



Economic Return to Adoption of Mechanical Thinning: The Case of New Mexico Chile

College of Agriculture and Home Economics
Cooperative Extension Service
Agricultural Experiment Station

In November 1998, the New Mexico Chile Task Force was formed to identify and implement ways to keep chile pepper production profitable in New Mexico and to maintain and enhance the research and development partnership between the New Mexico chile industry and New Mexico State University.

Chile Task Force reports will be issued periodically to consider issues of concern to the industry and to document the Task Force's progress in developing techniques and technologies to improve industry competitiveness in the 21st century global trade environment.



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Economic Return to Adoption of Mechanical Thinning: The Case of New Mexico Chile¹

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Introduction

Sandwiched between rapidly expanding foreign competitors and increasingly more stringent environmental and labor regulations, chile producers face many challenges that threaten their industry's future. The key to the survival of the industry in New Mexico is developing new technologies to cope with these challenges. To this end, the industry joined forces in 1998 with New Mexico State University's (NMSU) College of Agriculture and Home Economics to form the New Mexico Chile Task Force, a consortium of growers, processors, crop consultants, supply and equipment specialists, state and federal agricultural specialists and NMSU researchers and Extension specialists. Their objective is developing procedures and technologies to increase the southwestern chile pepper industry's viability. The task force has been successful in implementing a number of projects to this end: defining and implementing a best management practices program, developing mechanical harvesting and cleaning equipment, investigating drip irrigation and improving chile genetics.

The task force has recently focused on the development of a mechanical vegetable thinner. The result of collaboration between the task force and NMSU's Manufacturing Technology and Engineering Center (M-TEC) in the College of Engineering, this innovative equipment, designed to operate on a three-point hitch system, uses computer-controlled hydraulic knives to eliminate unwanted plants.

While introduction of new agricultural technology often creates expectations among stakeholders (Goss, 1979), it has yet to be determined whether the NMSU mechanical



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thinner can provide economic returns sufficient to entice the region's producers to adopt the technology. This paper examines the economic returns available to producers willing to adopt mechanical thinning as a substitute for contracted hand thinning. The analysis uses NMSU's cost and return estimates (Hawkes, Libbin, White, Lyons & Sullivan, 2004) as a basis for determining possible economic returns. The economic analysis shows that use of the mechanical thinner offers cost savings to chile producers operating in Southern New Mexico.

Mechanical Vegetable Thinning History

To compensate for poor seed germination, the result of soil types and poor environmental conditions related to planting times, vegetable farmers often plant more seeds than necessary to achieve a desirable final plant stand.³ These over-planted crops typically are hand thinned after plant establishment to achieve optimal plant densities. Hand thinning traditionally has been performed by low cost foreign labor (primarily Mexican nationals). This labor source's availability diminished when the Bracero program was terminated in 1964. The void of foreign laborers in the post-Bracero program years led to the development of several mechanical vegetable thinners. These early mechanical thinners used a variety of technologies to sense plant material and selectively thin vegetable crops. Sensing devices included electric photo eyes, photocells that recognize plant color and electric conducting circuits. These mechanical thinners, however, could not compete economically with hand thinning and were not adopted widely (J.W. Inman, personal communication, 2004).

Steadily rising labor costs, difficulties associated with securing a dependable work force, increasingly stringent hand-labor laws and pressure from low-cost foreign products in recent years have led many growers to rethink the traditional production management practice of hand thinning. Today there are a number of researchers and research institutions developing advanced computer technologies that can be used in conjunction with mechanical thinning and weeding.

Mechanical Vegetable Thinning's Current Climate

Changing markets and regulatory environments have forced producers to again look at mechanization as a means of reducing costs associated with hand thinning. Among the factors leading to re-evaluation include increasing wages and government regulation. Eastman, McClellan and Bagwell (1997) reported that between 1949 and 1996 minimum wages increased from \$0.75/hr to \$5.15/hr. Some states, such as California, are considering laws to further regulate hand labor used for thinning and weeding vegetable crops (California Department of Industrial Relations, 2003). In response to these pressures, three mechanization areas (precision planting, transplanting and mechanical thinning) are being developed.

³ Other crops that have been over planted and then thinned to a final stand after seed germination include sugar beets, lettuce, cauliflower, broccoli, celery, tomatoes and cotton. Technological improvements have led producers of some crops to eliminate the practice of over planting and the related thinning requirement. For example, celery and cauliflower primarily are transplanted, and cotton generally is planted using precision planting (J.W. Inman, personal communication, February 2004; E. Barnes, personal communication, January 29, 2004).

