Cultural Management of Trap Crops for Control of Sugarbeet Nematode[1]

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ABSTRACT

Trap crop varieties of radish (*Raphanus sativus* var. *oleiformis* Pres.) and mustard (*Sinapis alba* L.) are promising alternatives to nematicide for control of sugarbeet nematode (*Heterodera schachtii* Schmidt). To determine the most effective practices for using trap crops in Wyoming sugarbeet (*Beta vulgaris* L.) rotations, a series of replicated field trials were conducted from 1992 to 1997. These studies compared the effect of cultural management practices and nitrogen fertilization on production of trap crops. Dry matter production of radish and mustard trap crop was three times higher following small grains compared to corn (*Zea mays* L.) and dry bean (*Phaseolus vulgaris* L.). This is attributed to a longer growth period. Application of 45 to 56 kg N ha^{-1} fertilizer, increased dry matter production by one third. Application of nitrogen to plantings the last week of August, after corn silage or dry bean harvest, did not compensate for the lateness of planting, as fertilized trap crop yields were still less than half that of plantings made 15 days earlier. Similar low dry matter yield occurred from relay cropping onto corn and before knifing of dry bean. Nitrogen application, and volunteer small grain control, produced increased trap crop growth when radish and mustard followed small grains.

Additional Key Words: *Heterodera schachtii*, *Beta vulgaris*, *Raphanus sativus*, *Sinapis alba*, biological control, re-crop, nematicides.

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Sugarbeet nematode (SBN) (*Heterodera schachtii* Schmidt), is one of the most destructive pests of sugarbeet (*Beta vulgaris* L.) worldwide. Annual losses in sugarbeet of greater than 25% have been reported in the Western U.S.A. (Griffin, 1981). SBN is reported in all sugarbeet growing areas of Wyoming and is particularly severe in fields near processing plants where sugarbeet has been grown the longest (Gray, 1995). Trap crops are reported to be a promising alternative to nematicides for control of SBN in Europe (Cooke, 1991). Varieties of fodder radish (*Raphanus sativus* var. *oleiformis* Pres.) and yellow mustard (*Sinapis alba* L.), have been selected for resistance to SBN and their ability to reduce SBN soil populations. Technology for substituting trap crops for nematicides was first developed in Europe (Peterson, 1992).

Trap crops have been successfully used for sugarbeet nematode control in Europe for more than 10 years (Spittel, 1986). Trap crops are usually planted following small grain harvest the year preceding sugarbeet planting. Although Gardener and Caswell-Chen (1993), Koch et al. (1996), and Hafez and Sundararaj (1998) reported the potential of nematode trapping in the United States, additional information is needed on specific cultural practices to maximize effectiveness of trap crops grown in the United States where climate, soils, irrigation, rotations and management of sugarbeet differ from those of Europe. The common rotations in Wyoming are a 3-year rotation of sugarbeet:corn:dry bean and a 2-year rotation of sugarbeet:malting barley. Lengthening these rotations, which would reduce soil populations of *Heterodera schachtii*, may not be economically practical due to the high value and potential profitability of the sugarbeet crop and lack of other adapted and profitable cash crops for Wyoming's climate. However, modifying the rotation by second cropping with trap crops following harvest of the previous crop is appealing. Promotion of trap crop growth with proper nitrogen fertilization, modified establishment methods, and correct selection of trap crop variety could improve their effectiveness in SBN control. Methods are needed that facilitate early second crop planting of trap crops while producing dense stands with maximum root and shoot growth. The objective was to compare the effect of several cultural management practices on the growth and production of second crop radish and mustard trap crops grown in the central Intermountain region of the United States. Several trap crop species and varieties were also evaluated for adaptability to this region.

MATERIALS AND METHODS

A series of 19 replicated research/demonstration field trials using trap crops were conducted from 1992 to 1997 throughout Wyoming. Common management practices were followed at all locations, including removal of loose small grain straw when necessary, planting as early as possible with mustard, and/or radish at seeding rates of 19, and 26 kg ha^{-1}, respectively, and irrigating as soon as possible after planting. A positive correlation ($r^2 = 0.71$) has been shown between trap crop top-growth and root weight at flowering (Wilson et al., 1993). Therefore, we relied on top-growth as an indicator of potential trap crop effectiveness.

