THE EFFECTS OF ROW WIDTH, PLANT POPULATION AND NITROGEN LEVEL ON NO-TILL GRAIN SORGHUM PRODUCTION

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CHAPTER I

INTRODUCTION

Grain sorghum, sorghum bicolor (L.) Moench, is widely adapted in the tropics and temperate regions of the world. This is especially true for the more arid regions where drought and heat stress play important roles in determining crop selection. The southwestern great plains and Oklahoma in particular falls into this category.

No-till, a concept considered impractical before the onset of modern herbicides approximately 20 years ago, is now accepted in many areas as a realistic alternative for the modern day farmer. No-till has much to offer in soil erosion control and in conservation of soil moisture, time, and other factors. Despite these advantages, there are many disadvantages and unknowns that greatly increase the risk of no-till over the more traditional methods of seedbed preparation via conventional tillage.

Several factors the farmer has under his control in grain sorghum production are: (1) row width; (2) planting rate which influences final plant population; and (3) nitrogen level. There are considerable data documenting these effects under conventional and reduced tillage systems and it has generally been assumed that the same trends occur under no-till.

With this in mind, a two year field study was undertaken to gain additional data on the effects of row width, plant population, and nitrogen level under the no-till grain sorghum production setting. The objectives were:

1. To obtain data on optimal row width and plant population for a no-till grain sorghum production system.

2. To determine the effect of nitrogen rate on grain yield, grain protein, and nitrogen removed from the soil by the grain.

3. To obtain data on other variables under the no-till setting (100-kernel weight, test weight, plant lodging, plant height, and days to midbloom).

4. To obtain data on soil fertility levels under no-till in the areas of soil pH, nitrogen (NO_3^---N), phosphorous (P), and potassium (K) at a surface and subsurface soil depth.

CHAPTER II

LITERATURE REVIEW

Since the beginning of time, man has searched for improved methods of producing his food and fiber needs. Civilizations in the past have risen and fallen in relation to the stability of their agricultural base. The decay of many civilizations has been marked by the mismanagement, depletion, and loss of their soil resources and reserves. The United States stands today in danger of this same fate if we do not reverse soil destruction and soil loss trends of the past 100 years. Indeed, civilization, as we know it today, stands in imminent danger if we cannot learn to better use and preserve our soil reserves.

In producing food and fiber needs, man has always tilled the soil. The basic purpose of tillage is to prepare a seedbed for optimal growth of the crop desired. This includes weed control, residue management, soil aeration, and other factors. Traditionally, tillage has always exposed the soil to the detrimental and destructive effects of uncontrolled wind and water erosion. Erosion usually is the major culprit in soil loss and destruction. Erosion is a fact of life and sometimes is even beneficial. It cannot be elminated, but this does not mean it cannot be controlled.

Until the past 20 years, tillage has always meant some form of plowing (moldboard, sweep, chisel, disk, etc.) to control weeds and to prepare the seedbed. With the advent of herbicides and improved farm machinery, the concept of tillage takes on new meaning. Ultimately, tillage could mean the use of herbicides to control weeds and the use of specialized planting equipment to prepare the seedbed and aerate the soil, while leaving the surface virtually intact (zero tillage).

With this view in mind, tillage tends to fall into three distinct categories; conventional tillage (CT), minimum tillage (MT), and zero or no-tillage (NT). Conventional tillage normally refers to a primary tillage operation (plowing, chiseling, or a heavy disking), plus numerous secondary tillage operations (disking, field cultivations, harrowing) before planting. Normally surface residue is completely buried and the soil finely tilled with the surface totally bare. Minimum tillage is a very broad category which normally refers to any attempt to limit the number of field tillage operations while usually leaving some of the residue on the soil surface. Terms such as stubble mulch, reduced tillage, lo-tillage, etc., all refer to this same idea.

Phillips and Young (33) describe no-tillage as simply planting crops in previously unprepared soil by opening a narrow slot, trench, or band only of sufficient width and depth to obtain proper seed placement and coverage. Herbicides replace cultivation to control weeds and grasses with all surface residue being left on the soil surface.

No-till may be thought of as slot tillage, with the only area of the soil surface being disturbed being a narrow slot sufficient for seed placement. Hinkle (18) reports that the primary function of a no-till planter is to open a narrow slit for seed placement followed by some method to press the soil around the seed. This is usually accomplished by a coulter in front of a double disk or hoe opener (for seed placement) followed by a press wheel to firm the soil around the seed.

There are many modifications of this design with each designed to meet a specific need.

There are many advantages to no-till, with some being: control of soil erosion from wind and water, increased yeilds, moisture conservation, savings in time, labor, energy, and equipment costs, improved land use, and improved soil structure. Some of the disadvantages are: chemical costs, increased risks of weed, insect, pest and disease problems, yield reductions, and reduced seedling vigor. No-till is not a cure-all. A need exists for all systems of tillage. There is no substitute for good farm management.

Soil erosion by wind and water ultimately dictates land use, but economic pressures have strained both land resources and man's judgment (33). Silting of our lakes and streams, loss of soil productivity, excessive water runoff, and many other undesirable costly effects of erosion are some of the major reasons for the push toward reduced and no-till methods. Many studies (4, 5, 21, 28) have documented the erosion control benefits of no-till. McGregor et al. (28) found no-till cropping systems were very effective in reducing erosion, especially during storms with an excessive rate of rainfall. Blevins et al. (5) cites the higher erosion hazards of regions with large acreages of sloping land, adequate rainfall, and medium textured soils, which are particularly suited to no-till methods. Bennett et al. (4) noted no soil losses in no-till plots versus heavy losses in conventionally planted corn plots in hilly terrain. Simulated wind tunnel studies at Kansas State University have demonstrated high wind erosion potential of conventional tillage versus almost none for no-till with all surface residue left on top to protect the soil (33).

Increased land use, efficiency, and productivity are major advantages of no-till. Production of high intensity row crops is made possible in hilly terrain otherwise impossible under conventionall tillage (4). No-till allows planting of a second crop directly behind the combine in wheat-soybean or grain sorghum double cropping (14, 18, 32). Timeliness of planting is vital in a shortened growing season to take advantage of moisture reserves left after wheat harvest.

The major disadvantage of no-till is the total reliance on herbicides to control weeds (35). Most no-till failures and yield reductions reported are due to problems of increased weeds choking out the crop (18). Most herbicide failures are due to improper herbicide applications, timing, and poor weather conditions limiting the effectiveness of herbicidal activity (32). Chemical costs have also increased with increased dependence on herbicides and the increased tendency of pest and disease problems in the no-till setting (17).

