body washings of butterflies on *Gomphrena serrata*

Species name	Sample size (N)	Number of pollen grains		
		Range	Mean	S.D
Castalius rosimon	10	18 - 73	48.6	16.89
Leptotes plinius	10	27 - 86	55.7	19.97
Zizula hylax	10	21 - 65	44.6	15.27
Zizeeria karsandra	10	25 - 84	60.6	19.24
Zizina otis	10	16 - 68	44.7	17.45
Freyeria trochylus	10	22 - 76	52.1	17.84
Chilades laius	10	19 - 87	61.5	20.42
Euchrysops cnejus	10	12 - 62	47.2	16.52
Azanus jesous	10	23 - 87	61.7	17.46

Fruiting ecology and seed dispersal

Fruits mature within 3 weeks. The tepals gradually bulge, harden and cover the growing fertilized ovary; externally the tepals are surrounded by the bract and bracteoles. Natural fruit set is 95.37% while natural seed set is 71.84%. Fruit represents tepals, bract and bracteoles enclosed by abundant silky hairs; it is utricle, oblong, ovoid with a single compressed-ovoid, brown, glabrous and shiny seed (Fig. 3i-l). The fruits mature acropetally and fall off in the same way (Fig. 4j); they fall off together with the seeds from the mother plant (Fig. 4k). Fruits after reaching the ground, gradually shed tepals and expose the mature and dry seed by the time of monsoon season. The different parts of the fruit appeared to be an adaptation to inhibit loss of soil moisture during dry season. Fruits due to their light weight are dispersed easily by wind during dry spells and rain water during rainy season. During dry spells of rainy season and dry season, *Crematogaster* ants were found to carry fruits to their nests where they consume the fleshy elaisome or feed it to their larvae without damaging the seeds (Fig. 4l). Therefore, fruit dispersal is anemochorous, hydrochorous and myrmecochorous.

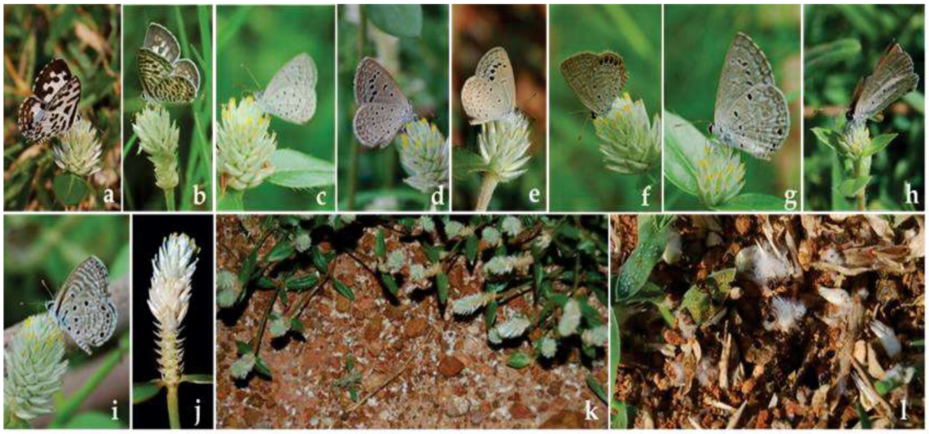

Figure 4. *Gomphrena serrata*: a. *Castalius rosimon*; b. *Leptotes plinius*; c. *Zizula hylax*; d. *Zizeeria karsandra*; e. *Zizina otis*; f. *Freyeria trochylus*; g. *Chilades laius*; h. *Euchrysops cnejus*; i. *Azanus jesous*; j. Fruited inflorescence dispersing fruits from the base to the tip; k. Fallen silky fruits with seeds inside; l. Fruit dispersal by red ants.