Precision planting

There are many types of precision planters, from those calibrated to ensure uniform seed distribution to variable rate seed planters that control density by computer using soil information coordinated through a global positioning system (GPS). With the introduction of high-cost hybrid seeds, many large-scale commercial producers have adopted some form of precision planting, although in the United States, advanced variable rate planting is mostly used in high-value crops (Lowenberg-DeBoer, 2003). While precision planting ensures optimal plant stands in the absence of adverse conditions, it does not eliminate problems associated with plant diseases, poor soil quality and poor weather conditions, which can radically reduce stand density after planting.

Transplanting

Transplanting chile pepper crops is an increasingly common practice used to reduce the need for thinning, combat problems associated with germination rates and post-emergence pests, diseases and environmental conditions, and reduce seed costs. While initially more expensive due to greenhouse production costs and labor costs associated with the transplanting process, transplanting provides potential advantages for chile producers that include a more uniform plant stand, a shorter growing season and less cultivation and irrigation. Establishing a transplanted chile pepper crop usually requires only one irrigation, while direct-seeded crops may need as many as three (Bosland, Bailey and Cotter, 1999; Katz, 2003).

Mechanical thinning

Scientists and engineers have been working on mechanization technologies to reduce the level of hand labor needed in the industry. A promising prospect (and a leading competitor for the thinner evaluated here) is the automatic weeder being developed by University of California at Davis (UC-Davis) researchers. The UC-Davis weeder combines digital video, GPS and computer technologies to identify and remove unwanted weeds. Computer algorithms analyze digitized images of crops and weeds within a crop row and isolate targeted weeds. These weeds subsequently are killed using high-speed herbicide streams or other weed deterrents. While the automatic weeder is not commercially viable today (machine accuracy and speed must be improved), UC-Davis researchers predict that the implement will be ready for commercial development within three years (Lee, 2003).

The NMSU prototype thinner, the basis of this analysis, provides thinning functions only (although researchers are exploring the feasibility of adding technologies to allow the machine to weed as well as thin). The thinner uses a standard closed-loop, self-contained hydraulic system to operate cutting blades that sweep back and forth across crop rows, pendulum-style. Sensors located at the front of the thinner detect plant material and signal computer-

controlled hydraulic solenoids to open and shut, operating the blades. Initial field testing indicated that the prototype thinner could be operated at a speed of two miles per hour, with an effective accomplishment rate of approximately 1.5 acres/hr (for the two-row prototype).

As the thinner travels down a crop row, each plant in the row breaks the beam of a through-beam photoelectric switch located at the front of the machine. The switch signals the computer that a plant is present at that particular location. The location information is maintained by a 360-line shaft encoder mounted on a coultter wheel following the tractor tires at the bottom of the furrow. Identification of plant location is accurate to 1/10-inch. Decisions on when the blade should actuate are based on the input from the photoelectric switches, operator variables and other incorporated sensors.

The thinner is a standard three-point implement, designed to be pulled by a tractor. It requires 12-volt power to be supplied by the tractor and a power-take-off (PTO) to run the hydraulic pump. The 40-GPM PTO pump (the size required for a six-row unit) needs only a 50-PTO HP tractor.

The computer-controlled prototype thinner provides significant advantages over existing mechanical blocking thinners. Its algorithms allow the machine to make intelligent decisions about where to actuate the cutting blade so that existing skips in the stand are not increased. For example, if there is a single plant in the middle of a 4-ft. long skip, a mechanical blocking thinner, set to remove 4 in. of material and leave 4 in. of material, would have a 50 percent chance of removing the single plant in the skip. The NMSU prototype, on the other hand, would leave that one plant unharmed 99 percent of the time.

Economic Returns to Mechanical Thinning

One of the principal reasons why the thinners of the 1960s and 1970s failed to attract a wide following among vegetable farmers was their inability to provide economic returns equal to or greater than those obtained from using hand labor. In this section we explore the economic returns associated with the NMSU thinner compared to returns associated with traditional hand labor.⁴ The analysis is limited to chile peppers grown in southern New Mexico's Doña Ana and Sierra counties.

Assumptions

The analysis summarized in this section is based on NMSU's cost and returns estimates published by NMSU's Cooperative Extension Service.⁵ The cost and return estimates, which use data collected from knowledgeable producers, state and federal agency professionals and others interested in crop production, have been published for more than 25 years (Sullivan,

⁴ In this study we look only at the economic returns associated with mechanical thinning of green and red chile production.

