

FLOWERING BIOLOGY, NECTAR SECRETION AND INSECT FORAGING OF THE RUNNER BEAN (*Phaseolus coccineus* L.)

Z b i g n i e w K o ł t o w s k i

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S u m m a r y

In the years 2002-2004 the biology of flowering, nectar secretion and foraging by insects of four runner bean cultivars was investigated at the Apiculture Division, Institute of Pomology and Floriculture in Puławy. Under Poland's condition runner bean starts to bloom towards the end of June and the blooming continues for 33 to 42 days. The flowers of runner bean develop exclusively in the morning, nearly 90% of their daily instalment developing from 5:00 to 7:00, summer daylight-saving time (4:00 to 6:00 Central European time).

Nectar starts to be secreted as soon as the bud stage. The buds to be developed into flowers in the morning to come, at mid-day contain already nearly 10% and in the evening around 36% of the total sugar amount. In the morning, freshly opened flowers contain nearly 70% of the total sugar amount. In runner bean flowers, resorption of sugars that have not been collected by insects starts in the evening but in picked flowers nectar persists on the following day, although in smaller quantity. Runner bean flowers secrete nectar copiously, at a rate of ca. 41 mg of sugars per 10 flowers concentrated at 35 to 45%.

Runner bean is visited mainly by the honeybee and by bumblebees for nectar. In the years of high short-tongued bumblebee populations their workers bite holes in many flowers and the honeybees will rather collect nectar through holes than the normal way. Once bean flowers have been bitten through by bumblebees nearly 70% of the total output of nectar sugars becomes available first of all for the honeybee.

Keywords: *Phaseolus coccineus*, flowering biology, nectar secretion, foraging by bees.

INTRODUCTION

Two bean species are of economic importance in Poland: common bean (*Phaseolus vulgaris* L.) and runner bean (*Phaseolus coccineus* L. = *P. multiflorus* Lam.). The former is a self-pollinated annual that secretes small amounts of nectar and is of negligible importance to beekeepers (Rahman and Patil 1986, Webster et al. 1982). Runner bean, though, is a perennial (in Poland grown as annual), cross-pollinated with large decorative flowers that secrete fairly large amounts of nectar eagerly sought by bee-like insects (Free 1993, Lipiński 1982).

The importance of runner bean as a forage species for bee-like insects has not been the subject of many studies. The data concerning the amount of secreted sugars were to be found only in Polish reports (Jabłoński 1988, Wróblewska 1991). The pollen output was assessed only by Wróblewska (1991). The reported sugar and pollen output data for that species (2 to 6 mg of sugars and 0.3 to 0.8 mg of pollen per flower) put the species on the list of good forage plants. The species also attracts other insects. However, flower morphology and flower size make the plant accessible solely to large bee-like insects such as the honeybee and bumblebees

(Blackwall 1971, Jabłoński 1988, Quagliotti and Marletto 1987, Wróblewska 1991). The role of those insects in the pollination of runner bean was studied repeatedly and their critical importance in fruit set and seed yield was consistently confirmed (Free 1966, Free and Racey 1968, Kendall and Smith 1976, Łabuda 1994, Williams and Free 1975).

At present in Puławy beekeeping value and pollination requirements of the new currently grown runner bean cultivars is being conducted. The process of flower opening, nectar secretion, visitation by insect pollinators, fruit and seed set are being investigated in detail. Some details of interest in connection with the flowering biology and nectar secretion of that species as well as those concerning visitation by pollinating insects are presented in this paper.

MATERIAL AND METHODS

The study was conducted in the years 2002-2004. Four runner bean cultivars: two dwarf cultivars Blanka and Eureka and two dwarf cultivars with short stolons - Felicja and Kontra were investigated. In the last year of the study cv. Westa was included in the set. Each year the experiment was laid out as randomized block design with four replications on a pseudo-

-podzolic soil in Puławy. Plot size was 10 m². The plots were direct-seeded at a spacing of 50 × 30 cm. All crop management recommendations were observed during the growing season (Grudzień 2003).

At blooming hourly records were kept of flower opening and of bee-like insects visiting the plots. In addition, measurements were made of the amount of secreted nectar using the pipette method (Jabłoński 2003). An apiary several colonies strong was always in the immediate vicinity of the site. A weather station was also set up there to provide reference weather data for experiment observations and records.

The data obtained on nectar secretion were subjected to ANOVA. The significance of differences was examined using Duncan's test at $\alpha = 0.05$

RESULTS

Runner bean grown in the experiments flowered towards the end of June/beginning of July, the flowering date being the earliest in 2002 and the latest in 2004. The cultivar-to-cultivar differences in days to flower were small never exceeding 3 days. In the successive years the blooming period was 38-50, 30-36 and 32-40 days, whereat cv. Kontra being the longest-blooming cultivar.

