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Competition and Control of Volunteer Jerusalem Artichoke in Various Crops

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With 3 figures and 1 table

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Abstract

A major production constraint in Jerusalem artichoke (*Helianthus tuberosus* L.) is caused by tubers which are not recovered at harvest. Such lost tubers raise a serious weed problem the following season. Winter wheat, oat, spring oilseed rape, sugarbeet, maize and ryegrass were grown in a field which had Jerusalem artichoke as the preceding crop in order to obtain information about their competitive ability and the efficacy of various control measurements against Jerusalem artichoke infestation. The Jerusalem artichoke treatments in these crops were: total control by regular hand weeding (TOC), mechanical/chemical control (MCC), and no control (NOC). Under the NOC treatment, Jerusalem artichoke infestation at harvest was variable among crops, with the number of shoots ranging from 9 to 25 m^{-2} in oat and maize stands respectively. The number of Jerusalem artichoke shoots in the MCC plots was reduced by 50 to 99 % in oat and maize, respectively. The highest crop yields in each of the six species were realized under the TOC treatment. Insignificant yield reductions were observed in the NOC treatment of wheat, oat, rape and ryegrass. However, under this management yield reductions of 91 and 81 % occurred in sugarbeet and maize respectively. Depending on the preceding crop, 1—9 shoots m^{-2} of Jerusalem artichoke were still recorded under the MCC plots in the following season. Consequently, for complete elimination of infestation, volunteers must be controlled in the second and probably in the third year following a Jerusalem artichoke crop.

Key words: *Helianthus tuberosus* L., Jerusalem artichoke, volunteer control, crop-weed competition, crop rotation, herbicides, mecoprop-P, clopyralid.

Introduction

Jerusalem artichoke (*Helianthus tuberosus* L.) is a high-yielding inulin crop. Among other applications, inulin is useful for the production of fructose, dietary fibres and as a substitute for phosphate in washing powder. Unfortunately, Jerusalem artichoke tubers which are not recovered at harvest cause a serious weed problem in the secondary crop. Harvest losses have been reported ranging from 21 to 106 tubers m^{-2} depending on the cultivar (SCHITTENHELM 1994). Control of Jerusalem artichoke infestation is difficult to attain since the large carbohydrate reserves of the tubers facilitate regrowth from axillary buds even after repeated cuttings.

Most reports on Jerusalem artichoke competition are available from North America where this plant causes serious problems as a perennial weed. WALL et al. (1986) reported that 26, 63, and 79 Jerusalem artichoke shoots m^{-2} caused barley yield reductions of 52, 90, and 97 %, respectively. WYSE et al. (1986) observed that Jerusalem artichoke densities of 1, 2, and 4 tubers m^{-1} of row reduced soybean yields by 31, 59, and 71 %, respectively. Heavy infestation of Jerusalem artichoke reduced the

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seed yield up to 52 % in corn and 97 % in soybean (WYSE and YOUNG 1980). However, fodder crops like alfalfa with a rapid regrowth following cutting have been found to compete quite well with weedy Jerusalem artichoke (WYSE and WILFAHRT 1982).

Pre-emergence and postemergence selective herbicides such as atrazine, dicamba, and 2,4-D have been tried in maize and soybean with varying success (RUSSEL and STROUBE 1980, WYSE and WILFAHRT 1982, DEL MONTE et al. 1988). Effective postemergence control has been achieved through application of the non-selective herbicide glyphosate (VANSTONE and CHUBEY 1978, RUSSEL and STROUBE 1980, WYSE and WILFAHRT 1982). Since such total herbicides are highly phytotoxic, selective application equipments are required for their use within a crop. Furthermore, for this technique to be effective, the Jerusalem artichoke canopy must be sufficiently taller than that of the crop. In soybean, COULTAS and WYSE (1980) did not attain satisfactory results from roller, pipewick and bobar wick application of glyphosate. Soybean yields were considerably reduced due to the interference with Jerusalem artichoke for up to 8 weeks prior to the herbicide application. Furthermore, single or double cultivation in soybean was not successful due to a limited control within the row (SPITZMUELLER and WYSE 1985).

