BEDDING AND NITROGEN TREATMENTS FOR SPICE PEPPER PRODUCTION

By

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FOR SPICE PEPPER PRODUCTION

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life. Thank you Dr. Motes.

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And finally, I give thanks to God. "The task ahead of us is never as great as the power behind us." Phil. 4:13.

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INTRODUCTION

Paprika and chile are specialty crops that are adapted to the southwestern United States and to southwestern parts of Oklahoma. Preliminary studies have shown that these crops could potentially be profitable alternatives for Oklahoma farmers if the crops are machine harvested. The future looks bright for expanded paprika and chile markets, but a major problem with machine harvesting these crops is lodging.

Lodging, as defined by Pinthus (1973), is the permanent displacement of stems from their upright position. Lodging can occur in areas with high winds and heavy rainstorms and where the growers irrigate and use high rates of fertilizer (Noor and Caviness, 1980). Lodged plants interfere with the harvesting procedure by placing the pods in unharvestable locations which are very near or on the ground. The harvester cannot retrieve these pods resulting in reduced yield. In addition, lodged plants can be uprooted or broken and plant parts can clog the harvester mechanisms.

Palevitch (1978) reported that mechanical harvesting is imperative if the market for spice peppers is expected to expand. Sundstrom et al.(1984) noted that little has been done in coordinating pepper culture with the designs and needs of mechanical harvesters. Efforts such as breeding and plant selections have helped to reduce lodging (Marshall, 1984). Cultural practices such as bedding and fertilization rates could also reduce lodging of pepper plants (Sundstrom et al., 1984).

To investigate lodging and its effect on chile and paprika, field experiments were conducted with these objectives:

1. Evaluate lodging, uprooting force and yield when paprika is grown under different bedding practices and two nitrogen rates.

2. Evaluate lodging, uprooting force and yield when chile is grown under different bedding practices and two nitrogen rates.

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CHAPTER ONE

LITERATURE REVIEW

A. Lodging

A problem in machine harvesting paprika and chile is plant lodging. Kahn (1985) described lodging as when the plant is sufficiently prostrate to place its fruit below the harvester level. Pinthus (1973) defined lodging as the permanent displacement of stems from their upright position. There are three types of lodging: branch, stem, and root lodging (Johnson et al., 1973; Pinthus, 1973). Root and branch lodging are most likely to occur in a pepper field. Root lodging by definition is when straight and intact stems lean from the ground level due to a weakening in the root system (Pinthus, 1967). Branch lodging occurs when the branch is loaded with fruit and bends to the ground or in severe cases the branch breaks (Johnson et al., 1973).

Lodging occurs for several reasons including hail and damage by nematodes, insects or other animals (Pinthus, 1973). Motes (1993) suggested sandy and loamy sand soils can provide favorable conditions for lodging. According to Noor and Caviness (1980), lodging occurs in areas with high winds and heavy rainstorms and where growers irrigate and use high rates of fertilizers. Careless cultivation, resulting in root damage, can also account for some lodged plants in a field as noted by Stoffella and Kahn (1986). Although many of these problems cannot be controlled, there are some practical ways to reduce lodging.

Lodging can be reduced by breeding and plant selection. Kahn (1985) tested lodging resistant and lodging susceptible paprika plants. The lodging resistant plants were found to have larger root systems than the lodging sensitive plants. The larger root systems provided better anchorage and resisted root lodging. Another way to avoid lodging is by reducing the within-row spacing (Kahn, 1992). A large number of plants (9-10 plants/m^2) resulted in reduced lodging percentages when compared to lower plant populations (Cooksey, 1993). High plant populations have been recommended for mechanically harvested paprika (Kahn et al, 1993).

Many cultural practices can be employed to reduce lodging. In areas with high winds, wind breaks can be used to improve stands at emergence and to reduce lodging (Motes, 1993). Precision cultivation in the field is also important so as to not disturb the root system. Banks (1992) noted that deep cultivation of cotton reduces yield due to root pruning. When cultivating, an additional 6-10 cm of soil hilled around the base of the plants is beneficial due to the added stability the extra soil provides (Marshall, 1984). Proper calibration of fertilizer equipment is also important. Too much N can lead to excessive growth and can promote lodging (Motes, 1993).

Lodging is not only undesirable but it is also costly. Lodged plants can reduce yields by not allowing the machine to harvest the pods that are below the harvesting level. Lodged plants can also clog the machine which delays harvest and reduces the efficiency of the harvest operation (Motes, 1993). With some cultural practice modifications and new technologies, improvements can be made to reduce this problem.

B.Nitrogen Rates

In addition to weed and insect control, N fertilization is vital in developing a healthy crop. Factors such as soil test results, plant spacing, and plant cultivars should be considered before deciding upon a fertilizer program. Soil tests should be taken prior to any fertilizer being applied. Soil test results will indicate soil pH and plant nutrients that are available in the soil. How much, if any, fertilizer should be applied preplant can be determined by using crop fertilizer recommendations. Additional fertilizer applications might be necessary during the growing season.

Well drained sandy soils generally leach more N than finer textured soils. Proper adjustments should be made regarding the amount of N used based on soil texture and rainfall. Depending on weather conditions, N rates on sandy soils could be two or three times that of finer textured soils (McCraw and Motes, 1991).

Nitrogen rates are usually different depending on what *Capsicum annuum* L. types are grown. These differences can be as much as 56 to 336 kg N·ha^{-1} in 'Anaheim chili' grown in California (Payero et al., 1990). Ahmed (1984) reported that 80 kg N·ha^{-1} was best suited for sweet peppers in Sudan. Sundstrom et al. (1984) stated that 112 kg N·ha^{-1} was most desirable for Tabasco peppers (*Capsicum frutescens* L.). Stroehlein and Oebker (1979) suggested that chile yields were highest when N rates ranged from 100 to 150 kg·ha^{-1}.

Nitrogen rates also play a part in determining the size of the plants. Plant size is important when machine harvesting is being considered. Marshall (1984) stated that an upright plant with narrow crotch angles is optimal for mechanical harvesting. Maness and Motes (1993) reported that plants were taller due to higher N rates. Sundstrom et al. (1984) showed that high N rates and increased plant populations produced a plant structure that was easier to machine harvest. Motes (1993) reported that excessive N fertilization promotes growth of the plant which can increase lodging.

C. Within-Row Spacing

Somos (1984) reported that paprika yield and plant development were affected by plant spacing. Marshall (1984) suggested that decreasing the within-row spacing would improve the machine harvesting of peppers.

A study by Sundstrom et al. (1984) on Tabasco peppers revealed that pepper yields were increased when in-row plant spacings were decreased from 81 to 10 cm. According to Johnson et al. (1973) a reduction in yield of pimento peppers occurred when plant in-row spacing increased from 12, 18, and 24 inches apart (about 30, 45, and 61 cm). Orzolek (1981) showed that plant populations greater than 49,400 plants/ha yielded more peppers than conventional commercial populations of 29,640 plants/ha. Higher populations of plants tend to reduce the number of fruit per plant (Kovalchuk, 1983) yet increase the total yield due to increasing the plant population per unit area (Ahmed, 1984).

The optimal within-row spacing for mechanical harvesting of peppers has varied from 20 plants/m (Kahn, 1992) to 15 (Wolf and Alper, 1984) to 10 plants/m by Palevitch and Levy (1984). Cooksey (1993) determined that a within-row spacing of 10 cm is recommended for paprika to be machine harvested. This recommendation of 10 cm for within-row spacing is also supported by Thomas et al. (1982) and Marshall (1984).

