Seedlings of oil pumpkins as an alternative to seed sowing: yield and production costs

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Ölkürbis-Jungpflanzen als Alternative zur Aussaat: Ertrag und Produktionskosten

1. Introduction

The Štajerska region located in northeastern Slovenia and partly in southern Austria has a long tradition of growing pumpkins (*Cucurbita pepo* L. ssp. *pepo Pumkin Group*) whose edible seeds are used mostly for producing oil for salad dressing. Depending on genotypes, the oil content of pumpkin seeds ranges from 40 to 50 %. The oil is dark green and contains free fatty acids. The content of vitamin E, especially gamma-tocopherol, is quite high (HILLEBRAND et al., 1996; IDOURAINE et al., 1996). Seeds and oil can be used in pharmacology and alternative medicine (WAGNER, 2000), especially when biologically produced. Consequently, the production of pumpkin seeds is on the increase, justifying research toward improved agricultural practices.

It is known for the production of Cucurbits that transplanted seedlings give higher yields and offer a more reliable production method (SPITTSTOESSER, 1990; ROBINSON and DECKER-WALTERS, 1997; WIEN, 1997) in comparison to direct seed sowing. If sowing is delayed the time lost can be compensated by sowing pre-germinated seeds having visible sprouts (0.5 cm length). It is necessary to sow pre-germinated seeds in moist soil.

Pumpkin seedlings grown in plug trays (also known as cell trays and module trays) are often transplanted to the field

Zusammenfassung

In dreijährigen Feldversuchen wurde der Einfluß von ungekeimtem Saatgut, gekeimtem Saatgut und Jungpflanzen im Multitopf auf das Pflanzenwachstum und den Ertag der Ölkürbisse (Sorte Gleisdorfer) untersucht. Das Saatgut wurde am 29. April und 1. Mai im Multitopf ausgesät und am 16. Mai ausgepflanzt, als auch die Versuchsaussaat durchgeführt wurde. Kräftig entwickelte Pflanzen aus Jungpflanzen hatten mehr und größere Früchte als die Pflanzen aus der Direktaussaat. Der Ertrag von Ölkürbissen aus Jungpflanzen wurde signifikanter höher (3.35 kg 20 m^{-2}) als der Ertrag aus ungekeimtem Saatgut (2.06 kg 20 m^{-2}) und aus gekeimtem Saatgut (2.54 kg 20 m^{-2}). Aber die Produktionskosten pro kg Körnerertrag waren bei der Direktaussaat (0.98 EUR kg^{-1}) niedriger als bei Auspflanzung (1.20 EUR kg^{-1}), wo der Profit ha^{-1}.

Schlagworte: Ölkürbis, Saatgut, Aussaat, Jungpflanzen, Ertrag, Kosten.

Summary

The effects of direct sowing, sowing pre-germinated seeds, and transplantations of seedlings of oil pumpkins (cv. Gleisdorfer Öilkurbis) on growth, yield and production costs were compared in three years of field experiments. Seeds were sown in plug trays on April 29 and May 1 and then the seedlings were transplanted on the sowing date of experiment (May 16). Plants that developed from transplanted seedlings were luxuriant and produced more and larger fruits than those grown from direct sowing. The seed yield obtained from transplants was significantly higher (3.35 kg 20 m^{-2}) than that obtained from direct sowing (2.06 kg 20 m^{-2}) and pre-germinated seeds (2.54 kg 20 m^{-2}). The break-even price per kg seed yield from direct sowing (0.98 EUR kg^{-1} seed yield) was lower than the costs from transplanted seedlings (1.20 EUR kg^{-1}) where the profit ha^{-1} was higher.

Key words: oil pumpkin, seed, sowing, seedling, yield, costs.

when they are three weeks in order to avoid transplantation shock (ADAMS et al., 1993; ROBINSON and DECKER-WALTERS, 1997). When the first true leaf is partially developed the seedlings may first be transplanted in plug trays with larger size holes to the height of cotyledons, in order to accelerate the development of adventitious roots. Plug trays should have large cell size (5 cm depth and volume larger from 5.0 cm^3) to ensure seedlings strong enough for successful transplantation (BAVEC, 2000). Seedlings have to be grown in optimal growing circumstances – a covered area. Whenever possible, exposure to temperatures under 10 °C and other stressful conditions should be avoided.

Production of oil pumpkins using seedling transplants has not yet been studied or observed in practice. In comparison to the traditional direct sowing of oil pumpkins in the field the objective of this work was to compare the use of seedlings (with developed compact root system, grown in plug trays) with direct sown and pre-germinated seeds for length of the growth and development period, and for yield, and to determine if there is economic advantage to transplanting.