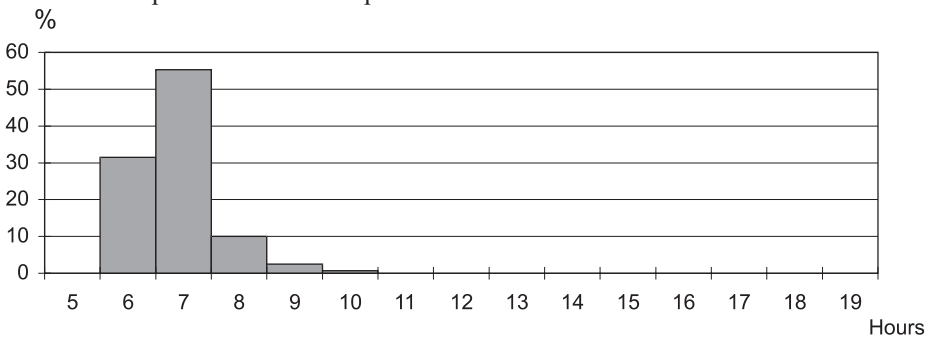


Fig. 1 Diurnal pattern of runner bean flower opening as measured by the counts of flowers opened over successive hours and expressed as the percentage of the total diurnal number of opened flowers

Table 1

The process of accumulation and resorption of nectar in runner bean flowers
(averaged over three measurements)

Flower development stage	Time of flowers and nectar sampling	Nectar weight per 10 flowers (mg)	% sugars in nectar	Sugars weight per 10 flowers (mg)	Sugars weight increment on previous measurement	% of total amount of sugars
Buds to open tomorrow	14:00	14.0	24.5	3.4	3.4	9.7
Buds to open tomorrow	20:00	47.3	26.5	12.6	9.2	35.9
Freshly opened flowers	8:00	71.4	35.8	24.2	11.6	68.9
Flowers that opened today	14:00	94.0	37.3	35.1	10.9	100.0
Flowers that opened this morning	20:00	80.0	35.5	28.5	- 6.6	81.2
Flowers that opened yesterday	8:00	0.0	-	-	-	-

Diurnal pattern of flower opening

As a result of hourly counts of freshly opened flowers in the observation plot it was found that runner bean flowers opened only in the morning. Nearly 90% of the total diurnal number of opened flowers developed from 5:00 to 7:00, summer daylight-saving time (4:00 to 6:00 Central European time). The remaining 10% of the flowers opened by 10:00 (Fig. 1).

Nectar accumulation

In order to collect the entire amount of nectar secreted by a flower of a given species during its lifespan first the process of nectar accumulation in the flowers should be examined. Nectar was found to be secreted already in the buds (Table 1). Flowers to be opened on the following day, the day before at 14:00 contained already 10% of the total amount of secreted sugars. At 20:00, ca. 36% of the total amount of sugars was already in the buds. On the following day in freshly opened flowers there was nearly 70% of the total amount. Sugars concentration of nectar

from the buds was ca. 10 percentage points lower than that from developed flowers in which it oscillated around 35-45% during sunny and warm weather.

The phenomenon of resorption

Nectar in flowers from which was it not collected by insects declined so rapidly overnight that the flowers were dry on the following morning. Nectar resorption was limited to flowers remaining on the plant. Flowers that were picked from the plant and stayed overnight in plastic bags in the morning and well into the noon hours contained ca. 50% of the sugars found upon their collection (Table 2). It indicates frugal assimilate management in runner bean plants.

Abundance of nectar secretion

Runner bean flowers were very copious nectar producers. The average output of 10 flowers was ca. 41 mg of sugars. The difference in nectar secretion rates among years were not large but statistically lower nectar output was confirmed for 2002

Table 2

Nectar persistence in picked flowers (average of six samples)

Flowers examined	Nectar sampling time	Nectar weight per 10 flowers (mg)	% sugars in nectar	Sugars weight per 10 flowers (mg)	Sugars weight decrease on previous measurement
on having been picked	17:00	87.8	40.7	35.7	-
on the following day	13:00	99.0	17.6	17.4	18.3

(Table 3). Among the cultivars cv. Kontra consistently produced the greatest amounts of nectar, whilst cv. Eureka was found to be statistically inferior in that respect.

No major differences were found in sugars concentration of nectar which averaged from 35 to 45%.

