Growth and Development of Oil-Radish and Yellow Mustard in Nebraska[†]

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ABSTRACT

Growth and development of two varieties of oil-radish *(Raphanus sativus)* and one variety of yellow mustard *(Sinapis alba)* were compared when planted every 15 days beginning April 1 and ending September 15. For each 5 C increase in soil temperature from April 1 to August 1 there was a 10 cm increase in trap crop height when crop height was measured 6 weeks after planting and planting occurred every 15 days beginning April 1. Although oil-radish and yellow mustard seeds would germinate and grow when planted from April 1 to September 15, maximum plant growth was observed when trap crops were planted between June 15 and August 15. The period of maximum plant growth corresponds to the period when average soil temperature at 15 cm was greater than 20 C. When oil-radish and yellow mustard were planted between April 15 and August 15 and harvested at flowering, percent protein and *in vitro* dry matter digestibility ranged from 13 to 17% and 64 to 79%, respectively.

Additional Key Words: *Raphanus sativus, Sinapis alba,* Nemex, Maxi, Pegletta, trap crop, *Heterodera schachtii,* beet cyst nematode, biological control.

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The sugarbeet cyst nematode or beet cyst nematode (BCN), *Heterodera schachtii* Schmidt, is one of the major pests of sugarbeets *(Beta vulgaris* L.) and is found in most of the sugarbeet growing regions in the United States (Altman and Thomason, 1971; Nematode Geographical Distribution Committee of the Society of Nematologists, 1984). Depending upon nematode densities, yield losses in the U.S. are reported from a trace to 70% (Altman and Thomason, 1971).

BCN currently is managed through cultural practices and soil applied nematicides (Altman and Thomason, 1971). However, interest has increased in incorporating biological control strategies into programs for BCN control. In France, trap crops of oil-radish *(Raphanus sativus* L.) and yellow mustard *(Sinapis alba* L.) stimulated BCN egg hatching and root invasion, but inhibited cyst development, resulting in reduced nematode density (Caubel, et al. 1985). Similar experiments conducted in the United States confirmed the effectiveness of oil radish in reducing the density of sugarbeet cyst nematode (Hafez and Hara, 1989).

Several varieties of oil-radish and yellow mustard trap crops developed in Germany provide effective biological control of BCN when planted after cereals (Steudel and Müller, 1981). Resistant varieties were designed to provide extensive root development to enhance hatching of nematode larvae but not support nematode reproduction (Caubel, et al. 1985). Optimum nematode suppression was achieved when oil-radish and yellow mustard were seeded to provide a dense ground cover and when soil temperatures were above 20 C (Caubel et al. 1985). In Germany trap crops of either oil-radish or yellow mustard are sown as early as possible after small grain harvest, preferably in early August (Peterson, 1992). The trap crops are allowed to grow through the remainder of the growing season. Upon flowering, trap crops are cut back to a height of 30 cm to prevent plants from producing seed. The trap crop is either plowed under in the fall or spring preceeding sugarbeet planting.

Climate, soils, and cropping systems in western Nebraska are different from those in sugarbeet production areas of Europe where the trap crop system was developed. To explore in more detail the use of trap crops to control BCN in this region, an experiment was designed to determine a time period during the growing season to plant oil-radish and yellow mustard to achieve maximum root and shoot development. Oil-radish and yellow mustard were also evaluated for their potential as a forage crop. A second phase of this study currently underway explores the effectiveness of trap crops for management of the sugarbeet cyst nematode.

MATERIALS AND METHODS

Field experiments were initiated near Scottsbluff, Nebraska, in the spring of 1990 and 1991. The experimental design was a split plot with 12 main plots and 3 subplots. All treatments were replicated four times. Main plots were 12 dates of planting beginning April 1 and ending September 15. Subplots were two varieties of oil-radish (Nemex, Pegletta) and one variety of yellow mustard (Maxi). Plots were located on a Tripp sandy loam (Typic Haplustoll) with a pH 8.3 and 0.8% organic matter content. A Tye (The Tye Company, P.O. Box 218, Lockney, TX 79214) all purpose drill was used to seed trap crops in rows spaced 20 cm apart. Seeds were planted 2.5 cm deep at a seeding rate of 42, 44, and 42 kg ha^{-1} for Pegletta, Nemex, and Maxi, respectively. Plots were 1.8 m wide by 9 m long. Soil was tilled to a depth of 10 cm with a power driven rototiller several days before each planting. Beginning in mid June plots were irrigated with an overhead irrigation system every 10 days until mid September.