⁵ These cost and return estimates, which assume above-average management, are not meant to fit any particular farm and must be adjusted to represent individual business and operating practices (Hawkes et al., 2004).

Table 1. Cost and return estimation assumptions

Land Use	
Total crop acreage	670 acres ^a
Green chile acreage	100 acres
Red chile acreage	100 acres
Basic Costs	
Labor & Management	
Equipment operator wage rate	\$5.95/hr
Vegetable crop supervision	\$1.00/acre
Purchased Inputs	
Diesel fuel	\$1.50/gal
Interest Rates	
Operating capital interest rate	6.5%
Equipment interest rate	6.5%
General Overhead	\$30,548 ^b
(includes mileage, domestic electricity, telephone, etc.)	
Equipment	
Tractor	140 hp (557 annual hours of use)
Thinner (4-row)	
Retail price	\$20,000
Accomplishment rate	2.5 acres/hr
Power source	140 hp tractor
Operators	1 operator
Hand thinning costs (contracted)	\$70 per acre

^a Acreage numbers for NMSU's cost and return estimates for Doña Ana County are 500 acres, of which 30 acres are planted in green and red chile. The analysis here uses larger chile acreages, and thus a larger farm size, to better represent commercial producers in the region.

^b General overhead costs are assumed not to vary significantly between a 500-acre farm and the 670-acre farm and are thus kept at NMSU cost and return estimates for a 500-acre farm.

Schaber, Libbin & Mayberry, 1986). Forty-nine crop cost and return estimates, representing assumptions and growing conditions specific to different growing regions in the state, are produced and disseminated annually.

This analysis uses underlying cost and return assumptions and calculations developed for Doña Ana and Sierra counties. In 2002 these two counties accounted for 5,462 acres of harvested chile peppers.⁶ This harvested acreage represented 33 percent of all New Mexico harvested chile acreage and 13 percent of total U.S. harvested chile acreage in 2002 (U.S. Department of Agriculture, National Agricultural Statistics Service, 2004). Numerous assumptions are made in calculating the cost and returns associated with a particular crop. Table 1 presents some of the significant assumptions made in the analysis presented here.⁷

Economic returns

Based on NMSU crop cost and return estimates, with mechanical thinning assumptions from table 1, the cost-savings estimates for a 670-acre farm, 200 acres of which are planted in chile peppers, is \$41.17 per acre over hand thinning with adoption of mechanical thinning

⁶ Includes all pepper varieties except bell peppers.

⁷ Yields are assumed to remain constant across thinning alternatives. Additional information regarding differences in yields may be examined in future research. For complete identification of all values assumed in the analysis, see Hawkes et al., 2004.

(assuming a \$20,000 four-row thinner operating at an accomplishment rate of 2.5 acres/hr). The present value of the savings, taken over the thinner's life, assumed to be 15 years, is \$82,450.⁸ No economic cost was assessed for the very real risk that hand-harvesting crews might be unavailable on the date needed.

The economic return reported above is a function of a wide range of variables, many of which may vary from producer to producer. The following sections examine changes in economic returns that result from changes in five key underlying assumptions (sensitivity analysis).⁹ In each case, all variables, except those specifically identified in the section, are set at the default values reported in the NMSU crop cost and return estimates for 2004.¹⁰ The five underlying variables examined in the sensitivity analysis include: thinner price, chile acreage, contracted hand labor, thinner efficiency and interest (or discount) rate. Values for each of these variables (thinner price = \$20,000, chile acreage = 200 acres, contracted hand labor = \$70 per acre, efficiency = 100% and interest rate = 6.5%) were varied up and down from the initial assumed value by 50 percent.¹¹ Figures 1 through 6 show the different per acre returns associated with changes for each of these key variables.

Economic returns and thinner price. The mechanical thinner evaluated here is expected to be available commercially in early 2005. The default price of the thinner used for this analysis, \$5,000 per row or \$20,000 for a four-row machine, was based on conversations with several agricultural equipment manufacturers. Economic returns will depend on the thinner's eventual price. Figure 1 shows the expected savings per acre for three different acreages (100 acres, 200 acres and 300 acres) and how those savings will vary based on the assumption that the thinner price will be \$20,000. For example, if a four-row thinner were to sell at a price of \$26,000 instead of the assumed \$20,000, the savings per acre would drop from \$41.17 to \$35.83 (this scenario is illustrated in Figure 2).

