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Foraging and pollination activity of *Musca domestica* L. (Diptera: Muscidae) on flowers of *Ricinus communis* L. (Euphorbiaceae) at Maroua, Cameroon

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Key words: *Musca domestica*, *Ricinus communis*, flower, nectar, pollen, pollination.

Abstract

To evaluate the impact of *Musca domestica* on fruit and seed yields of *Ricinus communis*, its foraging and pollinating activity were studied in Maroua, during two seasons of flowering (September - November 2010 and 2011). Treatments included unlimited inflorescences access by all visitors, bagged inflorescences to avoid all visits, and limited visits of *M. domestica*. Observations were made on 10 to 20 inflorescences per treatment of which all flower visitors were recorded. The seasonal rhythm of *M. domestica* activity, its foraging behavior on flowers, and its pollination efficiency (fruiting rate, number of seeds/fruit and percentage of normal seeds) were recorded. Individuals from 13 species of insects were recorded on flowers of *R. communis*, after two years of observations. *Musca domestica* was the most frequent with 46.07 and 31.70% of visits on flowers in 2010 and 2011 respectively. *Musca domestica* intensely foraged pollen in male flowers and nectar in female flowers. In females flowers the foraging speed was 15.09 flowers/min; the foraging activity of *M. domestica* resulted in a significant increase in fruiting rate by 89.79 and 80.74%; the number of seeds per fruit by 99.02 and 84.21% and the normal seeds per fruit by 76.02 and 75.98%, respectively in 2010 and 2011. This improved performance is justified by the positive action of *M. domestica* on the pollination of flowers of *R. communis*.

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Introduction

Reproduction depends on pollination (McGregor, 1976). Pollinators include some Hymenoptera, Coleoptera, Lepidoptera and Diptera; these insects collect pollen or nectar for their nutrition (Faegri and van der Pijl, 1979). Effective pollination by insects can increase fruit yield and quality of seed (Philippe, 1991, Vaissière and Izard, 1995, Segeren *et al.,* 1996, Morison *et al.,* 2000a). *Ricinus communis* is an oil crop originated from Africa and now cultivated worldwide (Rômulo *et al.,* 2012, Renata *et al.,* 2010). Since ancient times it has been exploited for its oil which was used as ingredient to cosmetics, shampoo, soap, hand lotion, laxative, fuel for lamps and as a high speed lubricant (Capasso *et al.,* 1994, Copley *et al.,* 2005, Morris *et al.,* 2011). Nowadays, castor bean is cultivated mainly for biodiesel production because the oil content of its seeds reach up to 50% (Melo *et al.,* 2008, Sailaja *et al.,* 2008, Vanajam *et al.,* 2008). The plant is perennial and can reach a heigth of 3 m; its leaves are very large (40-50 cm), palmately, green or red; the petiole and leaf veins can sometimes transferred to the red (Mousinho *et al.,* 2008, Words *et al.,* 2011). The inflorescence have at its base the male flowers and female flowers upper end (Rômula *et al.,* 2012). On the flowers, the petals were absent, the stamens are branched; the fruit is a spiny capsule with three lobes; the seed cuticle is marbled, shiny, and hard; the reproduction system is fundamentally allogamous (McGregor, 1976, Moffett, 1983, Rômula *et al.,* 2012). The female flowers produce nectar whereas the male flowers produce pollen. The two substances attract insects (Rômula *et al.,* 2012). The higher production is from Brazil (703 kg / ha), China (978kg/ha) and India (221kg/ha) (Inocencio and Mauricio, 2008, Mendes *et al.,* 2009). Currently the production of *R. communis* in Cameroon is very low whereas the demand for seeds is high (MINADER, 2010). Therefore, it is important to investigate on the possibilities of increasing the production of this plant in the country. This can be done if flowering insects of *R. communis* in each region are well known and exploited. Unfortunately no research has been reported on the relationships between *R. communis* and its anthophilous insects in Cameroon. During preliminary investigations on flower-insect relationships in Maroua before 2010 (unpublished data), *M. domestica* has been seen intensively visiting flowers of *R. communis*. The main objective of this research was to gather more data on the relationships between *R. communis* and flower visiting insects in Maroua, for an optimal management of pollination services in the region. Specific objectives were the registration of the activity of *M. domestica* on *R. communis* flowers, the evaluation of the impact of visiting insects on pollination, fruit and seed yields of this Euphorbiaceae, and the estimation of the pollination efficiency of *M. domestica* on this plant species.

