Potato Production on Wide Beds: Impact on Yield and Selected Soil Physical Characteristics

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ABSTRACT

Planting three rows of potatoes in a bed the width of two conventional rows offers an easily managed way to increase seed piece populations, with the potential of increasing tuber yield and enhancing tuber quality. A wide bed production system (3 rows of potatoes planted on a 1.9 m flat-topped raised bed) was compared to a conventional-ridged system (1 row of potatoes in sharply sloped ridges on 96 cm centers) in 1996 and 1997 on a Norfolk sandy loam soil and a Portsmouth fine sandy loam soil in eastern North Carolina. Potato plant stands, leaf area index at approximately 9 WAP, yield, and quality were measured. Soil temperature, soil moisture, and cone index, as a measure of soil penetration resistance, were also measured. wide beds were more moist than conventional ridges early in the season. Cone index was greater throughout the root profile in wide beds in two of three tests. The row on the west side of an individual wide bed was most similar to conventional ridges in daily soil temperature fluctuations between minimum and maximum temperatures, and had greater fluctuations than the middle and eastern rows of the wide bed. Total yield and yield of grade A potatoes were not significantly different between wide beds and conventional ridges at either site. At one site, yield of grade B potatoes was significantly less in the wide bed; among the three rows in the wide bed, the eastern row had significantly lower yield of grade B potatoes. Conventional ridges had a higher percent of green grade A potatoes than the wide beds in one of three trials. Under North Carolina conditions, changing production systems would be unadvisable for most growers because wide beds do not increase yield enough to justify spending the money for more seed and to change equipment.

INTRODUCTION

Yields of potatoes grown in North Carolina are lower than yields in other regions of the United States growing potatoes for similar uses. Atlantic, which makes up 75% of the 9,000 ha of potatoes grown in North Carolina, is used for chipstock. Atlantic has been shown to produce well in high density arrangements (Rykbost and Maxwell, 1993; DeBuchananne and Lawson, 1991). Close spacing of Atlantic seed pieces also reduced incidence of hollow heart (DeBuchananne and Lawson, 1991) and internal heat necrosis (Sterrett and Henninger, 1997). Close spacings are most frequently used when irrigation is also in use or water is not expected to be limiting during the growing season (Thornton and Sieczka, 1980).

In Texas, growing three rows of potatoes on a wide bed increases plant population by 50% and has proven profitable for growers (B. Neiderhauser, pers. comm.). However, when a grower tried the wide bed system in North Carolina, the grower observed that plant set and yield were generally higher in the two outer rows of the wide bed, and less in the middle row. In the wide bed, yield was not increased sufficiently to justify the increased seed expense and the new equipment that would be required to shift production systems.

wide beds have been tested in the United Kingdom, mainly for production of canning potatoes. Prestt and Carr (1984) reported that a flat-topped ridge, similar to a wide bed, conserved moisture better than a sharply sloped ridge, and

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hastened emergence by four to five days. Also, moisture was more evenly distributed through the flat-topped ridge and the soil surface was more conducive to moisture infiltration. In sharply sloped ridges, dry areas tended to form beneath the sides of the ridges and the steep sides encouraged runoff. Fisher *et al.* (1995) found increased yield in wide beds attributable to moisture conservation in the beds. The elimination of post planting cultivation may reduce damage to the roots and haulm and reduce the formation of clods that can damage tubers during harvest (Wayman, 1969). Scholz (1987) found that potatoes grown in 3 equidistant rows on 180 cm beds produced similar yields to potatoes grown in two ridged rows on 90 cm centers. Potatoes planted in ridges on 75 cm centers produced the highest yield of all three treatments.

Some disadvantages to wide beds have been observed. The moisture conservation properties of the soil may prevent the beds from warming quickly in the spring, which could delay emergence. Sale (1979) found emergence of potatoes to be linearly related to mean soil temperature to an optimum temperature of 22 to 24 C. The higher plant density associated with wide bed production could negatively impact many varieties of potatoes. As Russet Burbank plant density increased from 6400 plants ha^{-1} to 18225 plants ha^{-1}, Lynch and Rowberry (1977) found that total yield was not affected, but marketable yield decreased with increasing density. High densities of plants also can cause the plants to senesce earlier (Bremner and El Saeed, 1963). wide beds can make harvest more difficult and energy consuming (Thompson *et al.*, 1974) because of the increased volume of soil that must be moved in the beds, compared to ridges (Wayman, 1969).

