Economics of agriculture
SI – 2
UDK: 595.799:581.162.3

BUMBLEBEE COST-EFFECTIVENESS FOR SUNFLOWER POLLINATION IN ISOLATION CAGES

Sreten Terzić[1], *Vladimir Miklič, Jovanka Atlagić, Siniša Jocić, Ana Marjanović Jeromela, Boško Dedić*

Abstract

The lack of pollinators during sunflower seed production in isolation cages can lower the seed yield up to 90%. That is why we analyzed the cost-effectiveness of bumblebee usage as pollinators. Usual inbred line combinations for seed production were sown and efficiency of hand pollination was compared to open pollination and bumblebee pollination.

Bumblebees and honeybees were more efficient than hand pollination. Their constant presence during the whole flowering period led to better pollination conditions which reflected on increased seed yield. If pollination cost is compared per obtained kg of seed, than honeybees with 74 rsd/kg seem to be the best choice but not realistic because their colonies are too big for cages. Bumblebee colonies (694 rsd/kg) were as productive as open pollination but they were also twice as expensive in comparison to hand pollination (320 rsd/kg). Hand pollination impose as the best pollination method for sunflower under isolation cages, while in the cases when there is a lack of workers or the seed yield is of absolute importance bumblebees represent a good alternative.
Key words*: bumblebees, honeybees, isolation, pollination, sunflower*

Introduction

Sunflower is an open pollinated plant species originating from North America. After it was introduced to Europe in the XVI century, it was first used for ornamental porpoises and later recognized as an oil plant in Russia where the first sunflower cultivars were obtained at the end of the XIX century (Heiser, 1976). The main objective of

1 Ph.d Sreten Terzić, Research Assistant, Ph.D Vladimir Miklič, Senior Research Associate, Ph.d Jovanka Atlagić, Principal Research Fellow, Ph.D Siniša Jocić, Senior Research Associate, Ph.d Ana Marjanović Jeromela, Research Associate, MSc Boško Dedić, Research Trainee. Institute of Field and Vegetable Crops, Maksima Gorkog Street 30, 21000 Novi Sad
Corresponding author: Ph.d Sreten Terzić, 0214898415, e-mail: sreten.terzic@ifvcns.ns.ac.rs

breeding and obtaining cultivars was the increase of seed oil content. After the discovery of cytoplasmatic male sterility (CMS) the usage of heterosis and creation of hybrid sunflower was possible (Leclercq, 1969). Direct crosses of two or three inbred lines are used to produce a two- or three way sunflower hybrids. Large number of hybrids and therefore of inbred lines is needed because hybrids have narrow genetic base and different hybrids are needed for different agro ecological conditions (Škorić, 1988).

The need to create large number of sunflower hybrids and inbred lines directly increases pollination expenses because pollination is usually done manually in isolation cages. Although cultivated sunflower tolerates self-pollination quite good, in seed production under isolation cages the lack of pollinators can lead to a decrease in yield of up to 90% considering that CMS lines are involved (Špehar et all, 1986). That is why the usage of honeybees is recommended for seed production on larger areas in space isolation. That is both economically a good pollination method if the interest of honeybee growers is taken into consideration through bee hive renting, production of honey and increased sunflower yield.

The usage of isolation cages is frequent in breeding programs for selection and seed multiplication because the first stages of selection for new inbred lines is usually done with small number of plants. They cover relatively small area (30-50m^2) which in combination with reduced air circulation and increased air temperature can lead to conditions that are not suitable for a newly formed honeybee colony with only a few thousand workers. That is why the pollination is usually done by hand which has it's own advantages and disadvantages. The advantage of hand pollination is that if there comes to a mismatch of flowering period between the mother line and the line of father/ fertility restorer, the workers can store the pollen on +4C° and keep it that way till the mother line starts flowering. The disadvantage of hand pollination is the possibility of uncontrolled crosses because the same workers are entering isolation cages with different hybrid combinations and the pollen can unintentionally be carried to another cage.

That is why a project was conceived with the aim to analyze the bumblebees cost effectiveness for pollination in isolation cages, because their colonies are more suitable by size for pollination in cages than honeybees.