Foraging of runner bean flowers by insects

Flowers of runner bean were visited mainly by honeybees and bumblebees (buff-tailed bumblebee - *Bombus terrestris*, common ginger bumblebee - *B. pascuorum* and large red-tailed bumblebee - *B. lapidarius*) and, occasionally by solitary bees, various butterflies and dipterans (Table 4). In the first and the last year of study the honeybee was by far the

prevalent species (over 85% of all insects recorded in the field). Instead, in 2003 bumblebees were the most frequent visitors of runner bean flowers.

Biting through the flowers

In the second year the proportion of bumblebees in the total number of insects visiting runner bean plants was very high (over 50%) and, because of that, they drew little benefit thereof, especially the short-tongued bumblebees. After 2 weeks from the onset of blooming bumblebees biting through the flowers and honeybees using the holes made by bumblebees were observed. Counts of honeybees and of bumblebees gathering nectar through the holes were started and, at the same time, counting of solitary bees, butterflies and

Table 3

Abundance of nectar secretion by runner bean cultivars

Cultivar	Sugars weight per 10 flowers (mg)			
	Year 2002	Year 2003	Year 2004	Average
Blanka	38.08 bc	40.17 c	41.80 cd	40.02 b
Eureka	29.77 a	40.70 c	37.52 bc	36.00 a
Felicja	34.33 b	41.13 c	40.73 c	38.74 b
Kontra	45.47 d	51.83 e	49.29 e	48.86 c
Westa	-	-	43.95 *	43.95
Average	36.92 a	43.46 b	42.34 b	40.91

* - data for that cultivar were not included in ANOVA and mean value calculations

Table 4

Percentages of different insect groups visiting runner bean flowers

Insect group	Percentage		
	Year 2002	Year 2003	Year 2004
honeybees	85.5	32.9	94.2
bumblebees	8.2	51.4	4.6
solitary bees	1.2	0.6	0.5
butterflies	4.6	3.1	0.6
dipterans	0.5	12.0	0.1
Total	100.0	100.0	100.0

dipterans was discarded because of their relatively small numbers. Starting from that moment all flowers freely accessible to insects were bitten through by the buff-tailed bumblebee (*B. terrestris*). As is seen in Table 5 honeybees were by far more disposed to gather nectar through holes than the normal way.

In the final year few bumblebees biting through the flowers made their appearance also halfway through the blooming season but they were very sporadic. Flowers with the holes in the calyx were scarce and as few as 6% of honeybee foragers accessed the flowers through the holes bitten by the bumblebees. The remaining 94% of the bees gathered nectar the normal way pollinating flowers in the process.

It must be added that making holes in

the calices does not cause injury to the pistil and the flowers are capable of setting pods and seeds provided they have been previously visited by an insect that will leave pollen grains on the stigma.

Availability of nectar in bitten flowers

It was examined how much nectar is made available to other short-tongued insects by bumblebees biting through the flowers. Obviously, it depends on the development stage at which the flower was bitten. On average, after the buds were bitten through as much as nearly 70% of the total amount of sugars secreted as nectar were still available to insects (Table 6).

It bears out previously obtained results according to which it is already in the bud that more than 30% of the total output of sugars is secreted.

Table 5

Percentages of different insect groups visiting runner bean in the second part of the blooming season of 2003

Insect group	Percentage
Honeybees foraging the normal way	9.3
Honeybees foraging through the holes	46.5
Bumblebees foraging the normal way	7.5
Bumblebees biting through and foraging through the holes	36.7
Total	100.0

Table 6

Sugar weights in flowers developed from bitten vs. intact buds

Sample no.	Sugars weight per 10 flowers (mg)		Percentage of sugars made available
	Flowers developed from intact flowers	Flowers developed from bitten flowers	
1	44.20	34.57	78.2
2	25.33	15.60	61.6
3	28.50	19.20	67.4
4	29.67	19.03	64.1
Average	31.93	22.10	69.2

DISCUSSION

Some of the results from this study can be compared with those reported by other investigators. Time and duration of blooming is best compared with the records provided by Polish investigators because of similarity in climate conditions. Our records of the last days of June as the blooming onset time for runner bean closely agree with blooming dates reported by Wróblewska (1991, 1994) but are slightly earlier than the data by Jabłoński (1988) according to whom runner bean flowered as late as around 20th July. Obviously, variable weather conditions during the seasons under comparison exerted their influence. Greater differences were recorded for blooming duration because the present cultivars bloom for a much shorter time than old-line cultivars which was pointed out by Wróblewska (1994) as she found breeding lines to have a blooming period shorter by ca. two weeks than the local populations.

