

# Yield potential and fruit quality of scallop squash (*Cucurbita pepo* L. var. *patissonina* Greb. f. *radiata* Nois.) cultivars grown for processing

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## Abstract

Scallop squash fruits may be harvested at different stages of development. Small size fruits, intended both for the fresh market and the food industry, have the highest biological value. This study was conducted to determine the yield potential of scallop squash cultivars ('Polo F1', 'Disco', 'Gagat', 'Okra', 'Sunny Delight F1') grown on mulched (black polyethylene foil or black agrotexile) or unmulched soil, and harvested when fruits reached a diameter of 3–6 cm. Based on 3-year average data, the highest marketable and early yield was produced by 'Sunny Delight F1'. This cultivar is also appreciated by consumers for its yellow colored skin of fruits. Another advantage of this cultivar was its high nutritional value expressed by the highest content of dry matter, vitamin C, polyphenols and minerals (K, P, Ca, Mg), with limited tendency to nitrate accumulation. Among the other cultivars tested, 'Okra' showed high yield potential, 'Gagat' was a rich source of carotenoids, and 'Disco' – polyphenols. Black polyethylene foil and black agrotexile appeared to be equally effective mulching materials. The benefit from the application of mulch was a significant increase in yield without any change in the chemical composition of the fruit.

**Keywords:** synthetic soil mulches; fruit chemical composition

## Introduction

Scallop squash (*Cucurbita pepo* L. var. *patissonia* Greb. f. *radiata* Nois., Cucurbitaceae), like zucchini, belongs to the group of summer squashes which most commonly are harvested and eaten at an immature stage when the rinds are still soft. Scallop squash fruits are flat, rounded and scalloped with various colors of skin. If harvested at full maturity, scallop squash can reach a diameter of about 20 cm and a weight of 1.5–2.0 kg. Mature squash can be stored for 2–3 months and supplied to the market outside the growing season [1–3]. Immature fruits, which have a limited storage life potential, are supplied to the fresh market or used for processing, mainly for canning, freezing or dehydration [4]. Such fruits are harvested before the skin begins to harden, when they reach a diameter of 3–6 cm, and are used for processing or 6–12 cm diameter fruits are supplied to the fresh market. Sometimes, the male and female yellow flowers may be collected and used for consumption as a kind of special food, either alone or as a colorful addition to salads. The flowers are considered to be a valuable source of dietary and biologically active compounds [4,5].

Summer squashes, including scallop, are low in energy value and highly appreciated for high contents of minerals such as potassium, magnesium, calcium and iron, vitamin B complex, ascorbic acid, and carotenoids. The nutritional value of scallop squash is higher than cucumber due to its higher level of protein, vitamin C and carotenoids [6,7] and low tendency to accumulate nitrates or heavy metals [2,8]. Immature small squash fruits are a richer source of macro- and micronutrients, sugars, protein and vitamin C, compared to fruits harvested at the later stages of development [9,10].

Scallop squash is mainly a seed propagated minor crop in Central European countries, where it is commonly grown in home gardens. In the last few years, however, a growing interest has been observed in using small fruits for processing. Beside its high nutritional value, another advantage of scallop squash is that it has moderate soil nutrient and moisture requirements and better tolerance of low temperatures than the other species from the Cucurbitaceae family.

The objective of the study was to evaluate the fruit value (dry matter content, total sugars, vitamin C, carotenoids, total polyphenols, P, Mg, Ca, K, and nitrates) in five scallop squash cultivars included in the *Polish National List of Vegetable Plant Varieties* [11] and grown on mulched and unmulched soils for harvest of small size fruits suitable for processing. Black polyethylene foil and black agrotexile, which are the most common materials for weed control in vegetable crop production, were used in the experiment.

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## Material and methods

A field study was conducted in 2011–2013 at the Piastów Horticultural Research Station, near Wrocław (long. 17.00 E, lat. 51.05 N), on a sandy clay soil with 1.8% organic matter and pH in H<sub>2</sub>O of 7.1. The soil content of available forms of phosphorus was 55–64 mg dm<sup>-3</sup>, 50–68 mg dm<sup>-3</sup> of potassium, and 20–30 mg dm<sup>-3</sup> of mineral nitrogen (NH<sub>4</sub>-N + NO<sub>3</sub>-N), depending on the year of the study. Scallop squash was cultivated at the standard level of phosphorus and potassium available forms – 80 mg P and 200 mg K per 1 dm<sup>3</sup> of soil. The required doses of these nutrients were established on the basis of annual chemical analysis of soil samples and applied in the form of triple superphosphate and potassium sulphate 3–4 days before planting and mixed with the soil by harrowing. Nitrogen in the form of ammonium nitrate was used as a single preplant dose in the amount of 120 kg N ha<sup>-1</sup>.