Trap crop density, height, and stage of growth were recorded each week from crop emergence to flowering for each planting date. Oil-radish and yellow mustard were allowed to grow until plants began to flower. Plants were then cut at the soil surface and wet and dry top-growth weights were recorded. A 300 g subsample of plant top-growth was ground and percent crude protein was determined by the Kjeldahl procedure (Anonymous, 1955). The method outlined by Tilley and Terry (1963) was used for *in vitro* dry matter digestibility determinations. Plant roots were harvested from 0.1 m^2 area to a depth of 30 cm by digging plants with a shovel, removing soil, and recording wet and dry weights. Root length was measured to a depth of 45 cm by taking a 4.5 cm diameter core sample from six locations in each plot. Soil cores were divided into 0 to 15, 15 to 30, and 30 to 45 cm segments. Soil cores from each depth were combined and roots were extracted and measured using the method developed by Tennant (1975).

There was a significant interaction between treatments and years; however, the interaction effect was small relative to the average effect, the ranking of treatments was stable over years, and the interaction was ignored (Gomez and Gomez, 1984). Data for the 2-yr period were pooled and subjected to analysis of variance. Mean separation was performed using Fisher's Protected Least Significant Difference (LSD) Test at the 0.05 level of significance.

RESULTS AND DISCUSSION

The relationship between soil temperature and trap crop growth is important because sugarbeet cyst nematode development is

Table 1. Effect of planting date and variety on oil radish and yellow mustard growth and development at Scottsbluff, Nebraska, in 1990 and 1991.

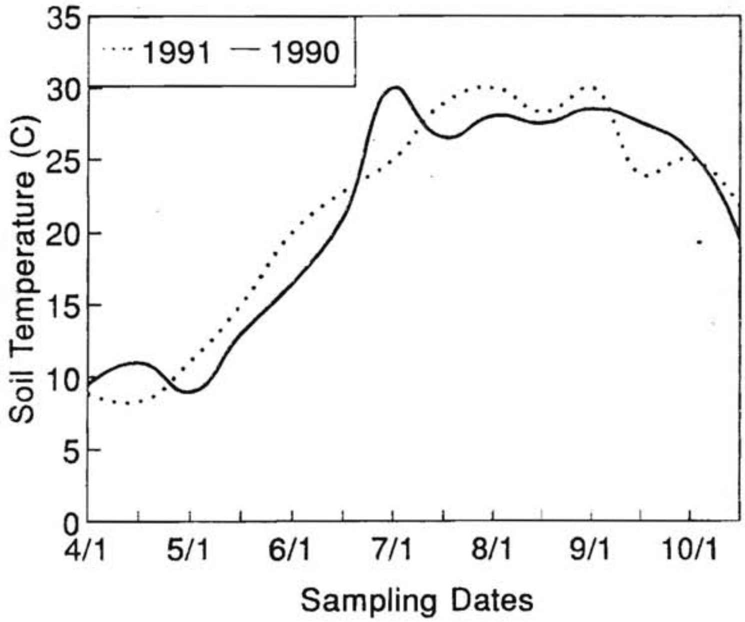
		Six weeks after planting		At the time of flowering[1]					
				Dry weights		Root length at various soil depths			
Date of planting	Variety	Plant density	Plant height	Top-growth	Total root weight to 30 cm	0-15	15-30	30-45 cm	Total
		(plants 0.1m $^{-2}$)	------ (cm) ------	------------- (g 0.1m $^{-2}$)	-------------	----- (cm root 1000 cm $^{-3}$ soil) -----			
April 1		14.5	6.6	15.9	1.5	575	203	138	915
April 15		14.1	11.6	30.9	2.5	633	277	305	1215
May 1		12.8	20.5	21.8	2.0	807	349	256	1412
May 15		11.1	35.3	27.4	2.3	835	400	258	1492
June 1		16.4	43.6	20.7	2.0	843	368	239	1450
June 15		19.5	47.6	33.8	3.1	1959	639	416	3014
July 1		16.1	41.4	31.0	3.3	1707	752	520	2979
July 15		15.3	58.9	36.8	2.8	2877	798	483	4158
August 1		25.0	60.9	24.4	2.2	2751	664	449	3864
August 15		23.2	44.5	20.2	3.3	1305	489	418	2212
September 1[1]		23.2	23.6	8.5	1.4	741	363	322	1424
September 15[1]		28.6	9.2	1.5	0.2	468	192	82	742
LSD (0.05)		2.8	4.5	16.6	1.5	337	142	129	489
	Nemex radish	15	30.2	33.4	3.4	1088	435	292	1815
	Pegletta radish	22	36.7	22.9	2.0	1399	467	329	2196
	Maxi yellow mustard	19	34.1	23.1	2.1	1389	471	350	2209
	LSD (0.05)	2	1.9	6.0	0.7	147	NS	NS	189