This research was undertaken within the region as described by Thorne, (1979), as part of the semi-arid and arid cool-temperate zones. The soil orders occurring in the zones include the Mollisols, Aridisols and associated Entisols. These soils are usually well supplied with many of the essential mineral elements and are usually neutral to alkaline in reaction. Salt accumulations are common hazards to successful farming within this region although salinity at the trial sites was not considered severe enough to influence crop growth. Nitrogen is generally inadequate in these soils for high yields of crops and the supply of available phosphorus is often low.

Trap Crop Yield Studies

Second cropping of trap crops ('Pegletta' or 'Adagio' radish or 'Maxi' or 'Metex' mustard) followed either cereal (spring barley, *Hordeum vulgare* L.; spring or winter wheat, *Triticum aestivum* L.; or spring oats, *Avena sativa* L.), corn grown for silage, *Zea mays* L. or dry bean, *Phaseolus vulgaris* L. Re-cropping results are based on 19 location means of trap crop dry matter production from trials in a randomized complete block design with six replicates after cereals and four replicates after corn and dry bean. Trials where trap crops followed cereals were located with cooperating sugarbeet growers in the Big Horn River Basin (northwestern Wyoming), while trials after corn and dry bean were with growers in the North Platte River Basin in Goshen County (southeastern Wyoming). Growing degree days (GDD) were based on 4.4° C and were calculated from data collected by U.S. Weather Service Reporting Station in the closest proximity to the field trials. These data were compared to historical means based on U.S. Weather Service Data.

Fertilizer Application

Nitrogen fertilizer-trap crop input studies followed either the harvest of spring barley, silage corn or dry bean. Ammonium nitrate fertilizer was broadcast at planting of the trap crop. Three fertilizer rates were used; 1) none, 2) a low rate of nitrogen of 45 to 56 kg N ha^{-1}, and 3) 90 to 112 kg N ha^{-1} or double the low rate of nitrogen. Nitrogen response results are based on trial means. Seven trials were pooled from the fertilizer and re-

Trap crop after malt barley: Spring grains mature early enough to allow an extended growth period for trap crops. Establishment methods which facilitate earlier planting and fertilizer application should enhance production. Seeding methods and fertilizer rates were evaluated in a split-plot design with four replicates in 1992 on the Hefenieder farm in the Big Horn River Basin near Worland, WY. 'Pegletta' radish was seeded on July 29 five days after malting barley harvest. Main plots were seeding method: 1) stubble planting with disk drill following glyphosate application at 1.12 kg ha^{-1}; 2) disking prior to disk drill seeding with no herbicide; and 3) stubble planting with disk drill without herbicide. Sub-plots were broadcast nitrogen fertilizer rates, 0, 56 and 112 kg N ha^{-1} before seedbed preparation. Seeding method and fertilizer rate were factorially arranged. No postemergent herbicide was used.

Trap crop varieties: As trap crops are new to the region, an assessment of the potential of commercially available varieties is useful. Before planting the trap crop variety study on the Hefenieder farm, loose barley straw was removed and the field was disked twice, and 56 kg ha^{-1} of nitrogen as ammonium nitrate was applied. Four trap-crop varieties with SBN reduction potential were compared in a randomized complete block design with four replicates. Mustard and radish were planted at 19, and 26 kg ha^{-1}, respectively, on July 29, 1992. The plots were furrow-irrigated twice. A tank mix of sethoxydim at 420 g ha^{-1}, and crop oil at 2338 ml ha^{-1}, was applied when barley was in the 2 to 3 leaf stage and radish was in the first true leaf stage. In 1993, Pegletta and Adagio radish were compared on fields at the Hefenieder Farm (different field than 1992) and at the Faegler Farm (Torrington).

Statistical analysis: Data were subjected to analysis of variance and mean separation was performed using Fisher's Protected Least Significant Difference Test (LSD) at the 0.05 level of significance. Where practical, data was pooled over locations.

