NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 31, 2014
Print ISSN 1222-4227; Online ISSN 2067-5720

THE SEED YIELD POTENTIAL OF CAMELIA – FIRST ROMANIAN CULTIVAR OF CAMELINA (*CAMELINA SATIVA* L. CRANTZ)

Ion Toncea

Research, Innovation and Technical Assistance Center for Organic Farming,
National Agricultural Research and Development Institute, Fundulea 915200, Calarasi County, Romania.
E-mail: toncea@ricic.ro

ABSTRACT

Camelia was registered in Romania as camelina (*Camelina sativa* L. Crantz*)* cultivar in 2011, but camelina seeds have been found in archaeological excavations from the transition Eneolithic to Bronze Age in different Romanian localities. "Inisor" and "lubit" are the Romanian popular common names for the camelina.

As a crop, camelina was recently grown in Romania, when ARTEGO Târgu Jiu used its seeds, oil and meal in regeneration rubber composition and the EU project ITAKA to support the use of sustainable biofuels in aviation was launched. A five year (2009-2013) yield trial in organic farming and a three year (2008-2010) yield trial in conventional farming established that camelina is a suitable crop to grow in Romania, producing in the best years, on the average, 1,231 kg ha seeds in organic farming and 2,427 kg seeds ha^{-1} in low input farming. The sowing time had a large effect on camelina seed yield in organic farming, ranging from simple to double, in the 683-1,502 kg ha^{-1} range in the late autumn, and from simple to six fold, in the 270-1,682 kg ha^{-1} range at early spring. A good yield potential was estimated in newly developed Camelia versatile cultivar – 1,682 kg ha^{-1} in organic farming and 2,829 kg ha^{-1} in low input farming. The hectolitre weight of Camelia ranged 66-69 kg hl^{-1} in autumn sowing time and 61-66 kg hl^{-1} in early spring sowing time.

Key words: *Camelina sativa* L. Crantz, yield potential, hectolitre weight, organic farming, low input, sowing time, cultivar.

INTRODUCTION

Camelia was registered in Romania as camelina (*Camelina sativa* L. Crantz*)* cultivar in 2011 (SIVTR, 2012), but camelina seeds were found in archaeological excavations from the transition Eneolithic to Bronze Age in different Romanian localities (Carciumaru, 2007). *Camelina sativa* L. Crantz is known in Romania under popular name of inişor or lubiț(a) (Ciocîrlan et al., 1975; Zamfirescu et al., 1958).

In context of improving harvesting equipments for crops with very small seeds, of growing demand for high edible oils rich in Omega-3 fatty acids and of approving commercial use of camelina fuel, the interest in *Camelina sativa* is increasing everywhere.

As crop, camelina was recently grown in Romania when, in 2011, ARTEGO Târgu Jiu used camelina seeds, oil and meal in regeneration rubber composition (David et al., 2011) and in 2012 the EU project ITAKA to support the use of sustainable biofuels in aviation was launched (ITAKA, 2012).

Many studies have demonstrated that camelina's yield potential is comparable with spring oilseed rape (Crowley and Fröhlich, 1998) and similar to that of many other *Cruciferae* (Putnam et al., 1993), but this potential remains unexploited (Ehrensing and Guy, 2008) and can be improved significantly through plant breeding and improved agronomic practices (Putnam et al., 1993).

The objective of the present study was to determine the effects of organic and low input farming systems, sowing time and ecosystem on the seed yield of 3 camelina genotypes, including Camelia, first Romanian camelina cultivar.