Materials and methods

Site and biological materials

The studies were conducted from June to October, in 2010 and 2011 in the locality of Mayel-Ibbé (Latitude 10° 62' N, Longitude 14° 33' E and altitude 400 m) in Maroua, Far North Region of Cameroon. This Region belongs to the ecological zone with three phytogeographical areas: Sahel-Sudanian, Sahelian and Sudanian altitude periodically flooded, with unimodal rainfall (Letouzey, 1985). It has a Sahel-Sudanian climate type, characterized by two annual seasons: a long dry season (November to May) and a short rainy season (June to October); August is the wettest month of the year (Kuete *et al.,* 1993). Annual rainfall varies from 400 to 1100 mm (Kuete *et al.,* 1993). The annual average temperature varies between 29 and 38°C. Temperatures range between 6 and 7°C (Kuete *et al.,* 1993). The experimental plot is an area of 304 m^2. The animal materiel was represented by insects naturally present in the environment including *Musca domestica* L. (Diptera: Muscidae). Vegetation was represented by wild species and cultivated plants. The plant material was represented by the seeds of *R. communis* collected at Tokombéré.

Planting and maintenance of culture

On May 25, 2010 and June 05, 2011, the experimental plots was cleaned and divided into six subplots of 4m x 4m each. Five seeds were sown in 4 lines per subplot, each of which had 4 holes per line. Holes were separated 1 m from each other, while lines were 1 m apart. Weeding was performed manually as necessary to maintain plots weed-free.

Determination of the mode of reproduction of Ricinus communis

On September 22, 2010, 20 inflorescences (belong to 20 plants) carrying 200 female flowers and 200 male flowers at the bud stage were labeled. 200 flowers belong to 10 inflorescences (each inflorescence carrying 10 female flowers and 10 male flowers) were left to be open pollinated (treatment 1) and 200 flowers belong to 10 inflorescences (each inflorescence carrying 10 female flowers and 10 male flowers) were bagged to prevent insect visits (treatment 2) (figure 1). On October 05, 2011, experiment was repeated. Twenty days after the shading of the last flower, the number of boll formed in each treatment was counted. For each treatment, the fruiting index (*Ifr*) was calculated using the following formula: $Ifr = (F_1/F_2)$, where F_1 is the number of fruit formed and F_2 the number of flowers initially labeled (Tchuenguem *et al.,* 2004). The out crossing rate (*TC*) was calculated using the formula:

$TC = \{[(Ifr_X - Ifr_Y/Ifr_X]x100\}$,

Where Ifr_X and Ifr_Y are mean fruiting indexes of free treatment and bagged treatment respectively (Demarly, 1977). The rate of self-pollination in the broad sense (*TA*) was calculated using the formula:

$TA = (100 - TC)$.

Study of the activity of Musca domestica on the flowers of Ricinus communis

Observations were conducted on flowers of treatment 1, each two days, from September 25 to October 17, 2010 and from October 8 to 30, 2011 during the following daily time frames 7-8 h, 9-10 h, 11-12 h, 13-14 h, 15-16 h and 17-18 h. The identity of all insects that visited *R. communis* flowers was recorded. All insects encountered on flowers were recorded and the cumulated results expressed in number of visits to determine the relative frequency of *M. domestica* in the anthophilous entomofauna of *R. communis.*

In addition to the determination of the floral insect's frequency, direct observations of the foraging activity on flowers were made on *M. domestica* in the experimental field. The floral rewards (nectar or pollen) harvested by this flies during each floral visit were registered based on its foraging behavior. Nectar or pollen foragers were expected to extend their proboscis to the base of the corolla and the stigma, while pollen gatherers were expected to scratch the anthers with their legs (Jean-Prost, 1987).

In the morning of each day, the number of opened flowers was counted. The same days as for the frequency of visits, the duration of individual flower visits was recorded (using a stopwatch) at least six times at hourly intervals between 7am and 6pm. Moreover, the number of pollinating visits with was defined as visits with contact between the insects and stigma upon a visit (Jacob-Remacle, 1988, Freitas, 1997), the abundance of foragers defined as the highest number of individuals simultaneously foraging on a flower or per 1000 flowers (A_{1000}) (Tchuenguem *et al.,* 2004) and the foraging speed, which is the number of flowers visited by a fly per minute were measured (Jacob-Remacle 1988). The abundance of flies per flower was recorded following the direct counting, during the same dates and daily periods as for the registration of the duration of visits. The foraging speed was calculated according to Tchuenguem *et al.,* (2004). The disruption of the activity of *M. domestica* by competitors or predators and the attractiveness exerted by other plant species on this insect was assessed by direct observations. The temperature and relative humidity in the station were registered every 30 min using a mobile thermo- hygrometer during all the sampling periods.

Evaluation of the impact of flower-feeding insects on *the yield of Ricinus communis*

This evaluation was based on the impact of visiting insects on pollination, the impact of pollination on fructification of *R. communis*, and the comparison of yields [fruiting rate, mean number of seeds per fruit and percentage of normal (well developed) seeds] of treatments 1 and 2. The fruiting rate due to the activity of insects (Fr_i) was calculated by the formula:

$Fr_i = \{[(Fr_1 - Fr_2)/Fr_1] \times 100\}$. Where Fr_1 and Fr_2 are the fruiting rate in treatments 1 and 2.

The fruiting rate (Fr) is : $Fr = [(F_2/F_1) \times 100]$. Where F_2 is the number of bolls formed and F_1 the number of female flowers initially set (Tchuenguem *et al.*, 2004).