The objectives of this study were: (1) to evaluate the effect of wide beds (WB) at a planting density of 21,060 seed pieces ha^{-1} and conventional ridges (CR) at a planting density of 14,175 seed pieces ha^{-1} on selected soil physical characteristics and potato yield and quality in North Carolina; (2) to determine if yield from the middle row of the wide bed was less than the outer rows; and if so, (3) to determine if the yield reduction could be due to differences in soil physical properties.

METHODS

Experiments were established and planted on 15 March 1996 and on 10 March 1997 at the Vernon James Research and Extension Center in Plymouth, NC in a Portsmouth soil (fine loamy, mixed, thermic, Typic Umbraquults) under non-irrigated conditions, and at the Peanut Belt Research Station in Lewiston-Woodville, NC on 12 March 1997 in a Norfolk soil (fine loamy, siliceous, thermic, Typic Kandiudults) under irrigation. At both sites, plots were oriented lengthwise from north to south. Preparation for both CR and WB included disking and initial hill formation on 97 cm centers. In the WB treatment, after the ridges were formed, two ridges were combined with a Massey Ferguson Tilrovator (Suffolk, VA) to make a single wide bed on 1.9 m centers. WB and CR plots were 3 beds and 3 rows, respectively, with the middle bed or row used for sampling.

In 1996, 123 kg N, P_2O_5, and K_2O ha^{-1} was broadcast on CR plots, while 250 kg N, P_2O_5, and K_2O ha^{-1} was inadvertently broadcast at planting on WB plots. An additional 127 kg N ha^{-1} was applied 6 weeks later to CR at hilling so that the same total N was applied (soil test results indicated that P and K were both very high). Split applications of N could have an effect on yield (Hensel and Locasio, 1987), but responses are not consistent under non-irrigated conditions on a loamy soil (Porter and Sisson, 1993). In 1997, 120 kg N, P_2O_5, and K_2O ha^{-1} was broadcast at planting, and 35 kg N ha^{-1} was applied as a sidedressing about six weeks after planting at both locations.

A no-till vegetable transplanter (RJ Equipment, Blanhelm, OH), with the press-wheels removed, was used to plant three rows of Atlantic potatoes 15 to 20 cm deep with 25 cm in-row spacing in WB plots. The between-row spacing was 50 cm. After planting, the rows were covered manually with a hoe.

In the CR plots, ridges were leveled. Seed pieces were hand-planted 25 cm apart in Plymouth and ridges reformed with a mechanical hiller. At Lewiston, a two-row Oliver pick-planter was used to plant the seed pieces and reform ridges. Ridges at both sites were reformed to a height of about 15 cm, causing the seed pieces to be planted approximately 10 cm deep. The CR plots were rehilled two additional times during the 1996 season, once at 5 weeks after planting (WAP), and again at 8 WAP. Weed and insect pests were managed per North Carolina Cooperative Extension Service recommendations in all plots.

Plant stands were counted approximately every 3 days for two to three weeks, beginning 15 April 1996, and 1 April 1997. Leaf area was measured and main stems counted approximately 9 WAP. Two individual seed pieces and resultant plants were randomly selected from each row in the WB and one row in the CR treatment (Kleinhenz and Bennett, 1992). The stems emerging directly from the seed piece were counted as main stems. Stems less than 4 mm in diameter were stripped off the main stems and leaf area was determined with a leaf area meter (LAMBDA Instruments Corp.).

Soil temperatures were measured in one row of the CR plots and each of the 3 rows of the WB; thermocouples were 10 cm deep and half-way between two plants in the middle of the row. Minimum, maximum and average soil temperatures were recorded every hour with a Campbell Scientific 21X Micrologger (Campbell Scientific, Inc., Logan, UT).

Soil moisture was determined gravimetrically (Gardner, 1986) approximately every two weeks in 1996. Ten samples (15 cm deep) were bulked for a single row of the CR treatment and the outside and middle rows of the wide bed. In 1997, soil moisture tension was measured with a "Quick-draw" SoilMoisture Probe (SoilMoisture, Santa Barbara, CA) approximately every 2 weeks at a depth of 15 cm. Two measurements were taken in the row between 2 plants per CR row, middle WB row and outer WB rows.