Both increased, equal, and depressed grain yields have been reported with no-till versus conventional tillage. Most of these yield differences have been attributed to soil type, weed control problems, and climatic factors. Increased yields generally have been noted on sandy to medium textured, well drained soils (5). Increased yields have also been noted in areas which have large acreages of moderate to severe slope (4). Reasons given for increased yield center around: decreases in soil moisture evaporation, a greater ability to store moisture; increased water infiltration rates; reduced water runoff; eliminating soil erosion losses; decreased soil temperatures; and improved soil structure. Most of these benefits are the result of the mulching effect of leaving the previous crop residues on the soil surface. These factors can often carry the crop through short term drought and avoid the development of detrimental moisture stresses in the plant. With increased water use efficiency comes increased yield (4, 5, 21, 27). Yield depressions (18, 23, 24, 27, 34, 39) have been noted on: poorly drained soils; under early planting conditions (where lowered soil temperatures decrease seed germination and seedling vigor); where severe weed infestation problems exist; and where soil compaction is a problem.

Soil type and cropping traffic sequence patterns are important factors in considering the need for tillage. Many studies report the mulching benefits of leaving the surface residue undisturbed. Koshi and Fryrear (26) report that mulching reduced bulk density, increased hydraulic conductivity, air porosity, total porosity, and organic matter content even in trafficked areas. Ehlers (13) reports no-tillage practice induces a reduction of porosity, but an increase of aggregate stability in the top soil layer of podzolic soils derived from loess. Clay-silt segregation is no longer observed and traffic pans are loosened by biologic activity. Water infiltration is enhanced.

Weatherly and Dane (40) studied the effect of tillage on soil-water movement and corn yields under four different tillage practices (conventional tillage without subsoiling, conventional tillage with subsoiling, no-till with subsoiling, and no-till without subsoiling) on a soil with a plowpan. The yields of no-till plots without subsoiling equaled the yield of the two subsoiled plots, while the conventionally tilled plots without subsoiling produced less. The two subsoiled treatments and the no-tillage without subsoiling treatment indicated root penetration and soil water uptake below 50 cm. Many other studies cite increased soil moisture holding capacity, reduced evaporation, and lower runoff values resulting in increased yields from surface mulches (5, 16, 21). Localized conditions and soil types may need some tillage to increase soil porosity, but in many instances tillage practices are the actual cause of soil hard pans and reduced soil water infiltration rates.

Tillage is generally considered essential to incorporate fertilizers and lime. No-till depends almost totally upon surface applications of fertilizers and lime. It has been postulated that subsurface soil deficiences of P and K, and low soil surface pH conditions would result, since phosphorous (P), potassium (K), and lime are classified as essentially immobile nutrients in the soil. Also with high rates of nitrogen fertilization, localized acid conditons would result at the soil surface inhibiting seedling vigor and decreasing phosphorous availability at the very time it is essential to the young plant's growth. These conditions would eventually lead to yield depressions if the soil was not mixed with some degree of regularity (31).

Research comparing yield and fertilizer efficiency under continuous no-till and conventionally tilled corn would tend to both uphold and negate the preceding assumptions. Belcher and Rayland (3) studied phosphorous adsorption of surface-applied phosphorous versus banding in the row. Phosphorous is considered the least mobile of the major plant nutrients. Applying all of the phosphorous on the soil surface was equally effective to banding phosphorous in the row. Moschler et al. (31) reported that no-till resulted in a nine year average corn yield increase of 25.6% on Lodi Silt loam, a six year average increase of 13.7% on Davidson clay loam and a five year average increase of 30.0% on Cecil clay loam. All fertilizer was surface applied. In another study Moschler et al. (30) studied comparative residual nutrient elements in the 0-20, and 20-40 cm soil layers after 11 years of consecutive no-till versus conventional tillage methods. Corn grown by both methods had received the same amounts of calcitic limestone and fertilizer. At the 0-20 cm soil depth considerably more phosphorous and slightly more nitrogen was recovered from no-till. Acid extractable phosphorous and calcium were also higher. At the 20-40 cm depth, soil pH and acid extractable phosphorous were higher in the no-tilled soil. The increases in soil pH and extractable phosphorous at the lower soil depths that were found in no-tillage soil were assumed to be from chemical or biological causes, or a combination of the two. The chemical cause was postulated to be an increase of surface applied phosphorous solubility due to surface applied nitrogen enhancing the downward movement of phosphorous. Biological causes were attributed to increased earthworm activity.

Field studies over an eight year period (29) compared continuous no-till with surface-applied lime to conventionally tilled corn with lime incorporated into the soil. Lime was essential for highest yields with both tillage methods but the yield increase due to surface-applied lime in no-till culture averaged 31.3%, compared to 13.5% yield increase for conventional tillage. Associated with the larger increase from lime of the no-tillage culture were 1) a higher pH in the 0-10 cm soil layer in the eighth year (6.4 versus 6.0) and 2) a larger increase in exchangeable calcium (Ca) and a reduction in exchangeable aluminum (Al) in the 0-10 cm layer. The pH and exchangeable Ca and Al in the 10-20 cm soil layers from both methods were almost identical.

Legg et al. (25) compared utilization of labeled-N fertilizer by silage corn under conventional and no-till culture. Labeled (^{15}N-depleted) ammonium sulfate was surface applied annually at rates of 85, 170, and 340 kg N/ha over a four year period. Four year average yields of silage total dry matter (TDM) for all nitrogen rates were 13,400 and 11,570 kg/ha, respectively, for no-till and conventional tillage. Four year midseason nitrogen recoveries were 42, 32, and 26% for no-till and 35, 27, and 16% for conventional tillage. Corresponding annual recoveries at silage harvest were 46, 53 and 46% for no-till and 53, 55, and 34% for conventional tillage. While these studies suggest adequate fertility results from surface applications of fertilizer and lime in the continuous no-till setting, they also indicate pH, phosphorous and potassium differences when comparing the surface and subsurface soil depths under no-till as compared to conventional tillage. Shear and Moschler (36) reported a distinct stratification in pH and available phosphorous with a less pronounced stratification in available potassium. There was a distinct pH drop at the 0-5 cm depth compared to the 15-20 cm depth under no-till, while the pH range was much more uniform under conventional tillage. Moschler et al. (29) noted a yield reduction for continuous no-till corn compared to conventionally tilled corn when no lime was added. These studies (29, 36) demonstrate a need for more frequent liming under no-till conditions. While studies (3, 31, 37) demonstrate an accumulation of phosphorous and potassium near the soil surface over time under no-till conditions, no yield reductions were reported due to this effect.

Much of the research involving no-till has been done with corn (Zea mays L.) simply because of its superior yield capabilities and its rather wide range of adaptability in the United States. Under drought and heat stress conditions and under some marginal soil types, corn quickly loses many of its advantages and becomes an extra high risk crop. Grain sorghum usually replaces corn as a summer crop under these conditions and is widely adapted to the high plains and southern half of the United States. No-till research involving grain sorghum has been done in Arkansas (18), Georgia (32), Texas (38), and other areas of the high plains verifying the potentials and problems of no-till. Much of the research cited has involved corn simply because of the greater abundance of literature involving no-till corn, and because of the many similarities involved in the production of both crops. The same tillage techniques, equipment, fertilizer needs, and herbicides (with some exceptions) which work for one, work for the other.