Materials and methods

To test the effectiveness of several pollination methods a trial was planned with combinations of inbred lines that are usually sown in the cages for seed production. The sown material included mother lines in sterile (CMS) and fertile form (B analogues) and fertility restorers for three commercial sunflower hybrids: Rimi (cages 1 and 2), NS-H-2023 (cages 3 and 4) and NS-H-2026 (cages 5 and 6). Each cage covered area of 48 square meters in which there were sown eight rows with 50 plants per row. Plants were irrigated using drip irrigation system.

Two middle rows were fertile inbred lines and the rest were sterile. Two cross combinations were sown per hybrid to determine if there were any differences in

the time needed for pollination of all the inflorescences in the mother line. The first combination included CMS line and a B analogue and the other a CMS line and a fertility restorer. Sawing time was planned for each genotype so that the flowering period is approximately the same.

The cages were used to compare the efficiency of hand- and bumblebee pollination. Out of the cages open pollination was used as a control. Normally present insects were found during flowering period in open pollination and honeybees made more than 75% of them. Honeybees were not brought to the trial on porpoise, but their presence was assured by the proximity of local honeybee keepers who in the same period had about 30 hives in less than 2 km from the trial. Bumblebee hives were brought in to the cages as ready hives with about 80 workers (Koppert – Natupol N hives). Seed yield was weighed on five inflorescences per cross combination and used as a base to calculate the total yield of 300 sterile mother plants. The time that workers spent in the cages was noted separately for every entry.

Results and discussion

Restorer lines (Rha-168, Rha-ses and Rha-ses-imi) are branched and they flower longer (in this trial 19-24 days) than CMS lines (HA-98-A, OCMS-74-A and HA-26-imi-A, 10-15 days). To make sure that flowering periods overlap, and because of shorter vegetative phase, CMS lines were sown 25 days after the restorer lines. Flowering periods overlapped in all six cages so that the bumblebees could transfer pollen and perform the pollination. The peak of flowering (75%) for all lines in open pollination occurred during the flowering period of isolated plants except for the line HA-98-A which flowered earlier than in the cage 2 (Table 1.). Longer flowering period of fertility restorers (Rha) in comparison to the mother lines (A and B) led to earlier sawing of sterile mother lines in cages 2, 4 and 6 (Table 1.).

Workers entered the cages six to ten times to perform the pollination and on average they spent inside 1,24 h or 75 minutes (Table 2.). Periods in which the workers performed pollination were almost twice as short than the periods which bumblebees had available for pollination if total pollination is analyzed in days (Table 2.).

Table 1. Sawing date, flowering duration in cages and the date when 75% of inflorescences flowered in open pollination for sown genotypes

Cage number:	Genotype	Sowing date	Flowering period in cages				Date of 75% flowering in open pollination
			Start	End	Duration (days)		
1.	HA-98-A	15.4.	2.7.	16.7.	14		10.7.
	HA-98-B	15.4.	2.7.	16.7.	14		10.7.
2.	HA-98-A	10.5.	18.7.	30.7.	12		13.7.
	Rha-168	**15.4.**	**8.7.**	**2.8.**	**24**		**10.7.**
3.	OCMS-74-A	15.4.	2.7.	14.7.	12		9.7.
	OCMS-74-B	15.4.	2.7.	14.7.	12		9.7.
4.	OCMS-74-A	10.5.	14.7.	29.7.	15		16.7.
	Rha-ses	**15.4.**	**13.7.**	**3.8.**	**20**		**15.7.**
5.	HA-26-imi-A	15.4.	2.7.	16.7.	14		9.7.
	HA-26-imi-B	15.4.	2.7.	16.7.	14		9.7.
6.	HA-26-imi-A	10.5.	19.7.	29.7.	10		21.7.
	Rha-ses-imi	**15.4.**	**13.7.**	**2.8.**	**19**		**16.7.**

Table 2. Periods in which the pollination was performed and the entry frequency of workers to cages