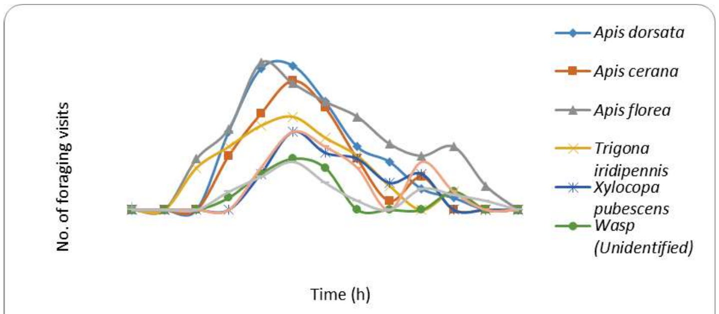

Fig. 5. Hourly foraging activity of bees, wasps and flies on *Alternanthera paronychioides*

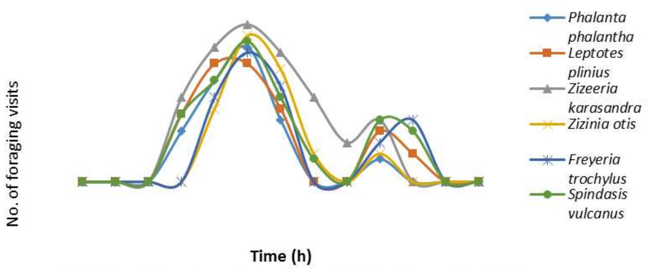

Fig. 6 Hourly foraging activity of nymphalid and lycaenid butterflies on *Alternanthera paronychioides*

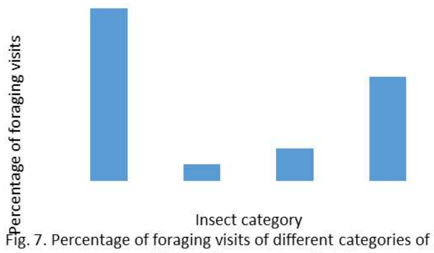

Fig. 7. Percentage of foraging visits of different categories of insects on *Alternanthera paronychioides*

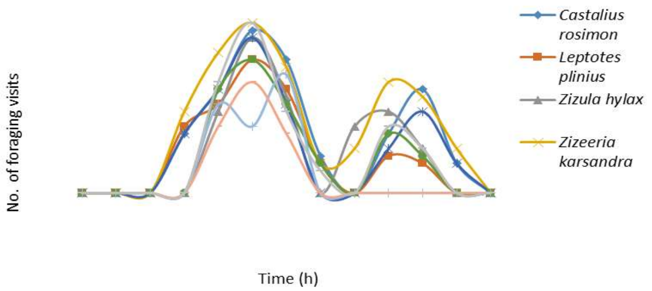

Fig. 8. Hourly foraging activity of lycaenid butterflies on *Gomphrena serrata*

DISCUSSION

Alternanthera paronychioides is a perennial herbaceous weed that reproduces by seed and also from perennial root system while *Gomphrena serrata* is an annual herbaceous weed and reproduces exclusively by seed. These plants appear during the wet season, and flower and fruit continually if the soil is sufficiently wet. Kajale (1940) and Anilkumar (2006) stated that Amaranthaceae flowers are uni- or bisexual and display monoecious or dioecious or polygamous sexual systems. The allogamy by dichogamy is said to be the norm in this family. Further, protogyny is functional to achieve cross-pollination in species with hermaphroditic flowers and in those demonstrating monoecism. In *A. paronychioides* and *G. serrata,* hermaphroditism and homogamy are functional. Kajale (1940) and Costea *et al.* (2003) reported that self-pollination is not a rare occurrence in Amaranthaceae members. In *A. paronychioides* and *G. serrata,* autonomous selfing occurs by gravitational pollination and by rain drops falling into the flowers and its function is reflected in the highest fruit or seed set rate in bagged flowers and all seeds are filled and viable.

