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Impact of Honeybee and Other Insect Pollinators on the Seed Setting and Yield Production of Black Cumin *Nigella sativa* L.

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ABSTRACT

Evaluation of Seasonal fluctuation of insect pollinators and the efficiency of honeybees for black cumin plants *Nigella sativa* pollination were carried out during the flowering periods stage of 2008 and 2009 seasons at Assiut Governorate. Four Orders of visitor insects were captured by the insect sweep net technique on black cumin plants. These Orders were Hemiptera, Coleoptera, Diptera and Hymenoptera. Orders Diptera and Hymenoptera were ranked as the most abundant species. Daily peak activity was detected at 12 noon and 2 pm in both experimental seasons. Honeybee that visits the black cumin plants leads to the increase of the number of seeds set and then yield production. Thus strategies to promote pollination by honeybee may be helpful in enhancing seed yield in *N. sativa* and other cultivated species.

KEY WORDS: black cumin, honeybee, insect pollinators, yield production.

INTRODUCTION

Co-evolution of flowering plants and their pollinators started about 225 million years ago (Price 1975). Stone carvings and bricks from the palace of Assyrian kings as early as 800 B.C. depict the significance of pollen and pollination of fruits that pollination enhances quality and yield of seeds and fruits. Lack of sufficient number of suitable pollinators causes decline in fruit and seed production (Partap 2001). Of the total pollination activities, over 80% is performed by insects and bees contribute nearly 80% of the total insect pollinators, and therefore, they are considered the best pollinators (Robinson and Morse 1989).

Flowering plants and honeybees have a special relationship in which both are benefited to each other; where honeybees get nectar (as food) and in turn facilitate the pollination process (Ricciardelli and Oddo 1981).

Black Cumin, *Nigella sativa* was discovered in Tutankhamun`s tomb, implying that it played an important role in ancient Egyptian practices. *N.igella sativa* seeds have been reported to contain essential oils, fixed oils, flavonoids, saponins, alkaloids and proteins (Zargari 1990; Burits and Bucar 2000 and Al-Ghamdi 2001). Because the traditional and folkloric uses of *N. sativa,* seed are supported by a long history of human experience, this plant may be an important source for the isolation of potential drugs (Nafisy 1989; Amin 1991 and Zargari 1990).

The aim of the present work is to study the population fluctuation of pollinator insects and the efficiency of the honeybees on the yield of black cumin plants, *Nigella sativa* L. under the prevailing conditions of Assiut Governorate, Egypt.

MATERIALS AND METHODS

The experiment of this investigation was conducted at Dirut district, Assuit Governorate, Egypt, during the two consecutive seasons, 2007/2008 and 2008/2009.

Insect pollinators of black cumin and their foraging activity

The black cumin was planted in the second week of November. An area about quarter Feddan (Feddan=4200 m²) was chosen and divided into rows, each was 60cm wide, seeds of cumin were sown in hills 30cm apart. Three plants were left in each hill, normal agriculture practices were carried out and no chemical pest control was applied. Successive samples of insect pollinators were taken a day weekly at two hours intervals (from 8 am to 4 pm) throughout the

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flowering period started from 13 of February to 11 of April 2008 and 12 of February to 9 of April 2009. Samples were taken by using "insect sweep net" technique; fifty double sweeps were made at each interval and transferred to the laboratory for inspection. All captured visitor insects were identified to genera and species. Climatic factors including, temperature (ºC) and relative humidity (RH %) were recorded. The correlation coefficient between the number of collected insects and the climatic factors were calculated according to Snedecor (1957).

Effect of honeybees and other pollinator insects on the yield production of black cumin plants

To evaluate the effect of honeybee pollination on the yield of black cumin plants, three treatments were adopted for two successive years (2008 and 2009). Nine random plots (2x2m) were used, three plots for each treatment. In the first treatment, plots were left for open pollination by honeybees and other insects. In the second treatment, plants were covered with wire screen cages 2x2x2m enclosing a nucleus colony, contained a mated laying queen, two brood and three more combs containing honey and covered with worker bees. Feeding of the nuclei began a few days before the blooming season and continued daily at 5 pm until the end of the season.