The aim of this study was to examine the interspecific competitive ability of various crops as well as the efficacy of mechanical/chemical control on Jerusalem artichoke infestation.

Materials and Methods

The study area was established in Braunschweig-Völkenrode on a field with loamy sand in 1993. The Jerusalem artichoke cultivar 'Topstar' was planted at a density of 33 333 plants ha^{-1}. This cultivar is high-yielding, of relative early maturity and has smooth medium size tubers. The land received a basal dressing of 135 kg K_2O ha^{-1}, 72 kg P_2O_5 ha^{-1} and 45 kg MgO ha^{-1} in autumn of the previous year. Nitrogen fertilizer was applied just before planting at a rate of 80 kg N ha^{-1}. Weeds were controlled mechanically by currying and ridging. The crop was harvested with a single row potato digger on 30 September 1993. Tubers of 2 cm diameters or less passed through the harvester chain and remained in the field. The base fertilization for the succeeding crops was performed on 1 October 1993 at the rates given above. The experimental field was fenced during winter in order to prevent damage by game.

Six secondary crop species: winter wheat (*Triticum aestivum* L.), oat (*Avena sativa* L.), spring oilseed rape (*Brassica napus* L.), sugarbeet (*Beta vulgaris* L.), forage winter rye (*Secale cereale* L.) followed by forage maize (*Zea mays* L.) and Italian ryegrass (*Lolium multiflorum* Lam.) were grown in the field prepared as described above. Sowing was performed with a 2.5 m seed drill. A precision seed drill was used in the case of maize and sugarbeet. The maize was directly sown into the rye stubble. All weeds other than Jerusalem artichoke were controlled by hand. Crops were irrigated whenever they showed symptoms of water shortage. The treatments for Jerusalem artichoke infestation control were: total control by regular hand weeding (TOC), mechanical/chemical control (MCC), and no control (NOC). In ryegrass, the mechanical control was achieved by cutting the grass three times and in maize by mowing of the forage rye just before sowing. In sugarbeet and maize, inter-row control of Jerusalem artichoke was performed with a rotary tiller whereas intra-row control was achieved by herbicide band spraying. Two postemergence systemic herbicides were used for Jerusalem artichoke control in the MCC plots: LONTREL 100 (100 g l^{-1} clopyralid) and DUPLOSAN KV (600 g l^{-1} mecoprop-P). LONTREL 100 in Germany is allowed to be used in sugarbeet, rape and maize (LEYHE et al. 1994). The herbicides were applied using a standard knapsack sprayer at a rate of 350 l water ha^{-1} operating at ca. 200 kPa. Details on crop management are summarized in Table 1.

Jerusalem artichoke volunteers started to appear at the end of April 1994. In wheat and oat, the first application of mecoprop-P was performed at the end of tillering. Since new volunteers emerged continuously, an additional spray was necessary in the stem elongation phase. Sugarbeets were hand harvested. All other crops were mown with a frontal attachment cutting unit. The Jerusalem artichoke shoots were separated from the crops aboveground plant parts in order to determine fresh weight and shoot numbers. Wheat, oat and rape were threshed in the field with a plot combine. The fresh weight of economic plant parts of each crop as well as the weight of straw and leaves were recorded. From each harvested fraction of a plot, five subsamples of 200 to 300 g were randomly selected and dried to constant weight in a forced-air oven at 105 °C. Plot yield data were then adjusted to a dry-weight basis. On 12 June 1995 the persistence of the various infestation control treatments was assessed by determining the number of newly developing Jerusalem artichoke shoots.