Cone index as an indication of soil penetration resistance was measured with a manual, semi-automatic cone penetrometer (Mobility Systems Division, Waterways Experimental Station, U. S. Army Corps of Engineers, Vicksburg, Miss.), to a depth of 60 cm on 18 April 1996 and 5 June 1997 at Plymouth, and 3 May 1997 at Lewiston. Ten readings were taken within potato rows per plot across the wide bed and from the top of the conventional ridge.

On 25 June 1996, and 23 June 1997, at Plymouth, and 30 June 1997 at Lewiston, 7.6 m from each plot were harvested to determine yield. Tubers were graded into U. S. Grade A (>48 mm), with 40% > 64 mm), Grade B (< 48 mm), and greens. Ten tubers were randomly selected from the grade A potatoes of each plot and were cut in half to determine the incidence of hollow heart and heat necrosis.

A randomized complete block design with four replications was used. Data were analyzed by analysis of variance to test for differences between WB and CR, and to test for the effects of rows within the wide bed (Wilkinson, L., 1990). Means were separated with Fisher's protected least significant difference (LSD) tests.

RESULTS AND DISCUSSION

Plant Emergence and Growth

There were no differences in plant stands among the three rows of the wide bed (data not shown). Final plant stands of WB and CR were not different at Plymouth in 1996, but in 1997, were slightly higher in WB (Figure 1). At Lewiston, however, WB had lower final plant stands than CR; the WB had cooler, wetter soils early in the season, which could have caused more seed piece decay and reduced final plant stands.

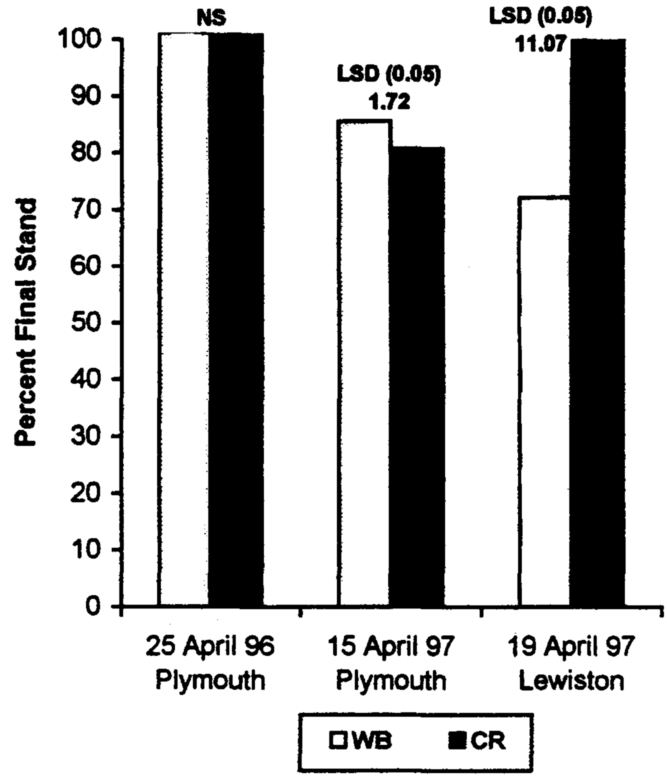

FIGURE 1.
Percent final plant stand, based on 25 cm in-row spacing, of wide beds (WB) and conventional ridges (CR) at Plymouth in 1996 and 1997, and at Lewiston in 1997. NS is not significant at P<0.05.

At 9 WAP, there were no differences in leaf area or stem counts at either site (data not shown). The increased plant density of the WB, 21,060 plants ha^{-1}, compared to 14,175 plants ha^{-1} in the CR, had no effect on leaf area index at 9 WAP.

Soil Temperature

At Plymouth in 1996, the differences in maximum and minimum soil temperature between WB and CR were very small (data not shown). With a few exceptions during the 1997 season, CR tended to have the greatest temperature fluctuations, mostly attributable to higher maximum temperatures (Figure 2).

