

**EFFECT OF INTERCROPPING CARROT (*Daucus carota* L.)
WITH FRENCH MARIGOLD (*Tagetes patula nana* L.)
AND POT MARIGOLD (*Calendula officinalis* L.)
ON THE OCCURRENCE OF SOME PESTS
AND QUALITY OF CARROT YIELD**

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Abstract

Intercropping combines different aspects of the interaction between organisms in ecosystems and may be classified as a pro-ecological method of plant cultivation limiting the harmful human interference in the environment, especially the use of chemicals. It also allows high yield, good quality, and economic productivity to be achieved. The aim of the present study, conducted in the years 2003–2004 in Mydlniki near Kraków, was to determine the effect of intercropping carrot Nardin F₁ with French marigold (*Tagetes patula nana* L.) ‘Kolombina’ and pot marigold (*Calendula officinalis* L.) ‘Promyk’ on carrot yield, its quality, and the occurrence of pests. On average in both years of the study, intercropping did not reduce total or marketable carrot yield. In 2003 intercropping contributed to a significant increase in marketable yield compared with yield from sole cropping. In 2004 the dry matter content was higher in the roots of carrots grown with pot marigold. The treatments intercropped with both French and pot marigold were characterized by an increased content of sugars in carrot roots and in 2004 year – of carotenoids. Intercropping had a significant effect on the number of roots damaged by the carrot rust fly, *Psila rosae*, (the best in this respect was the combination with *Tagetes*) and by nematodes (the best in this respect was the combination with *Calendula*). The number of larvae of carrot psyllid, *Trioza viridula*, was significantly lower in the plots where carrot was intercropped. The study did not find intercropping to have a positive effect on reducing the occurrence of the root aphid.

Key words: *Daucus carota*, quality of yield, companion plants, carrot rust fly, root aphid, carrot psyllid, nematodes

INTRODUCTION

Carrot has been grown for many years in different regions of Poland and has become a natural habitat for many pests (Michalik and Wiech, 2000; Szwejda and Wrzodak, 2007). To obtain high yield of good quality, growers seek opportunities to reduce the damage caused by some pests of carrots. Chemical carrot protection is expensive and sometimes unacceptable (e.g. in baby-food products). More and more often non-chemical methods of plant protection are used. One of them is intercropping. The relationship between intercropped components has become a point of interest for many authors as environmental resources management with respect to productivity and economic indicators (Neto et al. 2010). Foraging adults of phytophagous insects are attracted by host-plant volatiles and supposedly repelled by volatiles from non-host plants. The host-plant-finding behavior of insects may be disrupted by the close comparison of two plant species. Andow (1991) analyzed 209 studies involving 287 pest species. Compared with monocultures, in mixed cropping the population of pest insects was lower by 52% (149 species). Numerous studies have shown that mixed cropping of carrots with some plants reduced carrot damage by some pests (Uwah and Coaker, 1984; Rämert, 1993; Rämert and Ekbohm, 1996; Theunissen and Schelling, 2000; Luik et al. 2000). Therefore, limiting the use of pesticides should be mentioned among many advantages of intercropping. Intercropping also has a beneficial effect on soil structure and optimal utilization of the

factor habitat. This creates the conditions for activating the natural mechanisms that allow obtaining high yields with good nutritional value. The following factors are important in choosing the right partner for intercropping: mutual tolerance of selected species and beneficial impact on plant health (Carruthers et al. 2000; Jankowska et al. 2009; Adamczewska-Sowińska and Kołota, 2010).

The aim of the investigation was to determine the influence of intercropping carrot with French marigold and pot marigold on quality of carrot yield and on damage caused by some pests of carrots.

MATERIALS AND METHODS

The research was carried out in 2003–2004 in Mydlniki near Kraków (Poland), on brown soil developed from loess. A randomized block design was used in three replications on 10.13 m² plots. The combinations of the experiment included three treatments: sole cropping of carrot (*Daucus carota* L.) ‘Nandrin F₁’ (control plot), intercropping carrot with French marigold (*Tagetes patula nana* L.) ‘Kolombina’, and intercropping carrot with pot marigold (*Calendula officinalis* L.) ‘Promyk’. Carrot was sown in rows with interrow distances of 67.5 cm (the standard seeding rate of 2.5 kg per 1 ha). French or pot marigold was sown in rows between each carrot row, depending on the treatment. All species were sown on April 16th, 2003, and on April 23rd, 2004. Mineral fertilization was applied before sowing. It was quantified according to the results of the chemical analysis of the soil samples and supplemented to a level recommended for carrot: 140 mg N, 80 mg P, 120 mg K, and 80 mg Mg per 1 dm³ (Sady 2000). The plots were hand weeded regularly.