At maturity, fruits were harvested from each treatment. The mean number of seeds per fruit and the percentage of normal seeds were then calculated for each treatment.

Measuring the effectiveness of pollination by Musca domestica on Ricinus communis

In 2010, along with the development of treatments 1 and 2, 100 flowers (belong to 10 inflorescences carrying 10 female flowers) were isolated (treatment 5) as those of treatment 2. In 2011 the same experience was repeated. Between 7am to 9am, the gauze bag was gently removed from each newly bloomed flower of treatment 5 and 6 and the flowers observed for up to twenty minutes. Flowers visited by *M. domestica* were marked. After this manipulation, the flowers were protected once more. At fruit maturity, harvesting was done in each treatment. For each year of study, the digital input (Pfx) of *M. domestica* on fruiting is $Pfx = \{[(fz-fy)/fz] \times 100\}$, where fz and fy are the fruiting rate in treatment z (protected female flowers and visited exclusively by *M. domestica*) and y (protected flowers) (Tchuenguem *et al.*, 2004). The digital input (Pgx) of *M. domestica* in the number of seeds is $Pgx = \{[(gz-gy)/gz]\} \ x\ 100$ where gz and gy are the average number of seeds per boll in treatments z and y. The digital input ($Pgnx$) of *M. domestica* on normal seeds formation is $Pgnx = \{[(gnz-gny) / gnz]\} \ x\ 100$ where gnz and gny are the percentages of normal seeds in treatments z and y.

Data analysis

SPSS and Microsoft Excel software were used for three tests: Student's (t) for comparison of means, Pearson correlation coefficient (r) for the study of linear relationship between two variables, Chi-square ($\chi 2$) for the comparison of percentages.

Results

Reproductive system

The mean fruiting indexes were 0.98, 0.07, 0.94 and 0.11 in treatments 1, 2, 3 and 4 respectively. Thus in 2010, the allogamy rate was 92.86% and the autogamy rate was 7.14%. In 2011, the corresponding figures were 88.30 and 11.70%. It appears that *R. communis* has a mixed mating system, allogamous-autogamous, with the predominance of allogamy.

Activity of Musca domestica on the flowers of Ricinus communis

Seasonal frequency of visits

On the flowers for 20 and 20 days of the flowering periods in 2010 and 2011, 445 and 448 visits of 13 and 13 species of insects were counted on 200 and 200 flowers of *R. communis* respectively in 2010 and 2011. For the two cumulated years *M. domestica* comes first with 347 visits spread over all periods of flowering that is 38.86% of all visits recorded on *R. communis* flowers.

On the female flowers for 20 and 20 days of the flowering periods in 2010 and 2011, 296 and 291 visits of 10 and 11 species of insects were counted on 100 and 100 female flowers of *R. communis* respectively in 2010 and 2011. *Musca domestica* comes first with 157 and 108 visits spread over all periods of flowering that is 53.04% and 37.11% of all visits recorded on female flowers in 2010 and 2011 respectively (Table 1). The difference between these two percentages on the female flowers is highly significant (χ^2 = 15.03, *df* = 1, *P* < 0.001). For the two cumulated years *M. domestica* comes first with 265 visits spread over all periods of flowering that is 45.14% of all visits recorded on female flowers.

Table 1. Diversity of floral insects on *Ricinus communis* female and male flowers in 2010 and 2011, number and percentage of visits of different insects.

Insects			2010				2011				Total 2010		Total 2011		Total 2010/2011					
			F F		M F		F F		M F		MF and FF		MF and FF		MF		FF		MF and FF	
Order	Familly	Genus, species, sub-species	n_{ff1}	p_{ff1}(%)	n_{mf1}	p_{mf1}(%)	n_{ff2}	p_{ff}(%)	n_{mf2}	p_{mf2}(%)	nt1	pt1(%)	nt2	Pt2(%)	$n_{mf\,t}$	$p_{mf\,t}$(%)	$n_{ff\,t}$	$p_{ff\,t}$(%)	n_T	p_T(%)
Diptera	Muscidae	*Musca domestica* [np]	157	53.04	48	32.21	108	37.11	34	21.66	205	46.07	142	31.70	82	26.80	265	45.14	347	38.86
	Calliphoridae	(1 sp.) [R]	2	0.68	0	0	0	0	1	0.64	2	0.45	1	0.22	1	0.33	2	0.34	3	0.34
Hymenoptera	Formicidae	*Polyrachis* sp. [np]	19	6.42	89	59.73	21	7.22	102	64.97	108	24.27	123	27.46	191	62.42	40	6.81	231	25.87
	Vespidae	*Synagris cornuta* [R]	0	0	2	1.34	11	3.78	7	4.46	2	0.45	18	4.02	9	2.94	11	1.87	20	2.24
		Delta sp. [R]	5	1.69	3	2.01	7	2.41	0	0	8	1.80	7	1.56	3	0.98	12	2.04	15	1.68
Hemiptera	Coreidae	*Anoplocnemis curvipes* [P]	0	0	6	4.03	0	0	9	5.73	6	1.35	9	2.01	15	4.90	0	0	15	1.68
Lepidoptera	Lycaenidae	(1 sp.) [n]	9	3.04	0	0	17	5.84	0	0	9	2.02	17	3.79	0	0	26	4.43	26	2.91
	Pieridae	*Eurema* sp. [n]	46	15.54	0	0	51	17.53	1	0.64	46	10.34	52	11.61	1	0.33	97	16.52	98	10.97
	Acraeidae	*Acraea acerata* [n]	0	0	1	0.67	23	7.90	1	0.64	1	0.22	24	5.36	2	0.65	23	3.92	25	2.80
	Pieridae	*Catopsilia florella* [n]	7	2.36	0	0	15	5.15	0	0	7	1.57	15	3.35	0	0	22	3.75	22	2.46
Orthoptera		(sp. 1) [Dl]	2	0.68	0	0	3	1.03	2	1.27	2	0.45	5	1.12	2	0.65	5	0.85	7	0.78
		(sp. 2) [Dl]	9	3.04	0	0	12	4.12	0	0	9	2.02	12	2.68	0	0	21	3.58	21	2.35
Odonate	Zygoptera	(1 sp.) [Pr]	40	13.51	0	0	23	7.90	0	0	40	8.99	23	5.13	0	0	63	10.73	63	7.05
Total 13 species			296	100	149	100	291	100	157	100	445	100	448	100	306	100	587	100	893	100