Grain sorghums are well adapted to hot or warm regions with summer rainfall, where the annual precipitation is as little as 43 to 64 cm. However, grain sorghum is also highly productive on irrigated land and in humid regions. Better than 25% of the U.S. acreage was irrigated in 1972 (27).

Grain sorghum withstands extreme heat better than most crops. The most favorable mean temperature for growth is about 37°C with the minimum being 15°C. Consequently, only a part of the frost free season may be available to produce the crop (27).

Drought and plant stress usually result in a reduction of yield and product quality. The extent of the yield reduction depends not only upon the extent of the deficit but also on the stage of plant growth. In studying the susceptibility of grain sorghum to water deficit, Lewis et al. (26) found that the boot through bloom stage was the most sensitive period in terms of yield reduction. They recorded yield reductions of 17, 34, and 10% when the deficit occurred during the late vegetative to boot stage, the boot through the bloom stage, and the milk through soft dough stage, respectively. These findings are of considerable significance, especially under conditions of limited irrigation in attempting to make maximum use of limited water. In dryland farming, planting date is about the only variable the producer has control of in attempting to avoid plant stress during this critical period.

In studying grain sorghum it is helpful to have a standard set of terms describing the different growth stages of the plant. Vanderlip and Reeves (39) have suggested the following standards in describing the morphological or physiological growth stages of sorghum (Table I).

TABLE I

CHARACTERISTICS OF DIFFERENT GROWTH STAGES OF GRAIN SORGHUM

Growth Stage	Approximate days after emergence+	Identifying Characteristics
0	0	Emergence, coleoptile visible at soil surface
1	10	Collar of 3rd leaf visible
2	20	Collar of 5th leaf visible
3	30	Growing point differentiation. Approximately 8 leaf stage by previous criteria
4	40	Final leaf visible in whorl
5	50	Boot, Head extended into flag leaf sheath
6	60	Half-bloom. Half of plants at some stage of bloom
7	70	Soft dough
8	85	Hard dough
9	95	Physiological maturity. Maximum dry matter accumulation

+Approximate days required for hybrids of RS 610 maturity grown at Manhattan, Kansas.

Grain sorghum is capable of extremely high yields under optimal moisture, fertility, and climatic conditions. Full season varieties under irrigation have yielded over 13,000 kg/ha in the Oklahoma panhandle (12). In northeast Oklahoma, dryland yields of 6,300 kg/ha are common in a favorable year. Statewide yields average approximately 3,100 kg/ha.

Fertility requirements for grain sorghum vary according to soil fertility levels, yield goal, and method of harvesting. Nitrogen generally is the single most needed plant nutrient and as a general rule of the thumb (20), one kilogram of actual nitrogen is required per 25 kilograms yield goal. House (19) reports that varieties responsive to high levels of fertility produce 20 to 40 kg grain per kg applied nitrogen, whereas varieties developed in low fertility and droughty situations produce 6 to 10 kg grain per kg applied nitrogen. Phosphorous (P) and potassium (K) are usually applied only as required by soil test. A soil pH range of 5.5 to 7.0 is generally considered adequate. A 6,700 kg yield of grain (2) removes approximately 107 kg N, 20 kg phosphate (P_2O_5), and 25 kg potash (K_2O). The stover portion contains 113, 34, and 168 kgs respectively, of N, P_2O_5, and K_2O. From these figures it is apparent that when the whole plant is harvested, such as whole plant silage, fertility requirements are much greater.

Planting dates of grain sorghum vary widely across the southwestern United States, from extremely early to late in the growing season. This is especially true across Oklahoma. Variables taken into consideration in determining planting date include soil temperature, type of farming operation, cropping sequence, soil moisture levels and local climatic conditions and success ratios (11). As a general rule of thumb, a soil temperature of 25°C is required for optimal seed germination and seedling vigor (27). Under irrigated conditions planting generally does not take place until the soil has reached this temperature, unless there is a limited growing season. In double cropping situations such as wheat-grain sorghum (18, 32), planting occurs as soon as possible after wheat harvest.

Under dryland conditions in Oklahoma, there are two schools of thought concerning optimum planting date (11). One is to plant as early as possible, taking advantage of spring soil moisture reserves and the longest day lengths possible during the grain filling period for maximum yields. The goal is to have flowering occur before the extremes of drought and heat stress occur. The biggest disadvantage with early planting is reduced stands and plant vigor due to low soil and air temperatures. The other idea is to plant late, subjecting the vegetative stages to the greatest risk of drought and heat stress. Then the flowering period occurs after the worst of the summer drought and heat, since severe heat stress during flowering depresses yields. The biggest disadvantage here is almost a total reliance upon late summer and early fall rains during the flowering period, as soil moisture reserves are critically low by this time of year. Farmers have been successful under both systems as long as proper crop production management practices are followed. In northeastern Oklahoma, planting normally occurs as early as soil temperatures will allow without sacrificing stand. May 1st is considered standard planting time. In southwestern Oklahoma, planting occurs as late as the last of June and early July. As a general rule, the greatest yields result from early planting. Blum (6) and Nelson et al. (32), both report increased yield of grain sorghum, especially with limited soil moisture, with early planting versus late planting. Yield increases due to early planting were attributed to increased soil moisture reserves (32), decreased interference of biological factors (insects and disease), decreased water use during the vegetative stages (6), climatic conditions, and a greater photosynthetic time period during grain filling. Although in theory early planting would lead to the greatest yields, local conditions might warrant otherwise.

Just as planting dates vary widely, so do planting rates or optimal plant populations (6, 8, 11, 32). Some of the factors affecting planting rate are: soil moisture levels, climatic conditions, hybrid variety, soil fertility, irrigation capabilities, and planting date. Planting rates vary from a low of three kg/ha under limited moisture and arid conditions to a high of nine kg/ha or more under optimal irrigation, fertility, and climatic conditions. As a general rule (43), one kg of grain sorghum equals approximately 35,200 kernels. Plant populations would thus vary from approximately 105,600 to 316,800 plants/ha assuming all seeds germinated and grew. Under dryland conditons planting rates tend toward the lower end of this scale, as it has been shown that yield of grain sorghum is not drastically affected by a rather wide range of plant densities (7). This is due to its ability to compensate, through grain yield components, for changes in available space. Plant density also affects intrapanicle relationships between panicle weight components to the extent where intercomponent competition is evidenced. Genotype also interacts with component compensation with respect to grain yield.