A split-plot randomised complete block design with three replications was used in the experiment, with secondary crops comprising the main plots and the Jerusalem artichoke control treatments the sub-

Table 1. Management practices

Crop	Cultivar	Sowing date	Sowing rate kg ha^{-1}	Row width cm	Nitrogen fertiliser kg ha^{-1}	Harvest date	Jerusalem artichoke control in the MCC plots
Wheat	'Toronto'	5 Oct.	180	12	160	21 July	1.4 and 2.0 l ha^{-1} DUPLOSAN KV (11 and 25 May)
Oat	'Flämingsnova'	29 Mar.	169	12	80	20 July	2 l ha^{-1} DUPLOSAN KV (27 May and 9 June)
Rape	'Kardinal'	29 Mar.	15	24	120	4 Aug.	1.2 l ha^{-1} LONTREL 100 (27 May)
Sugarbeet	'Reka'	30 Mar.	[1]	50	160	5 Oct.	Band spraying of 1.2 l ha^{-1} LONTREL 100 (27 May) Rotary tilling between rows (10 and 24 May)
Rye	'Humbolt'	5 Oct.	180	12	60	11 May[3]	
Maize	'Diamant'	21 May	[1]	62.5	100	28 Sept.	Band spraying of 1.2 l ha^{-1} LONTREL 100 (28 June) Rotary tilling between rows (8 and 14 June, 12 July)
Ryegrass	'Turilo'	29 Mar.	52	12	220[2]	[4]	2 l ha^{-1} DUPLOSAN KV (25 and 27 May)

[1] Population densities in sugarbeet and maize were 87 000 and 127 000 plants ha^{-1}, respectively; [2] 100 kg ha^{-1} for the first cut and 60 kg ha^{-1} each for the second and third cut; [3] Harvested at a height of 75 cm; [4] Mowing dates were 14 June, 19 July and 22 August, respectively

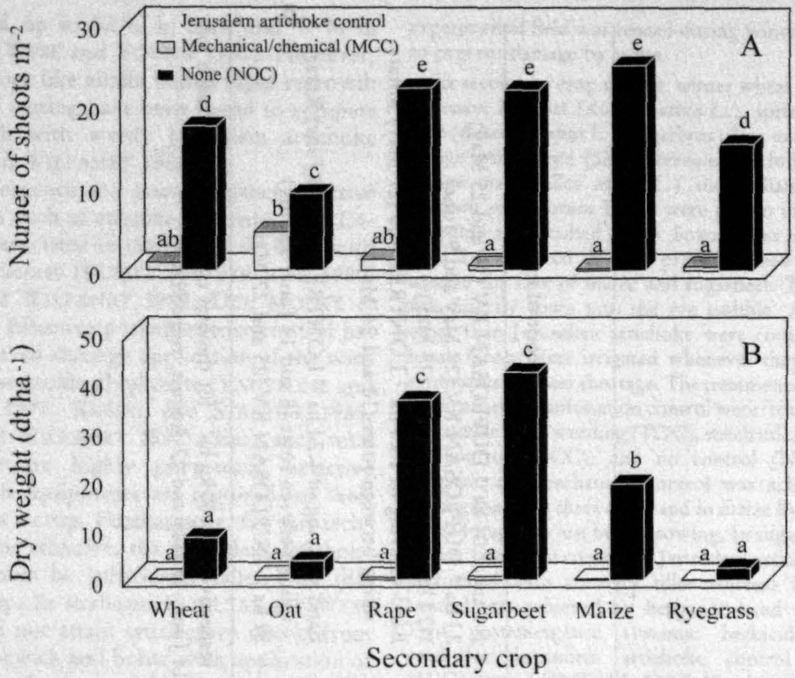

Fig. 1. Effect of infestation control in various secondary crops on (A) the number and (B) the dry weight of Jerusalem artichoke shoots. Columns labelled with the same lower case letter are not significantly different

plots. The subplots had a size of 7.8 × 5 m and were separated from each other by a 0.8 m buffer strip. The analyses of variance (ANOVA) was performed with the PLABSTAT computer program (UTZ 1988). A combined ANOVA was performed for the number and the dry-weight of Jerusalem artichoke shoots. The crop yield data were analysed separately for each crop according to a completely randomized block design. Replication was considered a random effect whereas the crops as well as Jerusalem artichoke control treatments were considered fixed effects. Treatment means were compared by Duncan's multiple range test. All statistical tests were performed at P = 0.05.