Comparison of percentages of *M. domestica* visits for two years: on female flowers (2010, 2011) X^2 = 15.03 ([ddl = 1; P < 0.001]); on male flowers (2010, 2011) X^2 = 21.81 ([ddl = 1; P < 0.001]); on female and male flowers (2010,2011) X^2 = 96.43 ([ddl = 1; P < 0.0001]); on male and female flowers (2010, 2011) X^2 = 0.85 ([ddl = 1; P < 0.1]); female and male flowers (2010) X^2 = 16.42 ([ddl = 1; P < 0.001]); female and male flowers (2011) X^2 = 40.55 ([ddl = 1; P < 0.0001]). $n_{ff\,1}$: number of visits on 100 female flowers in 20 days in 2010. $n_{ff\,2}$: number of visits on 100 female flowers in 20 days in 2011. $n_{mf\,1}$: number of visits on 100 male flowers in 20 days in 2010. $n_{mf\,2}$: number of visits on 100 male flowers in 20 days in 2011.nt1 and nt2: total of visits on female and male flowers in 2010 and 2011. Nt: total of visits on female and male flowers. $P_{ff\,1}$ and $P_{ff\,2}$: percentage of visits on female flowers in 2010 and 2011. $P_{mf\,1}$ and $P_{mf\,2}$: percentage of visits on male flowers in 2010 and 2011. $P_{ff\,1} = (n_{ff\,1}/296) \times 100$. $P_{ff\,2} = (n_{ff\,2}/291) \times 100$. $P_{mf\,1} = (n_{mf\,1}/149) \times 100$. $P_{mf\,2} = (n_{mf\,2}/157) \times 100$. Pt1 and Pt2: total of percentage of visits on female and male flowers. Pt1 = (nt1/445) x 100. Pt2 = (nt2/448) x 100. Pt: total of percentage. Pt = (nt/893) x 100. F F: female flowers. M F: male flowers. P: visitor collected pollen. N: visitor collected nectar. Pr: Predation. Dl: defloration. R: rest. Sp.: undetermined species.

On the male flowers in the same period, 149 and 157 visits of 6 and 8 species of insects were recording on 100 and 100 male flowers of *R. communis* respectively. *Musca domestica* comes second with 48 and 34 visits that were representing 32.21% and 21.66% of all visits recorded on male flowers in 2010 and 2011 respectively (Table 1). The difference between these two percentages on the male flowers is highly significant (χ^2 = 2 1.81, *df* = 1, *P* < 0.001]). For the two cumulated years *M. domestica* comes second with 82 visits spread over all periods of flowering that is 26.80% of all visits recorded on male flowers.

Table 2. Daily distribution of *Musca domestica* visits on 100 female flowers and 100 male flowers over 20 days of observation in 2010 and 2011 respectively, mean temperature and mean humidity of the study site.

Year	Parameter registered	Daily period (hours)					
		6-7	8-9	10-11	12-13	14-15	16-17
2010	Number of visits	8	21	45	79	42	10
	Temprarture (°c)	29.12	31.95	34.5	37.54	36.14	34.52
	Hygrometry (%)	72.4	63.8	59.2	52.4	46.9	48.8
2011	Number of visits	15	22	44	90	41	19
	Temprarture (°c)	27.2	31.4	34.06	37.21	35.9	34.34
	Hygrometry (%)	71.8	63.8	59.79	52.9	47.2	49.11

2010: for temperature and hygrometry, each figure represents the mean of 50 observations.
2011: for temperature and hygrometry, each figure represents the mean of 50 observations.