MATERIAL AND METHODS

A yield trial was set up from 2009 to 2013 with two sowing time: late autumn (29.10.2008, 24.11.2009, 01.11.2010,

Received 01 August 2013; accepted 03 February 2014. First online: 15 April, 2014. DII 2067-5720 RAR 2014-391

01.11.2011, 15.11.2012) and early spring (24.03.2009, 02.04.2010, 15.03.2011, 26.03.2012, 18.03.2013) and three camelina cultivars: Camelia registered in Romania, Calena, registered in Austria and Lindo, registered in Germany. The trial was placed in the field of Research, Innovation and Technical Assistance Center for Organic Farming of NARDI Fundulea ($44^0$30'N latitude, 68 m altitude, 10.5 ^{0}C mean air temperature and 571 mm rainfall), which belong to Romanian Plain ecosystem, in the split-plot system with three replication and 12 m^2 (1.5 x 8 m) plot size. The soil was chernozem, a loam textured type and no fertilizers, herbicides, fungicides or insecticides were used. Camelia and Lindo cultivars were tested in low input farming system too. Testing was carried on 3 years (2008-2010) in fields of 4 testing centres (Dej, Dilga, Mircea Voda and Sibiu) of the State Institute for Variety Testing and Registration (SIVTR), which belong to 3 ecosystems (Table 1).

Table 1. SIVTR locations where camelina cultivars were grown

Locations	Ecosystem	Air temperature	Rainfall	Elevation (m)	Latitude	Soil type
		Mean/year				
		(^{0}C)	mm			
Mircea Voda	Romanian Plain	11.0	447	37	$45^0$12'N	Cambic and vermi-mould
Dîlga		11.0	555	51	$44^0$25'N	Wet, Gleyed chernozem
Dej	Contact area of Transylvania Plain with Somesan Plateau	8.7	598	235	$47^0$09'N	Sandy loam clay loam
Sibiu	Sibiu depression	8.7	636	400	$45^0$61'N	Cambic mould

The sowing time of Camelia and Lindo cultivars was mostly late autumn, except Dej and Sibiu centres, where camelina cultivars were sown at two sowing times, in the early spring (2008 and 2009) and in the late autumn (2010). Fertiliser input consisted, in all SIVTR centres, in nitrogen and phosphate applied at 40-60 kg ha^{-1} and 30-60 kg ha^{-1} respectively. No herbicides, fungicides or insecticides were used. The plots were harvested directly, without desiccation, with a standard plot combine. At harvest, for each experimental plot, seed yield, expressed in kg ha^{-1} at 9% moisture content was determined. In organic farming, hectolitre weight expressed in kg hl^{-1} was also determined.

Statistical analysis

A three-way analysis of variance for Fundulea experiments and two-way analysis of variance for SIVTR yield trials was performed. Data from different SIVTR centres were analysed as replications.

The dispersion of seed yield in time was estimated by Coefficient of variation (CV) (Ceapoiu, 1968) and significance of differences by comparing with the Least Significant Difference (LSD).

RESULTS AND DISCUSSION

Two main characteristics of camelina were estimated in organic farming: seed yield potential and hectolitre weight, while only seed yield was determined in SIVTR low input farming system.

1. Seed yield potential in organic farming system

The data presented in Table 2 shows that Year (Y), Sowing time (St) and Cultivar (V), as well as interactions of year and sowing time (Y & St), and of year and cultivar (Y&V), sowing time and cultivar (St & V) and of all experimental factors (Y x St x V) had very significant effect on seed yield. The

interaction sowing time x cultivar (St x V) effect was not significant, which means that the camelina cultivars are versatile, with adaptation capacity to different sowing time.

The cropping year (Y), sowing time (St) and theirs interaction (Y x St) had the largest effect on organic camelina seed yield. The effects of cultivar (V) and its interaction with year (Y x V) and year and sowing time (Y x St x V) were also very significantly (P>0.01).