	Hand pollination						Bumblebee pollination		
Cage number:	Number of entries to cages	Total work hours in the cages (h)	Pollination start	Pollination end	Pollination duration (days)		Hive placed in the cage	Hive removed	Pollination duration (days)
1.	9	10	3.7.	16.7.	**13**		28.6.	26.7.	**28**
2.	9	14,5	14.7.	3.8.	**19**		4.7.	13.8.	**39**
3.	10	12	30.6.	16.7.	**16**		28.6.	26.7.	**28**
4.	10	11,8	14.7.	2.8.	**18**		4.7.	13.8.	**39**
5.	6	6,5	9.7.	17.7.	**8**		28.6.	26.7.	**28**
6.	8	8,9	14.7.	3.8.	**19**		4.7.	13.8.	**28**

For increased efficiency, workers first enter the isolation cages only when 10-20% of plants have started flowering, or in other words, when there is enough pollen produced on the fertile analogue (B) for pollination. Likewise, they end the pollination before all plants finish flowering because the seeds from the central part of the inflorescence are smaller than the ones from the periphery and combined with lower

number, have somewhat smaller impact on yield. Hand pollination can basically be derived to two visits of workers to the same inflorescence because of gradual flowering. In that way the pollen is applied on over 75% of inflorescence surface. First bumblebee hives were put in to the cages 1, 3 and 5 on the beginning of flowering on June 28th while the rest of the hives were fed with pollen till they were placed in the remaining cages on July 4th (Table 2.). Hives were placed in the cages on the beginning of flowering and removed after the last branches on fertility restorers finished flowering. That is why the number of days in which bumblebees performed pollination was 28 to 39 (Table 2.). That is not really needed because the sterile mother lines finished flowering after about 14 days. Having in mind that the working life of one bumblebee colony type Natupol N is about 8 weeks, one hive could be used in at least two cages with a pause in between in which the bumblebees would spend their pollen reserves from the previous cage.

To determine the cost effectiveness of various pollination methods, we first ascertained the cost per cage surface, and than by kilogram of obtained seed. Bumblebee hives type Natupol N are available from Kopert on the Serbian market at the price of 6.600 rsd each (Price confirmed on July 21st 2010). Because of constant fluctuation and differences in salaries in various companies, the salary of the worker performing pollination was presented as average gross income in the Republic of Serbia for May 2010. According to the Statistical office of the republic of Serbia it was 46.454 rsd (RSO, internet source). When honeybees are used on sunflower fields for pollination it is advised to place two to three hives per hectare (Anfinrud et. al, 1997) and according to the Serbian federation of beekeeping organizations (SFBO) the compensation per hive is approximately 630 rsd for the year 2010. and it is meant for the service of pollination in one locality during 15 to 20 days (SFBO, internet source).

Workers spent in the cages a total of 63,7 working hours while pollinating which is 8 working days. When calculated in rsd, the cost of hand pollination for all six cages was 16.900 rsd. For bumblebee pollination the cost of hive acquisition was 6 x 6.600 rsd which is in total 39.600 rsd. Honeybees were used in the trial as another pollinating method for comparison even though the crosses they made were performed in open pollination. In that case, pollen from other sunflower lines and hybrids was also present and it's availability probably increased overall seed yield. If we assumed that an ideal quantity of honeybees is 2,5 hives per hectare than a hypothetical cost for pollination of six cages (48m^2 each) would be 6 x 0,0048ha x 2,5 hives x 630 rsd which is in total 45,6 rsd. However, one can not place less than one hive per cage and the compensation for those hives would be far greater because of high honeybee mortality due to cramped space. The calculation including honeybee mortality leads to a figure starting at 6000 rsd for six cages.

When effeciency is analysed a conclusion can be made that pollination by bumblebees and honeybees were better than hand pollination. Their constant presence during whole flowering period directly led to better pollination conditions which reflected on seed yield. If the pollination cost is divided with obtained yield a clear comparison of cost effectiveness for the three used pollination methods can be made (Tables 3. and 4.).