RESULTS AND DISCUSSION

Trap Crop Yield Studies

Trap crop dry matter production following cereals was more than three times higher than production following corn or dry bean (Table 1). This is attributed to a much longer growth period of 1450 GDD following cereals compared to the re-crop intervals of 660 and 620 GDD following corn or dry bean, respectively. These results compare favorably with those of Wilson et al., (1993) in Nebraska where roughly triple the top growth occurred for August 1 plantings compared to September 1 plantings under

Table 1. Production of trap crops after three common rotation crops in Wyoming 1992-97.

Previous Crop	No. of Trials	Mean Planting Date	Dry Weight of Tops	Growing Degree Days
			($g\ m^{-2}$)	
Cereals	11	2 Aug.	314	1450† (+130)‡
Silage Corn	4	7 Sept.	80	660 (+50)‡
Dry Bean	4	7 Sept.	81	620 (+40)‡

†Based on 10 trials.
‡Departure from long-term average.

conditions in which a previous crop had not been grown during the season. Re-cropping after cereals resulted in trap crop production approaching the highest yields as reported by Wilson et al., (1993), while re-cropping after dry bean and silage corn did not, even though GDDs during the period of these trials exceeded the long term average. Considering these results, it appears that under proper management, re-cropping after cereals offers no yield penalty compared to growing trap crops without a previous crop at comparative planting dates. Planting trap crops after cereals allowed, on average, 36 days earlier planting than after silage corn or dry bean.

Fertilizer Application

Application of nitrogen to re-crop trap crops resulted in increased dry matter production probably because the previous crop of spring barley, silage corn or dry bean depleted the root zone soil reserves of nitrogen. The low application rate of N increased dry matter production by one third across seven experiments. The nonfertilized treatment yield was 820 kg ha^{-1} compared to 1090 kg ha^{-1} for the low application rate of N. Increases in dry matter production were similar between low and high N input, 33 and 37%, respectively. Based on these results, a broadcast application of 45 to 56 kg N ha^{-1} as ammonium nitrate is recommended at planting of trap crops in Wyoming.

Establishment Methods

Trap crop after silage corn: Data from each experiment were combined because the effect of years on treatments was not significant ($P>0.05$). Trap crop mustard responded to N fertilizer at the first two planting dates (Fig. 1). Trap crop response to N after silage corn only partially compensated for delay in planting. Dry weight from the middle planting date, high fertilizer treatment, remained approximately 200 g m^{-2} lower than that of the non-fertilized treatment from the earliest planting date, but was significantly ($P\leq0.05$) higher than the non-fertilized treatment for the middle planting date. Mustard was more responsive to planting date than to N fertilization.

Corn silage fresh weight and dry matter were reduced by early harvest (Table 2). Silage moisture content was highest at the earliest harvest. Total digestible nutrient (TDN) content of the silage based on analysis of composited samples ranged from 54.0 to 59.3, with the early harvest containing the lowest TDN. Silage from the early harvest would need to be at least 16% lower in moisture content in order to make acceptable silage. High moisture in corn silage results in loss of soluble nutrients from the silage by leaching during the stockpiling/fermentation process. Moisture content of 65 to 70% is considered optimum for corn ensilage (Mueller et al., 1987). In addition to the lower dry matter content and reduced quality of the corn silage resulting from early harvest, an addi-

Table 2. Corn silage fresh weight, moisture content, dry weight and total digestible nutrients in 1992 prior to trap crop planting at the UW-Research and Extension Center, Torrington, WY.

Harvest		Fresh	Moisture	Dry	Total Digestible
Stage[†]	Date	Weight	Content	Weight	Nutrients
		($Mg\ ha^{-1}$)	(%)	($Mg\ ha^{-1}$)	(%)
Blister (R-2)	6 Aug.	42.4	86	5.9	54.0
E Milk (R-3)	21 Aug.	52.4	82	9.5	59.3
M/L Milk (R-4)	6 Sept.	56.9	79	11.8	56.6
LSD 0.05		4.2	1.0	1.0	—

[†]Corn growth and development stage based on the method described by Ritchie et al (1992).