The diurnal flower opening pattern of runner bean as well as the data on early nectar secretion in buds fully corroborate the observations made by Jabłoński (1988) who recorded freshly opened flowers to occur only by 7:00 and the flowers already contained 30% of the total output of nectar sugars. The researcher stated

further that the nectar was resorbed by the plant before flower corollas were shed which was also confirmed in this study.

Data on abundance of nectar secretion by runner bean flowers which, averaged across three study years and four cultivars, was 41 mg sugars per 10 flowers are higher than those by Wróblewska (19-28 mg) but lower than the data by Jabłoński (64 mg). Plausibly, it can be accounted for by the genetic diversity of the material (different cultivars) but also by different soil and climate conditions of the experiments involved.

A fairly large variability was found in the percentage of different insect pollinator groups as well as in the manner in which the flowers were foraged upon over the successive years of the study. The percentage of the honeybee in relation to total number of insects varied from 33 to 94%. The literature data are also very inconsistent. However, all agree that bumblebees and honeybees are the main runner bean pollinators. Wróblewska (1991) states that honeybees were the chief foragers during her study of runner bean. Instead, Quagliotti and Marletto (1987) set the proportion of honeybees at 50 to 64%. Blackwall (1971) presents his results concerning the effectiveness of runner bean pollination by introducing the

division into two groups depending on the size of bumblebee population: a year with high population and a year with a negligible percentage of bumblebees. So there is no doubt that such discrepancies among years are normal and difficult to predict. What is important is that both honeybees and bumblebees foraging on runner bean flowers the normal way are equally effective as pollinators during their first visit which was found by Kendall and Smith (1976). All mentioned foreign investigators as well as Jabłoński (1988) described biting through flowers by short-tongued bumblebees. The biting-through alone does not exclude good pollination. The bitten flower can set fruits and yield seeds provided it is pollinated by an insect. However, in the years of massive appearance of hole-making bumblebees a slight reduction in the yields of runner bean was observed.

CONCLUSIONS

Under Poland's conditions runner bean starts to bloom at the end of June/beginning of July and blooms for 33 to 42 days, on the average.

Runner bean flowers open only in the morning, from 5:00 to 7:00 daylight saving-time (4:00 to 6:00 Central-Eastern European time) opening nearly 90% of their total diurnal instalment.

Nectar secretion starts already in buds. The buds that are to develop into flowers in the morning to come, at mid-day the previous day contain already nearly 10% and in the evening around 36% of the total sugars amount. In the morning, freshly opened flowers contain nearly 70% of the total sugars amount.

In runner bean flowers, resorption of sugars that have not been collected by insects starts in the evening but in picked flowers nectar persists on the following day, although in smaller quantity.

Runner bean flowers secrete nectar copiously, at a rate of ca. 41 mg of sugars per 10 flowers concentrated at 35 to 45%.

Runner bean is visited mainly by the honeybee and by bumblebees for nectar. In the years of high short-tongued bumblebee populations their workers bite holes in many flowers and the honeybees will rather collect nectar through holes than the normal way.

Once bean flowers have been bitten through by bumblebees nearly 70% of the total output of nectar sugars becomes available first of all for the honeybee.

REFERENCES

- Blackwall F.L.C. (1971)- A study of the plant/insect relationships and pod-setting in the runner bean (*Phaseolus multiflorus*). *J. Hort. Sci.*, 46:365-379.
- Free J.B. (1966)- The pollination of the beans *Phaseolus multiflorus* and *Phaseolus vulgaris* by honeybees. *J. Apic. Res.* 5(2):87-91.
- Free J.B. (1993)- Insect pollination of crops. 2nd edition, *Acad. Press*, London-New York, :263-270.
- Free J.B., Racey P.A. (1968)- The pollination of runner beans (*Phaseolus multiflorus*) in a glasshouse. *J. Apic. Res.* 7(2):67-69.
- Grudzień K. (2003)- Fasola na suche ziarno. [Bean for dry grain]. *Działkowiec* 633:48-49.
- Jabłoński B. (1988)- Nektarowanie i wydajność miodowa fasoli wielokwiatowej. [Nectar secretion and honey potential of runner bean]. *Pszczelarstwo* 39(8-9):8-10.
- Jabłoński B. (2003)- Metodyka badań obfitości nektarowania kwiatów i oceny miododajności roślin. [The investigation methods to nectar secretion of flowers and estimation of honey output of plants]. *Instytut Sadownictwa i Kwiaciarnictwa*, Skierniewice 2003, 30 s.
- Kendall D.A., Smith B.D. (1976)- The pollinating efficiency of honeybee and bumblebee visits to flowers of the runner bean *Phaseolus coccineus* L. *J. Appl. Ecol.* 13(3):749-752.