The price at which the present value of the returns (discounted over the expected life of the thinner) is equal to zero is \$66,306 (using the original base assumptions of \$20,000 price and 200 acres of thinned chile). At this price, the annual differences in economic returns resulting from adoption of the mechanical thinner (discounted over 15 years at a rate of 6.5%) will just compensate the producer for the purchase of the mechanical thinner today. In a sense, this value may be considered the most that a producer, fitting the assumptions of the budget (e.g., producing 200 acres of chile), would be willing to pay for the mechanical thinner.¹²

⁸ This is an estimate, as the analysis assumes thinner and tractor repair costs will remain constant over the thinner's life.

⁹ Many variables, besides the three addressed here, could be examined (e.g., changes in fuel prices). The three variables chosen for sensitivity analysis (thinner price, acreage and price of contracted labor) were found to be highly correlated with economic returns associated with the thinner.

¹⁰ Chile crop acreage in the NMSU crop cost and returns estimates are equal to 30 acres. This analysis uses a base of 200 chile acres (farm size of 670 acres) to better represent commercial chile production in the region.

¹¹ Thinner efficiency was varied downward from 100% efficiency to zero percent efficiency.

¹² This "willingness to pay" figure does not account for any type of risk behavior. For example, some producers may be willing to pay more for the mechanical thinner as a way to avoid possible liabilities associated with hand labor. Others may not be willing to pay as much, given the thinner is new to the market.

Economic returns and acreage. Cost savings associated with mechanical thinner adoption increase with increases in planted chile pepper acreage. The \$41.17 per acre savings identified in the economic analysis above is based on the assumption that total chile acreage is equal to 200 acres. Figure 3 shows how the expected per acre savings for three different thinner prices (\$10,000, \$20,000 and \$30,000) vary based on the variability of the initial assumption that chile crop acreage is 200 acres. For example, as indicated above, with a thinner price of \$20,000, the expected savings per acre for a farm producing 200 acres of chile is \$41.17. If the number of acres is reduced to 150 acres (again assuming the thinner price is \$20,000), the expected per acre savings drop to \$36.89.

The breakeven point (the number of acres at which the mechanical thinner becomes more profitable than hand thinning) is 42.4 acres. While not shown in figure 3, 42.4 acres is the point at which the solid line (\$20,000 price line), if extended, would cross the horizontal axis (the price at which mechanical thinning no longer provides expected savings above hand thinning).

Economic returns and contracted hand-labor price. Availability and price of contracted hand labor varies significantly across geographic locations. Anecdotal evidence suggests that contracted labor prices for hand thinning can vary from \$35 per acre to \$200 per acre, depending on season, year and geographic location.¹³ Figure 4 shows the sensitivity of differences between economic returns to mechanical thinning and hand thinning as the price of contracted labor increases. The breakeven point, at which mechanical thinning would no longer provide returns in excess of those related to contracted hand labor, is \$33.12 per acre.

Economic returns and thinner efficiency. Initial field research has suggested that the mechanical thinner can be an effective tool for thinning chile crops. However, the effectiveness of the thinner likely will depend on a number of factors including soil type and condition, weed coverage and irrigation practices.¹⁴ Depending on these conditions, additional hand labor may be required to adequately thin fields. Figure 5 shows the sensitivity of economic returns relative to thinner effectiveness. The analysis assumes that the cost of hand labor will be directly proportional to the effectiveness of the mechanical thinner. For example, if the mechanical thinner is 90 percent effective, per-acre costs will increase by 10 percent of the total per-acre hand thinning costs, where total per-acre thinning costs included contracted labor costs plus interest expenses associated with financing that expense. The analysis shows that the per-acre savings from adoption of mechanical thinning (identified above as \$41.17) are only achieved with a thinning efficiency of 100 percent. Per-acre returns decrease as efficiency decreases, reaching zero at a thinning efficiency of 42 percent.

Economic returns and interest rate. While the interest rate (both equipment interest rate and discount rate) of 6.5% is assumed to remain constant over the life of the thinner, it is likely that this historically low interest rate will change. Figure 6 shows the sensitivity of differences between economic returns to mechanical thinning and hand thinning as the

¹³ Information based on informal survey of producers during 2004 Chile Pepper Conference, Las Cruces, N.M.; conversations with producers in the Southwest; and producer comments during 2004 prototype field trials.

¹⁴ As indicated earlier, the analysis here assumes adoption of best management practices. Conditions affecting thinner efficiency are likely to be associated with this assumption.