Under extreme drought conditions, Brown and Schroder (8) report that row spacing and low plant populations resulted in reduced forage production and the highest grain yields. As soil moisture levels increased, yields increased as optimal plant populations tended to increase also, but within a rather wide range of plant populations. Blum (7) studied the effect of plant density and growth duration (maturity) on yield under limited water supply. He found that the grain yield of the late maturing was highest under the lower plant densities and that of an early maturing variety was highest under the high plant densities. The highest yield in the experiment was obtained with the earliest maturing hybrid seeded at high rates. The superiority of the early maturing hybrid at the highest density was attained through its ability to maintain larger grains per panicle in spite of increased interplant competition for water.

To summarize, under limited soil moisture, low planting rates of early season varieties generally produce higher yields as their water needs are the least. At the other extreme under optimal moisture, fertility, and climatic conditions, high planting rates of full season varieties yield the greatest, as water is not a limiting factor and a maximum photosynthetic period is possible during grain filling. Under conditions somewhere in between these extremes, where water deficits are possible, medium to low plant populations are optimal with grain sorghums component compensation ability to make maximum use of available water supply. Climatic conditions, fertility levels, and length of optimum growing season usually determine hybrid maturity variety selection. If forage production is desired along with grain yield, then increasing plant population increases total dry matter production with grain yield being held constant, up to the point where increasing plant populations start to depress grain yield.

Although planting date and rates present a highly variable picture, optimal row width for grain sorghum presents a much clearer picture, regardless of the variables involved. There is an abundance of research comparing yield of narrow row versus wide row grain sorghum (1, 8, 9, 10, 34). Almost without exception, they all point to increased yield potential for narrow rows (50 cm) over a wider rows (75 or 100 cm). There tends to be little advantage for rows much narrower than 50 cm. Brown and Schroder (8) cited one case though, of a yield advantage for wide rows (100 cm) when soil moisture was extremely limited. The 100 cm rows with low plant populations had reduced vegetative growth over narrow rows with similar populations. This resulted in a greater water use efficiency and a greater yield for the wide rows. However, in this same study, in the previous year the greatest yields occured with narrow rows (50 cm).

In comparing evapotranspiration rates of wide row (100 cm) versus narrow row grain sorghum, Chin Choy and Kanemasu (9) measured a 10% greater evapotranspiration rate for wide rows. This suggests an evapotranspiration advantage for narrow rows. With sufficient moisture, narrow rows outyield wide rows, and under limited soil moisture conditions, narrow rows used water more efficiently. Adams and Richardson (1) report a 20% yield advantage for 50 cm over 100 cm rows, the development of an earlier and more complete crop canopy, reduced runoff, and less soil loss with narrow rows of sorghum. Clegg et al. (10) measured visible radiation transmitted through sorghum canopies of 50, 75, and 100 cm rows. They reported the least visible radiation transmitted from the narrow row canopies, indicating more visible radiation would be available for photosynthesis with narrow row spacing. Under irrigated conditions (34), 50 cm rows outyielded wider row spacing of 75 and 100 cm and a narrower row spacing of 15 cm.

Although the preponderance of evidence indicates the yield advantages of narrow row (50 cm) grain sorghum, few farmers have adopted narrow rows over the wider 75 and 100 cm rows. There are several reasons for this. The foremost would probably be the need for total reliance upon herbicides for weed control with narrow rows, since it is almost impossible to cultivate narrow rows with modern tractors. Secondly, the yield advantages are not sufficient for many farmers to justify the added cost of switching their planting equipment over to narrower rows. Slowly though, as farmers purchase new planting equipment and as improved herbicide technology develops, farmers will probably move in the direction of narrower row grain sorghum.

Adequate weed control has been one of the principal problems associated with developing minimized tillage systems (22). This is especially true for grain sorghum since it is a rather small seeded crop in comparison to corn. As a general rule, the smaller the seed size the greater the susceptibility to herbicide injury and the easier to kill (23). Also, many of the herbicides cleared for use in grain sorghum are not cleared for Oklahoma's sandy soils. In a sandy soil they will easily leach to the seed germinating zone with any appreciable amount of rain and cause herbicide injury and kill. Atrazine (15) is a prime example of an excellent grain sorghum herbicide cleared for use in the heavy clay soils of northeastern Oklahoma, but its use results in a high risk of herbicide kill on lighter sandy loam soils. Also, within the no-till system the lack of the ability to incorporate a herbicide leaves the producer dependent upon rainfall to take the herbicide into the soil. If rain does not come soon enough, herbicide activity and effectiveness is greatly reduced. Also, with no-till the surface trash and residue tend to tie up herbicides and limit their effectiveness (35).

Despite these drawbacks, adequate weed control in the no-till setting looks promising. Robinson and Wittmus (35) reported most of the herbicides evaluated for use in no-till sorghum gave excellent weed control, even though residues of the previous year's crop averaged 5,000 kg/ha and covered 73% of the ground. Atrazine and atrazine combined with norea or prophaclor gave consistently good weed control. Atrazine and alachlor gave excellent weed control, but caused severe injury to sorghum. Tank mixes of herbicides can be very effective in preventing the build-up of resistant weed types, one usually kills the broadleaf weeds, the other kills grasses. Herbicide rotation and crop rotation helps prevent build-up of resistant weed types. A promising alternative for reducing herbicide injury and kill in grain sorghum is the use of seed safeners, allowing the use of a more effective herbicide. Also, there have been herbicides developed for sandy soils. Propazine (15) and Igran are examples of two effective herbicides cleared for use in grain sorghum, especially in sandy soils.

In the no-till setting, normally a contact herbicide (23) (usually paraquat or roundup) is tank mixed with the normal herbicide mix used preplant under conventional tillage. (Care should be taken to see if herbicides are compatible in a tank mix.) The contact herbicide burns off and kills any existing green vegetation, while the other herbicides provide long term weed control by killing weeds as they germinate.

Another problem compounded by the no-till setting is the increased build-up of herbicide residue in the soil (41, 42) due to the increased use of chemicals and slower breakdown rate of some chemicals in the no-till setting. In crop rotations, care should be taken in selecting herbicides that will break down in time and not cause excessive herbicide injury to the following crop. Also it is recommended that any major hard-to-kill perennial weed, such as johnsongrass, be brought under control before attempting no-till. In short, since no-till depends entirely upon herbicides for weed control, increased knowledge of how herbicides work, proper application techniques, rates, and time-ing is critical for success. Since herbicide effectiveness will make or break the no-till crop, a greater emphasis must be placed upon properly managing herbicides. If a grain sorghum producer cannot achieve effective chemical weed control under conventional tillage, he is sure to fail under no-till.

CHAPTER III

METHODS AND MATERIALS

A two year field experiment was conducted to study the effects of row width, within row plant spacing, and nitrogen level under a continuous monocrop no-till grain sorghum production system. The experimental site was the Agronomy Research Station, Perkins, Oklahoma, with a soil type of a Teller loam.