This insect has been active on *R. communis* flowers from 6 am to 17 pm, with a peak of visits between 12 am and 13 pm in 2010 as well as in 2011 (Figure 3).

Abundance of flies

In 2010, the highest average number of *M. domestica* simultaneously active was one per female flower, one for male flowers (*n* = 100; *s* = 0); 295.13 per 1000 female flowers (*n* = 50; *s* = 218.95; *max* = 833) and 88.03 per 1000 male flowers (*n* = 30; *s* = 23.42; *max* = 103); The difference between the average number of *M. domestica* per 1000 female and male flowers in 2010 was highly significant (*t* = 23.56; *df* = 78; *P* <0.001).

Table 3. *Ricinus communis* yields under pollination treatments.

Treatment	Year	Number Flowers	Number Fruit	Fruiting rate (%)	Seeds / fruit Mean	Seeds / fruit sd	Total number of Seeds	Number of Normal Seeds	% Normal seeds
Unlimited visits	2010	100	98	98.00	2.76	0.63	294	276	93.87
Bagged flowers	2010	100	7	7.00	0.02	0.14	15	2	13.33
Unlimited visits	2011	100	94	94.00	2.85	0.63	285	269	94.38
Bagged flowers	2011	100	11	11.00	0.27	0.86	27	4	14.81
M. domestica	2010	35	24	68.57	2.05	1.41	72	40	55.60
M. domestica	2011	35	20	57.14	1.71	1.50	60	37	61.66

In 2011, the corresponding figures were one per female and male flowers (*n* = 100, *s* = 0); 351.65 per 1000 female flowers (*n* = 50; *s* = 210.63; *max* = 800) and 48.13 per 1000 male flowers (*n* = 28; *s* = 9.31; *max* = 71); the difference between the average number of *M. domestica* per 1000 female and male flowers in 2011 was highly significant (*t* = 32.28; *df* = 76; *P* <0.001).

Floral substances taken

During each period of flowering of *R. communis, M. domestica* harvest regularly pollen on male flowers and nectar on female flowers (Figure 2).

Fig. 1. Plant of *Ricinus communis* showing a flower isolated from insects.

Rate of visits according to the flowering stages

Overall, visits of *M. domestica* were more numerous on treatments 1 and 3 when the number of open male and female flowers was highest. The correlation between the number of visits of *M. domestica* and the number of opened female flowers was positive and highly significant in 2010 (r = 0.68; df = 8; P <0.05) as well as in 2011 (r = 0.57; df = 8; P <0.05); The correlation between the number of visits of *M. domestica* and the number of opened male flowers was positive and highly significant in 2010 (r = 0.87; df = 8, P <0.05) as well as in 2011 (r = 0.74; df = 8, P <0.05) (Figure 4).

Fig. 2. *Musca domestica* eating nectar of a female flower of *Ricinus communis.*

Duration of visits per flower

The average duration of a visit of *M. domestica* per flower of *R. communis* varied significantly. In 2010, the mean duration of a visit was 5.55 sec (n = 157; s = 1.24; max = 6) for female flowers and 4.31 sec (n = 45; s = 2.88; max = 9) for male flowers; the difference between these two means is highly significant (t = 2.43; df = 200; P <0.01).

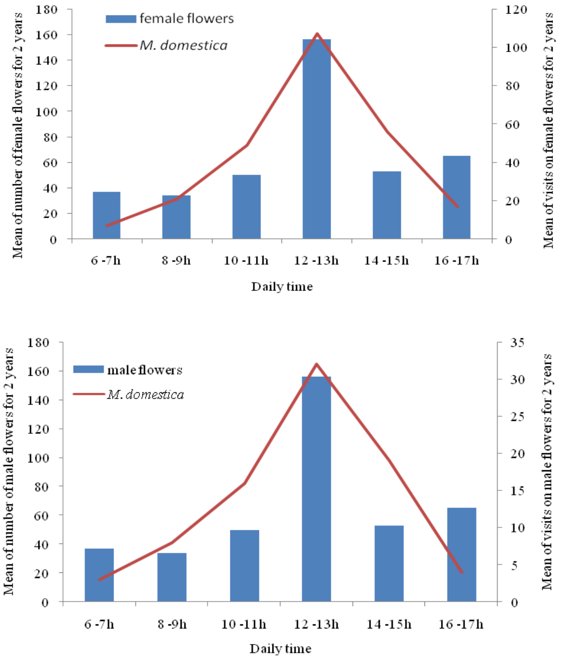

Fig. 3. Daily distribution of *Musca domestica* visits on 200 female flowers over 20 day (A) and 200 male flowers and 20 days (B).

In 2011, the corresponding results were 3.52 sec (n = 197; s = 1.72; max = 8) for female flowers and 2.91 sec (n = 30, s = 0.93, max = 6) for male flowers; the difference between these two means was highly significant (t = 9.83; df = 225; P <0.001).