2. Material and methods

The oil pumpkins field experiments with two direct sowing methods and transplantation of seedlings (Table 1) were conducted at the University Agriculture Center Maribor, Faculty of Agriculture, Slovenia (43° 34' N lat., 15° 38' E long.) in 1997–1999.

Seedlings production (for transplanted treatment) was carried out in plug trays in heated greenhouse, later seedlings were strengthened outside. Plug trays the size of 28 × 50 cm had 72 holes, the size of each was 3.7 × 4 cm and depth 5 cm. A hole volume of plug trays was approximately 5.5 cm^3. Plug trays were filled with the substrate (Asef) and contained one seed in every hole. Seeds emerged in a well-lit area at day temperatures from 20 to 25 °C and night temperatures 15 °C. Five days after the emergence plants were grown at 20 °C and subjected to constant airing through the day. After 14 days at the stage of the first proper leaf and the second leaf the plants were transfered outside greenhouse and covered during the night. After a month seedlings were transplanted to the experimental field. Seedlings were well developed (2–3 developed leaves,

Table 1: Experiment overview
Tabelle 1: Versuchsübersicht

Treatment	
A (direct-sown seeds)	Sowing of non-germinated seed in the depth of 3 cm, 3 to 4 seeds per hill and thinning later to achieve the desired i.e. identical number of plants in the experiment.
B (sowing of pre-germinated seeds)	Seeds were pre-germinated in moist turf at 22° C, 3 days before sowing sprouts were well visible. In this treatments 3 seeds per hill were sown in the depth of 3 cm.
C (transplanted seedlings)	Sowing in plug trays on May 1 in 1997 and 1998, and on April 29 in 1999. Seedlings developed first leaves, second leaves were in development stage. Seedlings were transplanted at the depth of cotyledons, one per hill because there was no risk present for seedlings not to grow. In the field, the seedlings were irrigated at transplanting.
Experiment overview	Cultivar Gleisdorfer Ölkürbis, a naked seeded pumpkin, oil content amounts 43–45 %, plant with long
Cultivar, seed characteristics	branched stems, registered in Slovenia since 1986, originally from Austria, seed germination 90 %, germination energy 88 %, seeds were treated with Captan (captan 50 %).
Experiment design	Randomized block, 4 repetitions, 20 m^2 (5 m × 4 m)
Soil characteristics	Sandy-loam, 6.5 pH (n/10 KCl), 2 % of humus, 22.0 mg P_2O_5/100 g soil (Al extraction), 26 mg K_2O/100 g soil (Al extraction)
Date of sowing and seedling plantings	May 16 in all years, sowing and planting were performed manually.
Fertilization	600 kg NPK ha^{-1} (N : P : K = 7 : 20 : 30) and 150 kg KAN-a ha^{-1} (25 % N). N fertilization was made before sowing (1/2) and at the stage before flowering (June 14 in 1st year, June 26 in 2nd year).
Plant population, inter-row spacing	1,0 plant per m^{-2}. Plants were planted 0,5 m from the edge of a plot, row spacing was 1 x 1m. Young plants were thinned in treatments A and B on May 31 to the final number because 3 to 4 seed per hill were sown.
Chemical protection	In the second half of June plants were infected with *Erysiphe cichoracearum* and *Sphaerotheca fuliginea* and protected with Bayleton special (triadimefon) in 0,5 % concentration. In the first half of August plants were infected with *Pseudomonas lachrymans* (Sm. Et Br.) Carsn.= *Bacterium lachrymans* Smith et Bryan.
Weed treatment	Manual mechanical treatment were used, once in 1st year and twice 2nd and 3rd year. Many times stems were corrected on the plot.
Date of harvesting	September 22

15 cm height and first visible flower buds) and roots were compact with substrate that endured the transplantation without damage. During growth seedlings were subjected to preventive plant protection against fungus with 0,25 % Antracol (propineb). For pests (lice, mites) 0,1 % Actellic-50 (pirimifos – methyl) was used.

In the vegetation period differences in plants growth and development during treatments were marked on June 2, June 26, July 28 and August 24. Manual harvesting was carried out when 75 % of fruits became yellowish-orange in color, epidermal layer was easy to pierce with a nail and seed was dark green and well rounded. At harvest time full-matured fruits were counted separately from every trial plot and their diameter was measured (only two years) and finally seeds were harvested by hand. Unripe green fruits and decayed fruits were counted. The fruit (only two years) and seeds mass were weighed. In every treatment seed moisture was analyzed on the basis of average sample weighing with standard drying procedure (3 days, 70 °C).