Results

The ANOVA revealed a significant variation among crops and infestation control treatments for the number and the dry weight of above-ground Jerusalem artichoke shoots. The crops × infestation control treatment interaction was also observed to be significant. Within the NOC treatment, significant differences were found among crops for both characters. In the MCC treatment, crops differed only with respect to the number of Jerusalem artichoke shoots. The individual ANOVAs indicated a significant variation among treatments for the roots and leaves dry weight of sugarbeet as well as for the forage dry weight of maize.

Jerusalem artichoke infestation in the NOC treatment was very variable among crops, ranging from 9 to 25 shoots m^{-2} in oat and maize, respectively (Fig. 1). At harvest time the Jerusalem artichoke dry weights were low in wheat, oat and ryegrass but high in rape, sugarbeet and maize. In all crops except for oat, the MCC treatment gave a fairly good control. In these crops the number of shoots m^{-2} was reduced by 94 to 99 % whereas this was only by 50 % in oat. Similar results were obtained for the Jerusalem artichoke shoot dry matter weight.

In all crops, the highest economic yields were obtained in the TOC treatment (Fig. 2). However, the dry matter economic yields were significantly lower in the NOC compared to the TOC treatment in only sugarbeet and maize. There was a tendency for higher dry weights

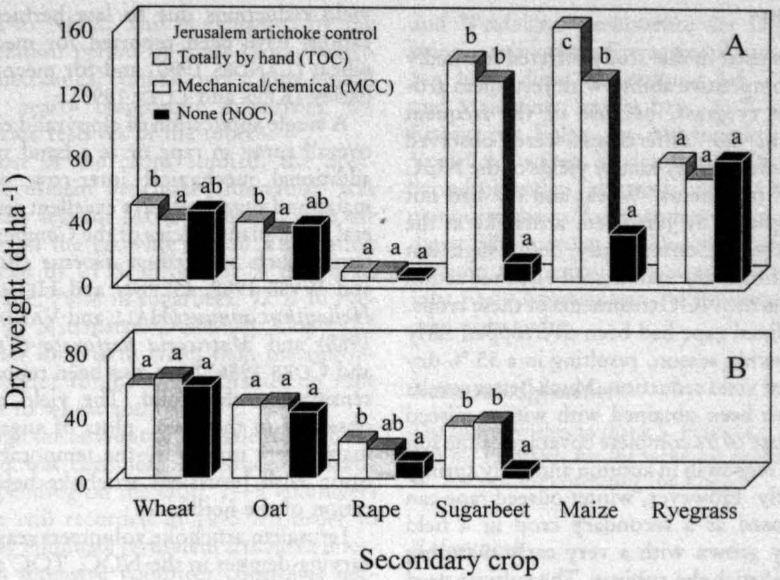

Fig. 2. Effect of Jerusalem artichoke artichoke control in various secondary crops on (A) the dry weight of economic plant parts and (B) the dry weight of stems and leaves. Within a crop, columns labelled with the same lower case letter are not significantly different

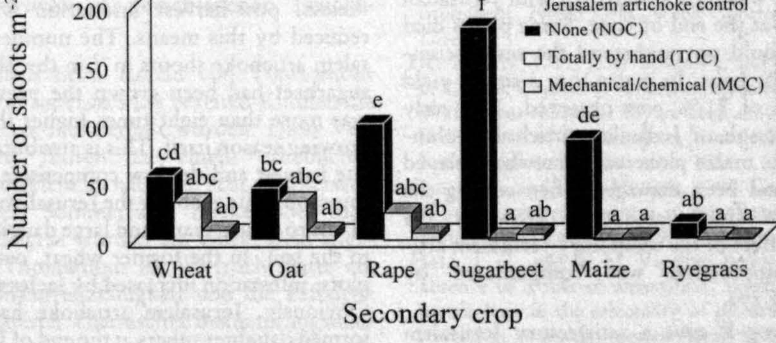

Fig. 3. Effect of various control measurements on post-harvest infestation with Jerusalem artichoke in different secondary crops. Columns labelled with the same lower case letter are not significantly different

of stems and leaves under MCC compared to TOC.