In the third treatment, plants were covered with similar cages mentioned above, so that all visitor insects were prevented from entering. The cages were placed randomly in the field at the beginning of flowering period until its end.

For yield assessment, ten randomly selected black cumin plants were taken immediately before harvest from each experimental plot and the following parameters were determined:-

- Mean No. of flowers/plant
- Mean No. of pods/plant
- Mean No. of seeds/plant
- Mean weight of seeds/plant (gm)
- Mean percentage of pod set
- Mean No. of seeds/pod
- Mean weight of 100 seeds (gm)
- Calculated seed yield/Feddan (kg)

All data were subjected to analysis of variance (ANOVA) through SPSS computer program. Means were compared using Duncan's Multiple Range tests.

RESULTS

Results in Table (1) indicate that during the two years of the study, 10 species within 10 genera belonging to 4 Orders of insect pollinators were captured by the insect sweep net technique on black cumin, *Nigella sativa* plants. These Orders were Hemiptera, Coleoptera, Diptera and Hymenoptera. The highest numbers of collected visitor insects were recorded from the 3rd week of February till the 2nd week of April in the following period of 2008 and 2009 seasons. Most abundant species were related to Orders Diptera and Hymenoptera representing (72.30 and 75.5%) and (14.14 and 13.7%) of the total insect pollinators during 2008 and 2009 seasons, respectively. *Phytomyza atricontis*, *Melanagromyza phaseoli* and *Liriomyza congesta* were the most abundant dipterous insect. The respective percentages of occurrence the three insects species were (30.72, 27.38 and 8.34%) and (33.1, 28.7 and 9.1%) of the total collected insects within the two experimental seasons, respectively. Hymenoptera had 3 species represented by *Apis mellifera* (11.2 and 10.6%), *Megachile submucida* (2.2 and 2.1) and *Polistes gallicus* (0.8 and 0.7%) for the two successive seasons, respectively. One species was recorded for the hemipterous insects, *Oxycarinus hyalinipennis* represented by 5.1 and 4.7% of the total pollinator insects during 2008 and 2009 seasons, respectively. The same trend was observed for Coleoptera, *Coccinella undecimpunctata*, recorded 8.4 and 6.1% of the total catch insects in the two experimental seasons, respectively.

Data in Table (2) show the daily activity of pollinator insects to black cumin plants from (8 am to 4 pm) during the blooming periods of 2008 and 2009 seasons. Daily peak activity of caught insect species on black cumin flowers was detected at 12 noon and 2 pm in both experimental seasons. The highest number of hemipterous insects was recorded at 2 pm (61 insect) of 2008 but in 2009 were 65 insects at 12 noon.

Peak activity of coleopterous insects was observed at 2 pm (93 insects) in 2008 and 75 insects at 10 am in 2009 season. *Melanagromyza phaseoli Phytomyza atricontis* and *Musca domestica* belonging to Order Diptera represented a highly number of insect pollinators (380, 360 and 57 insects) and (400, 506 and 50 insects) at 12 noon during the daily activity of 2008 and 2009 seasons, respectively.

According to the collected hymenopterous insects the highest day activity was in 2 pm whereas, *Apis mellifera* recorded 181 and 139 insects followed by *Megachile submucida* (26 and 32 insects) and *Polistes gallicus* (16 and 14 insects) for two tested seasons, respectively.

Positive correlation coefficient was found between temperature and the number of collected insects in the two tested seasons, while RH% recorded a negative correlation with the number of visitor insects during both tested seasons (Table 2).

The role of insect pollinators especially honeybees in the yield production of black cumin are represented in Table (3). A significant mean number of pod and seeds/plant were recorded in the open plots and bee pollination cages of black cumin plants in comparison with cages without honeybees (exclusion cages). The highest percentage of pod set was recorded for the open pollination (91.03 and 93.86%), while the insect exclusion treatment recorded the lowest value (55.78 and 41.22%) for two successive seasons, respectively.