Table 3. Sunflower seed yield on sterile lines and a pollination cost calculation per obtained kilogram of seed

Cage number:	Cross combination	Bumble bees	Hand		Bumble bees	Hand
		(Kg)*			(rsd./kg)	
1.	HA-98-A HA-98-B	5,62	10,89		1174,3	242,4
2.	HA-98-A Rha-168	9,20	7,79		717,4	491,3
3.	OCMS-74-A OCMS-74-B	9,69	9,37		681,1	338,0
4.	OCMS-74-A Rha-ses	13,69	11,64		482,1	267,6
5.	HA-26-imi-A HA-26-imi-B	9,98	5,11		661,3	335,7
6.	HA-26-imi-A Rha-ses-imi	14,74	9,72		447,8	241,7
	Average	**10,49**	**9,09**		**694,0**	**319,5**

** Least significant difference (LSD) for seed yield at 0,05 level = 1,93 kg*

Table 4. Sunflower seed yield on sterile lines and a pollination cost calculation per obtained kilogram of seed

CMS line	Yield (Kg)*	Pollination cost with one hive per cage (rsd./kg)	Pollination cost for honeybees out of the cages (rsd./kg)
HA-98-A	10,81	92,5	0,7
OCMS-74-A	15,40	64,9	0,5
HA-26-imi-A	15,40	64,9	0,5
Average	**13,87**	**74,1**	**0,6**

**LSD for seed yield at 0,05 level = 1,93 kg*

Large seed yield difference between specific cross combinations like HA-26-imi-A x HA-26-imi-B could not be only a result of higher bumblebee effeciency in comparison to hand pollination (Table 3.), but also a result of open pollination where the sterile mother lines were available for crossing with other present fertile genotypes and insects (Table 4).

Even though honeybees seem to be the best choice they are not a realistic one because their colonies are far too big for such small cages. Bumblebee colonies fitted the size of the used cages and provided seed yield that is significantly higher than from hand pollination and on the level with open pollination (Tables 3. and 4.). Bumblebees in comparison to honeybees start foraging on lower temperatures, their working hours are 50% longer and they finish a flower in shorter time (Corbet et al. 1993). Limiting

factor for bumblebee usage is the buying price which could be lowered two to three times indirectly through better seed production planning. By reusing the same colony in two cages, buying price would be similar to the cost of hand pollination.

Hand pollination imposes it self as the best of the three studied pollination methods for sunflower under isolation cages. Although in circumstances of worker shortage, exclusion of the possibility for uncontrolled crosses or the necessity of high seed yield, bumblebees are a good alternative.

References

1. Anfinrud, M.N., (1997): Seed production procedures. In: AA. Schneiter et al., (ed.) Sunflower Technology and Production. Agron. Monogr. 35. ASA, CSSA and SSSA, Medison, WI, pp. 697-708.

2. Corbet, S.A., Fussel, M., Ake, R., Fraser, A., Gunson, C, Savage, A., Smith, K., (1993): Temperature and the pollinating activity of social bees. Ecological Entomology, 18, pp. 17 -30.

3. Heiser, Ch.B., (1976): The sunflower. University Oklahoma Press, Norman.

4. Koppert (2010): Online product description. [Електронски извор]. [1 стр.] доступно на адреси http://www.koppert.com/pollination/seed-crops/crops/detail/natupol-beehive/

5. Leclercq, P., (1969): Une sterilite cytoplasmique chez le tournesol. Ann. Amelior. Plantes, 19: 99-106.

6. Republički zavod za statistiku (2010): Prosečne zarade po zaposlenom u Srbiji, u maju 2010. godine Objavljeno: 25.06.2010. [Elektronski izvor]. [1 str.] dostupno na adresi

http://webrzs.stat.gov.rs/axd/index1.php?SifraVesti=423&Link=

7. Savez pčelarskih organizacija Srbije (2010): Forum SPOS info [Elektronski izvor]. [1 str.] dostupno na adresi

http://spos.info/forum/index.php?action=printpage;topic=5762.0

8. Škorić, D., (1988): Inside sunflower breeding. Uljarstvo. Vol.25, br.1: 9-48.

9. Špehar, M., Radaković, Anka, Tomljenović, M., (1986): Uloga pčele medarice u polinaciji suncokreta i uljane repice u uvjetima Slavonije11-18. . Nauka u proizvodnji, 14, (1-2):