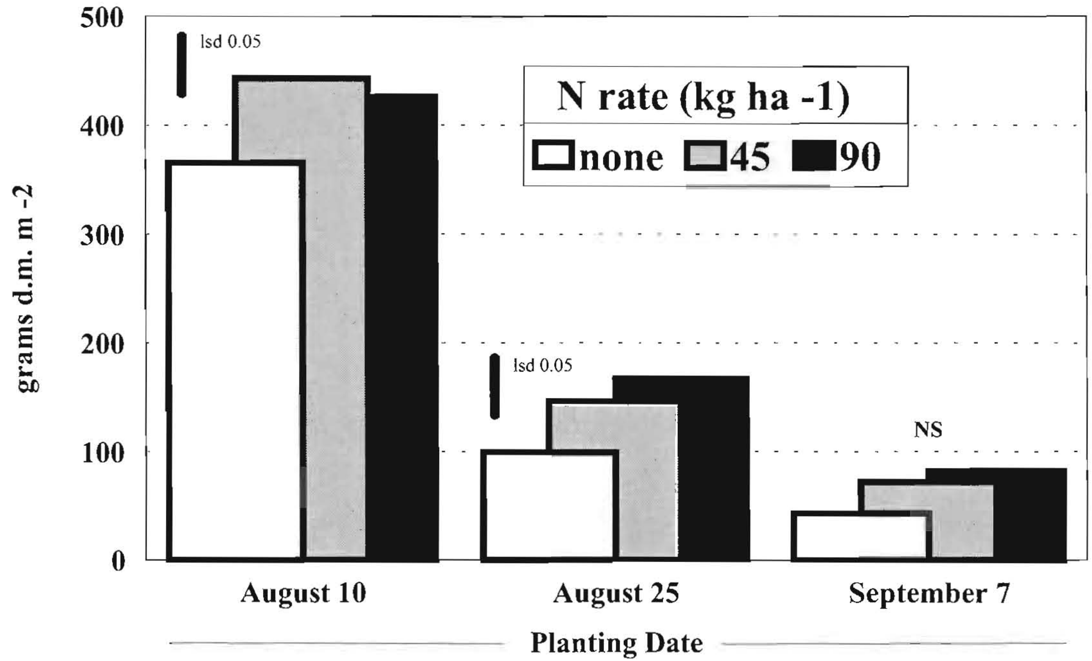

Figure 1. Influence of planting date and fertilizer rate on yield of 'Maxi' mustard planted as a second crop following silage corn at the UW-Research and Extension Center, Torrington, Wyoming, 1992-1993.

tional economic loss would be incurred due to the requirement for lower moisture content. This could be accomplished by the addition of dry matter. Ground grain or straw can be used to reduce moisture by 1% for each 15 kg of dry material applied per Mg of silage. The most practical harvest for silage was the last date, which resulted in low and unacceptable trap crop production, and production was not improved by fertilizer application (Table 2 and Fig. 1).

Mustard broadcast into standing corn: The high broadcast seeding rate of 'Maxi' mustard increased plant population in comparison to the lower rate, but did not result in significantly ($P>0.05$) higher top growth (Fig. 2). More importantly, growth of trap crops broadcast into corn (Fig. 2) was considerably less than growth following drilled trap crop after silage corn (Fig. 1) or broadcast or drilled trap crop after dry bean harvest (Fig 3). While acceptable stands could be attained through broadcasting into established corn, an acceptable level of trap crop growth did not occur. Competition for nutrients, water, and light by the corn, had a major negative impact on trap crop growth even though the corn was approaching maturity.