Reducing the within-row spacing produces a taller plant

(Kovalchuk, 1983; Marshall, 1984; Palevitch and Levy, 1984). The closer spaced plants aid in the machine harvesting process by decreasing the number of lateral shoots per plant (Palevitch and Levy, 1984) and by placing the fruit higher in the plant canopy (Marshall, 1984). Stoffella and Bryan (1988) reported that in higher plant populations the fruits are located higher in the plant canopy and suggested that this might increase lodging. However, Kahn (1992) reported that high populations of paprika plants decreased lodging. Sundstrom et al. (1984) also support this by theorizing that adjacent plant support in closely spaced populations reduces lodging of the branches.

Marshall (1984) stated that closer spacings produce taller plants with fewer, more flexible branches and narrower crotch angles. A smaller number of lateral shoots and a long stem beneath the main branching section is also more desirable for machine harvesting of sweet peppers (Palevitch and Levy, 1984; Thomas et al. 1982). Wider plant spacings produce larger plants with more side branches which can increase lodging (Motes, 1993).

Stem diameters in bell peppers are reduced when plants are spaced closely together (Stoffella and Bryan, 1988). Stoffella and Bryan (1988) also found at higher populations a lower shoot:root ratio occurred. The higher plant populations caused relatively larger root systems due to the competition for water and nutrients. The improved shoot:root ratio shows that the plants seem more efficient at nutrient absorption at higher populations (Stoffella and Bryan, 1988).

D. Bedding

Wolf and Alper (1984) stated that efficient mechanical harvesting of peppers requires the establishment of complementary horticultural practices. One such practice is the use of beds and soil that is hilled to the base of the plants. Wolf and Alper (1984) noted that level beds facilitate the use of multi-row harvesters. Marshall (1984) reported that hilling soil around the base of plants provides structural support for the plants to endure environmental hardships, such as high winds and rainstorms.

The bedding or hilling practice is common to other crops which are machine harvested. Banks (1992) reported in cotton that the soil which is used for bedding dries faster following wet periods and warms up faster for earlier planting dates. Hilling soil to the base of the cotton plant also provides control of small weeds (Banks, 1992). May (1992) noted that for mechanical harvesting of processing tomatoes, a well-shaped bed is required. The bed should be completely flat so that the machine can harvest the fruits efficiently while minimizing the amount of soil, rocks and clods which can be harvested as well.

In machine harvesting of pepper plants, uprooting of the plant is a serious problem (Marshall, 1984). Hilling soil to the base of the plants provides structural support and increases anchorage which helps to reduce plant uprooting problems during mechanical harvesting (Marshall, 1984). Stoffella and Kahn (1986) reported that evaluating root size can be an indirect method in determining uprooting resistance. Motes (1993) suggests that raised beds are desirable for paprika on flat land, even if the beds are only 5 cm high. Motes (1993) noted that when peppers are seeded on raised beds, the beds must be maintained to help prevent lodging and uprooting due to soil loss around plant stems.

E. Direct Seeding vs. Transplanting

Kovalchuk (1983) stated one way to make mechanization easier was to develop a better pepper plant. According to Marshall (1984), doubling or tripling the normal plant populations makes the plants easier to machine harvest. The closer within-row spacings cause the plants to grow taller (Kovalchuk, 1983; Marshall, 1984) and also produce higher yields (Ahmed, 1984; Sundstrom et al., 1984). This information would seem to support the theory of direct seeding over transplanting for mechanical harvesting of peppers.

Palevitch (1978) stated that mechanical harvesting of paprika would be easier with transplants rather than direct seeded plants. Palevitch (1978) also reported that the direct seeded plants had more vegetative growth than the transplants. Cooksey (1993) disagrees by reporting that the morphology of direct seeded plants was generally more favorable for mechanical harvest. Cooksey (1993) compared direct seeded paprika plants to transplants for desirable traits for mechanical harvesting and found that transplants were more massive plants with more branches and had larger vertical fruiting planes. Yield of the transplants was significantly higher in only one year when compared to direct seeded paprika plants in the three year study (Cooksey, 1993).

Marshall (1984) stated that direct seeded plants give fewer problems to the growers. A well established root system is vital because uprooting is a serious problem in mechanically harvested peppers (Marshall, 1984). Direct seeded plants have longer and stronger taproots (Orzolek, 1981; Weaver and Bruner, 1927). Orzolek (1981) reported that direct seeded plants are more vigorous and adaptable to stress conditions when compared to transplants. Cooksey (1993) stated that transplants should not be recommended for stand establishment of paprika intended for mechanical harvest.

F. Economics of Mechanical Harvesting

The American southwest is an area that grows many types of specialty peppers including paprika and chile. The leading state in production of these types of peppers is New Mexico. Many of the peppers that are grown in this region require multi-stage harvesting periods for the fruit (green, red and dried red). Harvesting the fruit is usually performed by hand, so field labor is needed throughout the fruiting season to harvest the crops.

Palevitch (1978) stated that if the paprika market in Israel is going to expand, mechanical harvesting is imperative. Two of the main restrictions in improving the paprika crop in Israel are the amount of time it takes to harvest the crop and shortages in the labor supply (Wolf and Alper, 1984). Each year growers face higher labor inputs (Orzolek,1981) and increased production and harvesting costs (Sundstrom et al., 1984). One of the largest problems associated with pepper production today is the availability of labor (Reinoso and Harper, 1991; Kovalchuk, 1983; Marshall, 1984).

A survey conducted in 1990 in Doña Ana County, New Mexico, identified the problems of large and small chile growers. The largest problem mentioned by both parties was the availability of labor (Reinoso and Harper, 1991). Many of the growers had contracted out their labor requirements for the year. Contractors would hire undocumented aliens during the harvest to fulfill these high labor demands. The wages of these undocumented workers were less than those of documented workers. In 1986 this type of bargain labor was gone due to the implementation of the Immigration Reform Control Act (IRCA) (Reinoso and Harper, 1991), which institutes penalties to employers who hire undocumented workers. This stopped the growers and labor contractors from hiring the undocumented workers. Both groups now have to provide documentation for each worker they hire. This can present a major problem for growers who need large crews to harvest their crops. This type of regulation has decreased labor availability and driven up the cost of labor. It also takes longer to harvest the crop, which further increases the cost of production. Increasing production and harvesting costs often cause growers to implement new cost cutting management and production techniques. Mechanical harvesting is a viable option to reduce costs and maintain profitability in some peppers.

In the Doña Ana County survey, 84% of the growers would buy a machine harvester if it were available. Seventy seven percent of the growers would consider contracting a custom harvest with a mechanical harvester (Reinoso and Harper, 1991).

Hand harvesting peppers is still employed where labor is available and economical. Due to the regulations restricting undocumented workers and immigration, growers are forced to look at new avenues to cut costs. Recent research on mechanical harvesters has shown that they can be effective and useful in harvesting many types of peppers (Marshall, 1984; Kovalchuk, 1983).

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CHAPTER TWO

BEDDING AND NITROGEN TREATMENTS FOR CHILE PRODUCTION

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Abstract: One of the problems associated with machine harvesting of chile peppers (*Capsicum annuum* L.) is plant lodging. Factorial combinations of four bedding treatments and two N rates were compared for effects on lodging and fruit yield of chile at Fort Cobb and Bixby, Okla. in 1992 and again at Bixby in 1993. Bedding treatments were: 1) no-bed; 2) no-bed with 5 cm of soil hilled to the base of plants; 3) bedded preplant but bed not sustained throughout the growing season; and 4) bedded preplant and bed sustained throughout the growing season. All plots received preplant N at a low rate of 45 $kg \cdot ha^{-1}$. In 1992 half of the plots received a high N rate of 90 $kg \cdot ha^{-1}$, while in 1993 half of the plots received a high N rate of 135 $kg \cdot ha^{-1}$. The high N rate produced taller and wider plants in all three studies. Pod yield and stem and leaf dry weights were also higher at the high N rate in all three studies. Bedding treatment #1 (no-bed) had the highest yields in two out of three studies. Uprooting resistance was higher due to bedding treatments #2 and #4 at Bixby in 1993. Plant lodging was not influenced by the bedding treatments. Plants had significantly greater lodging at the high N rate in one of the three studies.