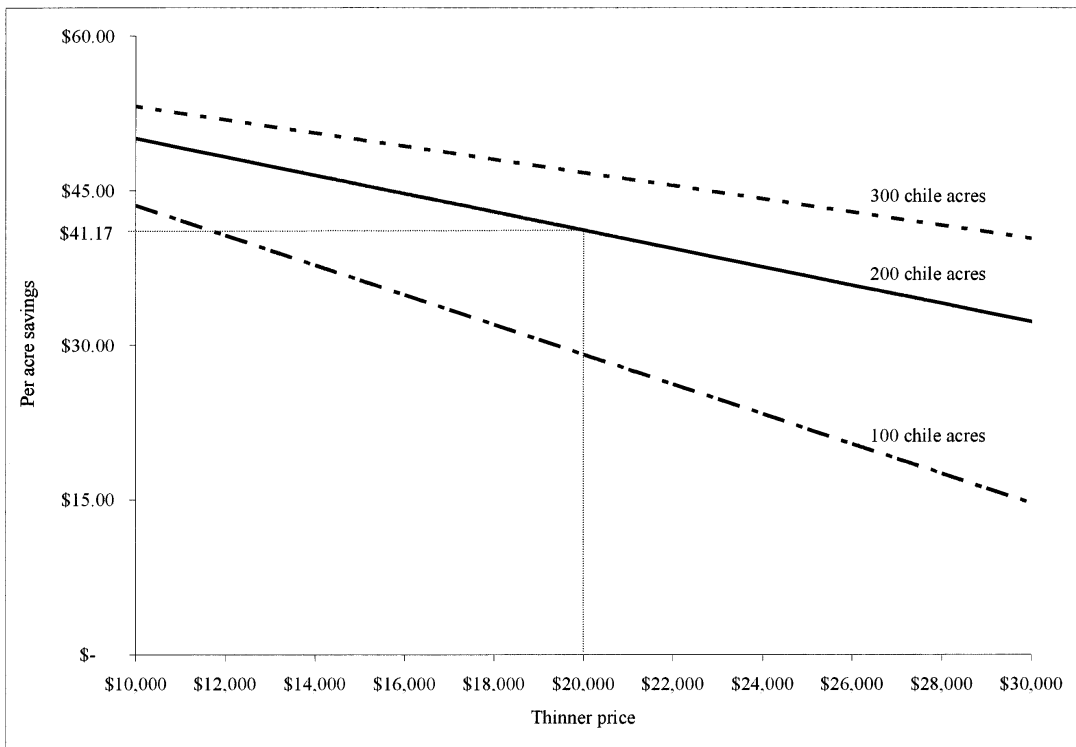


Figure 1. Economic returns to mechanical thinning, sensitivity to changes in mechanical thinner price.

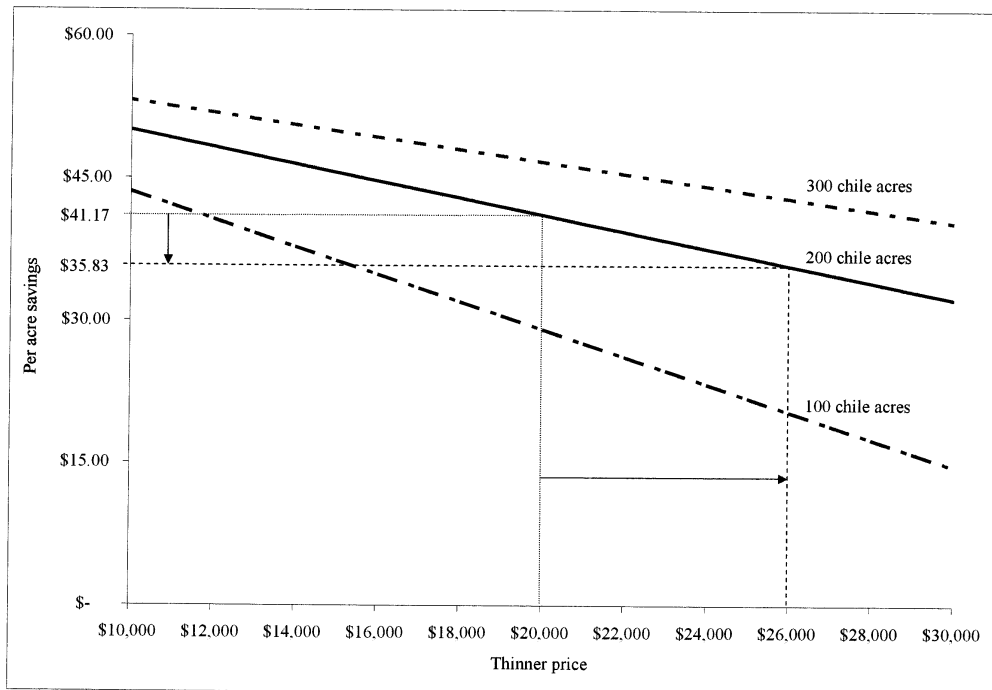


Figure 2. Illustration of decreases in per-acre savings resulting from increases in thinner price.