The experiment comprised five cultivars of scallop squash developed by the Polish breeders ('Polo F1', 'Disco', 'Gagat', 'Okra') and 'Sunny Delight F1' developed by Seminis Vegetable Seeds Company. Black polyethylene foil, 0.05 mm thick, and black agrotexile weighing 30 g per 1 m were used for weed control. The experiment was established as a two-factorial design in four replications. The experimental plot area was 8 m<sup>2</sup> (1.6 × 5.0 m), with 10 plants per plot.

Seeds of all tested cultivars were sown on 13–16 May at a spacing of 0.8 m apart in rows and 1.0 m between rows, with 3 seeds per spot. After emergence the seedlings were thinned to one per spot. Crop management followed the commonly accepted recommendations for this vegetable species, including hand weed control in this treatment without mulch.

Harvest of fruits with a diameter of 3–6 cm was conducted at 2-day intervals from the 8th of July till the end of fruit setting (10th of September). The only exception was the 'Sunny Delight F1' cultivar whose fruits reached the required size one week earlier. Fruits picked up to the end of July were considered as an early yield. At the time of maximum fruit setting and development (at the end of July), samples of 15 fruits from each plot were collected for chemical analysis.

The fruits were assessed for dry matter content (drying at 105°C to constant weight – PN-90/A-7501/03), total sugars (Loof Schoorl method – PN-90/A-7501/07), vitamin C (Tillmans method – PN-90/A-7501/11), carotenoids (spectrophotometric method) according to Rumińska et al. [12], total polyphenols (Folin–Ciocalteu method) according to Slinghard and Singleton [13], nitrates by the amount of NO<sub>3</sub>-N in f.w. (ion – selective method), P and Mg (colorimetric method), Ca and K (photometric method) according to Nowosielski [14].

The obtained data shown as the means for the 3-year study were subjected to statistical evaluation on the basis of analysis of variance for two factorial design. Post hoc cooperation of means between treatments was made using HSD Tukey's test at a significance level of  $\alpha = 0.05$ .

## Results

Black polyethylene foil and black agrotexile, which are mostly used as a soil cover for weed control in field vegetable crop production, caused a significant increase in marketable and early yield of scallop squash. Both these materials appeared to be almost equally suitable for mulching in production of this crop for harvest of small size fruits for processing. Irrespective of the cultivar, the increase in fruit yield obtained from the plots covered by black polyethylene foil and agrotexile was 15.8% and 13.2%, respectively, over that from the non-covered control. Similar effects were noted in the case of early fruit yield (Tab. 1). The mean values for all tested cultivars did not show any significant impact of soil mulching on the chemical composition of fruits. The only exception was higher nitrate accumulation and a decrease in total sugar content in fruits from plants grown on the soil covered with black foil compared to black agrotexile or the non-covered control (Tab. 2, Tab. 3).

The cultivars of scallop squash tested in this research differed in their color, shape, and productivity. 'Sunny Delight F1', which is highly appreciated for processing and especially for pickling, has an intensive yellow skin and rather flat

**Tab. 1** The effect of soil mulching on early and marketable yield of scallop squash cultivars (t ha<sup>-1</sup>).

Cultivar	Early yield				Marketable yield			
	b.p.f.	b.a.	control	mean	b.p.f.	b.a.	control	mean
Polo F1	3.09	3.61	2.80	3.17	11.58	13.55	10.51	11.88
Disco	3.68	3.27	2.64	3.20	13.82	12.26	9.89	11.99
Gagat	3.38	3.26	3.09	3.24	12.67	12.22	11.60	12.16
Okra	4.12	3.91	3.54	3.86	15.47	14.65	13.27	14.46
Sunny Delight F1	4.17	3.99	3.86	4.01	15.65	14.96	14.46	15.02
Mean	3.69	3.61	3.19	3.49	13.84	13.53	11.95	13.10
LSD <sub><math>\alpha = 0.05</math></sub> for: cultivar				0.36				1.35
type of mulch				0.28				1.04
mulch × cultivar				n.s.				n.s.

b.p.f. – black polyethylene foil; b.a. – black agrotexile.