Chile is a specialty crop that is adapted to the southwestern United States. Preliminary studies have shown that this crop could be a profitable alternative for many Oklahoma farmers if the crop is machine harvested. However, a potential problem with machine harvesting this crop is plant lodging.

Pinthus (1973) defined lodging as the permanent displacement of stems from their upright position. Kahn (1985) described lodging as having occurred when the plant is sufficiently prostrate to place its fruit below the harvester level. There are three types of lodging: branch, stem, and root lodging (Johnson et al., 1973; Pinthus, 1973). Root and branch lodging are most likely to occur in a pepper field. Root lodging by definition is when straight and intact stems lean from the ground level due to a weakening in the root system (Pinthus, 1967). Branch lodging occurs when a branch is loaded with fruit and bends to the ground or, in severe cases, breaks (Johnson et al., 1973).

Lodging occurs for several reasons, including hail and damage by nematodes, insects or other animals (Pinthus, 1973). Motes (1993) suggested that sandy and loamy sand soils favor plant lodging. According to Noor and Caviness (1980), lodging occurs in areas with high winds and heavy rainstorms and where growers irrigate and use high rates of fertilizers. Careless cultivation, resulting in root damage, can also account for some lodged plants in a field (Stoffella and Kahn, 1986). While many of these problems cannot be controlled, many cultural practices can be employed to reduce lodging. In areas with high winds, wind breaks can be used to improve stands at emergence and to reduce lodging (Motes, 1993). Precision cultivation in the field is also important so as to not disturb the root system. Banks (1992) noted that deep cultivation of cotton (*Gossypium hirsutum*) reduces yield due to root pruning. When cultivating, an additional 6-10 cm of soil hilled around the base of pepper plants is beneficial due to the added stability the extra soil provides (Marshall, 1984).

Proper calibration of fertilizer equipment is also important. Too much N can lead to excessive growth, which promotes lodging (Motes, 1993). Nitrogen rates vary depending on what pepper types and cultivars are grown. These differences can be as much as 56 to 336 kg N·ha^{-1} in 'Anaheim Chili' grown in California (Payero et al., 1990). Ahmed (1984) reported that 80 kg N·ha^{-1} was best suited for sweet peppers in Sudan. Sundstrom et al. (1984) stated that 112 kg N·ha^{-1} was most desirable for Tabasco peppers (*Capsicum frutescens* L.). Stroehlein and Oebker (1979) suggested that chile yields were highest when N rates ranged from 100 to 150 kg·ha^{-1}.

Nitrogen rates also play a part in determining the size of the plants. Plant size is important when machine harvesting is being considered. Marshall (1984) stated that an upright plant, with narrow crotch angles, is optimal for mechanical harvesting. Maness and Motes (1993) reported that plants were taller due to higher N rates. Sundstrom et al. (1984) showed that high N rates and increased plant populations produced a plant structure that was easier to machine harvest.

Somos (1984) reported that paprika yield and plant development were affected by plant spacing. Marshall (1984) suggested that decreasing the within-row spacing would improve the machine harvesting of peppers. Reducing the within-row spacing produces a taller plant (Kovalchuk, 1983, Marshall, 1984; Palevitch and Levy, 1984). The taller plant aids in the machine harvesting process by decreasing the number of lateral shoots per plant (Palevitch and Levy, 1984) and by placing the fruit higher in the plant canopy (Marshall, 1984). Lodging percentages were reduced when paprika peppers were grown at high populations (9-10 plants /m^2) as compared to lower populations (Cooksey, 1993). Wider plant spacings also produce larger plants with more side branches which can increase lodging (Motes, 1993).

Wolf and Alper (1984) stated that efficient mechanical harvesting of peppers requires the establishment of complementary horticultural practices. One such practice is the use of beds and soil that is hilled to the base of the plants. Wolf and Alper (1984) noted that level beds facilitate the use of multi-row harvesters. In machine harvesting peppers, uprooting of the plant is a serious problem (Marshall, 1984). Hilling soil to the base of the plants provides structural support and increases anchorage which helps to reduce plant uprooting problems during mechanical harvesting (Marshall, 1984). Stoffella and Kahn (1986) suggested that evaluating root size can be an indirect method of determining uprooting resistance.

Marshall (1984) stated that direct seeded pepper plants cause fewer problems to the machine harvest growers. Direct seeded pepper plants have longer and stronger taproots than the transplants (Orzolek, 1981). Orzolek (1981) reported that direct seeded plants are more vigorous and adaptable to stress conditions when compared to transplants. Cooksey (1993) stated that transplants should not be used for stand establishment of paprika intended for mechanical harvest.

Our objective was to evaluate lodging, uprooting force and yield when 'Oklahoma Chile' was grown under different bedding practices and two N rates.

Field experiments were conducted in 1992 at the Caddo Research Station, Fort Cobb, Okla., and the Vegetable Research Station, Bixby, Okla. The research was conducted at the Vegetable Research Station in Bixby again in 1993. The Cobb fine sandy loam (Alfisol) at Fort Cobb was fertilized with a broadcast, preplant-incorporated application of 45N-50P-0K $kg \cdot ha^{-1}$ in 1992 based on soil test results and OSU recommendations (McCraw and Motes, 1991). The Severn very fine sandy loam (Entisol) at Bixby was fertilized with a broadcast, preplant-incorporated application of 45N-22P-41K $kg \cdot ha^{-1}$ in 1992 and again in 1993. The preplant N represented a low rate of 45 $kg \cdot ha^{-1}$ applied to all plots in 1992 and 1993. Half the plots in 1992 received a sidedressing of 45 $kg \cdot ha^{-1}$ of N at early fruit set. This additional N represents the high rate of N. In 1993, the high N rate was increased from 90 to 135 kg·ha^{-1} after determining in 1992 that higher yields could possibly be reached by adding more N. This high rate of N was applied to half of the plots in 1993. Dates of sidedress fertilization in 1992 were 29 June at Bixby and 1 July at Fort Cobb. In 1993, fertilization occurred twice at Bixby due the extra amount of N that was added and the dates were 16 July and 27 August. The source of N in all the sidedressings was ammonium nitrate (34-0-0).

'Oklahoma Chile', an advanced breeding line, was direct field seeded at a rate of 1.7 kg·ha^{-1} at all sites in 1992. In 1993 at Bixby the seeding rate was increased to 2.1 kg·ha^{-1}. Plot length was 6.0 m at Bixby and 8.5 m at Fort Cobb. Between-row spacing was 0.9 m. Planting dates in 1992 were 9 Apr. at Fort Cobb and 10 Apr. at Bixby. Two planting dates were used in 1993 due to poor emergence resulting from inclement weather (Table 1). The first seeding date was on 12 April. Reseeding was on 17 May. Hand thinning was performed at each location to achieve the desired population of one plant every 7.5 to 10 cm within the row. Thinning occurred in 1992 at Bixby on 27 May, and on 4 June at Fort Cobb. Thinning at Bixby in 1993 occurred on 23 June.