Table 2. The three-way analysis of variance (ANOVA) of seed yield in different years, sowing time and camelina cultivars cultivated in organic farming system (Fundulea, 2009-2013)

Source of variation	The sum of squares (SS)	Degrees of freedom (df)	Mean square (MS)	F-value	F-table	
					0.05	0.01
Replication	91151.47	2				
Year (Y)	6070382.00	4	1517595.00	154.41	3.84	7.01
Error (Y)	78624.53	8	9828.07			
Sowing time (St)	1692713.00	1	1692713.00	89.40	4.96	10.04
Interaction (Y x St)	2367142.00	4	591785.40	31.25	3.48	5.99
Error (St & Y x St)	189344.90	10	18934.49			
Cultivar (V)	162985.10	2	81492.53	7.74	3.23	5.18
Interaction (Y x V)	602534.90	8	75316.87	7.15	2.18	2.99
Interaction (St x V)	34382.31	2	17191.16	1.63	3.23	5.18
Interaction (Y x St x V)	294888.60	8	36861.07	3.50	2.18	2.99
Errors (V & Y x V)	421116.10	40	10527.90			
Total	12005260.0	89				

1.1. The environment effect on camelina seed yield in organic farming system

The seed yield of camelina in Fundulea organic farming system varied between 382-1,412 kg ha^{-1}, according to climate characteristics of cropping year, and sowing time – late autumn and early spring (Figure 1).

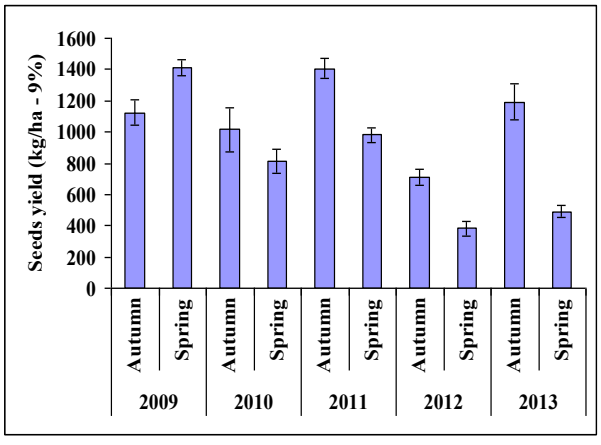

Figure 1. Environment effect on camelina seed yield in organic farming system (Fundulea, 2009-2013)

The best years for organic camelina were 2009 (1,268 kg ha^{-1}) and 2011 (1,194 kg ha^{-1}), and the bad years, 2012 (546 kg ha^{-1}) and 2013 (796 kg ha^{-1}). Under the effect of sowing time, organic camelina seed yield varied from single to double, between 683-1,502 kg ha^{-1} in the late autumn, and from simple to six fold, between 270-1,682 kg ha^{-1}, in the early spring (Table 3).

The organic seed yield of camelina in the late autumn sowing time is close with the camelina yield under dryland conditions (325-375 mm rainfall) in Montana/USA area, reported by Ehrensing and Guy (2008). The camelina seed yield in the early spring sowing time is, more or less, similar as high variability to camelina seed yield reported by Putnam (1993) in Rosemont, Minnesota (45^{0}N latitude).

The coefficient of variation (CV) in time of organic camelina seed yield ranged between 21.1-24.07% in the late autumn

sowing time, and between 43.44-56.37% in the early spring sowing time (Table 3).

Although all CV values of camelina seed yields exceed 20%, which means, according to Ceapoiu (1968), high variation, the CV values of camelina seed yield in the late autumn plots are lowest (21.18-24.07%) and CV values in the early spring plots are the highest (43,44-56,37%) for all camelina cultivars.

Table 3. The seed yield potential of camelina in organic farming system according to cropping year, sowing time and cultivar (Fundulea, 2009-2013)

Sowing time	Cultivar	2009	2010	2011	2012	2013	Average	C.V.
Autumn	Camelia	1268	955	1502	749	1130	1121	23.00
	Calena	1244	976	1311	683	1198	1083	21.18
	Lindo	863	1117	1409	697	1244	1066	24.07
Spring	Camelia	1682	778	1079	420	531	898	56.37
	Calena	1294	960	799	456	492	800	43.44
	Lindo	1259	698	1063	270	453	748	55.05

1.2. The seed yield potential of camelina cultivars in organic farming system

The highest seed yield (585-1,475 kg ha^{-1}) was obtained from Camelia cultivar, the second highest seed yield (569-1,290 kg ha^{-1}) was obtained from Calena and the lowest seed yield (483-1,236 kg ha^{-1}) from Lindo (Figure 2).