**Tab. 2** The effect of soil mulching on dry matter and total sugar content of scallop squash cultivars.

Cultivar	Dry matter (%)				Total sugar (% f.m.)			
	b.p.f.	b.a.	control	mean	b.p.f.	b.a.	control	mean
Polo F1	6.41	6.29	6.44	6.38	1.54	1.83	2.00	1.79
Disco	7.11	6.88	6.55	6.84	1.74	1.98	1.89	1.87
Gagat	6.60	6.24	6.13	6.32	1.50	1.86	1.83	1.73
Okra	5.64	5.52	5.79	5.65	1.69	2.04	2.01	1.91
Sunny Delight F1	6.89	6.99	6.69	6.86	1.55	1.58	1.58	1.57
Mean	6.53	6.38	6.32	6.41	1.61	1.86	1.86	1.78
LSD <sub>α=0.05</sub> for: cultivar				0.52				0.09
type of mulch				n.s.				0.07
mulch × cultivar				n.s.				0.16

b.p.f. – black polyethylene foil; b.a. – black agrotexile.

**Tab. 3** The effect of soil mulching on polyphenol and nitrate content of scallop squash cultivars.

Cultivar	Polyphenols (mg 100 g <sup>-1</sup> f.m.)				Nitrates (mg NO <sub>3</sub> <sup>-</sup> kg <sup>-1</sup> f.m.)			
	b.p.f.	b.a.	control	mean	b.p.f.	b.a.	control	mean
Polo F1	129	123	127	126	470	413	424	436
Disco	152	146	146	148	549	406	422	459
Gagat	85	85	75	82	580	508	551	546
Okra	79	75	76	76	557	521	498	525
Sunny Delight F1	144	146	144	144	335	247	225	269
Mean	118	115	114	115	498	419	424	447
LSD <sub>α=0.05</sub> for: cultivar				26				77
type of mulch				n.s.				59
mulch × cultivar				n.s.				n.s.

b.p.f. – black polyethylene foil; b.a. – black agrotexile.

fruit when harvested mature. The fruit shape coefficient of this cultivar, expressed as the ratio of vertical to horizontal diameter, was 0.82. A similar fruit shape coefficient was found for 'Okra' (0.78), while a significantly lower one was observed for 'Gagat' (0.90), 'Disco' (0.86), and 'Polo F1' (0.88). 'Gagat', which is almost spherical in shape, produces dark green fruits due to the highest amounts of chlorophyll [15], while 'Disco' and 'Polo F1' are characterized by light cream colored fruits.

Irrespective of the type of soil cover, the highest early and marketable yield of fruits was produced by 'Sunny Delight F1', followed by 'Okra'. Both these cultivars significantly over-yielded the others, e.g., 'Disco', 'Gagat', and 'Polo F1', among which the differences were negligible and not confirmed by statistical evaluation. Another advantage of the 'Sunny Delight F1' cultivar was early fruit setting, which resulted

in the first fruit harvest one week earlier compared to all other cultivars tested.

The results of chemical analysis of organic and mineral compounds indicate that among the evaluated cultivars of scallop squash 'Sunny Delight F1' may be considered to be the best offer for both the fresh market and processing, because of its high biological value expressed by the highest amounts of vitamin C, phosphorus, potassium, magnesium and calcium (Tab. 4–Tab. 6). The dry matter and polyphenol content was also high and similar to 'Disco' fruits. (Tab. 2, Tab. 3). The amount of carotenoids and total sugar, however, was considerably lower, especially if compared to 'Okra'.

The other investigated cultivars did not differ significantly in their content of potassium, phosphorus, calcium and magnesium, except for 'Polo F1' whose fruits were a richer source of potassium than those of 'Okra'. The 'Okra' cultivar

**Tab. 4** The effect of soil mulching on vitamin C and carotenoid content of scallop squash cultivars.

Cultivar	Vitamin C (mg 100 g <sup>-1</sup> f.m.)				Carotenoids (mg 100 g <sup>-1</sup> d.m.)			
	b.p.f.	b.a.	control	mean	b.p.f.	b.a.	control	mean
Polo F1	23.20	23.81	20.38	22.46	0.92	1.09	0.99	1.00
Disco	20.79	20.81	22.19	21.26	0.76	1.00	0.68	0.81
Gagat	17.30	16.91	15.83	16.68	1.62	1.68	1.68	1.66
Okra	16.45	16.05	14.87	15.79	1.45	1.84	1.83	1.70
Sunny Delight F1	28.07	25.23	26.90	26.73	0.93	1.01	0.79	0.91
Mean	21.16	20.56	20.03	20.59	1.13	1.32	1.19	1.22
LSD <sub>α=0.05</sub> for: cultivar				2.82				0.32
type of mulch				n.s.				n.s.
mulch × cultivar				n.s.				n.s.

b.p.f. – black polyethylene foil; b.a. – black agrotexile.