Weeds were controlled with a preplant incorporated application of napropamide at 1.7 kg·ha^{-1} plus cultivation at all locations in 1992. In 1993 at Bixby, an application of napropamide at 1.9 $kg \cdot ha^{-1}$ was made on 12 April. An additional application of napropamide was made after replanting on 17 May at the rate of 1.1 $kg \cdot ha^{-1}$. Plots were kept weed free by cultivation and hand hoeing as needed. Sprinkler irrigation was provided to supplement rainfall based on subjective soil moisture and crop observations at all locations both years.

The bedding treatments studied were: 1) no-bed; 2) no-bed with 5 cm of soil hilled to the base of plants; 3) bedded preplant but bed not sustained throughout the growing season; and 4) bedded preplant and sustained throughout the growing season.

Maintenance of bedding treatments 2 and 4 occurred on 14 July 1992 at Bixby, and 20 July 1992 at Fort Cobb. The treatments in 1993 needed to be sustained twice, 30 Aug. and 24 Sept., due to large amounts of rainfall which eroded the beds (Table 1).

Harvest occurred after frost each year to simulate grower practice. Harvest dates in 1992 were 6 Nov. at Fort Cobb, and 30 Nov. at Bixby. In 1993, harvest was on 3 November. Several plant measurements and observations were taken before harvest. Plant height and width were measured on three representative plants in the data row and the average value was recorded. The total number of plants and the number of lodged plants in the 3 m data row were counted. Pods that were touching the soil were also counted. Five plants in the data row were chosen at random to measure uprooting resistance. Uprooting resistance was measured by using a wire cable puller, spring scale, and a lever based on a fulcrum. The above ground plant material was cut off at soil level and placed in burlap bags. The bags were placed in driers at 48°C for one week. Data collected after drying included: stem diameter of 10 plants, total weight of plant matter, pod weight, and weight of 50 red pods. Pod pungency also was evaluated in the 1992 studies. Percent pods (pods as percentage of total plant weight) were calculated after harevst.

A 2 x 4 factorial arrangement of treatments was used in a split-plot experimental design arranged in randomized blocks with 6 replications. The main plots were N rates and the subplots were bedding treatments. A plot consisted of 4 rows with the two middle rows being used for data collection. Data were evaluated by analysis of variance and GLM procedures (SAS, 1982).

No significant interactions were found between the N rates and bedding treatments for any of the variables analyzed in the three studies.

Plant stand at harvest was not significantly different for bedding treatments or N rates (data not presented). Also, no significant differences were found between the N rates or the bedding treatments for pod pungency in 1992 (data not presented).

Plant height and width were significantly greater at the high N rate in all three studies (Table 2). The number of plants that were lodged was significantly greater at the high N rate only at Caddo in 1992 and not significantly influenced by N rates at Bixby either year (Table 2). The number of pods touching the soil, stem diameter, and uprooting force were not significantly affected by N rate in any of the three studies (Table 2).

The pod and stem and leaf dry weights were significantly greater with the high N rate in all three studies (Table 3). The average pod weight was significantly greater with the high N rate at Caddo in 1992, but not significantly different due to the N rate at Bixby either year (Table 3). Percent pods were significantly higher with the low N rate at Bixby in 1993 (Table 3). There were no significant differences in percent pods due to N rate in the other two studies (Table 3).

Plant height, number of plants lodged, and number of pods touching the soil were not significantly different due to bedding treatments in any of the three studies (Table 4). Plant width was significantly greater in bedding treatments #3 and #4 at Bixby in 1993, when contrasted with bedding treatments #1 and #2 (Table 4). There were no significant differences in plant width due to the bedding treatments in 1992 (Table 4). The plant stem diameters were significantly greater in treatments #3 and #4 at Bixby in 1992, when contrasted with treatments #1 and #2 (Table 4). There were no significant differences for stem diameter due to the bedding treatments at Caddo in 1992 or Bixby in 1993 (Table 4). Uprooting force was significantly greater in treatments #2 and #4 at Bixby in 1993, when contrasted with bedding treatments #1 and #3 (Table 4). There were no significant differences for uprooting force due to bedding treatments at Bixby in 1992 (Table 4). Uprooting force could not be determined due to dry soil conditions at Caddo in 1992 (Table 4).

The average weight of red pods and the stem and leaf dry weight were not significantly different for bedding treatments in all three studies (Table 5). Pod dry weight was significantly greater in treatments #1 and #3, at Bixby in 1992, when contrasted with treatments #2 and #4 (Table 5). There were no significant differences in pod dry weight due to the bedding treatments in the other two studies (Table 5). Values for percent pods were significantly higher in treatments #1 and #3, at Bixby in 1992, when contrasted with treatments #2 and #4 (Table 5). There were no significant differences for percent pods due to the bedding treatments for the other two studies (Table 5).

The high N rate produced taller and wider plants at all locations both years which agrees with results reported by Maness and Motes (1993). The high N rate resulted in more vegetative growth and pod set which was reported by Motes (1993). More vegetative growth can also be associated with more plant lodging (Motes, 1993); however, the high N rate increased lodging in only one (Caddo in 1992) of the three studies (Table 2). Lodging is not a current problem in chile, because the upright plant growth habit has been field selected over a 10 year period.

In 1993 at Bixby, the percent pod was lower at the high N rate than at the low N rate. This is due to adverse environmental conditions which caused replanting 35 days past the optimum seeding date (Table 1). Had the initial seeding made an acceptable plant stand, the percent pod would likely have been consistent with the 1992 values (Table 3).

The plant height and width were not significantly influenced by the bedding treatments except for plant width at Bixby in 1993, where bedded treatments (#3 and #4) produced wider plants. This could be attributed to the late replanting date. The beds may have provided a more favorable environment for early root growth as reported by Banks, (1992) which in turn promoted more top growth. This did not however make the plants any taller in 1993, just wider.

Uprooting of plants is not currently a problem for Oklahoma chile growers when harvesting the crop by machine since plants are cut off near the soil level and taken into the machine. Branch lodging is a problem since branches can be below the cutting mechanism as reported by Kahn (1985). There is grower interest in a stripper harvest system, which is faster, but requires stronger plant anchorage as Marshall (1984) found for mechanically harvesting peppers using a helix stripper mechanism. The hilled and sustained treatments, #2 and #4 in 1993 at Bixby, had greater plant uprooting resistance when compared to the flat and un-sustained treatments #1 and #3 (Table 4). The extra soil around the base of the plants provides structural support and increases anchorage which aids in reducing plant uprooting problems during mechanical harvesting (Marshall, 1984). The greater uprooting resistance in the hilled and sustained treatments indicates better anchorage, possibly due to greater root size as suggested by Stoffella and Kahn (1986).

Bedding treatments #1 and #3 produced greater yield than treatments #2 and #4 at Bixby in 1992 (Table 5). This possibly resulted from damage to root systems when sustaining treatments #2 and #4 during the growing season. The author can confirm that there was some visible damage being done to the feeder roots during this operation. According to Miller, (1986) any stress originating in either the roots or shoots affects the rest of the plant and can reduce yield. Root damage when cultivating was also observed by Zobel (1975). The root system provides the needed water and nutrients for plant growth as reported by Miller (1986) and Zobel (1986). The root system acts as a sink, as do the pods for carbohydrates as stated by Miller (1986). Once stress occurs to the roots, the plant assimilates are directed to the roots to rebuild the damaged area. This possibly explains why treatments #1 and #3, at Bixby in 1992, had greater yields than hilled and sustained treatments #2 and #4, which were subjected to the physical damage caused by cultivation. Banks (1992) reported reduced cotton yields due to root pruning caused by cultivation.