Neither TOC nor MCC gave a complete long-term Jerusalem artichoke control (Fig. 3). In wheat, oat, and rape, Jerusalem artichoke volunteers reappeared within about 6 weeks after harvest. During winter time, these newly emerging shoots were killed by frost. In all crops, the volunteers reappeared in 1995 from mid-May onwards. The extent of post-harvest Jerusalem artichoke infestation was highest in the NOC plots. In the previous wheat, oat, and rape plots, the numbers of volunteers were considerably less for MCC compared to TOC, whereas under both treatments the extent of the Jerusalem artichoke infestation in the plots grown with sugarbeet, maize and ryegrass remained largely similar.

Discussion

The crops used in this study differed markedly in their competitive ability with Jerusalem artichoke. In ryegrass, because of the frequent defoliation, no differences were observed among the forage dry matter yields of the NOC and TOC treatments. Wheat and oat had not been outgrown by Jerusalem artichoke at the time of harvest. Consequently, only a slight but non-significant dry matter seed yield reduction occurred in the NOC treatments of these crops. Spring oilseed rape had been overtopped early in the growing season, resulting in a 55 % dry matter seed yield reduction. Much better results might have been obtained with winter oilseed rape because of its complete coverage of the soil and rapid regrowth in autumn and early spring, respectively. However, winter oilseed rape can only be used as a secondary crop in a field previously grown with a very early maturing Jerusalem artichoke cultivar. The cultivar used in this study was harvested about 4 weeks beyond the optimal sowing date for winter oilseed rape at our location. Comprising a root dry matter yield reduction of 91 %, sugarbeet was least competitive among the crops studied. Sugarbeet was fully overgrown with Jerusalem artichoke at the end of June. Some plants died as they could not withstand the severe competition for light. In maize too, a severe yield reduction of 81 % was observed. The early season growth of Jerusalem artichoke volunteers in the maize plots was somewhat delayed as they had been damaged when cutting the forage rye winter catch crop. However, the positive effect of the temporary Jerusalem artichoke suppression was compensated by regrowing rye.

Mecoprop-P gave a satisfactory Jerusalem artichoke control in wheat and ryegrass. Within a few days after spraying, the volunteers either wilted and died or remained stunted. In ryegrass, a slight phytotoxic effect occurred after the application of mecoprop-P. However, only the first growth forage yield was reduced. Probably due to the cool weather condition after spraying, mecoprop-P was less effective in oat. The grain yields of wheat and oat were significantly reduced even though no visible plant injuries were observed. This yield reduction could be only explained by herbicidal damage, as Jerusalem artichoke competition did not reduce the seed yields in the NOC plots. Seed yield reductions due to late herbicide applications have been reported for mecoprop in wheat (LANDES 1990) and for mecoprop-P in barley (KEES and LUTZ 1993).

A single application of clopyralid either as an overall spray in rape or as a band spray with additional mechanical inter-row control in maize and sugarbeet gave excellent results. Several other plant species of the *Compositae* plant family such as *Cirsium arvense* (BOERBOOM and WYSE 1988, GLENN and HEIMER 1994), *Helianthus annuus* (HALL and VANDEN BORN 1988) and *Matricaria perforata* (THOMPSON and COBB 1986) have also been reported to be sensitive to clopyralid. The yield reductions observed in the MCC plots of sugarbeet and maize were caused by the temporary competition with Jerusalem artichoke before application of the herbicide.