Foraging speed of Musca domestica on the flowers of Ricinus communis

On the plot of *R. communis, M. domestica* visited 1 to 8 female flowers / min and 1 to 11 male flowers / min in 2010. The mean foraging speeds are 15.70 female flowers / min (n = 80, s = 5.21) and 14.48 male flowers / min (n = 89, s = 4.36) in 2010. The difference between these two means is highly significant (t = 11.09; df = 167; P < 0.001). For the two cumulated mean the foraging speeds are 15.09 flowers / min (n = 169; s = 4.78).

In 2011, the corresponding results were 1 to 10 female flowers / min and 1 to 9 male flowers; the mean foraging speeds are 13.66 female flowers / min (n = 55, s = 4.87) and 10.67 male flowers / min (n = 35, s = 3.59). The difference between these two means is highly significant (t = 14.95; df = 88; P < 0.001). For the two cumulated mean the foraging speeds are 12.12 flowers / min (n = 90; s = 4.23).

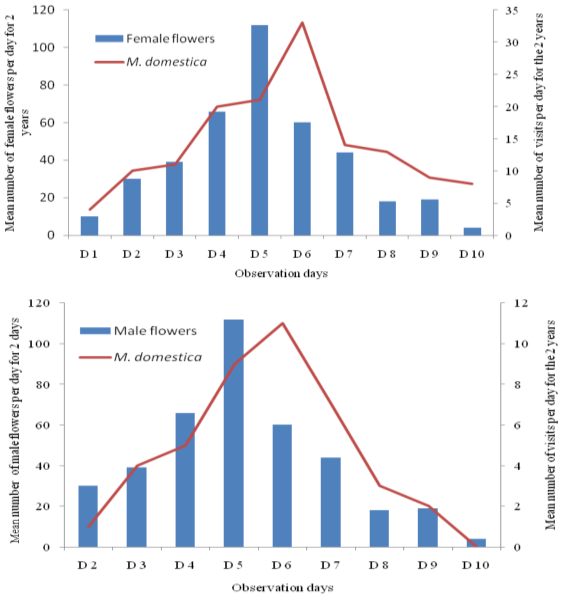

Fig. 4. Variation of number of female flowers (A), number of male flowers (B) and number of visits of *Musca domestica* on *Ricinus communis* in 2010 and 2011.

Influence of wildlife

Musca domestica flies are disturbed in their foraging by other individuals of the same species or other arthropods which are either predators or competitors for the search of nectar and/or pollen.

These disturbances have resulted in the interruption of certain visits. In 2010, for 157 visits of *M. domestica* on female flowers, 8 (5.09%) were interrupted by the same flies and 48 visits of *M. domestica* on male flowers, 4 (8.33%) were interrupted by the same flies. In 2011, for 108 visits of the same visit in female flowers, 5 (4.62%) were interrupted by the same flies and 34 visits on male flowers 3 (8.82%) were interrupted by the same flies.

During one foraging thus, all individual fly foraging on *R. communis* were observed moving from female to male flowers and vice versa. In 2010, for 157 visits of *M. domestica* on female flowers, 82 (52.22%) were observed moving on female to male flowers. In 2011 for 108 visits in female flowers, 66 (61.11%) were observed moving on female to male flowers. But in 2010, for 48 visits of *M. domestica* on male flowers, 37 (77.08%) were observed moving on male to female flowers. In 2011, for 34 visits on male flowers 23 (67.64%) were observed moving on male to female flowers.

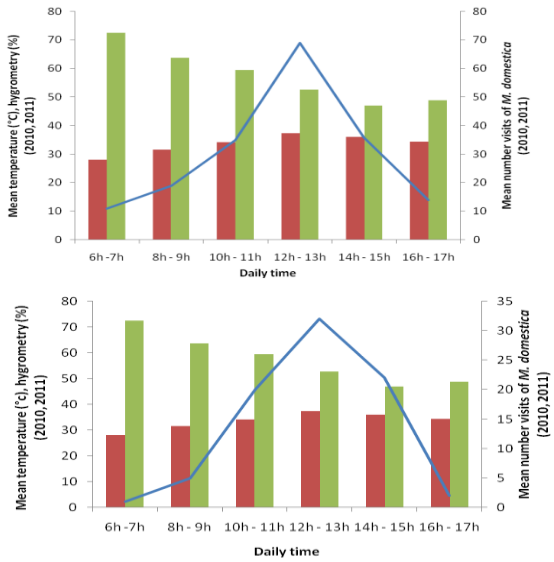

Fig. 5. Mean daily temperature, humidity and mean number of visits of *Musca domestica* on the female (A) and male (B) flowers of *Ricinus communis* in 2010 and 2011.

During the study period, other plant species located near the experimental field of ricin were also visited by *M. domestica* for nectar (ne) and / or pollen (po). Among these plants, there were: *Jathropha gossipiifolia* (Euphorbiaceae, ne), *Striga hermonthica* (Scrophulariaceae, ne), *Hibiscus asper* (Malvaceae, ne and po), *Sorghum bicolor* (Poaceae, po). During *M. domestica* foraging trips of 2010, on 157 visits on the female flowers, only 1 (0.63%) were made by and individual comming from *R. communis* to *Sorghum bicolor*.