Within the WB, the eastern and middle rows had lower temperature fluctuations than the western row (Figure 3). The western row was most like CR, with larger fluctuations in

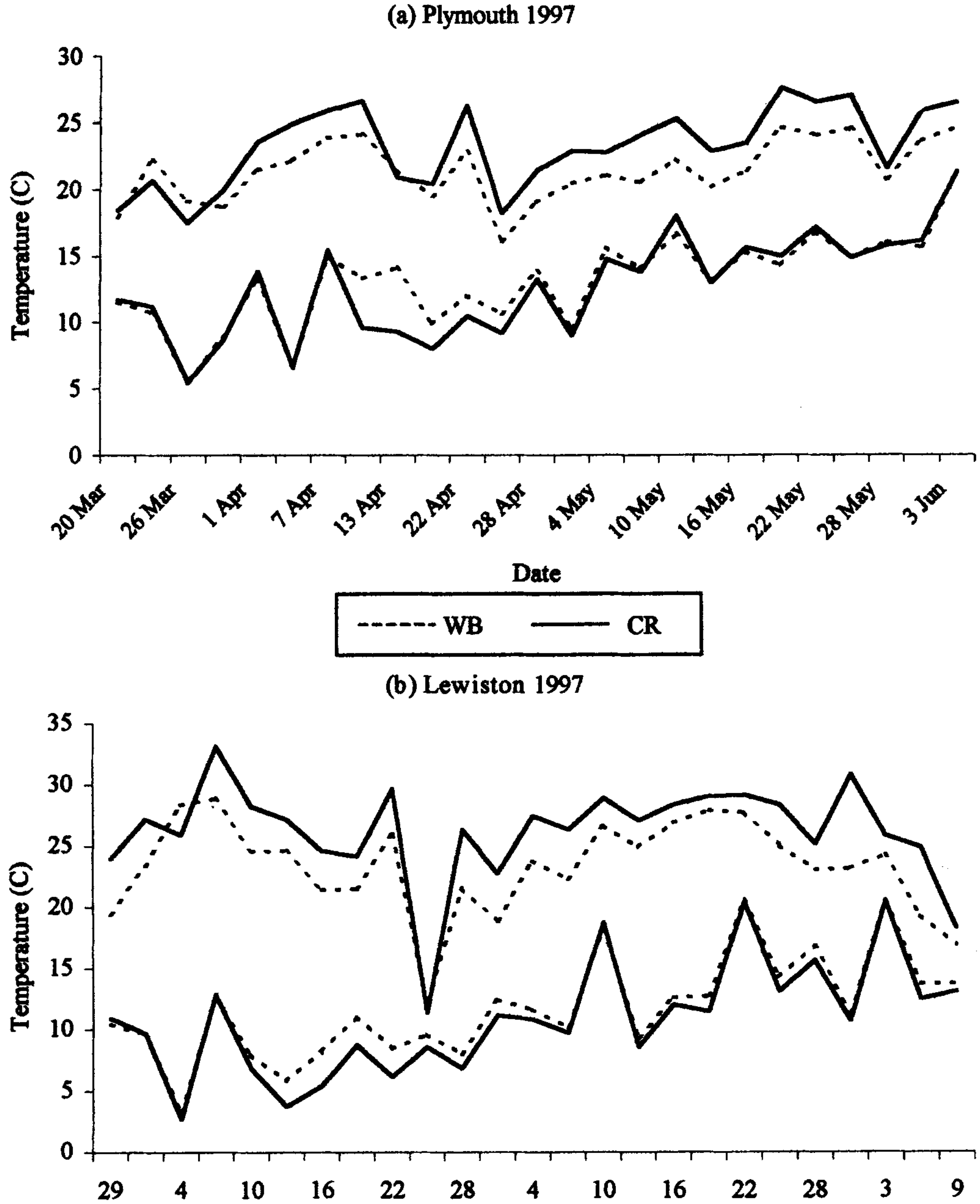

FIGURE 2.
Daily minimum and maximum soil temperatures of wide beds (WB) and conventional ridges (CR) at (a) Plymouth and (b) Lewiston in 1997.

temperature, especially later in the season. The western row of the wide bed was somewhat shaded in the morning and received full sun in the afternoon. Comparably, the conventional ridges received sun all day, suggesting that the afternoon sun was most important in changing soil temperatures.