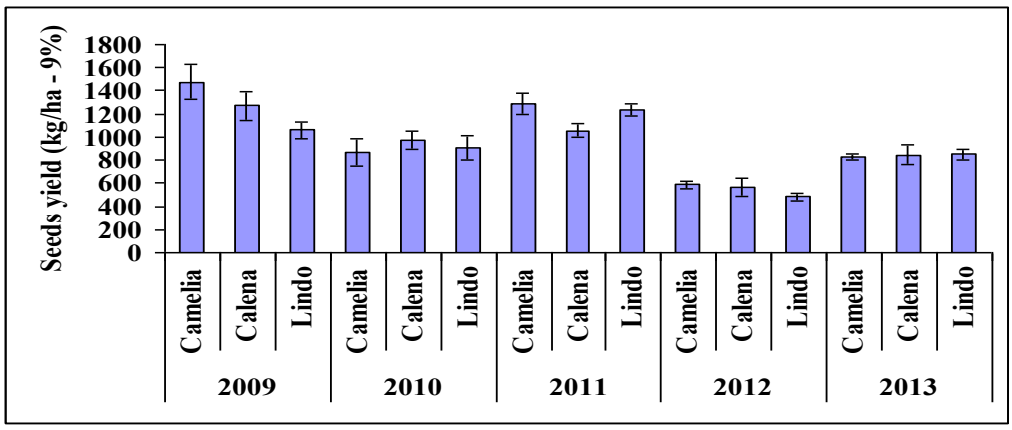

Figure 2. Seed yield of camelina cultivars in organic farming system (Fundulea, 2009-2013)

The camelina seed yield in Fundulea organic farming trial in autumn sowing time was penalized in 2010 by the frosty and long winter, and by the climate inversion of March, while in 2012 yield was reduced by the severe drought of November 2011 and March 2012. In spring sowing time, the camelina seed yield potential was penalized in 2012 and 2013 by the severe drought of March and by drought and high temperatures of April, respectively.

1.3. The hectolitre weight of camelina seeds in organic farming

The hectolitre weight, another characteristic of camelina varieties, is presented in Table 4 and Figure 3. The hectolitre weight was affected significantly by year (Y) and sowing time (St), as well as by theirs interaction (Y x St).

Also, the hectolitre weight does not seem to be a specific feature of the tested cultivars, because cultivar (V) and interaction cultivar x environment factors (Y x St x V) were not significant and interactions year x cultivar (Y x V) and sowing time x cultivar (St x V) were of a minor importance.

The hectolitre weight of organic camelina seeds ranged from 62 kg hl^{-1} in 2012, spring sowing time, to 69 kg hl^{-1} in 2013, autumn sowing time (Figure 3).

The highest and stable hectolitre weight of organic camelina seeds (66-69 kg hl^{-1}) was registered in autumn sowing time, and the smallest and variable hectolitre weight of camelina organic seeds (61-66 kg hl^{-1}) in spring sowing time (Figure 3).

Table 4. The three-way analysis of variance (ANOVA) of hectolitre weight in different years, sowing time and camelina cultivars cultivated in organic farming system (Fundulea, 2009-2013)

Source of variation	The sum of squares (SS)	Degree of freedom (df)	Mean square (MS)	F-value	F-table	
					0.05	0.01
Replication	0.58	2				
Year (Y)	56.70	2	28.37	65.44	6.94	18.00
Error (Y)	1.73	4	0.43			
Sowing time (St)	179.28	1	179.28	234.70	5.99	13.74
Interaction (Y x St)	58.84	2	29.42	38.52	5.14	10.92
Error (St & Y x St)	4.58	6	0.76			
Cultivar (V)	2.40	2	1.20	2.24	3.40	5.61
Interaction (Y x V)	8.21	4	2.05	3.83	2.78	4.22
Interaction (St x V)	4.75	2	2.37	4.43	3.40	5.61
Interaction (Y x St x V)	5.13	4	1.28	2.40	2.78	4.22
Errors (V & Y x V)	12.85	24	0.54			
Total	335.09	53				