[1]Plants were killed by freezing temperatures on October 25, 1990 and November 13, 1991 before plants had flowered.

influenced by temperature. BCN has a narrow temperature range for development (12 to 28 C), with maximum growth and reproduction occurring between 25 and 28 C (Thomason and Fife, 1962). It is, therefore, important to have a high density of trap crop roots present when BCN development can occur. Soil temperature at 15 cm averaged 14 C on May 15 and increased to 20 C by mid June (Figure 1). Soil temperature continued to increase through the summer until August 1 when it reached 27 C and then began to decline in September, and by mid October had fallen below 20 C.

Trap crop stands of 11 to 29 plants 0.1 m^{-2} were obtained from April to September plantings (Table 1). Plant density was greatest when crops were planted on September 15, followed by plantings made in August and early September. Trap crop plantings made in early April to mid July generally had reduced plant density as compared to late summer plantings. In 1990 trap crop density was reduced by heavy rain (2.2 cm) which occurred five days after the May 15 planting and moved soil into the drill furrow, buried seed and resulted in reduced oil-radish and yellow mustard emergence.

Figure 1. Average soil temperature at 15 cm near oil-radish plants during the 1990 and 1991 growing season.



Plant density varied between oil-radish varieties 'Nemex' and 'Pegletta' and yellow mustard variety 'Maxi'. When plant density was measured 6 weeks after planting and averaged over all planting dates, trap crop density was greater in areas seeded to Pegletta followed by Maxi and Nemex. There was a significant planting date by variety interaction (data not presented) which became evident when trap crops were planted in August and September. Density of the yellow mustard Maxi increased and surpassed the oil-radish varieties Nemex and Pegletta when trap crops were seeded on August 1, August 15, and September 1.

Trap crop height 6 weeks after planting increased with soil temperature (Table 1, Figure 1). For each 5 C increase in soil temperature from April 1 to August 1 there was a 10 cm increase in trap crop height when crop height was measured 6 weeks after planting and planting occurred every 15 days beginning April 1. Regression analysis of trap crop height 6 weeks after planting and soil temperature from April 1 to August 1 suggested that 84% of the variation in plant height was due to the dependent relationship between plant height and soil temperature. Trap crop height 6 weeks after planting began to decline when the crop was planted on August 15 and continued to decline until the last date of planting September 15. Soil temperature during the period declined but was coupled with a decrease in day length. Radish and mustard are long-day plants, and therefore, stem elongation and flowering respond to long days (days longer than a critical daylength) (Salisbury and Ross, 1985). As day length and temperature decreased in late August and September, trap crop height declined.

Plant height averaged over planting dates varied between oil-radish varieties and yellow mustard. Pegletta oil-radish height 6 weeks after planting was higher than Nemex radish or yellow mustard. Trap crop top-growth and root weights taken at the time of flowering were similar between plantings made on April 1 through June 1 (Table 1). Trap crops planted on June 15 and harvested at flowering had higher top-growth and root weights than crops planted on April 1. Trap crops planted in September did not flower due to a reduction in day length, temperature, and a killing frost which occurred on October 25, 1990 and October 27, 1991 and consequently had reduced top-growth and root weights. There was a positive correlation (r^2 = 0.71) between trap crop top-growth and root weight at flowering.