**Tab. 5** The effect of soil mulching on potassium and phosphorus content of scallop squash cultivar.

Cultivar	Potassium (% d.m.)				Phosphorus (% d.m.)			
	b.p.f.	b.a.	control	mean	b.p.f.	b.a.	control	mean
Polo F1	6.13	5.88	6.08	5.98	0.88	0.78	0.80	0.82
Disco	4.79	5.75	5.96	5.50	0.78	0.84	0.79	0.80
Gagat	5.25	5.75	5.50	5.50	0.68	0.73	0.68	0.70
Okra	5.50	5.13	4.92	5.18	0.78	0.79	0.76	0.78
Sunny Delight F1	6.54	7.00	6.75	6.76	0.92	1.02	0.92	0.95
Mean	5.52	5.90	5.84	5.75	0.81	0.83	0.79	0.81
LSD <sub>α=0.05</sub> for: cultivar				0.55				0.06
type of mulch				n.s.				n.s.
mulch × cultivar				n.s.				n.s.

b.p.f. – black polyethylene foil; b.a. – black agrotexile.

which, like ‘Sunny Delight F1’, has a high yield potential contained low amounts of vitamin C and polyphenols but exceeded all the others in its carotenoid level. A similar value of these compounds was found in fruits of the ‘Gagat’ cultivar.

In our study great differences in nitrate accumulation were found between tested cultivars. In ‘Gagat’ and ‘Okra’ fruits, the amount of NO<sub>3</sub>-N was twice as high as in ‘Sunny Delight F1’ and lower, but still significant, if compared to ‘Polo F1’ and ‘Disco’.

## Discussion

Black polyethylene foil and black agrotexile, which efficiently protect plants from weed infestation, are most often

used as synthetic mulches to cover the soil in vegetable crop production. Another important advantage of soil mulching found in the study was the significant enhancement of crop yield of scallop squash. Such beneficial results may be explained by the improvement of soil microclimate conditions, especially the enhancement of temperature in the root zone. According to Wien and Mionotti [16], it is the main advantage resulting from the use of synthetic mulches, as they provide for plant growth and an increase in yield. The benefits of enhanced root zone temperature are observed in species such as tomato, pepper, cucumber, melon, and zucchini as well as scallop squash [17–21]. The data obtained in the present study, similar to the previous research with zucchini [22], indicate that the increase in early yields was not associated with the acceleration of fruiting due to the use of synthetic mulches. However, the choice of cultivars

**Tab. 6** The effect of soil mulching on calcium and magnesium content of scallop squash cultivars.

Cultivar	Calcium (% d.m.)				Magnesium (% d.m.)			
	b.p.f.	b.a.	control	mean	b.p.f.	b.a.	control	mean
Polo F1	0.45	0.48	0.46	0.46	0.34	0.35	0.35	0.35
Disco	0.46	0.46	0.45	0.46	0.32	0.36	0.33	0.34
Gagat	0.45	0.45	0.43	0.44	0.38	0.36	0.36	0.37
Okra	0.46	0.44	0.45	0.45	0.36	0.39	0.35	0.36
Sunny Delight F1	0.51	0.49	0.48	0.49	0.39	0.42	0.37	0.40
Mean	0.47	0.46	0.45	0.46	0.36	0.37	0.35	0.36
LSD <sub>α=0.05</sub> for: cultivar				0.03				0.03
type of mulch				n.s.				n.s.
mulch × cultivar				n.s.				n.s.

b.p.f. – black polyethylene foil; b.a. – black agrotexile.

had a higher impact on fruit yield of scallop squash; among them, the best results were obtained from ‘Sunny Delight F1’, highly appreciated for its yellow color skin, and from ‘Okra’. A lower yield potential, similar for these cultivars, was found for ‘Disco’, ‘Gagat’ and ‘Polo F1’ and this is in agreement with the results obtained in the research conducted by Grzeszczuk [23].