Soil Moisture

At Plymouth in 1996, there were no differences in soil moisture content between the WB rows and CR rows, and no consistent trends between the middle and outer rows of the WB (data not shown). Soil moisture tensions approaching zero indicate high soil moisture content. Throughout 1997, there were no differences between the middle and outer rows within the WB, at either site (data not shown). Early in the season, the rows in the WB were more moist than CR at both sites (Figure 4). There were no differences

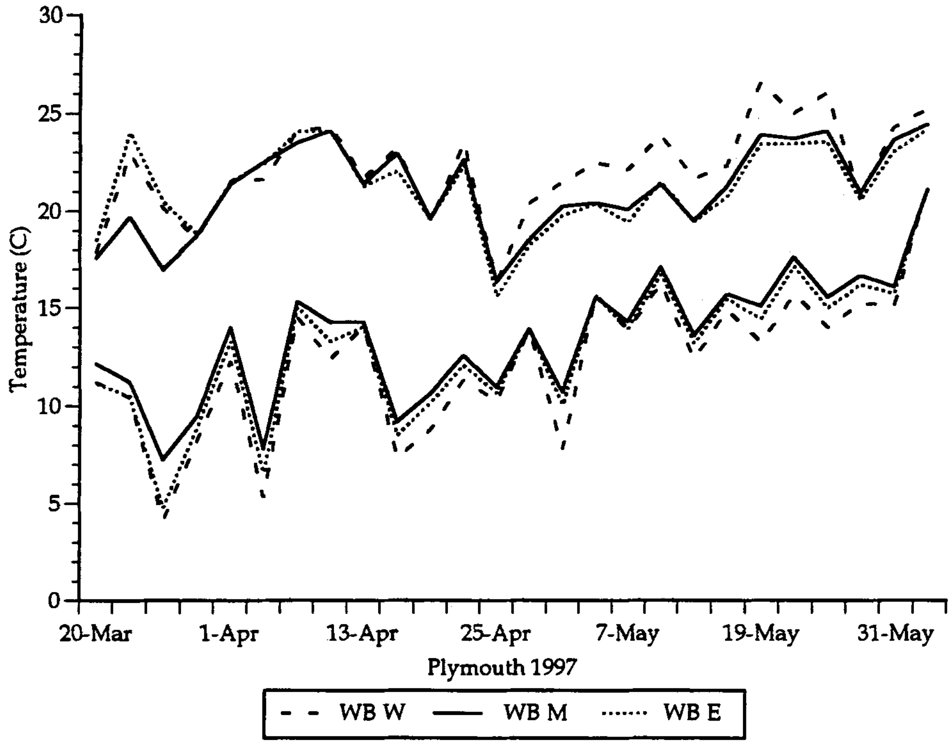

FIGURE 3.
Daily minimum and maximum soil temperatures in the west row (WB W), the middle row (WB M) and the eastern row (WB E) of the wide bed at Plymouth in 1997.