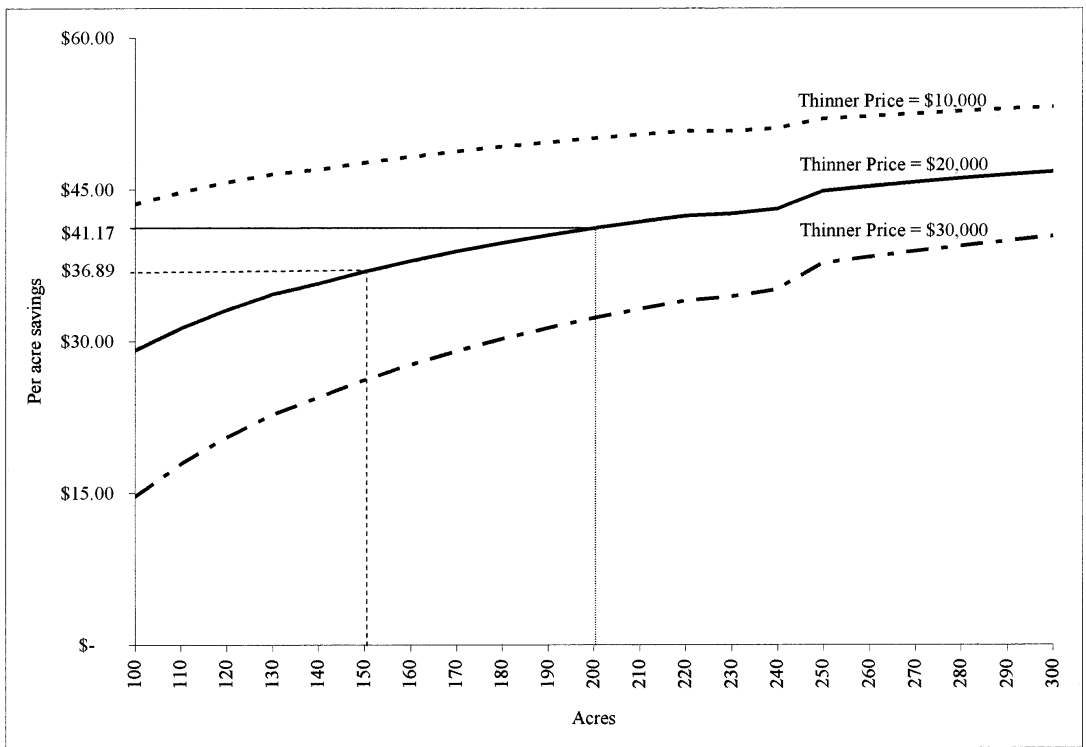


Figure 3. Economic returns to mechanical thinning, sensitivity to changes in chile acreage.