Weight of 100 seeds was (3.08 and 3.15 gm) for open visits allowed treatment, caged plants with honeybees (2.94 and 2.94gm) and caged plants without honeybees (2.82 and 2.66) (Table 3). No significant differences were found in the most treatments during the two tested seasons.

Table (1): Black cumin (Nigella sativa L.) insect pollinators collected a day weekly during the flowering season of 2008 and 2009 at Assuit governorate, Egypt.

Date / Insect species	2008											2009										
	13/2	20/2	27/2	6/3	13/3	20/3	27/3	4/4	11/4	Total	%	12/2	19/2	26/2	5/3	12/3	19/3	26/3	2/4	9/4	Total	%
Order: Hemiptera																						
Oxycarinus hyalinipennis	9	10	19	16	24	18	30	22	34	182	5.14	13	12	12	20	26	21	13	32	49	198	4.7
Order: Coleoptera																						
Coccinella undecimpunctata	0	4	5	14	18	54	76	42	84	297	8.40	0	0	0	2	3	33	58	64	97	257	6.1
Order: Diptera																						
Phytomyza atricontis	62	53	89	109	163	206	186	171	47	1086	30.72	77	119	145	103	256	296	121	219	58	1394	33.1
Melanagromyza phaseoli	23	39	63	122	151	198	128	182	62	968	27.38	41	44	59	174	181	247	216	165	83	1210	28.7
Liriomyza congesta	5	14	13	27	49	63	57	43	24	295	8.34	8	16	22	44	69	71	66	54	36	386	9.1
Syrphus corollae	0	0	3	2	3	5	12	6	7	38	1.07	2	2	0	3	4	7	9	8	11	46	1.1
Musca domestica	3	11	8	13	19	27	38	29	21	169	4.78	10	9	11	18	28	21	24	17	15	153	3.6
Total Dipterous	93	117	176	273	385	499	421	431	161	2556	72.30	138	190	237	342	538	642	436	463	203	3189	75.5
Order: Hymenoptera																						
Apis mellifera L.	5	18	46	52	72	64	53	60	27	397	11.23	3	29	58	65	54	82	75	55	36	457	10.8
Megachile submucida	0	4	7	12	8	16	7	13	9	76	2.14	2	5	6	10	10	13	15	17	12	90	2.1
Polistes gallicus	0	0	2	3	4	6	4	5	3	27	0.76	0	0	1	3	5	4	6	4	8	31	0.7
Total Hymenopterous	5	22	55	67	84	86	64	78	39	500	14.14	5	34	65	78	69	99	96	76	56	578	13.7
General total	107	153	255	370	511	657	591	573	318	3535		156	236	314	442	636	795	603	635	405	4222	
Mean temperature (C°)	13.3	11.8	14	21.8	17	23	18.5	20	21.5	r1 = +0.79		19.5	24	21	23	20.5	24	21.5	24.5	23	r1= +0.37	
Mean R.H. %	48	44	46	38	43	33	42	42	50	r2 = -0.74		54	49	50	55	54	47	46	47	53	r2= -0.45	

r (0.01= 0.798) r (0.05= 0.666)

Table (2): Daily activity of Black cumin (Nigella sativa L.) insect pollinators at two-hour intervals during the flowering seasons of 2008and 2009 at Assuit governorate, Egypt.