For costs calculation of oil pumpkin production direct expenses comprise material expenses (seed retail price, substrate, fuel oil) and work expenses without the covered area amortization because an amortized material or simple protective area can be used. The price of pure nutrients was calculated using the smallest squares method on the basis of purchase prices of various mineral fertilizers. People and machine labor was determined on the basis of standards considering the size of the field and distance from a farm as well as machinery and other specific farm characteristics. Preparation of machines and transport to the field were included in work expenses for individual phase.

Processing of statistical data was made for the randomized complete block design with four repetitions in computer program Stat graphics + For Windows 2.1. Results (fruit weight, number of harvested fruits, number of decayed fruits, average diameter of fruits, weight of fresh pumpkins) were analyzed with the assistance of variance analysis and variance homogeneity test (F-test, * indicate significance at $P = 0.05$, ** at $P = 0.01$). Differences between results of individual treatments in each year and year averages were tested with the Tukey test, where in the results different letters indicate significant difference at the 95 % confidence level.

During the experiment the precipitation sum in vegetation period (from May to September) ranged from 565 mm in 1997 to 785 mm in 1999 (more years average is 566 mm). In 1998 the second half of May was very cold which reflected in poor and uneven seed germination and slow growth of seedlings in the open area. In 1998 June, July and August were warmer in comparison with 1997 (Table 2) compensating for the initial stagnation in plant growth.

Table 2: Rainfall sum and average temperature during vegetation period in experimental field
Tabelle 2: Gesamt-Niederschlagsmenge und Durchschnittstemperaturen in der Vegetationsperiode während des Feldversuches

Month	Rainfall (mm)			Temperature (°C)		
	1997	1998	1999	1997	1998	1999
January-April	130	278	210			
May	81	46	176	16.4	15.7	15.8
June	148	136	163	19.0	19.9	18.8
July	152	193	175	19.9	20.7	20.8
August	107	139	206	19.8	20.8	19.3
September	78	173	65	16.1	15.1	17.6
May -September	565	681	785			

Table 3: Description of growth stages in oil pumpkin plants depending of dates and treatments
Tabelle 3: Beschreibung der Wachstumsphasen der Ölkürbisse in Abhängigkeit von Zeitpunkt und Versuchsvariante

Treatment*	Description of growth stage			
	June 2	June 26	July 28	August 24
A- Direct-sown seeds	2 sprout leaves with leaf	First flowers in full efflorescence		
B- Sown of pre-germinated seeds	Stems 10 cm long, 2 to 3 developed leaves	Efflorescence, first fruits are developed, diameter to 2 cm		Half of fruits are ripe, there is no difference between treatments
C – Transplanted seedlings (sowing May 1)	Stems 10 to 15 cm long, 3 to 4 leaves, first flower foundations	Exuberant plants, fruits equally developed, diameter 6 to 8 cm	Significantly higher number of fruits with long diameter	regarding ripening, but diameter and number of fruits were longer and higher

* A, B sowing and C transplanting date was May 16

3. Results

Plants that developed from seeds sown in the permanent spot grew and developed more slowly in comparison to plants developed from seedlings. Many morphological differences between all treatments appeared in the beginning of June (Table 3).

Years and treatments had a significant influence on fruit weight, number of fruits, diameter of fruits and seed yield while the interactions year x treatment had insignificant influence on studied parameters (Table 4).

Table 4 shows that the fruit weight varies according to year average, namely in transplanted treatment 1/3 higher weight was noted when compared to the weight in direct-sown and pre-germinated treatments. Higher fruit weight was noted in 1997 in transplanted treatments, sometimes even 3 times higher in comparison with direct-sown and pre-germinated treatments, which was the consequence of many decayed fruits. Treatments had significant influence on fruit weight in 1998 as well but weight did not vary to such extent as in 1997.

Influence on number of harvested fruits varied considerably. Testing of differences showed there is no difference between treatments except between direct-sown and pre-germinated group and transplanted treatment. In 1997 differences between direct-sown and transplanted treatments, pre-germinated and transplanted treatments were significant while in 1998 there were no significant differences between treatments. Lower number of harvested fruits (from 7.5 to 17.7 per plot) in 1997 was the consequence of disease (Table 1) which divided the yield in half in comparison to 1998. Number of decayed fruits in 1997 comprised almost half of all fruits and varied between 5 and 11 per plot. Significant differences in the number of decayed fruits appeared in direct-sown and transplanted treatments, in 1998 also in pre-germinated and transplanted treatments. In both years transplanted treatment gave the highest number of decayed fruits.

Fruit diameter does not depend on treatments in year average while in 1997 differences regarding average fruit diameter (from 17.1 to 21.9 cm) were significant between direct-sown and pre-germinated group and transplanted treatment. There were no differences in 1998 but a trend of increasing average diameter from direct-sown to transplanted treatment was noted.