The experimental factors consisted of three row widths (25, 50, and 75 cm), three within row plant spacing (10, 15, and 30 cm), and three nitrogen levels (0, 90, and 180 kg/ha). The experimental design was a ramdomized complete block with three replications, a 3 x 3 x 3 factorial arrangement consisting of 27 treatments (Table II). Plot size was 4.3 x 12.2 meters. Plot treatments were located on the same plot of ground both years.

The three row widths and three within row plant spacings resulted in seven different plant populations ranging from a low of 44,000 to a high of 400,000 plants/ha. The equivalent planting rates represent quite adequately the range of planting rates used across Oklahoma. These rates range from a low of approximately 2-3 kg/ha in the more arid western regions to a high of 8-10 kg/ha in the more humid eastern portions of the state.

As for seedbed preparation, there was none, except for the residue from the previous year's crop being rotary mowed. This tended to increase trash problems though, as residue was all thrown to one side instead of being distributed evenly. Also, the crop grown on the experimental site the previous year was grain sorghum.

TABLE II

EXPERIMENTAL FACTORS

Row Width (cm)	Within Row Plant Spacing (cm)	Nitrogen Level (kg/ha)	Plant Population (plants/ha)	Planting Rate (kg/ha)[t]
25	10	0	400,000	12.9
		90		
		180		
	15	0	266,600	8.6
		90		
		180		
	30	0	133,300[i]	4.4
		90		
		180		
50	10	0	200,000	6.2
		90		
		180		
	15	0	133,300[i]	4.4
		90		
		180		
	30	0	66,600	2.1
		90		
		180		
75	10	0	133,300[i]	4.4
		90		
		180		
	15	0	88,900	2.8
		90		
		180		
	30	0	44,400	1.5
		90		
		180		

[i]Indicates same population occurring at each of the three different row widths.

[t]Assumes 90% seed germination and plant survival rate and 33,000 seed/kg.

The planter used was a John Deere 25 cm (10 inch) sod drill, set at a planting rate of 12.9 kg/ha. This planting rate was derived from the approximation that the hybrid variety "ACCO BR-Y93" contains 33,000 seed/kg. This medium maturity bird resistant hybrid was selected for its maturity class (medium maturity hybrids generally represent the optimal maturity class for grain yield under north central Oklahoma dryland conditions), and for its resistance to bird damage. Planting dates were June 9, 1982 and June 8, 1983.

Immediately after planting the following herbicides were applied for weed control: (1) propazine { 2-chlora-4.6 bis (isopropylamino)-s-triazine } at the rate of 1.12 kg/ha; (2) propachlor (2-choloro-N-isopropylacetanilide) at the rate of 1.62 kg/ha; and (3) paraquat (1, 1-dimethyl-4, 4-bipyridinium ion) at the rate of 1.12 kg/ha in 1982 and 2.24 kg/ha in 1983. In 1983, an additional application of paraquat at the rate of 1.12 kg/ha was applied the middle of May to kill existing green weeds and conserve soil moisture. Also in 1983 prior to grain sorghum emergence, spot applications of glyphosate { N-(phosphonomethyl) glycine } were applied manually with a small hand sprayer to weeds resistant to paraquat (tank mix concentration was 15 grams herbicide/liter water).

After emergence was complete, the unwanted rows and plants were hand pulled in 1982. In 1983, the unwanted rows were killed by applying glyphosate via a moist sponge attached to the end of a hoe, and then the resulting rows were thinned by hand to the appropriate plant populations. In 1982, nitrogen was applied July 15 after thinning was complete. In 1983, nitrogen was applied June 20 prior to thinning. In both years, a Cyclone Seed spreader was used to spread the ammonium nitrate (NH_4NO_3)

fertilizer. Also in both years phosphorous (P) and potassium (K) was applied according to soil test recommendations before planting. In 1982, there was no P or K applied. In 1983, 50 kg/ha P_2O_5 and 0 kg/ha K_2O was applied.

Although this experiment was basically intended to be a complete dry land study, a 2.5 cm application of irrigation waster was applied both years to ensure a crop. In 1982, this occurred July 21, following nitrogen fertilization, and when the crop was in the vegetative stage of growth. In 1983, this occurred August 9 when the crop was in the late boot to early bloom stages of growth.

During the month of August each year, Sybron/Taylor soil test thermometers were set out to monitor soil temperatures during the late boot through full bloom stages of plant growth. Soil temperature readings were taken at 1300 hours. One plot from each of the row-width and plant-spacing treatments at the 90 kg/ha nitrogen level was randomly selected for data collection (9 plots total).

Harvest date both years was late September. A preselected representative row 6.1 meters long was hand harvested from each plot. Prior to harvest; plant lodging percent, plant height, and bloom data, were taken from this same row. The grain was then threshed out of the heads using a stationary Vogel type plot thresher. A dial type spring scales was used to measure plot head weight and grain weight. A Toledo scale was used to measure test weight. Grain protein percent and 100-kernel weight were determined from a grain sample taken from each plot. In determining 100-kernel weight, the grain was counted using an electronic seed counter and weighed using a Mettler electronic balance. Grain protein percent was determined using the Udy Dye binding technique.

After harvest of each year, soil tests were taken from each plot at the 0-15 cm and 15-30 cm depths. Soil test data {pH, nitrate-nitrogen (NO_3^--N), phosphorous (P), and potassium (K)} were determined by the Oklahoma State University Water, Soil and Forage Testing Lab. The soil sampling date for the 1982 crop year was February 1984, and for the 1983 crop year, November 1984.

CHAPTER IV

RESULTS AND DISCUSSION

Climatic Environmental Data

Before discussing the results of this study it would first be helpful to examine the climatic conditions influencing the grain sorghum growing season for the years 1982 and 1983. In particular the time period during which the late vegetative through grain filling stages of growth occurred will be examined in greater detail.

A comparison of the rainfall data (Table III), for the years 1982-83 versus the long term average (LTA), resulted in above average rainfall for the preplanting period (January--May) and also for the month of June (when planting and the early vegetative stages of growth occurred). In both years during the month of July, rainfall was below average with July of 1983 receiving virtually none (the vegetative through early boot stages occurred during this time period). Rainfall for the month of August (the late boot through early grain filling growth period), was also drastically below normal for both years. In September (during which the late grain filling through senescent stages of growth occurred), rainfall was again below average for both years.

Table IV gives the results of the average daily air temperature readings for the months of July and August, along with the average of the soil temperature readings for the month of August. No comparison with the long term average is given. From the data it can be observed that 1983 was definitely hotter than 1982 for both months.

TABLE III

PERKINS 1982-83 RAINFALL VS. LONG TERM AVERAGE (LTA) DURING THE EFFECTIVE GROWING SEASON (JUNE-SEPTEMBER)

Time Period	Rainfall Amount in Years		
	LTA	1982	1983
	cm		
January-May	34.1	57.2	41.2
June	11.7	13.4	13.8
July	8.9	5.3	0.05
+August	8.1	0.8	2.4
September	9.7	2.2	4.9

+Effective grain filling period approximately August 1 through September 10.