Injury to the root system seems to play an important role when the plant is developing as reported by Miller (1986). The percent pod at Bixby in 1992, shows that treatments #1 and #3 produced higher pod percentages than treatments #2 and #4. Sometime during the growing season when the maintenance of treatments #2 and #4 was being performed, some injury may have occurred to the root system by cultivation as reported by Banks (1992) in cotton. Perhaps destroying some of the feeder roots reduced the set of pods for a short time. Lower pod yields in treatments #2 and #4 confirm that pod set was reduced since pod size remained unchanged (Table 5).

The no-bed treatment appears to be the best practice based on these studies. The no-bed treatment had the highest pod yields in two of three studies. The high N rates used in both years (90 and 135 $kg{\cdot}ha^{-1}$) produced plants that were taller and wider than the low N rate. The pod and stem and leaf dry weights also were greater with the high N rates in all three studies. The high N rate (135 kg·ha^{-1}) used in 1993 seems to be the best rate to recommend for growers which closely reflects a recommendation by Sundstrom et al. (1984) of 112 kg N·ha^{-1} for Tabasco peppers. The 1993 data do not support this conclusion exactly, but the growing season was reduced 35 days due to replanting. The extra 35 days of growing season could have been enough to show that the rate of 135 kg·ha^{-1} would be the best recommended rate for a commercial operation. The above mentioned rate falls in the range suggested by Stroehlein and Oebker, (1979) who reported that chile yields were increased when N rates ranged from 100 to 150 kg·ha^{-1}. The number of plants that were lodged was not significantly different with bedding treatments. In one of three studies, the high N rate produced greater lodging. Plant uprooting is not a current problem for direct seeded Oklahoma chile since the crop is cut off above the soil at harvest. A strong taproot gives the plant a sturdy root system. A well established root system is vital to withstand the force of a stripper type machine harvester which is under test to harvest chile in Oklahoma. The importance of plant uprooting force will increase should the harvest mechanisms used by growers change to the faster stripper type action.

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Table 1. Monthly precipitation for the Caddo and Vegetable Research Stations (cm).

	Growing season months							
	April	May	June	July	Aug.	Sept.	Oct.	Total
			Caddo, 1992					
Actual	4.5	20.8	13.7	9.6	19.1	3.4	0.4	71.6
Normal	6.1	10.9	8.0	8.0	6.4	6.9	6.0	52.2
			Bixby, 1992					
Actual	12.8	14.0	13.4	7.7	8.6	10.9	4.4	71.7
Normal	9.0	11.0	11.7	7.3	7.9	12.0	9.3	68.2
			Bixby, 1993					
Actual	12.1	19.4	4.1	3.0	7.5	23.6	6.9	76.6
Normal	9.0	11.0	11.7	7.3	7.9	12.0	9.3	68.2

Table 2. Effects of N rates on plant characteristics for Oklahoma Chile.

Treatment	Plant height (cm)	Plant width (cm)	No. of plants lodged (m^{-2})	No. of pods touching soil (m^{-2})	Stem diam. (mm)	Uprooting force (N)
			Caddo, 1992			
Low N Rate 45 kg·ha^{-1}	42	46	0.4	0.4	9.7	---
High N Rate 90 kg·ha^{-1}	50	52	0.7	0.7	10.1	---
Significance	**	**	*	NS	NS	---
			Bixby, 1992			
Low N Rate 45 kg·ha^{-1}	53	45	0.0	1.1	11.2	294
High N Rate 90 kg·ha^{-1}	58	48	0.0	1.5	11.7	304
Significance	**	**	NS	NS	NS	NS
			Bixby, 1993			
Low N Rate 45 kg·ha^{-1}	55	46	0.0	1.5	9.1	294
High N Rate 135 kg·ha^{-1}	63	52	0.4	2.2	9.8	294
Significance	**	**	NS	NS	NS	NS

^{NS,*,**} Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 3. Effects of N rates on plant and pod dry weights for Oklahoma Chile.

Treatment	Avg. wt. of individual red pod (g)	Pod dry wt. ($\text{kg}\cdot\text{ha}^{-1}$)	Stem and leaf dry wt. ($\text{kg}\cdot\text{ha}^{-1}$)	Pods as % of total plant wt.
		Caddo, 1992		
Low N Rate 45 $\text{kg}\cdot\text{ha}^{-1}$	.26	2526	2233	52
High N Rate 90 $\text{kg}\cdot\text{ha}^{-1}$	.28	3391	3042	53
Significance	**	**	**	NS
		Bixby, 1992		
Low N Rate 45 $\text{kg}\cdot\text{ha}^{-1}$	.26	2259	2648	46
High N Rate 90 $\text{kg}\cdot\text{ha}^{-1}$	.27	2858	3200	47
Significance	NS	**	**	NS
		Bixby, 1993		
Low N Rate 45 $\text{kg}\cdot\text{ha}^{-1}$	.16	1857	2621	41
High N Rate 135 $\text{kg}\cdot\text{ha}^{-1}$	.16	2154	3999	35
Significance	NS	**	**	**

NS,*,** Nonsignificant or significant at $P \le 0.05$ or 0.01, respectively.

Table 4. Effects of bedding treatments on plant characteristics for Oklahoma Chile.

Bedding treatments	Plant height (cm)	Plant width (cm)	No. of plants lodged (m^2)	No. of pods touching soil (m^2)	Stem diam. (mm)	Uprooting force (N)
			Caddo, 1992			
1. No-bed	48	50	0.7	0.7	9.9	---
2. No-bed hilled	46	50	0.4	0.4	9.6	---
3. Bedded	46	47	0.4	0.7	10.5	---
4. Bedded-sustained	45	49	0.4	0.4	9.5	---
Contrasts of treatments						
1. #1,#2 vs #3,#4	NS	NS	NS	NS	NS	--
2. #2,#4 vs #1,#3	NS	NS	NS	NS	NS	--
			Bixby, 1992			
1. No-bed	57	46	0.0	0.7	11.5	294
2. No-bed hilled	55	46	0.0	1.1	10.7	294
3. Bedded	55	48	0.0	2.6	12.3	284
4. Bedded-sustained	55	47	0.0	1.1	11.6	294
Contrasts of treatments						
1. #1,#2 vs #3,#4	NS	NS	NS	NS	*	NS
2. #2,#4 vs #1,#3	NS	NS	NS	NS	NS	NS

Table 4 continued.

Bedding treatments	Plant height (cm)	Plant width (cm)	No. of plants lodged (m^2)	No. of pods touching soil (m^2)	Stem diam. (mm)	Uprooting force (N)
			Bixby, 1993			
1. No-bed	60	48	0.4	1.9	9.3	255
2. No-bed hilled	56	47	0.0	3.0	9.0	314
3. Bedded	60	50	0.4	1.5	9.4	275
4. Bedded-sustained	59	52	0.4	1.5	9.9	324
Contrasts of treatments						
1. #1,#2 vs #3,#4	NS	**	NS	NS	NS	NS
2. #2,#4 vs #1,#3	NS	NS	NS	NS	NS	**

NS,*,** Nonsignificant or significant at $P \le 0.05$ or 0.01, respectively.

Table 5. Effects of bedding treatments on plant and pod dry weights for Oklahoma Chile.

Bedding treatments	Avg. wt. of individual red pod (g)	Pod dry wt. ($kg \cdot ha^{-1}$)	Stem and leaf dry wt. ($kg \cdot ha^{-1}$)	Pods as % of total plant wt.
		Caddo, 1992		
1. No-bed	.27	3222	2733	54
2. No-bed hilled	.27	2829	2639	51
3. Bedded	.27	2903	2738	51
4. Bedded-sustained	.27	2881	2442	54
Contrasts of treatments				
1. #1,#2 vs #3,#4	NS	NS	NS	NS
2. #2,#4 vs #1,#3	NS	NS	NS	NS
		Bixby, 1992		
1. No-bed	.26	2835	3066	48
2. No-bed hilled	.26	2456	2878	46
3. Bedded	.27	2576	2876	47
4. Bedded-sustained	.26	2367	2877	45
Contrasts of treatments				
1. #1,#2 vs #3,#4	NS	NS	NS	NS
2. #2,#4 vs #1,#3	NS	**	NS	*

Table 5 continued.

