

Comparative Study in Seed Yield and Flowers Attractivity to Bee Visitors Between *Nigella Sativa* L. and *Nigella Damascena* L. (*Ranunculaceae*) Grown Under Semiarid Conditions

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Abstract

This experiment was carried out during the growing season 2005 at the campus of Jordan University of Science and Technology (32°22' N, 35°49' E), Jordan. Two different *Nigella* species were used in this experiment; *Nigella sativa* L. and *Nigella damascena* L. This study was aimed to identify the bee visitors of *Nigella* species and the pollination requirements of *Nigella* flowers grown under semiarid conditions. The results showed that flowers of both *Nigella* species were visited by seven different bee visitors. However, flowers of *N. damascena* were more attractive to bees than *N. sativa* flowers. *N. damascena* produced on average significantly higher plant, more number of branches per plant, more seed yield, total seed weight and higher number of capsules per plant. On the other hand, *N. sativa* produced its flowers and matured nearly two weeks earlier than *N. damascena*. There is no interaction between *Nigella* species and pollination treatments for all yield parameter. *N. damascena* was higher in number of ovaries, seeds per capsules, seed set percentage, seeds per plant and total seed weight than *N. sativa* under treatments conditions. Also, flowers of both *Nigella* species under open treatment produced higher yield compared to other pollination treatments.

Key-words: *Nigella sativa*, *Nigella damascena*, pollination, Black cumin, emasculation.

Introduction

Nigella L. (*Ranunculaceae*) includes about 20 species such as (*Nigella sativa* L., *Nigella damascena* L., and *Nigella arvensis* L.). They are widely distributed in Mediterranean regions and West Asia (Hegnauer, 1973). *Nigella* species consumption has increased during last few years especially in Middle East countries; therefore *Nigella* appears to be potential multi-purpose crops of possible interest (Riaz et al., 1996). *Nigella sativa* and *Nigella damascena* are herbaceous plant of annual growth. Both *Nigella* species have determinate flowers, producing hermaphrodite flowers which characterized by the presence of nectariferous petals and the an-

droecium comprises a large number of stamens. While the gynoecium is composed of a variable number of multi-ovule carpels, developing into a follicle after pollination, with single fruits partially connected to form a capsule-like structure with single fruits. *Nigella* seeds are small, rough surface and an oily white interior (Zohary, 1983).

The reduction in flower size and other characters correlated with flower size, plant height and leaf size may be an adaptive response to drought or low pollinator abundance (Strid, 1969; Andersson, 1997; 2003). Pollination plays an important role in flowering plant reproduction and fruit set for plant communities (Cor-

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bet et al., 1991; Buchmann and Nabhan, 1996). The reproductive system of *Nigella* plants is self-pollination with some extent of cross pollination (McGregor, 1976; Elmer, 2004). Moreover, Irregular of yield is a common problem in seed set of *Nigella* cultivated under semiarid conditions, the variations in crop production have been related to pollination failure (Wilcock and Neiland, 2002) or drought effect (Strid, 1969). Some researchers reported that the bees is the main pollinator to most plant flowers in natural and semi-natural condition during flowering stage (Richards, 1986; Buchmann and Nabhan, 1996) and sometimes flies and butterflies (Schneider et al., 1994). The main *Nigella* flower pollinators were honeybees (Ricciardelli and Persano, 1981; Weber, 1992) as well as bumble-bees (*Bombus lucorum*, *Bombus lapidarius*), wasps (*Polistes dominulus*, *Eumenes pedunculatus*, *Cerceris arenaria*, *Philanthus triangulum* and *Ammophila sabulosa*), *Halictus* sp., *Chrysis* sp. and *Lasioglossum* sp. are major flower visitors in Austria (Weber, 1992; 1995). *Colletes punctatus* and *Epeolus fasciatus* in Hungarian (Weber, 1993). The roles of insects in the pollination of *Nigella* and pollination requirements are not yet evaluated. The main objectives from this study were to identify the bee visitors of both *Nigella* species (*Nigella sativa* L., *Nigella damascena* L.) and the pollination requirement of *Nigella* flowers grown under semi-arid conditions.

Materials and methods

Site description

This experiment was carried out during the 2005 growing season in the campus of Jordan University of Science and Technology (JUST), Ramtha (32°22' N, 35°49' E), Northern of Jordan. This area characterized by semiarid Mediterranean climate with of mild rainy (200-250 mm) winters and dry hot summers. The soils used were shallow rocky silt clays.