TABLE IV

AIR AND SOIL TEMPERATURE DATA AFFECTING GRAIN FILLING PERIOD

Condition	Month	Year	
		1982	1983
		°C	
Average Daily High	July	32.2	35.6
Average Daily Low	July	20.6	20.6
Average Daily High	August	35.0	37.2
Average Daily Low	August	21.7	21.7
Soil Temperature	August	29.4	31.7

The results from the analysis of variance of the soil temperature readings are in Table VI. Both years, there was a significant effect due to row width (Table V). In 1983 there was a significant row width within row plant spacing interaction (Figure 1). As row width increased past 50 cm, soil temperature tended to increase. There was no significant effect due to row width between the 25 and 50 cm treatments. One might conclude that the shading effect of the crop canopy was not enhanced below the 50 cm row width, indicating no advantage for the narrower row width, and that there was an increased proportion of unshaded ground at the wider 50 cm row width.

TABLE V

EFFECT OF ROW WIDTH AND WITHIN ROW PLANT SPACING ON SOIL TEMPERATURE

Variable	Year	
	1982	1983
Row Width (cm)	°C	
25	28.6 A	31.5 C
50	29.2 A	30.8 C
75	30.6 B	32.3 D
Plant Spacing (cm)		
10	29.2	31.2
15	30.0	31.8
30	29.2	31.6
LSD (.05)	0.7	1.0

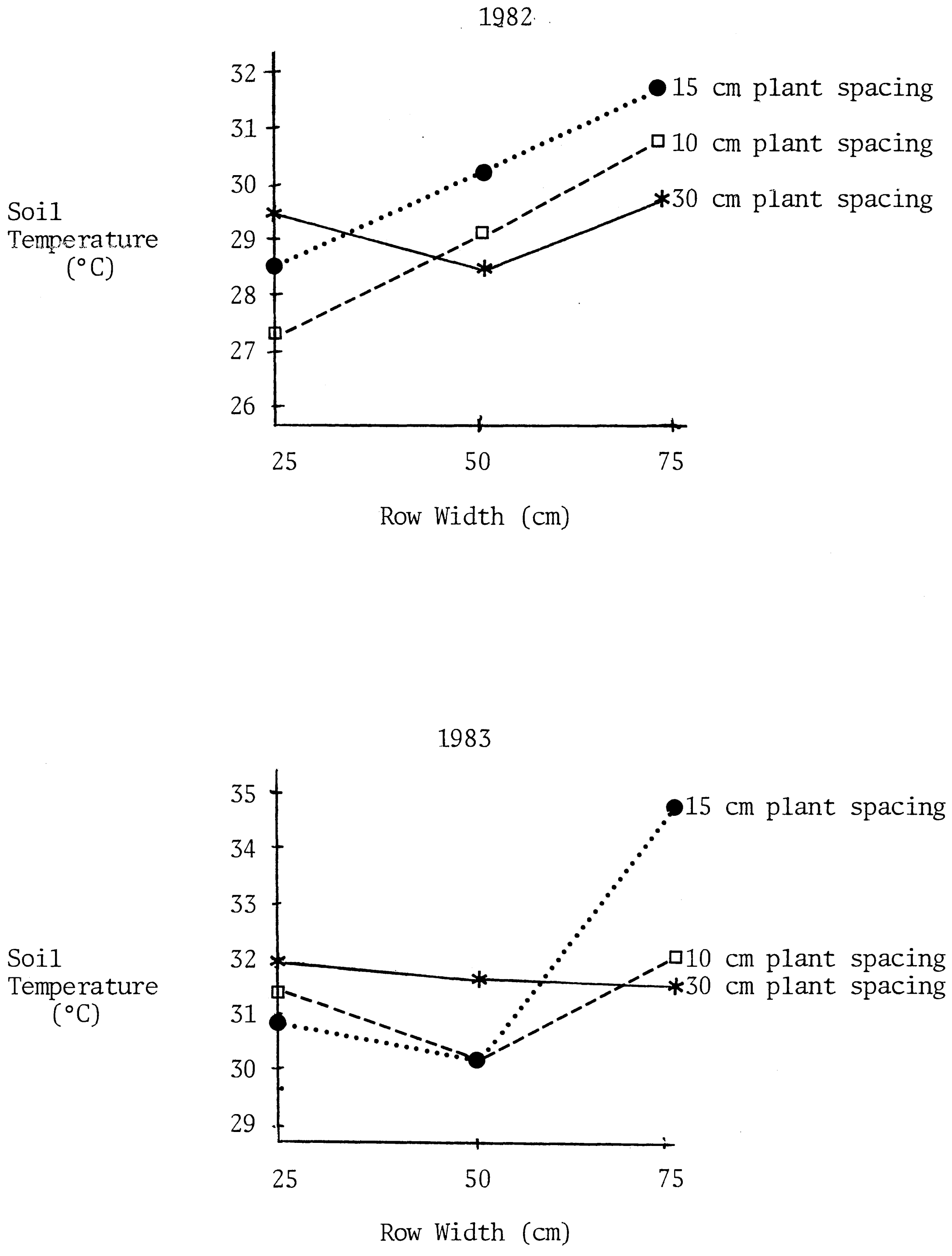

Figure 1. Effect of Row Width x Plant Spacing on Soil Temperature (°C) for 1982 and 1983.

TABLE VI

SOIL TEMPERATURE DATA ANALYSES OF VARIANCE

	1982			1983		
Source	D.F.	M.S.	F-Ratio	D.F.	M.S.	F-Ratio
Replication	13	31.5	10.9**	14	107.9	56.4**
RW	2	43.5	14.8**	2	26.0	13.6**
WRPS	2	8.4	2.9	2	4.6	2.4
RWXWRPS	4	7.3	2.5	4	19.5	10.2**
Error	104	2.9		112	1.9	

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

The following conclusions can be drawn from the analysis of the climatic data for years 1982 and 1983:

1. In both years there was above average precipitation during the preplant and planting periods.

2. In both years precipitation was drastically below normal, despite receiving a 2.5 cm supplemental irrigation during the late vegetative through the early bloom stages of growth.

3. Drought and heat stress was much greater in 1983 compared to 1982.

In addition to the above factors, some degree of weed control also needs to be mentioned. In 1982, weed control was considered adequate across all plots. But in 1983, weed control ranged from adequate in most plots to poor in some plots. Weed control was rated visually with adequate having no severe buildup of a weed population and poor having a severe weed population causing visual plant stress. Weed control problems were due more to location than to any treatment factor. In 1983, there was a severe buildup of crabgrass {(Digitaria sanguinalis (L.) Scop)} and sandbur (Cenchus pauciflorus Benth) populations. This increase of weed problems also contributed to an increase in plant stress in 1983 compared to 1982.