Pumpkins yield differs significantly between treatments of sowing (direct-sown, pre-germinated) and trasplanted seedlings where the difference in yield between groups is 1.37 kg 20 m^{-2} (37 %). In 1997 transplanted treatments had three times higher yield in comparison with direct-sown and pre-germinated group while in 1998 yield was higher whereas the differences between treatments were smaller (Table 4).

4. Discussion

Not only Cucurbits in vegetable production (SPITTSTOESSER, 1990; ADAMS et al., 1993; ROBINSON and DECKER-WALTERS, 1997; WIEN, 1997) but also field crop – oil pumpkins production can be based on transplanted seedlings according to our results. Considering the expenses for production with 10000 seedlings (the lowest advised plant population), seedling cost price is 0.04 EUR. What we have to determine is

Table 4: Effects of direct-sown seeds (A), pre-germinated sown seeds (B) and transplanted seedlings (C) on seed yield and yield characteristics of oil pumpkins

Tabelle 4: Effekte direkt (A) bzw. vorgekeimt (B) ausgesäter und gepflanzter (C) Ölkürbisse auf Kornertrag und Ertragsmerkmale

Treatment (T)	Fruit weight (kg 20m^{-2} or per 20 plants)			Number of harvested (unripe and decayed) fruits 20m^{-2} or per 20 plants				Fruit diameter (cm)			Seed yield (kg 20m^{-2}) or per 20 plants[y]			
Year (Y)	**			* (*)				**			**			
T	**			** (**)				ns			**			
T x Y	ns			ns				ns			*			
	1997	1998	Average	1997	1998	1999	Average	1997	1998	Average	1997	1998	1999	Average
A	19.3b	88.1b	53.7b	8.7b (5.0b)	22.2b (0.5c)	21.7	17.5 (1.8)	17.1c	21.6	19.3	0.89c	3.01b	2.30b	2.06b
B	22.4b	102.0b	62.2b	7.5b (10.5a)	25.5b (1.7b)	20.0 (0.3)	17.7 (4.2)	19.0b	21.5	20.2	1.60b	3.53b	2.48b	2.54b
C	61.2a	145.2a	103.2a	16.3a (11.0a)	34.3a (3.2a)	21.3	24.0 (4.7)	21.9a	22.3	22.1	2.61a	4.72a	2.71a	3.35a

[y] at harvest there was 49, 50, 50 and 51% dry matter, A, B, C, respectively

ns no significant differences

* significance indicated at $P = 0.05$, ** at $P = 0.01$)

[a,b,c, d] means within column followed by the same letter are not significantly different at the 95% confidence level (Tukey's test)

Table 5: Oil pumpkins production enter price budget*
Tabelle 5: Analytische Kalkulation der Ölkürbis-Produktionskosten

	Production based on seed sowing			Production based on seedlings		
Type of expense	Quantitive Kg, l, hours ha^{-1}	Price EUR kg^{-1}, l^{-1}, $hour^{-1}$	Value EUR ha^{-1}	Kg, l, hours ha^{-1}	Price EUR kg^{-1}, l^{-1}, $hour^{-1}$	Value EUR ha^{-1}
Seed, seedlings	6	6.98	41.88	10000	0.04	399.93
Fertilizers, fungicides			149.08			149.08
Sowing, seedling plantings			69.80			125.56
Combine harvesting	3,3		86.03	3,3		86.03
Drying of seed yield	900	0.02	180.00	1200	0.2	240.00
Provision: mechanical services	23,6	8.65	204.14	22,3	8.65	192.89
Laobur (net)	44	2.32	102.31	41,5	2.32	96.28
Tax			9.48			9.48
Indirect expenses			44.18			44.18
Total costs			886.9			1343.43
Break even price (EUR kg^{-1} of seed yield)			0.98			1.20

* field surface 1 ha, remoteness 1 km

whether transplanted seedling are economically justifiable. Analytical calculation of oil pumpkins production by method of sowing or seedling plantings shows (Table 5) that production expenses are acceptable regarding purchase price of dry pumpkin seeds which ranges from 1.39 to 2.32 EUR kg^{-1}. Cost price of 1kg of seed yield in sowing treatments (direct-sown, pre-germinated seeds) has been estimated to 0.98 EUR kg^{-1} with 900 kg seed yield ha^{-1}. In transplanted treatment with 1200 kg of dry seed yield ha^{-1} the cost price of pumpkins is 1.20 EUR kg^{-1}. In this case more then 30 % higher seed yield should compensate transplanted seedling expenses, and increase profit ha^{-1} for 15 %.

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