- Lipiński M. (1982)- Pożytki pszczele i miododajność roślin. [Honey pastures and honey output of plants] Wyd. III. PWRiL, Warszawa, :277.
- Łabuda H. (1994)- Biologia kwitnienia i plonowanie fasoli wielokwiatowej (*Phaseolus coccineus* L.). Cz. II. Czynniki warunkujące plonowanie. [Flowering biology and yielding of runner bean (*Phaseolus coccineus* L.). Part II. The yield factors]. *Mat. Ogólnopolskiej Konferencji Naukowej „Strączkowe rośliny białkowe”* s.:36-44.
- Quagliotti L., Marletto F. (1987)- Research on the pollination of runner bean (*Phaseolus coccineus* L.) for dry grain production. *Advances in Hort. Sci.* 1:43-49.
- Rahman S.A., Patil G.V. (1986)- Floral biology and insect visitors in relation to the fruit set in *Phaseolus vulgaris* L. and *Phaseolus mungo* L. *Proceedings of the National Academy of Sciences of India*, B 56(4):378-380.
- Webster B.D., Ross R.M., Evans T. (1982)- Nectar and the nectary of *Phaseolus vulgaris* L. *J. of the Am. Society for Hort. Sci.* 107(3):497-503.
- Williams I.H., Free J.B. (1975)- The pollination and set of the early flowers of runner bean (*Phaseolus multiflorus* L.). *J. Hort. Sci.*, 50:405-413.
- Wróblewska A. (1991)- Attractiveness of *Phaseolus* L. flowers for pollinating insects. *Acta Horticulturae*, 288:321-325.
- Wróblewska A. (1994)- Biologia kwitnienia i plonowanie fasoli wielokwiatowej (*Phaseolus coccineus* L.). Cz. I. Biologia i obfitość kwitnienia. [Flowering biology and yielding of runner bean (*Phaseolus coccineus* L.). Part I. Biology and abundance of blooming]. *Mat. Ogólnopolskiej Konferencji Naukowej „Strączkowe rośliny białkowe”* s.:29-35.

BIOLOGIA KWITNIENIA, NEKTAROWANIE I OBLÓT PRZEZ OWADY FASOLI WIELOKWIATOWEJ (*Phaseolus coccineus* L.)

K o ł t o w s k i Z .

S t r e s z c z e n i e

W latach 2002-2004 w Oddziale Pszczelnictwa ISK w Puławach badano biologię kwitnienia, nektarowanie i oblot przez owady zapylające czterech odmian fasoli wielokwiatowej. W warunkach Polski zakwita ona na przełomie czerwca i lipca i kwitnie średnio od 33 do 42 dni. Kwiaty fasoli wielokwiatowej rozkwitają tylko rano, a od godziny 5⁰⁰ do godziny 7⁰⁰ czasu letniego (4⁰⁰-6⁰⁰ czasu środkowoeuropejskiego) rozkwita prawie 90% całodobowej ich porcji.

Nektar zaczyna wydzielać się już w pąkach. Pąki mające rozkwitać jutro rano, w południe zawierają już prawie 10% całkowitej ilości wydzielanych cukrów, wieczorem zaś już około 36%, natomiast świeżo rozkwitłe kwiaty rankiem dnia następnego prawie 70% całkowitej ich ilości. W kwiatach fasoli wielokwiatowej wieczorem rozpoczyna się zjawisko resorpcji nektaru nie pobranego przez owady, ale w kwiatach zerwanych nektar utrzymuje się jeszcze w dniu następnym, choć w mniejszej ilości. Kwiaty fasoli wielokwiatowej nektarują bardzo obficie, wydzielając średnio około 41 mg cukrów z 10 kwiatów o koncentracji od 35 do 45%.

Fasolę wielokwiatową odwiedzają głównie pszczoły miodne i trzmielce dla zbioru nektaru. W latach o większej liczbie trzmieli krótkojęzyczkowych robotnice ich przegryzają wiele kwiatów, a pszczoły miodne chętniej zbierają nektar przez otwory niż drogą normalną. Po przegryzieniu kwiatów fasoli wielokwiatowej przez trzmielce prawie 70% całkowitej ilości wydzielanych w nektarze cukrów staje się dostępne przede wszystkim dla pszczoły miodnej.

Słowa kluczowe: fasola wielokwiatowa, biologia kwitnienia, nektarowanie, oblot przez owady.