The roots were harvested on September 17th, 2003, and on September 30th, 2004. After harvest, leaf length as well as root length and diameter were assessed on thirty randomly selected carrot plants from each plot. Total and marketable yield were also estimated. In the roots selected from marketable yield, dry matter content (drying method), total sugars (anthrone method by Yemm and Wills 1954), and carotenoids (colorimetric method with 96% ethyl alcohol by Lichtenthaler and Wellburn) were estimated. Separation of means was performed with t-Student test, with $\alpha = 0.05$. During harvest, the weight of roots damaged by the carrot rust fly, root aphid and nematodes was analyzed. The number of carrot psyllid larvae was counted twice during the growing period. Duncan’s multiple test ($\alpha < 0.05$) was used for statistical analysis of the results.

RESULTS AND DISCUSSION

The effect of intercropping carrot with French marigold and pot marigold on the quality of carrot yield varied in different years of investigation. In 2003 intercropping had no influence on carrot leaf length, root length and diameter. In 2004 carrots intercropped with French marigold had the longest roots of the maximum diameter (Table 1). Their length and diameter increased in relation to those intercropped with pot marigold about 9.8% and 10.2%, while in relation to the sole crop of carrot this increase was about 4% and 6%, respectively. In both years of investigation, there was no impact of intercropping on leaf length in carrot. Several factors, such as competition among crops, type of cultivar, and spatial arrangement of planting can have a significant impact on the rate of growth of component crops (Neto et al. 2010).

Table 1
The effect of carrot intercropping with French marigold and pot marigold on chosen morphological carrot features

| Type of cultivation | Leaf length (cm) | | | Root length (cm) | | | Root diameter (cm) | | |
|-----------------------------|------------------|--------|--------|------------------|--------|--------|--------------------|--------|-------|
| | 2003 | 2004 | Mean | 2003 | 2004 | Mean | 2003 | 2004 | Mean |
| Carrot (sole crop) | 39.13a | 45.96a | 42.55a | 20.65a | 19.56b | 20.11a | 4.10a | 3.94ab | 4.02b |
| Carrot with French marigold | 39.70a | 47.61a | 43.66a | 21.57a | 20.39c | 20.98a | 4.12a | 4.20 b | 4.16b |
| Carrot with pot marigold | 41.08a | 43.71a | 42.40a | 20.63a | 18.38a | 19.51a | 3.75a | 3.77a | 3.76a |

Means followed by the same letter within a column are not significantly different ($\alpha = 0.05$)

In 2003 the cultivation of carrots intercropped with French marigold and pot marigold did not affect total yield (Table 2), while marketable yield increased in the intercropped plots, being the highest in the treatments with French marigold. In 2004 lower total yield was harvested in the intercropped plots compared to sole cropping and there was no effect of intercropping on marketable yield of carrot roots. To sum up, on average intercropping did not reduce total or marketable yield in the study years. The investigations of Ogbu-

ehi and Orzolek (1987) show the beneficial effect of intercropping on vegetable yields, which confirms the results obtained in this experiment in 2003. Yields in an intercropping system highly depend on mutual competition of chosen components, climatic conditions during the growing season in particular years and sowing date of the components (Poniedzialek and Kunicki, 1995; Adamczewska-Sowińska and Kołota, 2010; Jędrszczyk and Poniedzialek, 2007).

Table 2
The effect of carrot intercropping with French marigold and pot marigold on carrot yield ($t \times ha^{-1}$)

| Type of cultivation | Total yield | | | Marketable yield | | |
|-----------------------------|-------------|---------|---------|------------------|---------|---------|
| | 2003 | 2004 | Mean | 2003 | 2004 | Mean |
| Carrot (sole crop) | 44.67 a | 72.14 b | 58.41 a | 10.18 a | 29.27 a | 19.73 a |
| Carrot with French marigold | 42.99 a | 52.01 a | 47.50 a | 26.96 b | 22.17 a | 24.57 a |
| Carrot with pot marigold | 45.62 a | 39.51 a | 42.57 a | 20.02 b | 23.08 a | 21.55 a |

Means followed by the same letter within a column are not significantly different ($\alpha=0.05$)

In the present investigation, dry matter, total sugar and carotenoid content depended on the year and type of cultivation (Table 3). Intercropping did not affect the content of dry matter in carrot roots, except for the carrot intercropped with pot marigold in 2004 in which dry matter content was significantly higher. Total sugar and carotenoid content were higher in carrot ro-

ots intercropped with both French and pot marigold, but the differences depended on the year of cultivation. Similarly, Adamczewska-Sowińska and Kółta (2010) found that intercropping eggplant with white clover and perennial ryegrass did not affect the content of dry matter, vitamin C, reducing sugars and macroelements in its fruits.