Kajale (1940) considered that most species of Amaranthaceae are anemophilous. Piotrowska (2008) stated that virtually all Amaranthaceae are wind-pollinated but the plants produce less pollen than other anemophilous species. Muller & Borsch (2005) stated that although anemophily is considered to be the norm in Amaranthaceae, many genera are in fact frequently visited by insects. Borsch (1998) reported that white or cream coloured flowers of many genera are insect-pollinated. Kubitzki *et al.* (1994) mentioned that entomophily appears to be functional, particularly by bees. In *A. paronychioides* and *G. serrata*, the flower characters such as nectar production and yellow anthers with white tepals are important characters that draw insects to the flowers for effecting pollination. Insect pollination occurs on the day of anthesis and also until the noon of the next day in *A. paronychoides*, but it occurs only on the day of anthesis in *G. serrata*. Bees, wasps, syrphid flies and butterflies pollinate *A. paronychioides* but only butterflies pollinate *G. serrata*; their role in pollination is realized in the pollen recovered from their body washings. Reduced levels of nectar and emptied flowers due to nectar feeding by thrips causes intense foraging activity due to which pollination rate increased manifold. Therefore, the two species are auto-pollinated and also by rain drops and insects.

Kapralov *et al.* (2012) reported that many genera in Amaranthaceae produce 1-seeded fruits with a firm apex bearing the style and very thin, membranous walls which appear to be an adaptation to the xerophytic condition in which most species with fruits of this nature grow, when rains come, the ripe seed swells, bursts the capsule and falls to the ground. *A. paronychioides* and *G. serrata* produce 1-seeded fruits due to production of a single ovule per flower. The fruits do not have a firm apex bearing the style and stigma and very thin, membranous pericarp. Borsch (1998) reported that a high proportion of Amaranthaceae have dry capsular fruits which open by irregular rupturing of thin walls. But, *A. paronychioides* and *G. serrata* produce seed inside the fruit formed of bulged tepals enclosed by the bract and bracteoles. The fruited globose heads fall to the ground as individual units in *A. paronychoiodes* whereas the individual fruits consisting of seed enclosed by bulged tepals, the bract and bracteoles fall off to the ground in *G. serrata*. The fruits gradually free the seed from the enclosed parts by the time of rainy season. The well developed fruit components suggest a role to inhibit loss of moisture from the seed as in case of several new world genera including *Gomphrena* (Kapralov *et al.,* 2012). Further, the very light weight fruit components accompanied by thick hairy growth in case of *A. paronychioides* and dense silky hair in case of *G. serrata* enable the fruits to disperse easily by wind and also to float in water during rains. It is pertinent to mention the finding of Kapralov *et al*. (2012) that fruits of some *Alternanthera* species produce corky cells that enable them to float in the permanent or seasonal water in which they grow. Since *A. paronychioides* also grows in watered agricultural lands, such corky cells if present in the fruit layers would definitely benefit this plant to float during rains or in well irrigated crop lands.

Costea *et al.* (2003) reported that the seed dispersal in Amaranthaceae is performed by wind, water, animals and humans. *A. paronychioides* exhibits anemochory and hydrochory while *G. serrata* shows anemochory, hydrochory and myrmecochory. In the latter species, aril form of elaisome at the terminal portion of the seed attracts *Crematogaster* ants which elicit the transport of the entire fruit to the nest by them. These ants separate the seed from the fruit components and then consume the elaisome or feed it to their baby ants after which they deposit in garbage piles either in the nest or outside the nest. Edwards *et al.* (2006) stated that elaiosomes function as rewards for ants. Gorb & Gorb (2003) reported that myrmecochory provides the seed with protection from seed predators, a safe place for seed survival during unfavorable periods such as fires and/or a microsite rich in nutrients. Goldblatt (1997) stated that the physiological and energetic costs of developing elaiosomes are likely to be much smaller than developing fleshy fruits, so they are cheap to make. Milewski (1983) mentioned that ants need to be abundant at levels that guarantee that seeds will be picked up and the seed traits need to directly influence the subsequent fate of seeds. Myrmecochory may be favoured by selection in more open, drier or less predictable habitats due to the higher availability of ants or to the lower costs of developing a reward for dispersal. It is true in case of *G. serrata* which grows in open and less predictable habitats. All the three seed dispersal syndromes (anemochory, hydrochory and myrmecochory) functional in this species enable it to colonize new environments or habitats. These two plant species propagate seasonally during rainy season, *A. paronychioides* from seed and perennial root stock and *G. serrata* exclusively from seed.

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