Time of the day / Insect species	2008							2009						
	8 am	10	12	2 pm	4	Total	%	8 am	10	12	2 pm	4	Total	%
Order: Hemiptera														
Oxycarinus hyalinipennis	13	27	48	61	33	182	5.14	12	42	65	52	27	198	4.7
Order: Coleoptera														
Coccinella undecimpunctata	10	65	76	93	53	297	8.40	14	75	59	45	64	257	6.1
Order: Diptera														
Phytomyza atricontis	36	185	360	308	197	1086	30.72	45	210	506	395	238	1394	33.1
Melanagromyza phaseoli	60	270	380	172	86	968	27.38	76	312	400	288	134	1210	28.7
Liriomyza congesta	18	50	71	127	29	295	8.34	24	73	90	116	83	386	9.1
Syrphus corollae	0	7	15	14	2	38	1.07	0	11	14	13	8	46	1.1
Musca domestica	14	43	57	36	19	169	4.78	20	32	50	40	11	153	3.6
Total Dipterous insects	128	555	883	657	333	2556	72.30	165	638	1060	852	474	3189	75.5
Order: Hymenoptera														
Apis mellifera L.	21	56	92	181	47	397	11.23	35	91	118	139	74	457	10.8
Megachile submucida	5	18	23	26	4	76	2.14	6	13	27	32	12	90	2.1
Polistes gallicus	0	0	9	16	2	27	0.76	0	3	12	14	2	31	0.7
Total Hymenopterous	26	74	124	223	53	500	14.14	41	107	157	185	88	578	13.7
General total	177	721	1131	1034	472	3535		232	862	1341	1134	653	4222	

Table (3): Effects of open-pollination, honey bees pollination and insect exclusion plots on the Black cumin (*Nigella sativa* L.) yield production at Assiut Governorate, Egypt during 2008& 2009 seasons.

Season	2008				2009			
Treatments	Open pollination	Honey bees pollination	Insect exclusion	F-value	Open pollination	Honey bees pollination	Insect exclusion	F-value
Mean No.of flowers/ plant	25.18a	29.36a	25.81a	0.45	21.54a	22.27a	25.63a	0.33
Mean percentage of pod set	91.03%	71.65%	55.78%		93.86%	82.93%	41.22%	
Mean No. of pods/ plant	22.63a	19.27ab	14.0b	3.95*	20.09a	17.72a	9.72b	4.36*
Mean No. of seeds/pod	74.51a	53.99b	32.11c	26.34**	75.01a	65.69a	29.52b	26.71**
Mean No. of seeds/ plant	1600.36a	1012.54b	460.54c	18.36**	1532.54a	1062.81a	305.27b	10.97**
Mean weight of seeds/ plant (gm)	4.79a	2.98b	1.29c	20.40**	4.61a	3.12a	0.98b	11.48**
Mean weight of 100 seeds (gm)	3.08a	2.94ab	2.82b	2.42*	3.15a	2.94a	2.66a	2.15
Calculated seed yield/ feddan (kg)	1033.90a	656.86b	286.88c	18.57**	1016.12a	688.44a	197.60b	12.15**

Mean weight of seeds/feedan (Kg.)/2 years.

Treatments	Open pollination (Control)		Honey bee pollination		Insect exclusion	
	Weight	Ratio	Weight	Ratio	Weight	Ratio
Seeds yield/feddan	1025.01	----	672.65	65.61%	242.24	23.63%

* : Significant ** : Highly significant Ratio: calculated as control plot 100%
a: Within each column, figures followed by same letter do not differ at 5% level (F- test)
ab: Figures differ at 5% level. C: Figures differ at 5% level

Results obtained in Table (3) revealed that black cumin plants gave the highest significant yield (1033.90 and 1016.12 Kg/Feddan) in the open pollination treatment followed by honeybees alone (656.86 and 688.44 Kg/ Feddan) for two experimental seasons, respectively. Crops prevented from insect pollinators gave the lowest yield (286.88 and 197.60 Kg/Feddan) for 2008 and 2009 seasons, respectively.

According to the collected seed yield from the two tested seasons, honeybee pollination caused 65.61% of the seed yield from the open pollination (control) while, insect exclusion yielded 23.63% of the control (Table 3).