Mustard after dry bean: Broadcast planting of 'Maxi' mustard into dry bean prior to knifing on August 27 provided 96 additional GDD over the September 1 drilling date. Dry matter accumulation at sampling on October 16, however, was similar for the two planting methods at comparable seeding rates. The high broadcast seeding rate of 42 kg ha^{-1} resulted in a higher plant density than the 21 kg ha^{-1} rate (Fig. 3). High broadcast seeding rate following dry bean produced a greater dry matter yield (Fig. 3) than the low drilled seeding rate ($P\leq0.09$). However, the August 10 planting date following corn silage produced more dry matter than the high seeding rate following dry bean (Fig. 1). Application of N fertilizer significantly ($P\leq0.05$) reduced plant density (Fig. 4). This was likely due to N fertilizer particles coming into direct contact with germinating seed causing seedling mortality. However, final dry matter production tended to increase especially at the 90 kg ha^{-1} rate (Fig. 4) but production from this practice was less than from the early planted trap crop following corn (Fig. 1). A significant interaction occurred between planting method and nitrogen fertilizer rates with respect to plant density. Nitrogen applied to the broadcast plantings caused a 47 to 53% decrease in mustard plant density but nitrogen had no effect on plant density with drilling (data not shown). With drilling, seed was protected from N fertilizer by a layer of soil. Adequate stands were obtained from broadcasting without fertilizer even at the lower seeding rate. Ammonium nitrate was broadcast on the surface and is thought to be responsible for mortality of surface-germinating mustard seed in the broadcast seeding method. If nitrogen fertilizer is

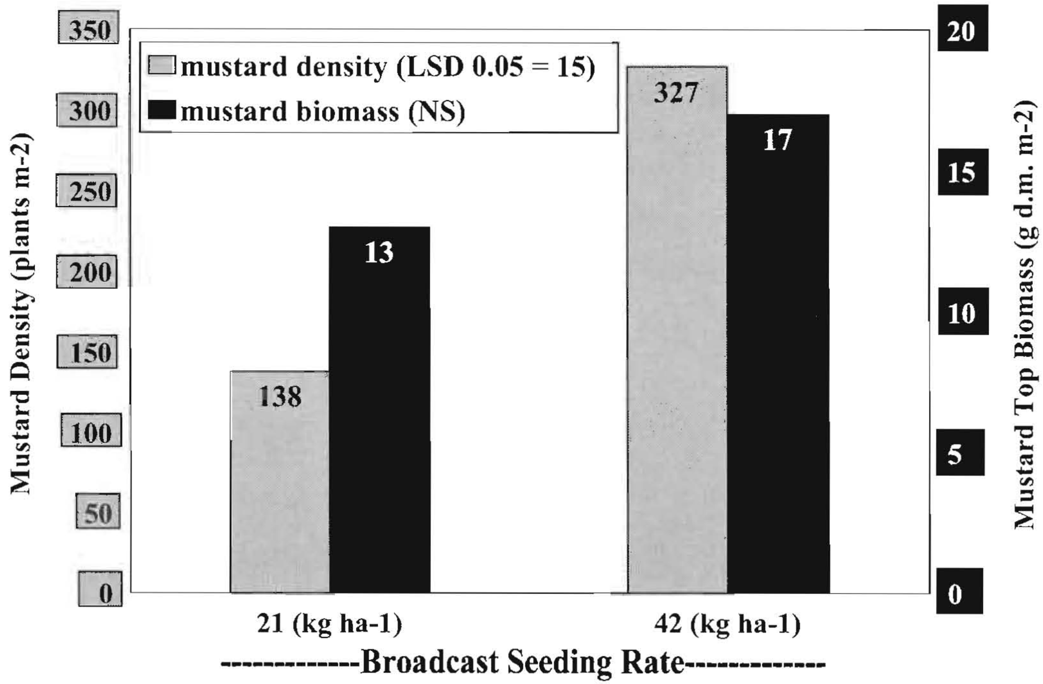

Figure 2. Influence of seeding rate on mustard density and biomass when broadcast into standing corn at the UW-Research and Extension Center, Torrington, Wyoming, 1992.