Yield Data

The analyses of variance for the 1982 and 1983 yield variables are presented in Tables VII and VIII. The variables analyzed included grain yield, grain protein percent, test weight, 100-kernel weight, plant lodging, plant height, and days to midbloom. In 1982, nitrogen (N) significantly influenced all variables except plant height. Row width (RW) significantly affected all variables except plant lodging, while only plant lodging was significantly affected by within row plant spacing (WRPS). The significant interactions were: N X RW for test weight and plant height; N X WRPS for test weight and plant lodging; RW X WRPS for test weight; and N X RW X WRPS for test weight.

In 1983, nitrogen significantly affected grain yield, grain protein, plant lodging, plant height and days to midbloom. Row width significantly affected all variables except grain protein. Within row plant spacing was only significant for plant height. The only significant interactions were N X RW and RW X WRPS for days to midbloom.

Grain Yield

Grain yield was significantly influenced by nitrogen rate and row width (Tables VII and VIII). Tables IX, X, and XI present the mean

TABLE VII

ANALYSIS OF VARIANCE FOR 1982 YIELD DATA

Source	DF	Grain Yield		Grain Protein		Test Weight		100 Kernel wt.		Plant Lodging		Plant Height		Mid Bloom		N Removed in Grain	
		M.S.	F-Ratio	M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F
Rep	2	565457	0.66	66.59	**29.07	.00012	0.26	.232	*.0181	.032	1.63	214.42	*4.63	120.61	**15.82	945.11	*3.94
Nitrogen (N)	2	13064809	**15.32	184.25	**80.43	.0066	**14.26	1.202	**22.52	.673	**34.67	129.59	2.80	227.04	**27.91	11,011.5	**46.85
Row Width (RW)	2	3608751	*4.23	9.96	*4.36	.0204	**44.08	.874	**16.37	.001	.055	673.91	**14.54	56.35	**6.93	528.5	2.20
NXRW	4	483913	.57	2.21	.97	.0064	**13.86	.075	1.40	.013	.650	186.82	**4.03	12.62	1.55	239.1	.99
Within Row Plant Spacing (WRPS)	2	20217	.02	1.41	.61	.0011	2.31	.080	1.51	.195	**10.02	40.70	.88	8.47	1.04	86.5	0.36
NXWRPS	4	37892	.04	4.76	2.08	.0025	**5.40	.038	.71	.146	**7.55	45.72	.99	1.70	.21	155.9	0.65
RWXWRPS	4	1289652	1.51	3.31	1.44	.0017	*3.70	.067	1.25	.036	1.86	42.02	.91	3.30	.40	674.9	*2.81
NXRW XWRPS	8	574625	.67	1.96	.86	.0032	**6.96	.058	1.09	.014	.72	32.88	.71	6.50	.80	97.7	0.41
Error	52	852819		2.29		.00046		.053		.019		46.34		8.13		240.15	
Coefficient of Variation		27.89		13.80		2.79		10.59		95.04		7.67		3.85		26.28	

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

TABLE VIII

ANALYSIS OF VARIANCE FOR 1983 YIELD DATA

Source	DF	Grain Yield		Grain Protein		Test Weight		100 Kernel Wt.		Plant Lodging		Plant Height		Mid Bloom		N Removed in Grain	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F
REP	2	981549	**2.07	12.70	**10.26	.000384	.64	.033	0.87	29.93	1.31	15.61	.69	1.62	.32	291.5	2.42
N	2	15758303	**33.17	170.31	**137.67	.000631	1.06	.037	.97	123.65	**5.40	132.94	**5.87	1550.34	**284.27	10093.5	**83.67
RW	2	6925679	**14.58	.322	.26	.02787	**46.69	.577	**15.21	253.00	**11.06	2482.75	**109.65	454.48	**83.33	2084.9	**17.28
NXRW	4	292748	.62	2.90	2.34	.000994	1.66	.063	1.66	28.45	1.24	20.99	.93	92.27	**16.92	99.7	0.83
WRPS	2	1010023	2.13	.131	.11	.000229	0.38	.050	1.31	46.07	2.01	249.78	**11.03	10.78	1.98	323.7	2.68
NXWRPS	4	169287	.36	1.00	.81	.000448	0.75	.017	.44	6.52	.29	15.61	.69	10.23	1.88	52.4	0.43
RWXWRPS	4	482150	1.02	2.02	1.63	.000219	0.37	.031	.83	12.86	.56	18.12	.80	16.68	*3.06	112.7	0.93
NXRW SWRPS	8	728367	1.53	.73	.59	.000339	0.57	.030	.80	7.54	.33	22.64	.67	8.06	1.48	177.1	1.47
Error	52	475057		1.24		.000597		.038		22.88				5.45		120.634	
Coefficient of Variation		30.62		10.89		3.34		16.28		118.22		6.38		3.49		28.57	

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

effects of nitrogen rate, row width, and plant spacing on grain yield. Figures 2 and 3 graphically illustrate the yield response to nitrogen and row width, respectively.

As expected, in both years there was a significant increase in yield due to nitrogen (N) for the 90 and 180 kg/ha rates over the 0 kg/ha rate. There was no significant difference between the 90 and 180 kg/ha N rates. However, it is interesting to note the response to N at the 90 and 180 kg/ha rates illustrated in Figure 2. In 1982 a yield depression is indicated, and in 1983, a yield enhancement is indicated for the 180 kg/ha N rate. At the same time in 1983 overall yield was substantially less than 1982 (approximately 1000 kg/ha less), meaning less N needed in 1983 and a greater potential for a yield depression for the higher rate. Several observations might be noted here: (1) there was a different set of growing conditions in 1983 than in 1982 resulting in a differing response pattern to N rate; (2) N was applied immediately after planting in 1983, whereas N was applied about five weeks after planting in 1982. This could have an effect on N uptake, availability, and usage; (3) 1983 was the second year of the study and continuous no-till conditions could affect N availability and uptake.

There was a significant yield depression for the 25 cm row width over the 50 and 75 cm row widths, of about 700 and 500 kg/ha respectively in 1982, and about 750 and 950 kg/ha respectively in 1983 (Table X). There is no significant difference in yield between the 50 and 75 cm row widths. It might be noted though, that the data showed a slight yield depression in 1982, and a slight yield enhancement in 1983 for the 75 cm row width over the 25 cm row width.