Table 3
The effect of carrot intercropping with French marigold and pot marigold on the level of chosen root components

| Type of cultivation | Dry matter (% d.w.) | | | Total sugars (% d.w.) | | | Carotenoids ($mg \times g^{-1}$ d.w.) | | |
|-----------------------------|---------------------|--------|--------|-----------------------|-------|--------|--|-------|-------|
| | 2003 | 2004 | Mean | 2003 | 2004 | Mean | 2003 | 2004 | Mean |
| Carrot (sole crop) | 9.43a | 9.41a | 9.42a | 4.10a | 4.30a | 4.20a | 0.13a | 0.13a | 0.13a |
| Carrot with French marigold | 9.71a | 10.34a | 10.03a | 5.04ab | 5.16a | 5.10b | 0.14a | 0.15b | 0.15a |
| Carrot with pot marigold | 10.33a | 11.99b | 11.16a | 5.27b | 4.69a | 4.98ab | 0.14a | 0.16b | 0.15a |

Means followed by the same letter within a column are not significantly different ($\alpha=0.05$)

In the present research, carrot roots were infested by the carrot rust fly (CRF), *Psila rosae* (F.), root aphid, *Pemphigus phenax* B&B, and nematodes. Larvae of the carrot psyllid, *Trioza viridula* Zett., were noted on carrot leaves. These species cause significant economic losses in Poland (Michalik and Wierzch, 2000; Szwejd and Wrzodak, 2007). The largest number of roots damaged by the carrot rust fly was obtained in the control plots (sole cropping) (Table 4). In both years of observation the number of carrot psyllid larvae on carrot plants growing in the plots with French marigold and pot marigold was significantly lower compared with the sole carrot crop (Table 5). In the initial orientation of pests to the host, olfactory stimuli from the carrot plant seem to be the most important. CRF and other carrot pests are attracted to chlorogenic acid (Cole et al. 1988). Attractiveness of carrot cultivars to pests varies (Michalik and Wierzch, 2000; Łuczak, 2007). The proximity of plants that are non-host may mask the scent of the host plant, which hinders finding it. Intercropping seems to have a large effect on insects that oviposit in the soil, such as the carrot fly *Psila rosae* (Rämert, 1996; Rämert and Ekbohm, 1996). Numerous studies have shown that intercropping carrots with a cover crop reduces carrot rust fly damage (Rämert, 1993; Rämert and Ekbohm, 1996; Theunis-

sen and Schelling, 2000). Luik et al. (2000) found that intercropping of carrots with garden beans significantly disoriented pests and decreased the damage of carrots by *Psila rosae* and *Trioza viridula*. Uvah and Coker (1984) noted that mixed cropping carrots with onions reduced attacks by carrot fly. Marigold (*Tagetes* spp.), which is a popular bedding plant, can be used as such cover crop. Finch et al. (2003) studied three marigold species which reduced the number of eggs laid by cabbage root fly females. Janowska et al. (2009) found a significant reduction in the number of cabbage pests in plots where cabbage was intercropped with *Tagetes* and *Calendula*. The use of plants to provide nectar and pollen resources to natural enemies through habitat management is a growing focus of conservation biological control. Janowska (2007, 2010) found that in plots where cabbage was intercropped with French marigold and pot marigold aphid parasitizing, number of predatory syrphids and role of diamondback moth parasitoids were greater.

In the years 2003 and 2004, a distortion of the root structure and typical nematode damage symptoms were observed. Carrots affected by nematodes often exhibit forking of the taproot, stubbing of the roots as well as unsightly galls on the taproot and secondary roots. A smaller number of damaged roots was

recorded in the plots where carrot was intercropped with pot marigold. These differences were significant not only in relation to the sole crop but also in relation to intercropping with French marigold (Table 4). Mari-

gold (*Tagetes* spp.) was one of the first plants reported to be highly resistant to root-knot nematodes (P l o e g, 2002). Also S z a k i e l et al. (2008) noted that marigolds had an overall suppressive effect on nematodes.