Plant materials

The seeds were brought from Plant Production Department, Faculty of Agriculture, Jordan University of Science and Technology, Jordan. Seeds of both *N. sativa* and *N. damascena* were planted on the 10th of March 2005 by hand at a common rate. Seeds were sown at 15 cm spaced be-

tween plants within the row and one meter spaced between replication. Granular fertilizers DAP (Diammonium phosphate 18% N and 46% P₂O₅) was added to the soil before planting at a rate of 100 kg ha⁻¹. Plants were planted under rainy condition but to prevent effect of drought on crop during growth plants were irrigated by drip irrigation to maintain 70-90% from field capacity (Rowarth et al., 1997) dependent on tensiometers. Weeds were controlled by hand, when needed.

Pollination studies

Five pollination treatments, open pollination (natural pollination by insects and wind), cross pollinated of caged flowers (emasculated flowers hand pollinated with pollen grains from other plant), self pollinated of caged flowers (emasculated flowers hand pollinated with pollen grains the same flower), open pollinated emasculated flowers (plant with emasculated flowers accessible to naturally occurring insect pollinators) and control or cover pollination (prevent pollination by insects by using a net bag with 1x1-mm mesh size) were used in this experiment. Two *Nigella* species; *N. sativa* and *N. damascena* were used in this experiment. To compare between two species the plant height, branch per plant, number of chambers, capsules per plant, days to flowering and days to harvesting were recorded during the experiment. After maturation of seeds plants were removed from soil, cleaned and seeds manually separated by hand and the number of seeds per capsule, number of seeds per plant and total weight of seeds per plants were recorded.

Bee visitors

Bees were caught by a national park net by sweep netting the bees that had visited the flowers in the transect area. Insect visitors were collected for one day every three days interval between 9:00 and 16:00 during the entire flowering period from May to June. The collected specimens were kept in special storage insect boxes. Voucher specimens of bees are kept in the Laboratory of Beekeeping, Faculty of Agriculture, Jordan University of Science and Technology.

Statistical analysis

The experiment was planned as a split-plot of randomized completely block design (RCBD)

with twelve replicates. Data were analyzed by analysis of variance (ANOVA) using SAS program. Differences between treatments means was separated according to least significant difference LSD at 0.05 probability level.

Results and discussion

Bee visitors

Nigella flowers of both species have pollen and nectar but they were non attractive to bees. During the flowering period, a total of 675 bees were visited *Nigella* flowers. 255 bees were visited *N. sativa* flowers, while 420 bees were visited *N. damascena* flowers as shown in Figure (1). All collected insect specimens were Hymenoptera insects including *Apis mellifera*, *Andrena* spp., *Lasioglossum pauxillum*, *Anthophora albigena*, *Polistes dominulus*, *Bombus terrestris*, *Eucera nigrescens*, *Anthidium undulatum* and *Heriades syriaca*). 66.8% of bee insects were honeybees, followed by *Anthophora albigena* (7%) and *Andrena* sp. (6.9%). *N. damascena* flowers were more attractive in bee numbers (35.7% and 64.3% were visited *N. sativa* and *N. damascena* flowers respectively), and in diversity that *N. sativa* were visited by seven different bee species, while *N. damascena* flowers visited by nine species. The rest of flower visitors were shared in lows numbers which means that their contribution to pollination of the *Nigella* flowers seems to be small and unreliable. The unattractively of *Nigella* flowers to insect visitors could be attributed to quantity and quality of pollen and nectar in the flowers or the flowering of more suitable plant competitors at the same date of *Nigella* flower opening. Furthermore, *N. damascena* flowers attracted more bee numbers and species may be as a result of longer flowering period over *N. sativa* and delayed of flower opening which coincide with the drying of different wild plant species which consider a plant competitor in the field. These results are in agreement with the observations made by Ricciardelli and Persano (1981); Weber, 1992 and Engels et al. (1994), that *Apis mellifera* workers were the main flower visitor of *Nigella* flowers. Furthermore, other bee species such as *Bombus lucorum*, *Bombus lapidarius*, *Polistes dominulus*, *Eumenes pedunculatus*, *Cerceris arenaria*, *Philanthus triangulum*, *Am-*