Bedding treatments	Avg. wt. of red pods (g)	Pod dry wt. ($kg \cdot ha^{-1}$)	Stem and leaf dry wt. ($kg \cdot ha^{-1}$)	Pods as % of total plant wt.
		Bixby, 1993		
1. No-bed	.16	2080	3252	39
2. No-bed hilled	.15	1857	3229	37
3. Bedded	.16	1911	3325	37
4. Bedded-sustained	.16	2174	3434	40
Contrasts of treatments				
1. #1,#2 vs #3,#4	NS	NS	NS	NS
2. #2,#4 vs #1,#3	NS	NS	NS	NS

^{NS,*,**} Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

CHAPTER THREE

BEDDING AND NITROGEN TREATMENTS FOR PAPRIKA PRODUCTION

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Abstract: One of the problems associated with machine harvesting of paprika peppers (*Capsicum annuum* L.) is plant lodging. Factorial combinations of four bedding treatments and two N rates were compared for effects on lodging and fruit yield of paprika at Bixby, Okla. in 1992 and 1993. Bedding treatments were: 1) no-bed; 2) no-bed with 5 cm of soil hilled to the base of plants; 3) bedded preplant but bed not sustained throughout the growing season; and 4) bedded preplant and bed sustained throughout the growing season. All plots received preplant N at a low rate of 45 $kg \cdot ha^{-1}$. In 1992 and 1993, half of the plots received a high rate of N of 90 $kg \cdot ha^{-1}$. All pod yield variables (red, other, and total) were increased by the high N rate in 1992. Stem and leaf dry weights were greater in both years with the high N rate. All pod yield variables were greater under bedding treatments #1 and #2 in 1992. Uprooting resistance was higher in bedding treatments #2 and #4 in both years. Plant lodging was not significantly influenced by the N rates or the bedding treatments.

Paprika is a specialty crop that is adapted to the southwestern United States. Preliminary studies have shown that this crop could be a profitable alternative for many Oklahoma farmers if the crop is machine harvested. However, a potential problem with machine harvesting this crop is plant lodging.

Pinthus (1973) defined lodging as the permanent displacement of stems from their upright position. Kahn

(1985) described lodging as having occurred when the plant is sufficiently prostrate to place its fruit below the harvester level. There are three types of lodging: branch, stem, and root lodging (Johnson et al., 1973; Pinthus, 1973). Root and branch lodging are most likely to occur in a pepper field. Root lodging by definition is when straight and intact stems lean from the ground level due to a weakening in the root system (Pinthus, 1967). Branch lodging occurs when a branch is loaded with fruit and bends to the ground, or in severe cases, breaks (Johnson et al., 1973).

Lodging occurs for several reasons, including hail and damage by nematodes, insects or other animals (Pinthus, 1973). Motes (1993) suggested that sandy and loamy sand soils favor plant lodging. According to Noor and Caviness (1980), lodging occurs in areas with high winds and heavy rainstorms and where growers irrigate and use high rates of fertilizers. Careless cultivation, resulting in root damage, can also account for some lodged plants in a field (Stoffella and Kahn, 1986). While many of these problems cannot be controlled, many cultural practices can be employed to reduce lodging. In areas with high winds, wind breaks can be used to improve stands at emergence and to reduce lodging (Motes, 1993). Precision cultivation in the field is also important so as to not disturb the root system. Banks (1992) noted that deep cultivation of cotton

(*Gossypium hirsutum*) reduces yield due to root pruning. When cultivating, an additional 6-10 cm of soil hilled around the base of pepper plants is beneficial due to the added stability the extra soil provides (Marshall, 1984).

Proper calibration of fertilizer equipment is also important. Too much N can lead to excessive growth and promotes lodging (Motes, 1993). Nitrogen rates vary depending on what pepper types and cultivars are grown. These differences can be as much as 56 to 336 kg $N \cdot ha^{-1}$ in 'Anaheim Chili' grown in California (Payero et al., 1990). Ahmed (1984) reported that 80 kg $N \cdot ha^{-1}$ was best suited for sweet peppers in Sudan. Sundstrom et al. (1984) stated that 112 kg $N \cdot ha^{-1}$ was most desirable for Tabasco peppers (*Capiscum frutescens* L.). Stroehlein and Oebker (1979) suggested that chile yields were highest when N rates ranged from 100 to 150 $kg \cdot ha^{-1}$.

Nitrogen rates also play a part in determining the size of the plants. Plant size is important when machine harvesting is being considered. Marshall (1984) stated that an upright plant, with narrow crotch angles, is optimal for mechanical harvesting. Maness and Motes (1993) reported that plants were taller due to higher N rates. Sundstrom et al. (1984) showed that high N rates and increased plant populations produced a plant structure that was easier to machine harvest.

Somos (1984) reported that paprika yield and plant development were affected by plant spacing. Marshall (1984) suggested that decreasing the within-row spacing would improve the machine harvesting of peppers. Reducing the within-row spacing produces a taller plant (Kovalchuk, 1983, Marshall, 1984; Palevitch and Levy, 1984). The taller plant aids in the machine harvesting process by decreasing the number of lateral shoots per plant (Palevitch and Levy, 1984) and by placing the fruit higher in the plant canopy (Marshall, 1984). Lodging percentages were reduced when paprika peppers were grown at high populations (9-10 plants/m^2) as compared to lower populations (Cooksey, 1993). Wider plant spacings also produce larger plants with more side branches which can increase lodging (Motes, 1993).

Wolf and Alper (1984) stated that efficient mechanical harvesting of peppers requires the establishment of complementary horticultural practices. One such practice is the use of beds and soil that is hilled to the base of the plants. Wolf and Alper (1984) noted that level beds facilitate the use of multi-row harvesters. In machine harvesting of peppers, uprooting of the plant is a serious problem (Marshall, 1984). Hilling soil to the base of the plants provides structural support and increases anchorage which helps to reduce plant uprooting problems during mechanical harvesting (Marshall, 1984). Stoffella and Kahn (1986) suggested that evaluating root size can be an indirect method of determining uprooting resistance.

Marshall (1984) stated that direct seeded pepper plants give fewer problems to the machine harvest growers. Direct seeded pepper plants have longer and stronger taproots than the transplants (Orzolek, 1981). Orzolek (1981) reported that direct seeded plants are more vigorous and adaptable to stress conditions when compared to transplants. Cooksey (1993) stated that transplants should not be recommended for stand establishment of paprika intended for mechanical harvest.

Our objective was to evaluate lodging, uprooting force and yield when 'Paprika 50' was grown under different bedding practices and two N rates.

Field experiments were conducted in 1992 and 1993 at the Vegetable Research Station, Bixby, Okla. The Severn very fine sandy loam (Entisol) at Bixby was fertilized with a broadcast, preplant-incorporated application of 45N-22P-41K $kg \cdot ha^{-1}$ in 1992 and again in 1993 based on soil test results and OSU recommendations (McCraw and Motes, 1991). The preplant N represented a low rate of 45 $kg \cdot ha^{-1}$ applied to all plots in 1992 and 1993. Half the plots received a sidedressing of 45 $kg \cdot ha^{-1}$ of N at early fruit set in both years. This additional N represents the high rate of N. Dates of sidedress fertilization were 29 June and 16 July in 1992 and 1993, respectively. The source of N in all the sidedressings was ammonium nitrate (34-0-0).