Daily rate of visits

Musca domestica has been active on the female and male flowers of *R. communis* from 6 am to 18 am, with a peak of visits between 12 am and 13 pm in 2010 and 2011 (figure 3). Climatic factors have influenced the activity of *M. domestica* on the female and male flowers of *R. communis* in field conditions (Table 2). The correlation was positive and significant between the number of visits of *M. domestica* on the female flowers of *R. communis* and temperature in 2010 (r = 0.82; df = 4; P <0.05) and in 2011 (r = 0.71; df = 4; P <0.05). The same results were found on the male flowers in 2010 (r = 0.81; df = 4; P <0.05) and in 2011 (r = 0.78; df = 4; P <0.05). The correlation between the number of visits of *M. domestica* on the female flowers of *R. communis* and the relative humidity of the air was negative and significant in 2010 (r = - 0.79; df = 4; P <0.05]). On the male flowers, the correlation between the number of visits and the relative humidity of the air was negative and significant in 2010 (r = - 0.52; df = 4; P <0.05) (figure 5).

Impact of flowering insects on pollination and yields of Ricinus communis

During nectar harvest, flowering insects of *R. communis* are in regular contact with the anthers and stigma. These insects therefore increase the possibilities of this Euphorbiaceae pollination. Table 3 presents the results on fruiting rate, number of seeds per fruit and percentage of normal seeds in different treatments. The comparison of figures from this table shows that:

a) The difference observed was highly significant between fruiting rate of free opened female flowers (treatment 1) and that of bagged female flowers (treatment 2), in 2010 (χ^2 = 166.04; df = 1, P <0.001) and in 2011 (χ^2 = 138.13; df = 1; P <0.001). Consequently, the fruiting rate of unprotected female flowers was higher than that of protected female flowers in 2010 and in 2011. The fruiting rate due to the action of flowering insects was 92.85% in 2010 and 88.29% in 2011. For all of the female flowers studied, the fructification rate attributed to the influence of insects was 90.57%.

b) There was a highly significant difference between treatments 1 and 2 (t = 29.46; df = 103; P <0.001) the first year and the second year (t = 39,09; df = 103; P <0.001) as far as the mean number of seeds per boll is concerned. Consequently, a high mean number of seeds per fruit in opened female flowers (treatment 1) noticed compared to bagged female flowers (treatments 2). The number of seeds per fruit attributed to the activity of flowering insects was 99.27% in 2010 and 90.52% in 2011, giving an overall mean of 94.89%.

c) There was a highly difference significant between the percentage of normal seeds of treatment 1 and that of treatment 2 in the first year (χ^2 = 102.58; df = 1; P <0.001) as well as the second year (χ^2 = 142.77; df = 1, P <0.001). Thus, the percentage of normal seeds in opened female flowers was higher than that of protected female flowers in 2010 and in 2011. The percentage of normal seeds due to the action of flowering insects was 85.79% in 2010 and 84.30% in 2011. For all the female flowers studied, the percentage of the normal seeds due to flowering insects was 85.04%.

Pollination efficiency of Musca domestica on Ricinus communis

During the nectar and pollen harvest on inflorescences of *R. communis*, *M. domestica* were always in contact with stigma and anthers. Thus, this *M. domestica* highly increased the pollination possibilities of *R. communis* female flowers. The comparison of figures from table 3 shows that:

a) The difference observed between the fruiting rate of treatments 2 and that of treatment 5 was highly significant in 2010 (χ^2 = 55.56; df = 1; P <0.05) as well as 2011 (χ^2 = 31.20; df = 1; P <0.05). The fruiting rate of female flowers exclusively visited by *M. domestica* (treatment 5) was significantly higher than that of fema le flowers bagged during their flowering period (treatment 2) in 2010 and in 2011.

The fruiting rate due to *M. domestica* foraging activity was 89.79% in 2010 and 80.74% in 2011. For all the flowers studied, the fruiting rate attributed to the influence of *M. domestica* was 85.26%.

b) There was a highly significant difference between treatments 2 and 5 the first year (t = - 7.00; df = 90; P <0.01) and the second year (t = - 7.57; df = 95; P <0.01). Consequently a high mean number of seeds per fruit from female flowers visited exclusively by *M. domestica* (treatment 5) were noticed compared to bagged female flowers (treatment 2). The percentage of the number of seeds per fruit due to *M. domestica* was 99.02% in 2010 and 84.21% in 2011. For all the flowers studied, the percentage of the number of seeds per fruit attributed to the influence of *M. domestica* was 91.61%.

c) There was a highly significant difference between the percentage of normal seeds of treatment 5 and that of treatment 2 in first year ($\chi2$ = 8.86 [df = 1, P <0.01]) as well as the second year ($\chi2$ = 16.40 [df = 1, P <0.01]). Thus the percentage of normal seeds of female flowers exclusively visited by *M. domestica* was higher than that of bagged female flowers in 2010 and in 2011. The percentage of the normal seeds due to *M. domestica* was 76.02% in 2010 and 75.98% in 2011. For all the flowers studied, the percentage of the number of seeds attributed to the influence of *M. domestica* was 76.00%.