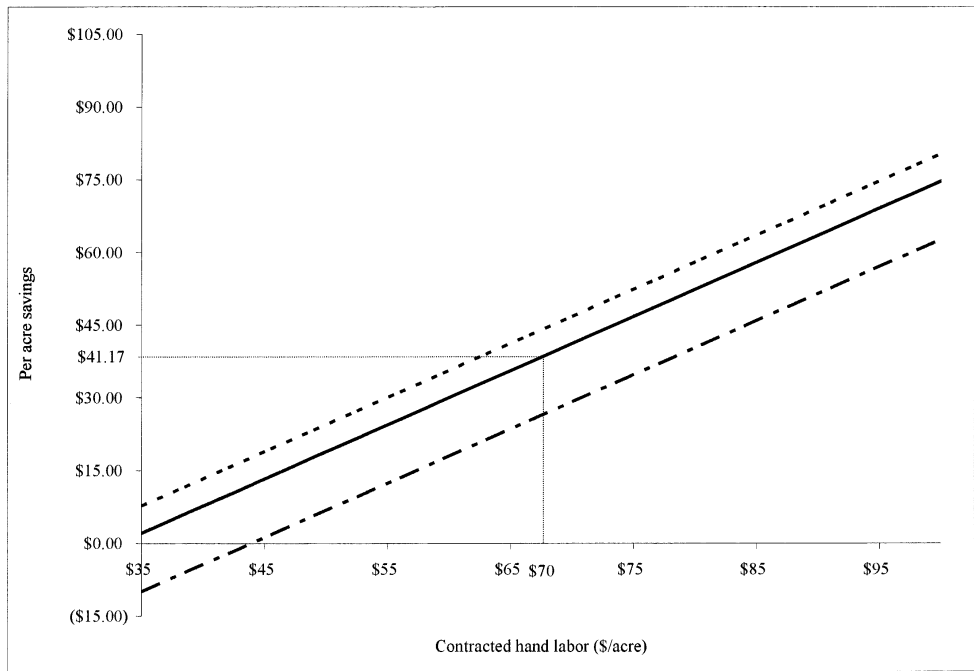


Figure 4. Economic returns to mechanical thinning, sensitivity to changes in contracted hand-labor rates.

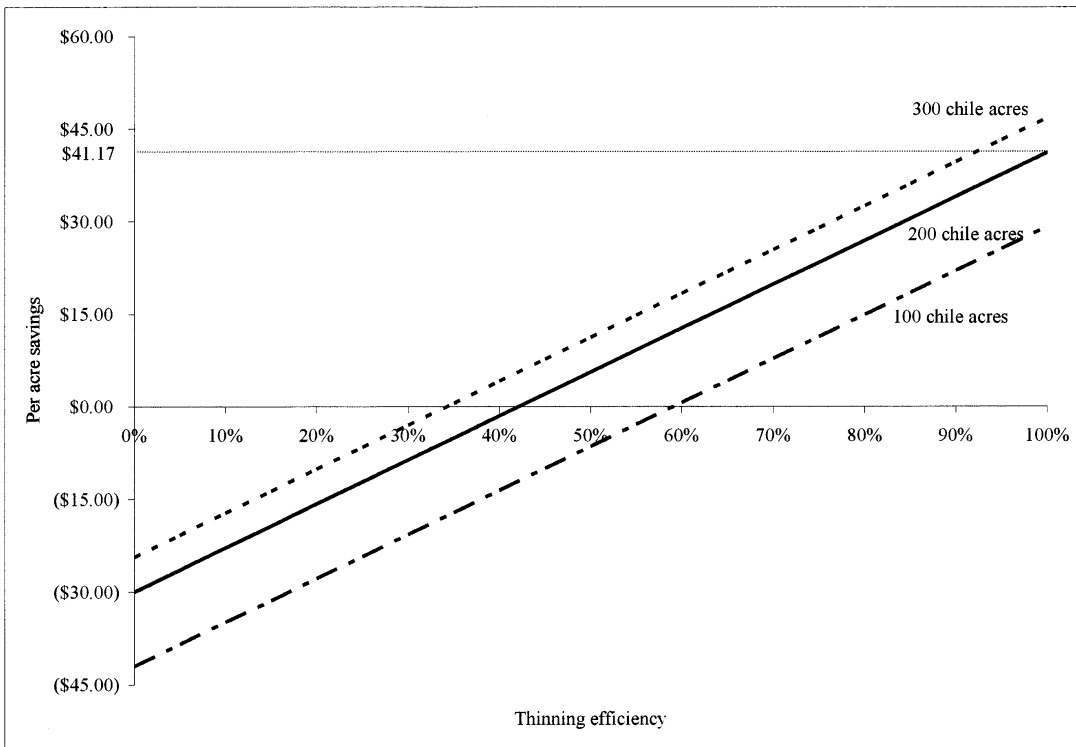


Figure 5. Economic returns to mechanical thinning, sensitivity to changes in thinner efficiency.