Scallop squash is commonly recognized as a rich source of biologically active components, especially vitamin C, carotenoids (Tab. 4), polyphenols (Tab. 3), and minerals (Tab. 5, Tab. 6) [2,7]. However, the nutritional value of fruits is highly dependent on the stage of maturity at harvest and can also be influenced by the cultivar. There are many reports indicating that, like in zucchini, fruits harvested at early stages of development, when they have a diameter ranging 3–6 cm, have the greatest nutritional value due to higher amounts of protein, carotenoids, ascorbic acid and macronutrients, but lower nitrate accumulation [7,21,24,25]. Furthermore, small size fruits are more delicate in both texture and flavor, and for this reason they are preferred by consumers and the food industry. As proven in this study, the nutritional value of such fruits was significantly affected by the cultivars, among which the highest content of the most valuable components was found in ‘Sunny Delight F1’. Like in the study conducted by Grzeszczuk [2], the cultivars ‘Disco’, ‘Gagat’ and ‘Polo F1’ appeared to be a rich source of minerals, showing no significant differences in the content of particular macronutrients. The impact of soil mulching on the nutritional value of fruits was negligible and this finding

is in agreement with the studies previously conducted on zucchini [22] and cucumber [20].

A great advantage of scallop squash fruits, especially if harvested at early stages of maturity, is the low content of nitrates which, depending on the type of material used for mulching and the cultivar, ranged between 225 and 580 mg kg<sup>-1</sup> f.w. A low level of nitrate accumulation in fruits of different species from the Cucurbitaceae family, including pumpkin, winter squashes, zucchini and scallop squash, was reported by Danilčenko [8]. Higher, but still acceptable, levels of 550 mg kg<sup>-1</sup> f.w. in small size fruits and 774 mg kg<sup>-1</sup> f.w. in fully matured ones were determined by Grzeszczuk [26]. Similar relations between the size of fruits and the content of nitrates were observed in zucchini [27].

## Conclusions

Among the cultivars tested, ‘Sunny Delight F1’ showed the highest yield potential, earliness of fruit setting and nutritional value expressed by the content of dry matter, vitamin C, polyphenols, calcium and magnesium. Low nitrate accumulation is also an advantage.

A yield of ‘Okra’ plants was similar to ‘Sunny Delight F1’, however ‘Okra’ fruits contained higher amounts of sugar and carotenoids, but a lower content of vitamin C and polyphenols.

Soil mulching increased marketable and total yield of scallop squash and had no impact on fruit chemical composition.

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## Authors’ contributions

The following declarations about authors’ contributions to the research have been made: research designing: EK; conducting experiment: AB; writing the manuscript: EK.

## Competing interests

No competing interests have been declared.

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## Plonowanie i jakość owoców różnych odmian patisona (*Cucurbita pepo* L. var. *patissonina* Greb. f. *radiata* Nois.) uprawianych dla przetwórstwa

### Streszczenie

Owoce patisona (*Cucurbita pepo* L. var. *patissonina* Greb. f. *radiata* Nois., Cucurbitaceae) mogą być zbierane w różnych fazach dojrzałości. Najwyższą wartość biologiczną wykazują owoce małe przeznaczone na potrzeby rynku świeżego oraz dla przetwórstwa. W doświadczeniu porównano plonowanie 5 odmian patisona (‘Polo F1’, ‘Disco’, ‘Gagał’, ‘Okra’, ‘Sunny Delight F1’) uprawianych na glebie ściółkowanej (czarna folia, czarna agrowłóknina) oraz bez ściółkowania. Owoce były zbierane, gdy ich średnica osiągała wielkość 3–6 cm. 3-letnie badania wykazały, że najbardziej wydajną dla przetwórstwa odmianą dającą najwcześniejszy plon jest odmiana ‘Sunny Delight F1’, bardzo atrakcyjna dla konsumenta ze względu na żółty kolor skórki. Uzyskane wyniki wskazują, że odmiana ta posiada wysoką wartość odżywczą wyrażającą się najwyższą zawartością suchej masy, witaminy C, polifenoli i związków mineralnych (K, P, Ca, Mg), oraz najmniejszą tendencją do akumulacji azotanów. Spośród pozostałych odmian ‘Okra’ wydała wysoki plon i podobnie jak odmiana ‘Gagał’ była bogatym źródłem karotenoidów, a ‘Disco’ – polifenoli. Zarówno czarna folia jak i czarna agrowłóknina okazały się cennym materiałem do ściółkowania gleby. Zastosowane ściółki korzystnie wpłynęły na plonowania roślin, nie miały wpływu na skład chemiczny owoców patisona.