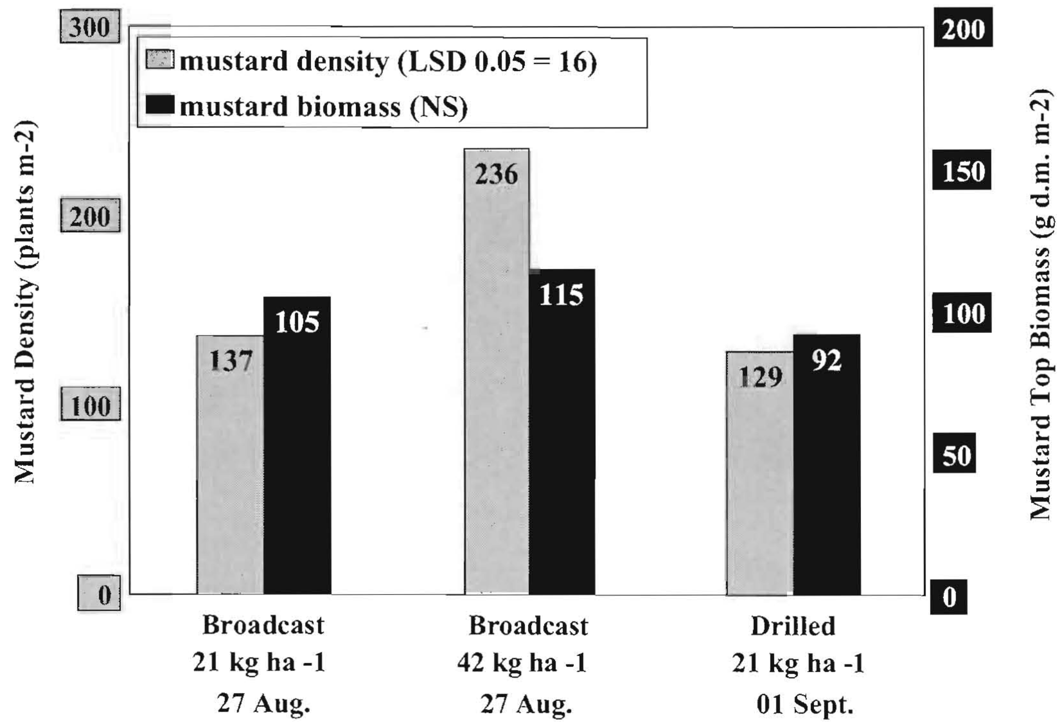

Figure 3. Influence of seeding rate and seeding method on mustard density and biomass when sown into dry bean stubble at the UW-Research and Extension Center, Torrington, Wyoming, 1992.

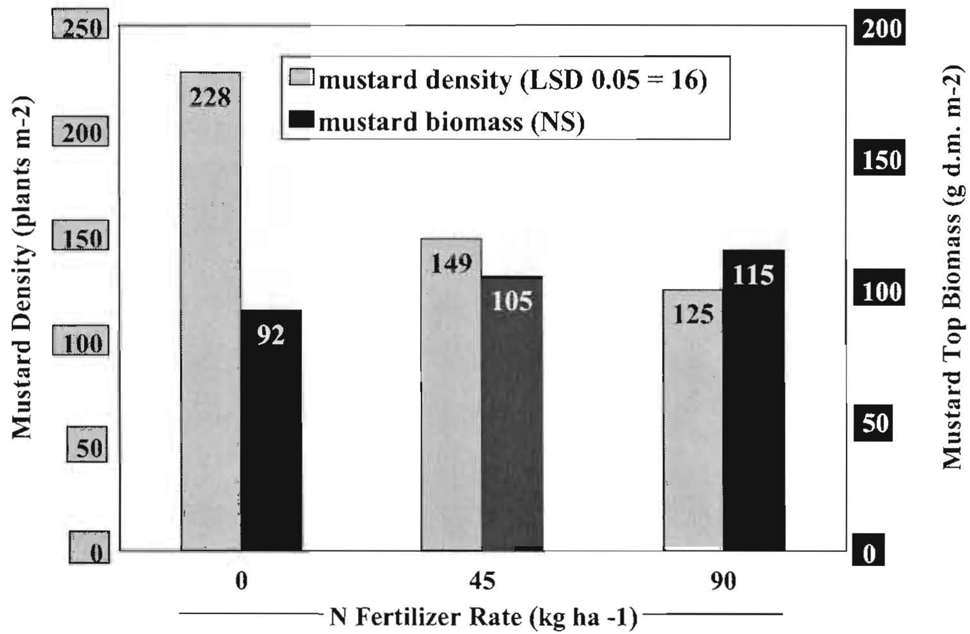

Figure 4. Influence of broadcast N rate on mustard density and biomass at the UW-Research and Extension Center, Torrington, Wyoming, 1992.

used with broadcast seeding, care will need to be taken to insure that seed does not come into direct contact with fertilizer.