'Paprika 50', an advanced breeding line with an upright growth habit, was direct field seeded at rates of 5.6 and 3.2 kg·ha^{-1} in 1992 and 1993, respectively. Plot length was 6.0 m both years. Between-row spacing was 0.9 m. Planting date in 1992 was 6 April. Two planting dates were used in 1993 due to the poor emergence resulting from inclement weather (Table 6). The first seeding date on 12 April. Reseeding was on 17 May. Hand thinning was performed at each location to achieve the desired population of one plant every 7.5 to 10 cm within the row. Thinning occurred on 27 May and 28 July in 1992 and 1993, respectively.

Weeds were controlled with a preplant incorporated application of napropamide at 1.7 kg·ha^{-1} plus cultivation in 1992. In 1993, an application of napropamide at 1.9 kg·ha^{-1} was made on 12 April. An additional application of napropamide was made after replanting on 17 May at the rate of 1.1 kg·ha^{-1}. Plots were kept weed free by cultivation and hand hoeing as needed. Sprinkler irrigation was provided to supplement rainfall based on subjective soil moisture and crop observations both years.

The bedding treatments studied were: 1) no-bed; 2) no-bed with 5 cm of soil hilled to the base of plants; 3) bedded preplant but bed not sustained throughout the growing season; and 4) bedded preplant and sustained throughout the growing season.

Maintenance of bedding treatments 2 and 4 occurred on 14 July 1992 at Bixby. The treatments at Bixby in 1993 needed to be sustained twice, 30 Aug. and 24 Sept., due to large amounts of rainfall which eroded the beds (Table 6).

Harvest occurred after frost each year to simulate grower practice. Harvest dates were 18 Nov. and 1 November in 1992 and 1993, respectively. Several plant measurements and observations were taken before harvest. Plant height and width were measured on three representative plants in the data row and the average value was recorded. The total number of plants and the number of lodged plants in the 3 m data row were counted. Pods that were touching the soil were also counted. Five plants in the data row were chosen at random to measure uprooting resistance. Uprooting resistance was measured by using a wire cable puller, spring scale, and a lever based on a fulcrum. The above ground plant material was cut off at soil level and placed in burlap bags. The bags were placed in driers at 48°C for one week. Data collected after drying included: stem diameter of 10 plants, total weight of plant matter, pod weight, weight of marketable red pods, and weight of cull pods. Percent pods (pods as percentage of total plant weight) were calculated after harvest.

A 2 x 4 factorial arrangement of treatments was used in a split-plot experimental design arranged in randomized blocks with 6 replications. The main plots were N rates and the subplots were bedding treatments. A plot consisted of 4 rows with the two middle rows being used for data collection. Data were evaluated by analysis of variance and GLM procedures (SAS, 1982).

No significant interactions were found between the N rates and the bedding treatments for any of the variables analyzed in the two studies.

Plant stand at harvest was not significantly different for bedding treatments or the N rates (data not presented).

Plant height, number of plants lodged, number of pods touching the soil, and uprooting force were not significantly different between N levels for both years (Table 7). Plant width was not significantly different due to N rates in 1992, but was significantly greater in 1993 with the high N rate (Table 7). The stem diameter was significantly greater both years when the high N rate was used (Table 7).

The red pod yield was significantly greater at the high rate of N in 1992, but was not significantly different due to N rate in 1993 (Table 8). The other pod yield (orange, bleached, green, or fungus infested) was significantly greater both years with the high N rate (Table 8). The total pod yield (red + other) was significantly greater in 1992 at the high N rate, but was not significantly different due to N rate in 1993 (Table 8). The stem and leaf dry weights were significantly greater in both years at the high N rate (Table 8). Values for percent pods were not significantly different either year due to N level (Table

8).

Plant height, width, stem diameters, and number of plants lodged were not significantly different due to bedding treatments in either year (Table 9). The number of pods touching the soil was significantly greater in bedding treatments #3 and #4 in 1993, when contrasted with treatments #1 and #2 (Table 9). There were no significant differences in the number of pods touching the soil due to the bedding treatments in 1992 (Table 9). Uprooting force was significantly greater in treatments #2 and #4 in both years, when contrasted with treatments #1 and #3 (Table 9). In 1993, uprooting force was also significantly greater in treatments #3 and #4 when contrasted with treatments #1 and #2 (Table 9).

The red pod yield was significantly greater in treatments #1 and #2 in 1992, when contrasted with treatments #3 and #4 (Table 10). Other pod yield was significantly greater in treatments #1 and #2 in 1992, when contrasted with treatments #3 and #4. Other pod yield was also significantly greater in treatments #1 and #3 in 1992, when contrasted with treatments #2 and #4 (Table 10). Total pod yield was significantly greater in treatments #1 and #2 in 1992, when contrasted with treatments #3 and #4 (Table 10). Stem and leaf dry weight was significantly greater in treatments #1 and #2 in 1992, when contrasted with treatments #3 and #4 (Table 10). Percent pod was significantly greater in treatments #1 and #2 in 1992, when contrasted with treatments #3 and #4 (Table 10). Bedding treatments had no significant effects on pod yield, stem and leaf dry weights, and percent pods in 1993 (Table 10).

There were fewer significant effects for the different N rates in 1993 than in 1992. The reason for fewer significant differences in 1993 was due to an unfavorable growing environment. Yield values show how unfavorable 1993 actually was for growing paprika (Table 6). Pod dry weight in 1992 at the low N rate was 1200 kg·ha^{-1}. The 1993 dry pod weight at the high N level was 671 kg·ha^{-1}. This is approximately one half of the previous year's yield at the lowest N level. Planting date in 1992 was 6 April. The original planting date in 1993 was 11 April. Higher than normal precipitation rates for April and May, 1993 led to almost no paprika stand one month later (Table 6). Due to wet soil conditions, replanting the experiment could not be accomplished until 17 May, 1993. The difference between the initial seeding date and reseeding date in 1993 was 35 days. The late replant date coupled with an early killing freeze (-7°C on 31 Oct.) produced an unfavorably short growing season.

The stem diameters were significantly greater both years at the high N rate (Table 7). This response agrees with the report by Maness and Motes (1993) when paprika stem weight was greater at high N rates. All of the pod yield variables (red, other, and total) were significantly greater in 1992 due to the high N rate (Table 8). This result agrees with the report by Maness and Motes (1993) stating that yields of both red and non-red pods were greater at the high N rates. Other pod yield was significantly greater in 1993 due to the high N rates. Motes (1993) reported that N should not be applied late in the growing season. The fertilization practice would stimulate plant growth into October. The fruit set late in the season would not have time to develop and turn red before frost (Motes, 1993). Sidedress fertilization for the 1993 study occurred on 16 July. The date of fertilization was delayed due to inclement weather at the start of the growing season which forced a late replanting date (Table 6). Therefore, the increase in other pod yield can be attributed to undesirable environmental factors. Stem and leaf dry weights were significantly greater in both studies with the high N rate. The high N rate resulted in more vegetative growth and pod set which was reported earlier by Motes (1993).

The number of pods touching the soil was significantly greater in bedding treatments #3 and #4 in 1993. Plants are more likely to lodge when subjected to heavy rainstorms and high winds as reported by Noor and Caviness (1980). Heavy rainstorms occurred in September 1993 (Table 6). The number of pods that were touching the soil in 1993 can be attributed to environmental factors. The bedded treatments

#3 and #4 endured more stress from the lack of rainfall (June and July 1993; Table 6) and the environmentally induced stress possibly reduced the root size of the bedded treatments. The unfavorable conditions for root growth could have produced a weaker root system which resulted in more lodging and in turn more pods touching the ground.