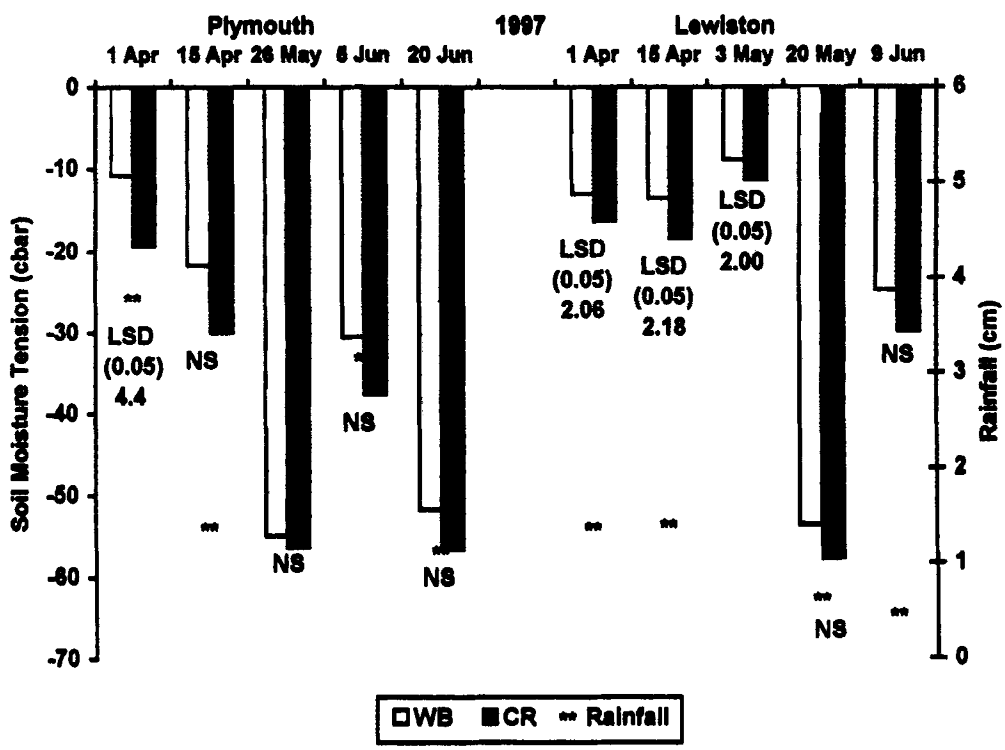

FIGURE 4.
Soil moisture tension of wide beds (WB) and conventional ridges (CR) and total cm of rainfall the week before sampling date at Plymouth and Lewiston in 1997. Error bars are equal to LSD (0.05). NS is not significant at P<0.05.

between CR and WB later in the season, at either site. wide beds may have increased potential to retain moisture as suggested by Prestt and Carr (1984). However, the higher density of plants in the wide bed may require more water, possibly canceling the benefit of moisture retention.

Cone Index

Cone index at Plymouth in 1996 (Figure 5) in WB was greater at each depth measured compared to CR. As cone index increases, the soil becomes more resistant to penetration by roots, tubers, and other soil biota. Below 15 cm, the cone index in CR increased at a faster rate than WB until 40 cm deep. There were no differences between treatments at Plymouth in 1997 from 0 cm to 30 cm; below 30 cm, the cone index in WB was significantly greater than in CR. At Lewiston, WB had greater cone indices than CR at most depths, even though the soil was moister in WB than CR on this date. If all other factors are similar, moist soils tend to have a lower cone index than dry soils.

Vepraskas (1988) suggested that, when comparing soils with the same moisture contents, a cone index greater than or equal to 3.0 MPa restricted root growth severely. The WB had greater cone indices in this zone at Lewiston. High cone indices (> 3.0 MPa) were observed at much shallower depths in WB than in CR, which could be from the extensive preplant tillage and traffic required to make the wide beds. Tillage equipment ran over the entire wide bed, much closer to where the seed pieces were placed, compared to conventional ridges where the equipment was further below the seed pieces, due to the process of ridging.

Yield

There were no differences in yields between WB and CR, or among the rows in WB at Plymouth either year (Table 1). While realizing that timing of N application could have an effect on yield (Hensel and Locasio, 1987), yield data for 1996 are reported because the data are consistent with other year and site data. Yield responses to split applications of N are