Trap crop root length at harvest from all dates of planting was greatest in the 0 to 15 cm soil depth and decreased as soil depth increased to 45 cm (Table 1). Sixty two percent of the total root length was present in the upper 15 cm of soil with 22% in the 15 to 30 cm segment and 16% in the 30 to 45 cm section of the soil profile. Total oil-radish and yellow mustard root length at flowering in the 0 to 45 cm segment of the soil profile increased with soil temperature from April 1 to August 1 (Table 1, Figure 1). Regression analysis of trap crop root length at harvest and soil temperature from April 1 to August 1 suggested that 87% of the variation in root length was due to the dependent relationship between root length and soil temperature. Trap crop root length at harvest began to decline when the crop was planted on August 15 and continued to decline until the last date of planting September 15. When trap crop root length in the 0 to 45 cm segment of the soil profile was averaged over planting dates, Nemex oil-radish root length was less than that of Pegletta oil-radish and Maxi yellow mustard. There was a significant planting date by variety interaction (data not shown) which became evident when trap crops were planted in early August. Root length in the 0 to 15 cm segment of the soil profile for the yellow mustard Maxi increased and surpassed the oil-radish varieties Nemex and Pegletta when trap crops were seeded on August 1.

Oil-radish and yellow mustard plant height 6 weeks after planting and trap crop root length at harvest responded similarly to soil temperature. A positive correlation ($r^2 = 0.79$) between trap crop height and root length suggests that measuring plant height can provide an estimate of root length.

Although oil-radish and yellow mustard seeds would germinate and grow when planted from April 1 to September 15, plant growth increased as soil temperature increased through August 1. The period of maximum plant growth corresponds to the period when average soil temperature at 15 cm was greater than 20 C (Table 1, Figure 1).

When oil-radish and yellow mustard were planted between April 15 and August 15 and harvested at flowering, percent nitrogen and protein of the top-growth ranged from 1.9 to 2.7% and 12 to 17%, respectively (Table 2). *In vitro* dry matter digestibility of the above plant materials ranged from 64 to 79%. Trap crop nitrogen, protein, and *in vitro* dry matter digestibility increased with September plantings because the crop was harvested before flowering in an immature stage of growth. When trap crops were averaged over planting dates Maxi yellow mustard and Nemex oil-radish had higher percent nitrogen and protein contents than Pegletta oil-radish. *In vitro* dry matter digestibility was greatest with oil-radish variety Nemex.

Trap crops planted on July 15 and harvested at flowering have the potential to produce 3680 kg ha^{-1} of dry matter (Table 1) with a protein content of 14% and in vitro dry matter digestibility of 72% (Table 2). In addition to their potential to suppress sugarbeet cyst nematode, trap crops may also have potential as forage for livestock.

Table 2. Effect of planting date and variety of oil radish and yellow mustard on nitrogen or protein content and dry matter digestibility at Scottsbluff, Nebraska in 1990 and 1991.

		At the time of flowering[†]		
Date of Planting	Variety	Nitrogen	Protein	*In vitro* dry matter digestibility
		----------	(%)	----------
April 15		2.1	13.1	64.5
May 1		2.4	15.1	71.6
May 15		2.4	15.1	70.1
June 1		2.6	16.3	71.5
June 15		1.9	12.0	65.2
July 1		2.6	16.5	74.3
July 15		2.3	14.6	72.2
August 1		2.3	14.9	74.5
August 15		2.7	17.4	79.5
September 1[†]		3.6	22.7	82.8
September 15[†]		3.9	24.6	82.6
LSD (0.05)		0.3	1.5	2.9
	Nemex	2.7	16.8	77.6
	Pegletta	2.5	15.8	73.1
	Maxi	2.8	17.4	69.8
	LSD (0.05)	0.1	0.8	1.4

[†]Plants were killed by freezing temperatures on October 25, 1990 and November 13, 1991 before plants had flowered and were harvested in an immature stage of growth.

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