Jerusalem artichoke volunteers reappeared at varying degrees in the NOC, TOC and MCC treatments of all crops in spring 1995. Except for ryegrass, the infestation in the NOC treatments was considerably higher than in 1994. However, the NOC treatment in ryegrass was not absolutely without control since these plots had been cut three consecutive times. Nevertheless, post-harvest infestation was hardly reduced by this means. The number of Jerusalem artichoke shoots m^{-2} in the plots where sugarbeet had been grown the previous year was more than eight times higher than in the growing season itself. This is attributable to the late harvest and the low competitive ability of this crop, thus enabling the Jerusalem artichoke plants to return many and large daughter tubers to the soil. In the former wheat, oat and rape plots, infestation increased by factors of 3 to 5. Obviously, Jerusalem artichoke had already formed daughter tubers at the end of July. Even though the maize was harvested late in the season, infestation only increased by a factor of 3, which was much less than for sugarbeet. This could be accounted for based on the competitiveness of maize compared to sugarbeet.

Although kept free of Jerusalem artichoke throughout the growing season, the TOC plots of wheat, oat and rape again attained infestation levels of 59, 74 and 23 %, respectively of the NOC plots. In these crops mechanical control alone did not reduce Jerusalem artichoke infestation to an acceptable level within one season. In sugarbeet and maize on the other hand, infestation with TOC was considerably less compared to NOC. This is explained by the long vegetation period of these crops, which allowed mechanical control over a long period and thus nearly completely exhausting the carbohydrate reserves of the tubers.

For most of the crops studied, the post-harvest Jerusalem artichoke infestation was considerably less for MCC compared with the infestation in the growing season. Infestation was reduced by 21 % in oat, 52 % in wheat, 73 % in rape, 78 % in sugarbeet, 92 % in rye-grass and 93 % in maize. Obviously, clopyralid has a better long-term effect than mecoprop-P, since better results were obtained in rape compared to wheat and oat.

Although the amount of Jerusalem artichoke infestation was considerably reduced in some cases, depending on the crop, 1—9 volunteers m^{-2} were still recorded in 1995. In order to completely eliminate Jerusalem artichoke infestation, an intensive volunteer control is necessary for at least 2 years following a Jerusalem artichoke crop.

Zusammenfassung

Konkurrenz und Kontrolle von Topinamburdurchwuchs in verschiedenen Fruchtarten

Ein Problem beim Anbau von Topinambur (*Helianthus tuberosus* L.) bereiten Knollen die bei der Ernte nicht erfaßt wurden. Diese Verlustknollen führen zu einem erheblichen Unkrautproblem im nächsten Jahr. Winterweizen, Hafer, Sommerraps, Zuckerrübe, Mais und Weidelgras wurden auf einem Feld angebaut das Topinambur als Vorfrucht hatte um deren Konkurrenzfähigkeit und die Effizienz von mechanisch/chemischen Bekämpfungsmaßnahmen zu untersuchen. Es wurden folgende Maßnahmen zur Kontrolle des Topinamburdurchwuchses durchgeführt: vollständige Bekämpfung durch regelmäßige Handhacke (TOC), mechanisch/chemische Bekämpfung (MCC) sowie keine Bekämpfung (NOC). In der NOC Behandlung war zum Erntezeitpunkt ein sehr unterschiedlicher Topinamburbesatz mit 9 bis 25 Trieben m^{-2} bei Hafer bzw. Mais zu verzeichnen. In den MCC Parzellen konnte die Zahl der Topinamburtriebe um 50 bis 99 % bei Hafer bzw. Mais reduziert werden. Bei allen sechs Fruchtarten wurde der jeweils höchste Ertrag in der TOC Behandlung erzielt. In der NOC Behandlung von Weizen, Hafer, Raps und Weidelgras verursachte der Durchwuchs keine signifikanten Ertragsreduktionen. Dagegen hatte diese Behandlung bei Zuckerrübe und Mais einen um 91 bzw. 81 % geringeren Ertrag zur Folge. In Abhängigkeit von der Vorfrucht waren in den MCC Parzellen im darauffolgenden Jahr noch immer 1 bis 9 Topinamburtriebe m^{-2} vorhanden. Bis zur vollständigen Eliminierung des Durchwuchses sind im zweiten und möglicherweise noch im dritten Jahr nach Topinambur Bekämpfungsmaßnahmen notwendig.

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