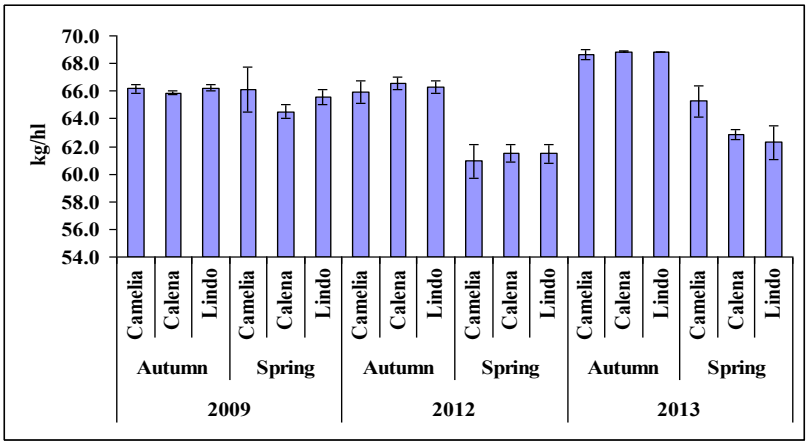

Figure 3. Hectolitre weight in different years, sowing time and camelina cultivars cultivated in organic farming system (Fundulea, 2009-2013)

1.4. Seed yield potential in low input farming system

The seed yield potential in low input farming system was strongly influenced by the growing environment (Y).

A small not significant differences ($P<0.05$) between cultivars (V) and a minor significant interaction between studied factors (Y x V) can be observed too (Table 5).

Table 5. The two-way analysis of variance (ANOVA) of seed yield in different years and camelina cultivars cultivated in low input farming system (SIVTR, 2008-2010)

Source of variation	The sum of squares (SS)	Degree of freedom (df)	Mean square (MS)	F-value	F-table	
					0.05	0.01
Replication	265581.30	3				
Year (Y)	1151432.00	2	575716.00	22.94	5.l4	10.92
Error (Y)	150610.70	6	25101.78			
Cultivar (V)	79352.00	1	79352.00	4.97	5.12	10.56
Interaction (Y x V)	160512.00	2	80256.00	5.03	4.26	8.02
Error (V & Y x V)	143552.00	9	15950.22			
Total	1951041.52	23				

Yield of camelina in SIVTR low input farming trial were in the 1,761 to 2,829 kg ha^{-1} range, averaging about 1,985-2,269 in 4 altitudes, 1,891-2,141 kg ha^{-1} in 3 years, and 2,095 kg ha^{-1} in Lindo and 2,210 kg ha^{-1} in Camelia cultivars (Table 6). The seed yield was significantly influenced only by the climate conditions – significantly lower in 2008 and significantly higher in 2010 than average of trial camelina seed yield. Altitude and variety did not influence significantly camelina seed yield. This remark is sustained by CV data, which were in the 4.89-11.31% range in the years, 8.75-14.92% in the altitudes, and 10.53-15.77% in the cultivars study. The data in different altitudes and varieties suggested a yield penalty in altitude under 50 m, and high yield potential of Camelia cultivar respectively. This variety yielded 5.5% above the Lindo variety mean and 2.7% above the trial average. The low input seed yield of camelina was similar to the camelina yield trails data at Moscow, Idaho (2,353-2,690 kg ha^{-1}) reported by Ehrensing and Guy (2008), as well as with camelina yield ranging (1,050-1,700 kg ha^{-1} in 1993 and 1,450-3,250 kg ha^{-1} in 1994) in two Austrian locations (Gross Enzersdorf and Reichersberg), reported by Vollmann et al. (1996).