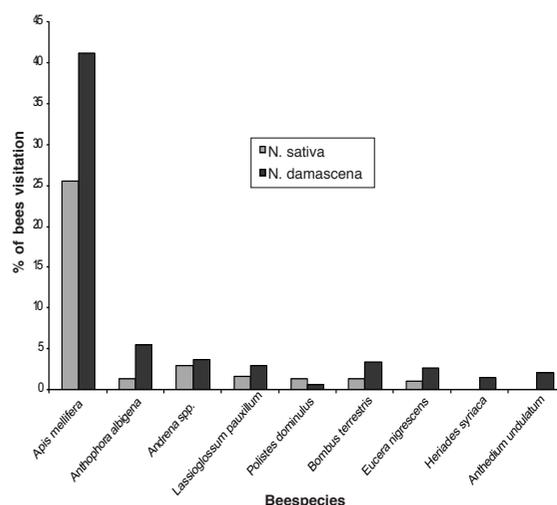


Figure 1. Diversity and visitation frequency of *N. sativa* and *N. damascena* grown under semiarid conditions.

mophila sabulosa, *Halictus* sp., *Chrysis* sp., *Lasioglossum* sp., *Colletes punctatus* and *Epeolus fasciatus* were major flower visitors in Austria and Hungarian (Weber, 1992; 1993; 1995).

The number of visitors is very important in pollination due to increase effective pollinator (Primack and Silander, 1975; Herrera, 1989; Proctor et al., 1996). The unattractively of *Nigella* flowers to wild bees may be attributed to several factors such as the presence of other floral resources. In the present study, *N. sativa* flowering coincided with that of other species such as *Centaurea syriaca* and *Sinapis alba* and *S. arvensis* which are important for apiculture in Jordan due to their abundant nectar and the large floral patches they form throughout the area (Zaitoun and Vorwohl, 2003). Honeybees are important pollinator known in other crops such as pear (*Pyrus* spp.) orchards surrounded by *Sinapis alba* and *Stellaria* spp. this results was found by Stephen (1958). A similar result was found in plum (*Prunus* spp.) and almonds (*Amygdalus communis*) orchards growing next to *Sinapis alba* (Vansell, 1952; Eisikowitch and Lupo, 1989).

Morphological characteristics

Table 1 shows the morphological characteristics of *N. sativa* and *N. damascena* grown under semiarid conditions. *N. damascena* produced on average significantly ($P \leq 0.05$) higher plant (50 cm) and more number of branches per plant (20.7) compared to *N. sativa* (35 cm height and

Table 1. Morphological characteristics of *N. sativa* and *N. damascena* grown under semiarid conditions.

Species	Parameter					
	Plant height (cm)	Branch per plant	No. of chambers	Capsules per plant	Days to flowering	Days to harvesting
<i>N. sativa</i>	35	9.5	5.3	8.5	50	88
<i>N. damascena</i>	50	20.7	5.5	18	68	105
LSD (0.05)	3.7	4.5	0.31	4.3	2.9	3.0

9.5 branches per plant). Moreover, *N. damascena* produced significantly more seed yield per plant and total weight (1386 and 5.6 gm) than *N. sativa* (597 and 2.5 gm per plant). *N. damascena* produced significantly higher number of capsules per plant (18) than *N. sativa* (8.5). Although, the exceptional character was Number of chambers per capsule, that *N. sativa* and *N. damascena* produced on average 5 chambers per capsule. On the other hand, days to flowering and days to harvesting were significant difference between two species at ($P \leq 0.05$). The mean number of days from sowing to start flowering was 50 and 68 days for *N. sativa* and *N. damascena* respectively. This period was extended to 88 and 105 days to harvesting *N. sativa* and *N. damascena* seeds respectively. These results were in agreement with Filippo (2002), who reported that the *N. damascena* longer, more Branch number per plant, capsules per plant, seed yield, total yield, early flowering and harvesting than *N. sativa* grown under Mediterranean condition.