Trap crop radish after malt barley: Application of 56 kg N ha^{-1} increased trap crop growth by 34% in glyphosate treated barley stubble, by 41% in a tilled seed bed, and by 63% in barley stubble not treated with herbicide (Fig. 5). An additional 56 kg ha^{-1} of N (112 kg ha^{-1}) further increased growth of the trap crop in herbicide treated stubble, but stimulated little additional growth in a tilled seed bed or in stubble not treated with herbicide. Radish growth was less, overall, with seeding in stubble not treated with herbicide due to competition from uncontrolled volunteer barley. Growth response to N following malt barley would be expected, since N fertilization of malt barley is limited to avoid the detrimental effects of excess N on quality of malt barley. In the same study, seeding method did not affect radish stands, however, stubble planting following straw removal and glyphosate application improved radish top growth production.

Trap crop varieties: On the Hefenieder field in 1992, radishes were stunted, perhaps due to a poorly drained heavy soil, which may have maintained excessive soil moisture. 'Metex' mustard produced more top growth than 'Adagio' radish or 'Maxi' mustard (Fig. 6). 'Pegletta' and 'Adagio' radish produced similar top growth yield. About 10 to 20% of 'Pegletta' radish plants had flowered at sampling on October 23, compared to none in 'Adagio' radish. All radish and mustard varieties displayed very good cold tolerance with no sign of die-back from frost injury at the October 23 evaluation date.

Radishes grown on a different test site on the Hefenieder Farm in 1993 produced more growth than in 1992, even though they were planted later and had fewer GDDs in 1993. Soil conditions, particularly moisture, appeared to be more favorable in 1993. 'Adagio' out-yielded 'Pegletta' radish by about 10% (data not shown).

Summary: Planting date appears to be the most important factor in trap crop growth. In years where the previous crop can be removed and trap crops planted by the last week of August, supplemental N application is recommended. Supplemental N did not, however, make up for late planting as fertilized trap crop yields from August 25 planting were less than half that of the August 10 plantings. Nitrogen application to late planted trap crop, will likely not result in adequate growth for effective nematode trapping. Early removal of corn silage for trap crops shows promise, but early harvest will result in lower silage dry matter and quality, and higher moisture. The possibility of grazing low nitrate corn followed by planting of trap crop could provide an economical means of nematode trap cropping. Broadcast application of trap crop over sprinkler irrigated corn resulted in acceptable plant densities, but competition from corn resulted in