Uprooting plants can be a problem for Oklahoma paprika growers when harvesting the crop using a modified cotton stripper. The machine harvesting method that strips pods from the plant requires strong plant anchorage as reported by Marshall (1984). The hilled and sustained treatments, #2 and #4 in both years, had greater plant uprooting resistance when compared to the flat and un-sustained treatments #1 and #3. The bedded treatments #3 and #4 in 1993, also had greater plant uprooting resistance when compared to treatments #1 and #2 (Table 9). The extra soil around the base of the plants provided increased anchorage which would help to reduce plant uprooting during mechanical harvesting. The greater uprooting resistance in the hilled and sustained treatments indicates better anchorage and possibly larger root size as suggested by Stoffella and Kahn (1986).

All pod yield variables were significantly greater in 1992 due to the bedding treatments #1 and #2 (Table 10). Miller (1986) reported that root growth usually occurs near the surface in moist soil. The moist soil environment allows the roots to expand with little resistance and promotes a water gradient into the new roots as reported by Miller (1986). Banks (1992) noted in cotton that beds dry faster than flat land following wet periods. This indicates that if any moisture stress occurs from lack of rainfall or irrigation, the bedded treatments would be stressed before the non-bedded treatments. Stress to roots can reduce yield as noted by Miller (1986) and Banks (1992). Stem and leaf dry weights and percent pod were also greater in bedding treatments #1 and #2 in 1992. Significance in both variables can be attributed to less moisture stress in bedding treatments #1 and #2 between irrigation and rainfall cycles as mentioned previously.

The observations that can be made from this study to benefit paprika growers are that bedding treatment #2, (no-bed with 5 cm of soil hilled to the base of the plants) appears to be the best practice. The grower will probably cultivate the rows for weed control purposes, so hilling additional soil to the plant can easily be accomplished with cultivation. The extra soil around the plant provides structural support and increases anchorage which reduces plant uprooting problems during stripper harvesting. The high N rate (90 $kg \cdot ha^{-1}$) appears to be the best for growers. Total pod yield was significantly greater in 1992 due to the high N rate (Table 8). The 1993 data for total pod yield do not support this conclusion exactly. The growing season was reduced 35 days due to replanting. The extra 35 days of growing season could have been enough to show that the rate of 90 $kgN \cdot ha^{-1}$ would be the best recommended rate for a commercial operation. Stem and leaf dry weights were significantly greater both years due to the high N rate. The number of plants lodged was not significantly different due to bedding treatments or N levels. Plant uprooting can be a problem for direct seeded paprika. The force of the stripper type mechanism requires a well established root system and a strong taproot. This is to ensure the plants are not uprooted during the harvesting operation. The uprooted plants can clog the harvester which slows harvest operations and increases the trash content of the harvested product. Decreasing the trash content is an important goal for the grower, because trash requires hand labor to remove which increases the grower's cost and reduces quality.

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Table 6. Monthly precipitation at the Vegetable Research Station (cm).

	Growing season months							
	April	May	June	July	Aug.	Sept.	Oct.	Total
				1992				
Actual	12.8	14.0	13.4	7.7	8.6	10.9	4.4	71.7
Normal	9.0	11.0	11.7	7.3	7.9	12.0	9.3	68.2
				1993				
Actual	12.1	19.4	4.1	3.0	7.5	23.6	6.9	76.6
Normal	9.0	11.0	11.7	7.3	7.9	12.0	9.3	68.2

Table 7. Effects of N rates on plant characteristics for Paprika 50.

Treatment	Plant height (cm)	Plant width (cm)	No. of plants lodged (m^2)	No. of pods touching soil (m^2)	Stem diam. (mm)	Uprooting force (N)
			1992			
Low N Rate						
45 $kg \cdot ha^{-1}$	64	48	1.5	4.1	8.9	157
High N Rate						
90 $kg \cdot ha^{-1}$	68	51	1.9	5.2	9.4	167
Significance	NS	NS	NS	NS	*	NS
			1993			
Low N Rate						
45 $kg \cdot ha^{-1}$	53	41	1.5	3.0	7.8	186
High N Rate						
90 $kg \cdot ha^{-1}$	58	47	1.9	4.1	8.7	186
Significance	NS	*	NS	NS	*	NS

^{NS,*} Nonsignificant or significant at $P \leq 0.05$.

Table 8. Effects of N rates on plant and pod dry weights for Paprika 50.

Treatment	Pod yield (kg·ha^{-1})			Stem and leaf dry wt. (kg·ha^{-1})	Pods as % of total plant wt.
	Red	Other[z]	Total[y]		
			1992		
Low N Rate 45 kg·ha^{-1}	615	585	1200	1761	40
High N Rate 90 kg·ha^{-1}	778	730	1508	2208	41
Significance	**	**	**	**	NS
			1993		
Low N Rate 45 kg·ha^{-1}	259	270	529	1240	30
High N Rate 90 kg·ha^{-1}	319	352	671	1635	29
Significance	NS	*	NS	*	NS

[z] Other pod yield includes orange, bleached, green, and fungus infested.

[y] Total pod yield includes red plus other.

[NS,*,**] Nonsignificant or significant at $P \le 0.05$ or 0.01, respectively.

Table 9. Effects of bedding treatments on plant characteristics for Paprika 50.

Bedding treatments	Plant height (cm)	Plant width (cm)	No. of plants lodged (m^2)	No. of pods touching soil (m^2)	Stem diam. (mm)	Uprooting force (N)
			1992			
1. No-bed	66	51	1.5	4.8	9.0	147
2. No-bed hilled	67	50	1.5	4.4	9.0	167
3. Bedded	64	48	1.5	4.8	9.4	147
4. Bedded-sustained	66	49	1.1	4.8	9.2	167
Contrasts of treatments						
1. #1,#2 vs #3,#4	NS	NS	NS	NS	NS	NS
2. #2,#4 vs #1,#3	NS	NS	NS	NS	NS	**
			1993			
1. No-bed	55	44	1.9	3.0	8.3	157
2. No-bed hilled	56	44	1.1	2.6	8.2	206
3. Bedded	56	44	1.5	3.7	8.6	177
4. Bedded-sustained	55	44	1.9	4.4	7.9	226
Contrasts of treatments						
1. #1,#2 vs #3,#4	NS	NS	NS	*	NS	*
2. #2,#4 vs #1,#3	NS	NS	NS	NS	NS	**

[NS,*,**] Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 10. Effects of bedding treatments on plant and pod dry weights for Paprika 50.

Bedding treatment	Pod yield ($kg\cdot ha^{-1}$)			Stem and leaf dry wt. ($kg\cdot ha^{-1}$)	Pods as % of total plant wt.
	Red	Other[z]	Total[y]		
			1992		
1. No-bed	811	733	1544	2027	43
2. No-bed hilled	778	681	1459	2112	41
3. Bedded	567	667	1234	1908	39
4. Bedded-sustained	630	548	1178	1891	38
Contrasts of treatments					
1. #1,#2 vs #3,#4	**	**	**	*	**
2. #2,#4 vs #1,#3	NS	*	NS	NS	NS
			1993		
1. No-bed	281	304	585	1424	28
2. No-bed hilled	311	300	611	1490	29
3. Bedded	304	311	615	1438	29
4. Bedded-sustained	256	330	586	1397	30
Contrasts of treatments					
1. #1,#2 vs #3,#4	NS	NS	NS	NS	NS
2. #2,#4 vs #1,#3	NS	NS	NS	NS	NS

[z] Other pod yield includes orange, bleached, green, and fungus infested.

[y] Total pod yield includes red plus other.

[NS,*,**] Nonsignificant or significant at $P \le 0.05$ or 0.01, respectively.

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