Table 4
The influence of intercropping on the occurrence of some pests on carrot roots

| Type of cultivation | Roots infested by pests (%) | | | | | | |
|-----------------------------|----------------------------------|---------|---------|-----------|---------|---------|---------------------------------------|
| | Carrot fly <i>Psila rosae</i> | | | Nematodes | | | Root aphid <i>Pemphigus phenax</i> |
| | 2003 | 2004 | Mean | 2003 | 2004 | Mean | 2003 |
| Carrot (sole crop) | 46.50 b | 42.00 b | 44.25 b | 5.50 c | 23.33 c | 14.42 c | 5.46 a |
| Carrot with French marigold | 15.60 a | 18.66 a | 17.13 a | 1.50 b | 11.33 b | 6.42 b | 12.00 b |
| Carrot with pot marigold | 36.10 ab | 21.00 a | 28.55 a | 0.30 a | 2.66 a | 1.48 a | 33.30 c |

Means followed by the same letter within a column are not significantly different (<0.05)

Table 5
The influence of intercropping on the occurrence of carrot psyllid (*T. viridula*) on analyzed plants

| Type of cultivation | Carrot psyllid <i>Trioza viridula</i> Zett | | | | | |
|-----------------------------|---|----------------|-------------|-----------------|-----------------|--------------|
| | No./10 plants | | | | | |
| | 2003 14 VII | 2004 15 VII | Mean VII | 2003 13 VIII | 2004 16 VIII | Mean VIII |
| Carrot (sole crop) | 2.00 b | 3.00 b | 2.50 b | 5.33 b | 7.00 b | 6.20 b |
| Carrot with French marigold | 0.33 a | 1.00 a | 0.66 a | 1.66 a | 2.66 a | 2.20 a |
| Carrot with pot marigold | 0.33 a | 1.00 a | 0.66 a | 1.66 a | 2.66 a | 2.20 a |

Means followed by the same letter within a column are not significantly different (<0.05)

CONCLUSIONS

1. Intercropping did not have a decreasing effect on total and marketable carrot yield.
2. Intercropping had a positive influence on total sugar content in carrot roots.
3. There was no effect of intercropping on the level of dry matter and carotenoid content.
4. Intercropping had a significant effect on decreasing the number of roots damaged by the carrot rust fly, *Psila rosae*, (the best in this respect was the combination with *Tagetes*) and by nematodes (the best in this respect was the combination with *Calendula*) and decreasing the number of larvae of carrot psyllid, *Trioza viridula*.
5. In 2003 intercropping was not found to have a positive effect on reducing the occurrence of the root aphid.

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**Wpływ uprawy współrzędnej
marchwi (*Daucus carota* L.)
z aksamitką (*Tagetes patula nana* L.)
i nagietkiem (*Calendula officinalis* L.)
na występowanie szkodników oraz wysokość
i jakość plonu marchwi**

Streszczenie

Uprawy współrzędne, wykorzystujące różne aspekty wzajemnego oddziaływania na siebie organizmów w ekosystemach, można zaliczyć do metod pro-ekologicznych, ograniczających szkodliwą ingerencję człowieka w środowisko, a przede wszystkim zużycie środków chemicznych. Pozwalają również osiągnąć wysoki plon, dobrą jakość i wydajność ekonomiczną. Badania prowadzone w latach 2003–2004 w Mydlnikach, k. Krakowa miały na celu określenie wpływu uprawy współrzędnej marchwi 'Nandrin F₁' z aksamitką (*Tagetes patula nana* L.) 'Kolombina' i nagietkiem (*Calendula officinalis* L.) 'Promyk' na wielkość i jakość plonu marchwi oraz stopień porażenia roślin przez szkodniki. Średnio dla obu lat badań nie stwierdzono obniżenia plonu ogólnego i handlowego marchwi pod wpływem uprawy współrzędnej. W 2003 roku uprawa współrzędna wpłynęła na znaczne zwiększenie plonu handlowego w porównaniu z plonem w uprawie jednorodnej. W 2004 obserwowano wyższą zawartość suchej masy w korzeniach marchwi uprawianej współrzędnie

z nagietkiem. Pod wpływem uprawy współrzędnej, zarówno z aksamitką jak i nagietkiem obserwowano wzrost zawartości cukrów w korzeniach marchwi, a w 2004 roku karotenoidów.

Stwierdzono znaczący wpływ uprawy współrzędnej na liczbę uszkodzonych korzeni przez połyśnicę marchwiankę *Psila rosae* (najlepsza pod tym

względem była kombinacja z aksamitką) i nicienie (najlepsza okazała się kombinacja z nagietkiem). Na poletkach z uprawą współrzędną marchwi stwierdzono istotnie mniejszą liczbę larw golanicy zielonki *Triozza viridula*. Nie stwierdzono pozytywnego wpływu na obniżenie zasiedlenia korzeni przez bawełnicę topolowo-marchwianą.