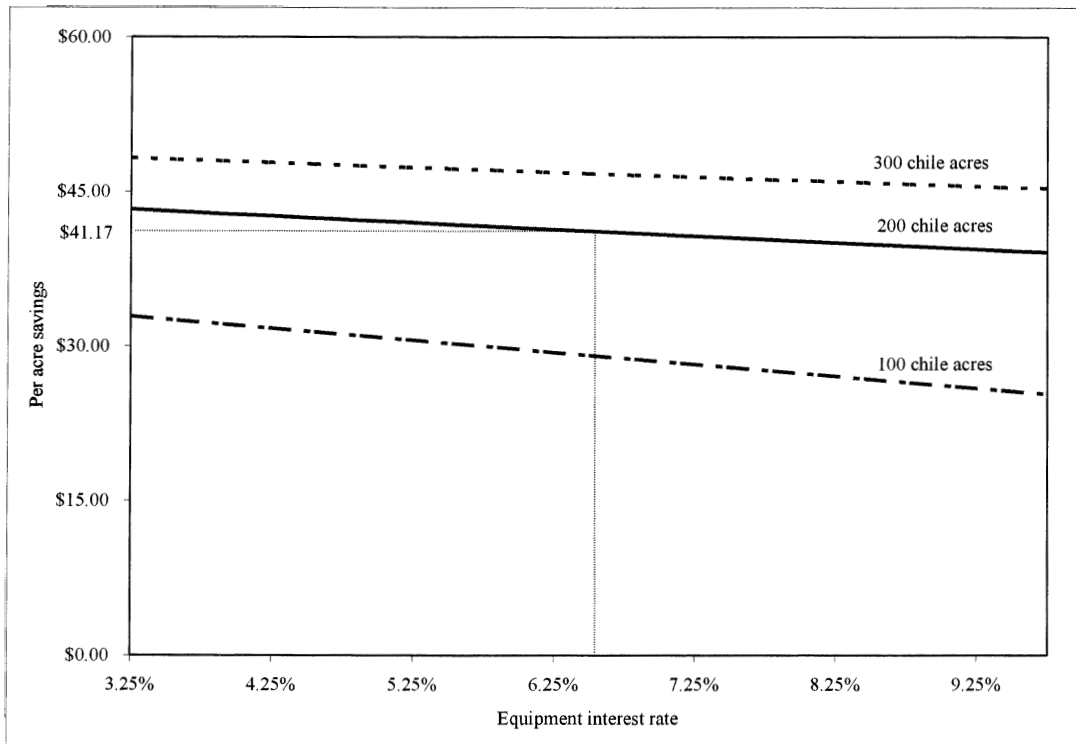


Figure 6. Economic returns to mechanical thinning, sensitivity to changes in equipment interest rates.

equipment interest rate changes. Per-acre cost savings for all chile acreages examined (100, 200 and 300 acres) decrease with increases in equipment interest rates.

In addition to per-acre cost savings decreasing with increases in equipment interest rates, the present value of savings attributable to mechanical thinning decreases when equipment interest rates (also used as discount rate in present value calculations) increase. For example, when the interest rate (discount rate) is 3.25%, the present value of cost savings is equal to \$104,753, compared to \$82,450 when the rate is 6.5% and \$66,172 when the rate is 9.75%.

Conclusions and Future Research

A number of forces surrounding the vegetable industry are encouraging producers and researchers to re-examine the feasibility of substituting capital for labor in the production processes. While earlier attempts to mechanize crop thinning failed, today's computer technologies promise to further mechanize vegetable production, including chile production.

This paper has examined the economic returns associated with adoption of mechanical thinning using a thinner developed by NMSU researchers. Based on underlying information from NMSU's cost and return estimates, adoption of mechanical thinning in the chile industry appears feasible. This study's findings are consistent with others relating to technology adoption (i.e., larger producers are expected to achieve greater returns for adopting mechanized technologies).

This analysis focuses only on chile pepper production and the returns associated with adopting mechanical thinning technologies for chile peppers. However, the NMSU thinner shows great promise for adaptation to other vegetable/row crops (e.g., sugar beets, lettuce and spinach). Additional analyses, using cost and return estimates for these crops, need to be conducted.

While it is believed that the assumptions used here are reasonable, it is unlikely that all assumptions used in this analysis will apply to any given farm operation. Future research may include extensions of the analysis to incorporate risk associated with key variables, such as fuel costs and accomplishment rates.

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New Mexico Chile Task Force Publication List

Report 1: An Industry-University Response to Global Competition

Report 2: Chile Seed Germination as Affected by Temperature and Salinity

Report 3: Yield and Quality of Machine-Harvested Red Chile Peppers

Report 4: Chile Seed Quality

Report 5: Guidelines for Chile Seed Crop Production

Report 6: Improving Chile Harvesting and Cleaning Technologies

Report 7: Farm Labor Employers' Handbook

Report 8: New Mexico's Chile Pepper Industry: Chile Types and Product Sourcing

Report 9: Economic Impact of Southern New Mexico Vegetable Production and Processing

Report 10: Chile Pepper Growers' Notes: 2003

Report 11: Developing New Marketing Strategies for the Southwestern Chile Industry

Report 12: Incidence of the Beet Leafhopper, *Circulifer tenellus* (Homoptera:Cicadellidae), in New Mexico Chile

Report 13: Plant Spacing/Plant Population for Machine Harvest

Report 14: Economic Return to Adoption of Mechanical Thinning: The Case of New Mexico Chile



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