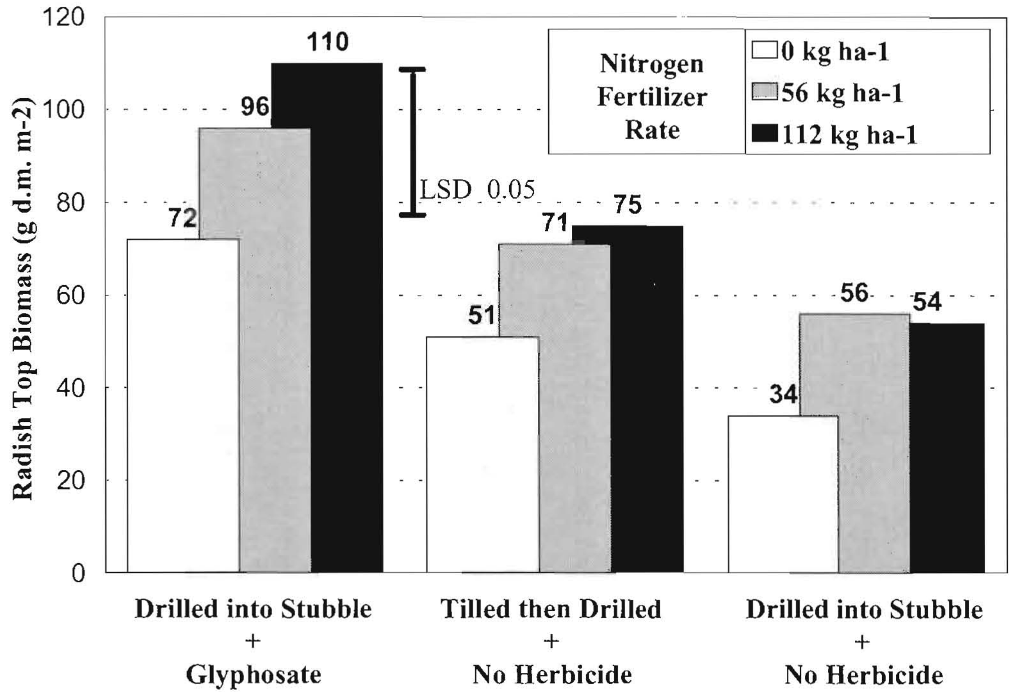

Figure 5. Effect of seeding method and nitrogen rate on growth of 'Pegletta' radish following barley harvest on radish seeded 7/29/92 at the Hefenieder Farm, Worland, Wyoming

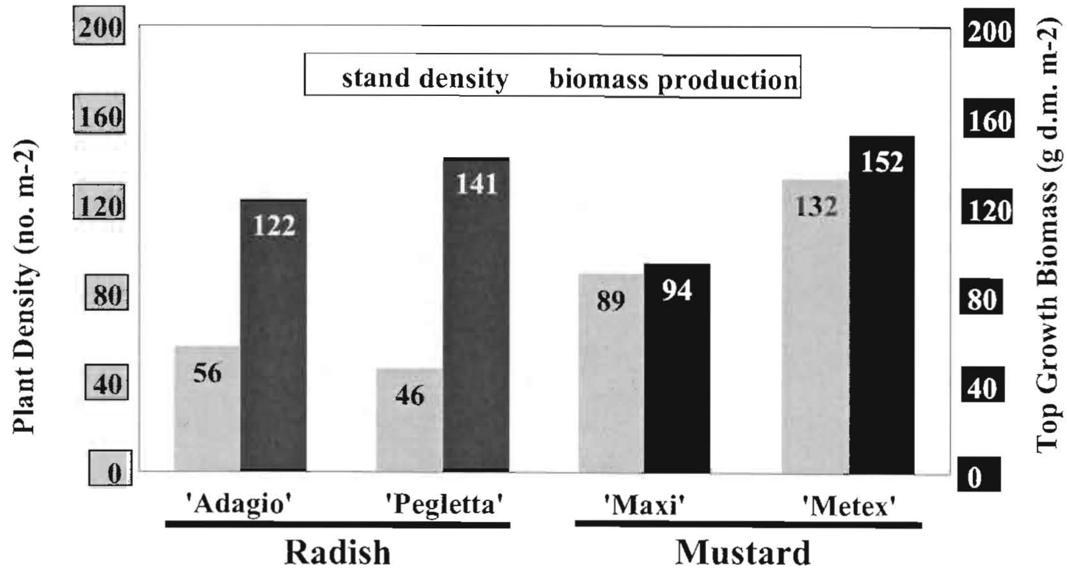

Figure 6. Impact of radish and mustard variety on stand density and growth sown at Worland, Wyoming, 1992

unacceptably low trap crop growth. Additionally, broadcast application of trap crop prior to knifing of beans will not compensate for lateness in trap crop establishment. Based on these results, trap cropping in Wyoming should be conducted following cereals, while producers should avoid planting trap crops after full season silage corn or dry bean.

Currently, in Wyoming, cereal malting barley is a major rotational component of sugarbeet systems in the Wind River and Big Horn Basin irrigated production regions. Re-cropping with 'Adagio' radish or 'Metex' mustard trap crops with N application immediately following cereal harvest is advisable along with the use of herbicides to control volunteer cereal. Glyphosate is currently labeled for control of volunteer cereal in fallow, while sethoxydim is labeled for the control of grasses in mustard.

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