Yield production

Table 2 shows the effects of pollination treatments on number of ovaries, seeds per capsules, seed set percentage, seeds per plant and total seed weight for two species. There is no interaction between *Nigella* species and pollination treatments for all yield parameter. There are significant difference in number of ovaries between species at ($P \leq 0.05$), but not between treatments. *N. damascena* had higher number of ovaries than *N. sativa* which caused an increase in the total seed number of *N. damascena* as compared to *N. sativa*. Significant differences at ($P \leq 0.05$) in seeds number per capsule, total seed number and weight per plant were found among species and pollination treatments. *N. damascena* had greater number of seeds per capsule than *N. sativa* under all pollination treatments. Open pollinated treatment pro-

duced significantly more seeds set per capsule than other treatments in both species. In the present study the high seed set obtained may be attributed to the *N. damascena* had higher number of branches per plant than *N. sativa* and the mild spring conditions and suitable daily temperature which favored the activity of potential insect pollinators. The increased seed set and yield under open-pollinated conditions have been reported in different crops such broad beans (Frusciante and Monti, 1980; Stoddard and Bond, 1987), Lupines (Williams, 1987), Alfalfa (Robinson et al., 1989), Red clover (Osborne et al., 1991) and different other crops listed by McGregor (1976) and Free (1993). These results also indicated that wind did not play an important role for pollination success since the emasculated open pollinated treatment resulted in non seed production compared with the control. Seed-set success is influenced not only by pollination success but also by post-pollination processes such as pollen germination activity, pollen tube growth, and development of fertilized seeds (Stephenson, 1981; Lee, 1988). Variations in the quality of pollen received by flowers have been related to directional movement of pollinators, to the order of development of flowers, (Wyatt, 1982; Nilsson, 1983; Berry and Calvo, 1991; Brunet and Charlesworth, 1995; Brunet, 1996) and to insufficient pollen receipt (Lee, 1988; Berry and Calvo, 1991; Brunet and Chalesworth, 1995). Total seed weight was greatly affected by *Nigella* species and treatments at ($P \leq 0.05$). *N. damascena* had significantly greater seed weight than *N. sativa* as a result of the genetic high number of capsules per plant and the high number of seeds per capsule under all pollinated treatment. The increased seed numbers in open pollinated flowers resulted in the highest total seeds weight than other treatments in both species. Similar results have been obtained with many other species (Holtsford,

Table 2. Effects of pollination treatments on number of ovaries, seeds per capsule, seed set %, seeds per plant and total seed weight (g) of *N. sativa* and *N. damascena* grown under semiarid conditions.

Treatments	Species	Parameter				
		Number of ovaries	Seeds per capsule	Seed set %	Seeds per plant	Total weight (g)
Open pollinated	<i>N. sativa</i>	85	76	89	986	3.4
	<i>N. damascena</i>	140	135	96	2622	9.2
Cross pollinated	<i>N. sativa</i>	84	61	73	579	2.6
	<i>N. damascena</i>	139	103	74	1141	5.9
Self pollinated	<i>N. sativa</i>	83	51	61	569	2.7
	<i>N. damascena</i>	139	88	63	1121	5.4
Emasculated	<i>N. sativa</i>	84	37	44	150	1.0
	<i>N. damascena</i>	140	69	49	732	2.5
Covered/Control	<i>N. sativa</i>	85	50	59	701	2.4
	<i>N. damascena</i>	140	87	62	1314	4.7
Main Effects	<i>N. sativa</i>	84	55	63	597	2.5
	<i>N. damascena</i>	140	97	69	1386	5.6
	Open pollinated	113	105	93	1804	6.3
	Cross pollinated	112	82	73	860	4.2
	Self pollinated	109	70	64	845	4.1
	Emasculated	113	53	47	441	1.8
	Covered/Control	113	69	61	1008	3.6
LSD ¹ (0.05)		7.9	7.4	6.8	274	0.82
LSD ² (0.05)		6.9	9.1	6.5	376	1.2
LSD ³ (0.05)		‡ ns	ns	n.s	n.s	n.s

† ^{1,2}: Fisher's Least Significantly Difference to compare accession means, treatment means, or treatment x accession interaction; ‡ ns: not statistically significant.

1985; Devlin, 1989; Karoly, 1992; Brunet, 1996).

In summary, both *N. sativa* and *N. damascena* are adapted to grow under semiarid conditions with different productivity rate and were visited by a diversity of insect pollinators. In spite of *N. damascena* produced more yield than *N. sativa* under our experimental conditions; it delayed in flowering and maturation which may expose it to drought conditions prevailed in the area.

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