Table 6. The seed yield potential of camelina in low input farming system (SIVTR, 2008-2010)

Altitude (m)	Yield (kg ha^{-1})	C.V. (%)	Year	Yield (kg ha^{-1})	C.V. (%)	Variety (name)	Yield (kg ha^{-1})	C.V. (%)
37	1984.83	8.75	2008	1890.50	4.89	Camelia	2210.08	15.77
51	2203.67	14.81	2009	2140.63	8.15	Lindo	2095.08	10.53
235	2153.00	14.92	2010	2426.63	11.31	LSD 5%	116.5242	
400	2268.83	13.74	LSD 5%	194.08		-	-	
LSD 5%	224.11		-	-		-	-	
Min yield	1761							
Max yield	2829							
Average yield	2152.58							

CONCLUSIONS

The seed yield potential of camelina depended mostly on weather characteristics of cropping year, farming system, sowing time and cultivar.

In Fundulea area, the best years for organic camelina were 2009 and 2011, and the bad years, 2012 and 2013, regardless of sowing time and cultivar. In low input farming system, the best year for camelina seed yield was 2010 and the bad year was 2008.

Camelina has been shown to respond to farming system similarly many crops: on the average 953 kg ha^{-1} seeds in organic farming and 2153 kg ha^{-1} seeds in low input farming.

The effect of sowing time on camelina seed yield in organic farming varied from single to double, in the late autumn, and from simple to six fold, at early spring.

A good yield potential has been estimated in newly developed Camelia cultivar during the present study, both in organic and low input farming systems.

The hectolitre weight of organic Camelia seeds was higher in autumn sowing time than in early spring sowing time.

REFERENCES

Carciumaru, M., 2007. *Cultivarea plantelor in Dacia* (*Plants cultivation in Dacia)*. Thraco-dacica, VIII, 1-6.

Ceapoiu, N., 1968. *Metode statistice aplicate în experienţele agricole şi biologice (Statistic methods applied in agriculture and biology experiments)*. Edit. Agro-Silvică, Bucharest: 55.

Ciocîrlan, V., Chirilă, C., Badea, I., 1975. *Determinator de buruieni (Weeds classification)*. Edit. Ceres, Bucharest.

Crowley, J.G. and Fröhlich, A., 1998. *Factors affecting the composition and use of Camelina*. TEAGASC Arable Crops Research Centre, Oak Park, Co Carlow.

David, V., Angliţoiu, F., Toncea, I., Tomescu, C.-S., Grămadă, I., Mincan, M., Vîrjan, Gh., 2011. *Compoziţie de cauciuc regenerat utilizând produse vegetale sau derivaţi ai acestora şi procedeul de obţinere a compoziţiei (Regenerate rubber compozition by using the plant products and preparing compozition method)*, Patent no. RO 127830 B1/21.10.2011; www.osim.ro

Ehrensing, D.T. and Guy, S.O., 2008. *Camelina*. Oilseed Crops, Extension Service, Oregon State University: 1-7.

ITAKA, 2012. *EU Project to Support the Use of Sustainable Biofuels in Aviation*. www.itaka-project.eu

Putnam, D.H., Budin, J.T., Field, L.A. and. Breene, W.M., 1993. *Camelina: a promising low-input oilseed*. 314-322. In: J. Janick and J.E. Simon (eds.): 314-322, New crops, Wiley, New York.

State Institute for Variety Testing and Registration (SIVTR), 2012. *Official Catalogue of Varieties and Hybrids Crop Plants in Romania*. Bucharest, p.111. www.istis.ro

Vollmann, J., Damboeck, A. Eckl, A., Schrems, H. and Ruckenbauer, P., 1996. *Improvement of Camelina sativa, an underexploited oilseed.* In: J. Janick (ed.), Progress in new crops: 357-362. ASHS Press, Alexandria, VA.

Zamfirescu, N., Velican, V., Saulescu, N., Valuta, Gh., Cantir, F., 1958. *Camelina*. Fitotehnia II (Phytotechnics II). Edit. Agro-Silvica, Bucharest: 318-322.