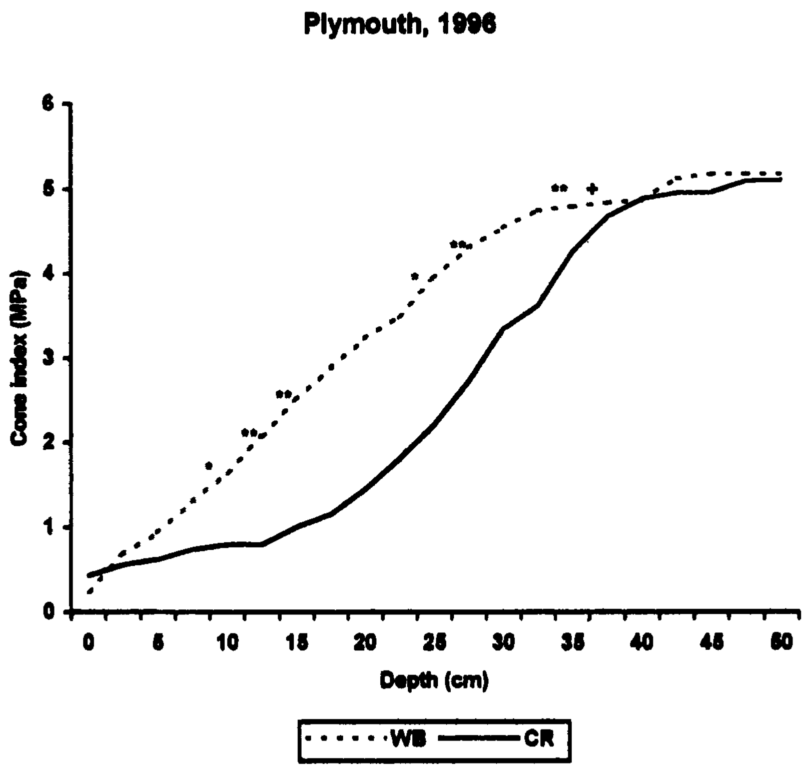

FIGURE 5.
Cone index in wide beds (WB) and conventional ridges (CR) at Plymouth in (a) 1996 and (b) 1997, and (c) Lewiston in 1997. +, *, ** designate significance at P<0.1, 0.05, and 0.01, respectively.

TABLE 1.—*Yield and grades of potatoes (t ha⁻¹) harvested from conventional ridges (CR), and the total wide bed (WB Total), and west (WB W), middle (WB M) and east (WB E) rows of wide beds at Plymouth in 1996 and 1997 and Lewiston in 1997.*

	Plymouth 1996				Plymouth 1997				Lewiston 1997			
	A's	B's	Total[1]	% Green[2]	A's	B's	Total[1]	% Green	A's	B's	Total[1]	% Green
CR	25.78	1.06	27.98	0.39	23.84	1.83	28.02	6.89	27.22	5.42	35.11	2.35
WB Total[3]	22.80	1.63	28.54	3.61	26.05	2.62	29.68	0.48	25.25	4.24	31.78	2.82
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	3.34	NS	0.70	NS	NS
WB W	22.77	2.00	27.88	3.49	24.20	2.24	27.31	0.58	28.40	4.61	34.17	2.50
WB M	21.44	1.42	26.58	4.59	26.58	2.38	29.98	0.32	27.97	4.83	34.63	0.87
WB E	24.27	1.96	31.24	4.77	27.45	3.25	31.50	0.56	19.45	3.29	24.46	6.30
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.68	NS	NS

[1]Total yield includes grades A, B, culls and greens.
[2]Percent of grade A tubers with 5% or greater area green.
[3]WB Total = WB W + WB M + WB E.

inconsistent (Porter and Sisson, 1993) on a loam soil under non-irrigated conditions.

In Lewiston, marketable and total yields were not different between WB and CR, or among the three rows in WB. However, WB produced less B grade potatoes than CR, and WB E produced the fewest B grade potatoes among the WB rows. The reduction in yield within WB E could have been sufficient to reduce the average yield of WB.

Compaction, due to excessive tillage and traffic, also may have effected yield in the wide bed. However, if the individual beds were kept between the same wheel tracks from year to year, compaction could be reduced (Dickson *et al.*, 1992). Potato yields have been increased compared to conventional hills by using non-trafficked wide bed production systems (Dickson *et al.*, 1992; Prestt and Carr, 1984).

There were no differences among the three WB rows in the percentage of grade A-sized potatoes that were green at Lewiston. Contrary to expectations, at Plymouth in 1997, CR had significantly greater greening than WB. Seed pieces were planted deeper in WB than CR; Kouwenhoven (1970) showed that tuber greening could be decreased to almost zero when seed pieces were planted 19 cm deep in sandy soils. There were no differences in greening between CR and WB with either of the other trials. The incidence of hollow heart and internal heat necrosis was less than 3.25% in all cases, and was not different among the three rows of the WB, or between WB and CR (data not shown).

CONCLUSIONS

In this study the use of wide beds did not increase yields. Further, it would be prohibitively expensive for most North Carolina growers to replace their conventional equipment with the equipment to plant and manage wide beds. The increased cost of seed needed to plant at a higher density adds even more expense. If seed and proper equipment are readily available to growers, adjustment of fertilizer application rates and timing, use of irrigation if available, and manipulation of seed spacing in order to minimize competition among potato plants may optimize production in wide beds.

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