DISCUSSION

It is well known that, the insect pollinators play an important role for improvement the quality and quantity of plant yield. The black cumin plant is one of these plants which affected adversely by the insect pollinators especially it is come in the first class among medical plants. Table (1) show that the most pollinators to the black cumin plants were dipterous insects recoding (2556 &3189 individuals), followed by hymenopterous insects counted (500 &578 individuals), while the minimum number of insects visited the black cumin plants was hemipterous insects (182&198 individuals) during two successive seasons 2008 and 2009. Regarding to the activity of insect pollinators the mean number of insects increased gradually with the abundance of blooming, whereas hemipterous and coleopterous insect pollinators were found in a high numbers at the 9th week of flowering. On the other hand, the 6th week of flowering of black cumin plant attended the maximum activity of both dipterous and hymenopterous insect pollinators. These results were observed during the two seasons of experiments 2008 and 2009. According to the correlation coefficient between the air temperature and mean number of counted insect pollinators, there was a highly positive correlation and negative correlation found with RH%. From daily activity of black cumin insect pollinators results in Table (2) show that the activity of black cumin pollinators beginning at the morning (8 a. m.) and reached to the maximum activity between 12 p.m. and 2 p.m., then the activity decreased till sunset. This time of insect pollinator activities was observed in all recorded insect orders during the two seasons 2008 and 2009. An important aspect used in many pollination studies is the number of visits made by pollinators, Proctor et al. (1996), reported that the flowers of black cumin were visited by butterflies, syrphid flies, beetles and low flies. Also, Ricciardellid and Oddo (1981) and Munawar et al. (2009), mentioned that flowers of *Nigella sativa* were visited by honeybee workers and preferred it instead of other crops in the same time.

From the obtained results, the yield productivity of anise plant affected by insect pollinators and honey bees treatments. As shown in Table (3) open pollination treatment recorded the highest mean number of pods/plant (22.63&20.09) followed by honey bee pollination (19.27&17.72), while the less number of umbels (14.0&9.72) was obtained from insect exclusion plots for two experimental seasons respectively. A significant mean number of seeds/ pod was obtained in open pollination plots (74.51&75.01) followed by honeybee pollination (53.99&65.69) and very low in the other treatment of insect exclusion plots (32.11&29.52) during 2008 and 2009 seasons. According to the weight of 100 seeds the results indicate that no significant differences were found in the most treatments during the two tested seasons. The results were corroborated the findings of Garcia et al. (1998) for melon plants, Nizar and Khairela (2004) and Munawar et al. (2009), for *Nigella sativa* pollination. The mean weight of seeds per feddan considered one of the important roles of pollination treatment on the yield productivity; it was very high in open pollination followed by honey

bee pollination plots, while the insect exclusion plots produced the lowest value for the two tested seasons 2008 and 2009. Similar information has been documented for Cucumber plants (Sajjanar et al. 2004). In Pakistan, Munawar et al. (2009), found that open plot visit of honeybees and other pollinator insects of *Nigella sativa* was significantly yielded seeds different from the caged plants without honeybees. Also, caged plants with honeybees only differed significantly from the caged without honeybees.

The collected seed yield of two tested seasons (Table3) results indicated that insect pollination is very important for high yield crop production and the presence of honeybee colonies is very necessary to ensure adequate pollination. These results are in accordance with those obtained by D' Albore and D' Ambrosio (1979) in Italy and Sihag (1986) in India, they found that open pollinated of coriander plants produce more seeds than those prevented from insect visits. Also, Hussein et al. (1991) reported that the maximum yield of seeds from three tested umbelliferous plants was obtained in case of open pollination followed by honeybee pollination then pollination excluding insects.

Conclusion

Four Orders of insect pollinators were captured by the insect sweep net technique on black cumin, *Nigella sativa* L. plants. These Orders were Hemiptera, Coleoptera, Diptera and Hymenoptera. Most abundant species were related to Orders Diptera and Hymenoptera. Daily peak activity of caught insect species on black cumin flowers was detected at 12 noon and 2 pm in both experimental seasons. Visits of honeybees in black cumin increased the number of seeds set and yield production. Thus strategies to promote pollination by honeybee may be helpful in enhancing seed yield in *N. sativa* and possibly in other related species.

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