Discussion

Musca domestica were the main floral visitor of *R. communis* during the observation periods. This fly is known as insect visiting the flowers of other plant species such as *Phaseolus vulgaris* (Fabaceae) in Ngaoundéré (Cameroon) (Kingha *et al.,* 2012), *Gossypium hirsutum* (Malvaceae) in Maroua (Cameroon) (Dounia and Fohouo, 2013), *Phaseolus vulgaris* (fabaceae) in Maroua (Camaroon) (Douka and Fohouo 2013). The significant difference between the percentages of *M. domestica* visits of studied years could be attributed to the experimental site variation in 2010 and 2011. It is known that anthophillous insect fauna of a plant species varies over time (Moffett *et al.,* 1975, Elfawal *et al.,* 1976, Moffett *et al.,* 1976, Tchuenguem Fohouo, 2005). The peak of *M. domestica* activity on the female and male flowers was in the midday, which corresponds to the period of the high availability of nectar on female flowers and pollen on male flowers of *R. communis*. Furthermore, this nectar and pollen is produced in large quantities and is easily accessible to insects (Mousinha *et al.,* 2008, Mendes *et al.,* 2009, Words *et al.,* 2011, Rômula *et al.,* 2012). The decreased of the activity between 14 and 17 pm could be related to the decrease of the temperature in the experimental field. In fact insects severally prefer warm or sunny days for good floral activity (Kasper *et al.,* 2008). Besides, rainfall has been documented as an environmental factor that can disrupt the floral insect activity (McGregor, 1976).

The abundance of *M. domestica* per 1000 flowers and the positive and highly significant correlation between the number of *R. communis* flowers and the number of *M. domestica* visits underscores the attractiveness of *R. communis* nectar and pollen with respect to this fly.

The significant difference between the mean duration of a visit per flower in 2010 and 2011 could be attributed to the availability of floral products or the variation of diversity of flowering insects from one year to another. During each of the two flowering periods of *R. communis, M. domestica* intensely and regularly harvested nectar on female flowers and pollen on male flowers for their nutrition. The disruptions of visits by other insects reduced the duration of certain *M. domestica* visits. This obliged some flies to visit more flowers during a foraging trip. Similar observations were made for: a) *Apis mellifera adansonii* (Hymenoptera: Apidae) workers foraging on flowers of *Entada africana* (Fabaceae) flowers, *Psidium guajava* (Myrtaceae) (Tchuenguem *et al.,* 2007), *Croton macrostachyus* (Euphorbiaceae), *Syzygium guineense* var. *guineense* (Myrtaceae) (Tchuenguem *et al.,* 2008a), *Persea* *americana* (Lauraceae), *Vitellaria paradoxa* (Sapotaceae) (Tchuenguem *et al.,* 2008b), *Vigna unguiculata* (L.) (Fabaceae) (Tchuenguem *et al.,* 2009a), *Combretum nigricans* (Combretaceae), *Erythrina sigmoidea* (Fabaceae), *Lannea kerstingii* (Anacardiaceae), *Vernonia amygdalina* (Asteraceae) (Tchuenguem *et al.,* 2010), *Gossypium hirsutum* (Malvaceae) (Dounia and Fohouo 2013; Mazi *et al.,* 2013), *Phaseolus vulgaris* (Fabaceae) (Douka and Fohouo 2013); b) *Chalicodoma cincta cincta* (Hymenoptera: Megachilidae) foraging on flowers of *Cajanus cajan* (Fabaceae) (Pando *et al.,* 2011b); c) *Xylocopa olivacea* (Hymenoptera: Megachilidae) workers foraging *Phaseolus vulgaris* flowers (Kingha *et al.,* 2012); d) *Xylocopa calens* (Hymenoptera: Megachilidae) foraging on flowers of *Phseolus coccineus* (Pando *et al.,* 2011a).

The fly individuals had a high affinity with respect to *R. communis* when compared to the neighboring plant species, indicating their faithfulness to this Euphorbiaceae, a phenomenon known as "floral constancy" (Louveaux 1984). Flower constancy is an important aspect in the management of pollinators. For this research, it indicates that *M. domestica* can provide benefits to pollination management of *R. communis.*

During the collection of nectar on female flowers and pollen on male flowers of the same inflorescence, *M. domestica* regularly carry pollen to male and female flowers and touch the stigma. They were also able to carry pollen with their hairs, legs and mouth accessories from a male flower of one plant to stigma of female flower of the same plant (geitonogamy), or to that of another plant (xenogamy). *Musca domestica* can thus influence self- pollination as well as cross-pollination (Milfont *et al.,* 2009).

The higher productivity of fruits and seeds in unlimited visits when compared with bagged flowers showed that insect visits were effective in increasing cross-pollination. Our results confirmed those of Rômula *et al.,* (2012) in Brazil, who revealed that *R. communis* flowers set little fruits in the absence of insect pollinators.

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