TABLE IX

EFFECT OF NITROGEN RATE ON GRAIN YIELD

Nitrogen Rate	Year 1982	Year 1983
kg/ha	-----------------kg/ha-----------------	
0	2533 A	1382 C
90	3874 B	2551 D
180	3525 B	2819 D
LSD (.05)	504	376

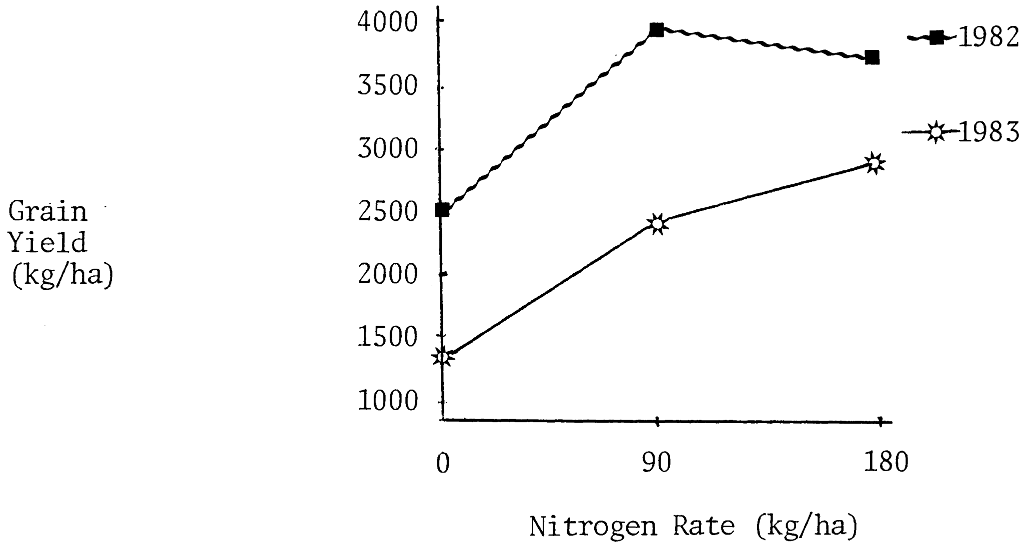

Figure 2. Effect of Nitrogen Rate on Grain Yield

TABLE X

EFFECT OF ROW WIDTH ON GRAIN YIELD

Row Width	Year 1982		Year 1983	
cm	kg/ha			
25	2905	A	1675	C
50	3616	B	2450	D
75	3411	B	2627	D
LSD (.05)	504		367	

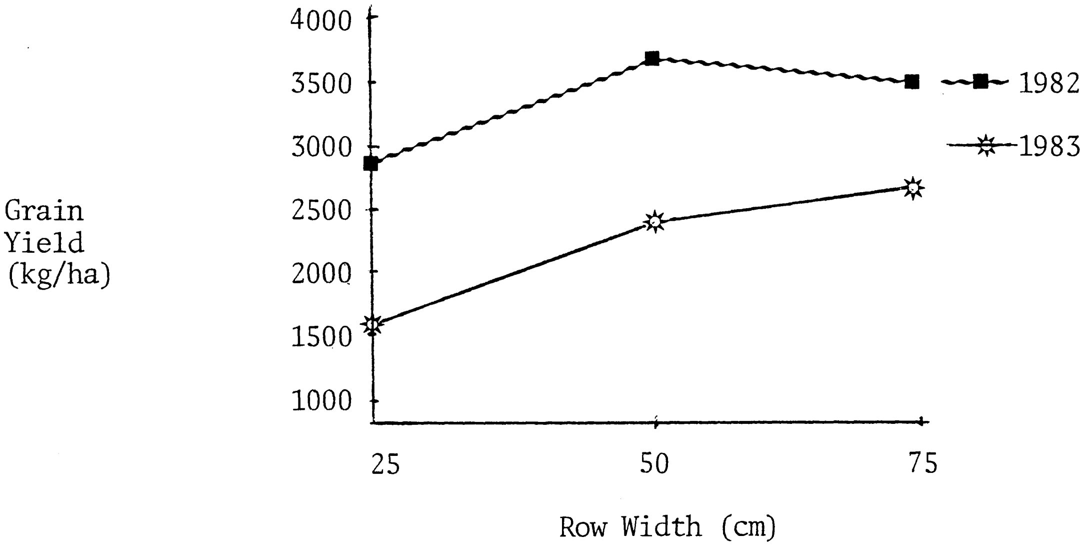

Figure 3. Effect of Row Width on Grain Yield.

TABLE XI

EFFECT OF WITHIN ROW PLANT SPACING ON GRAIN YIELD

	Year	
WRPS	1982	1983
cm	---kg/ha---	
10	3350	2054
15	3323	2441
30	3280	2257
LSD (.05)	NS	376

This might be expected though as greater drought and heat stress were experienced in 1983. Wider rows, with lower corresponding plant populations, tend to result in less forage production and a greater proportion of the total dry matter production in the grain fraction as compared to narrower rows.

By combining the three row widths and three within row plant spacings, nine different plant populations result. Table XII is the result of analyzing this study as a two factor experiment. The results are comparable to the effect of row width. In neither year were any of the six plant populations from the 50 and 75 cm row width treatments significantly different. There was a significant yield depression for some of the higher plant populations of the 25 cm row width treatments. Numerically, the 50 cm RW by 30 cm WRPS treatment (66,600 plt/ha) resulted in the highest yield in 1982. In 1983, the highest yield came from the 50 cm RW by 15 cm WRPS treatment (133,300 plt/ha).

Table XIII presents the mean yields from each of the 27 treatment effects. Here the highest yield both years came from the 50 cm RW and the 30 cm WRPS treatments (66,600 plt/ha) at the 90 kg/ha N rate in 1982 and the 180 kg/ha N rate in 1983. One might estimate the yield capability of no-till grain sorghum by averaging the 12 treatment mean yields from the 50 and 75 cm row widths at the 90 and 180 kg/ha nitrogen rates (since there was a significant yield depression for the 25 cm RW and the 0 kg/ha N rate). The result is a 3850 kg/ha yield for 1982, and a 2700 kg/ha yield for 1983.

Grain Protein

Grain protein was significantly affected by N both years and by RW

TABLE XII

AVERAGE EFFECT OF PLANT POPULATION ON YIELD VARIABLES

Plants Per Hectare	RW-WRPS (cm-cm)	Grain Yield		Grain Protein		Test Weight		100-Kernel Wt.		Plant Lodging		Plant Height		Days to Mid Bloom		N in Grain	
		1982	1983	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983
		kg/ha		%		kg/liter		g		%		cm		days		kg/ha	
400,000	25-10	3252	1252	12.5	10.8	.76	.69	1.99	0.97	12	1.0	85.2	60.7	76.8	73.2	65.9	22.0
266,600	25-15	2992	2049	11.3	9.8	.72	.69	2.02	1.04	6	0.9	79.9	64.7	75.8	72.2	54.6	34.7
133,300	25-30	2472	1724	11.0	10.0	.74	.70	1.96	1.01	28	1.0	84.1	67.7	74.6	69.5	44.8	29.0
200,000	50-10	3269	2277	10.7	9.7	.78	.74	2.10	1.23	9	2.4	88.3	72.5	74.1	66.1	55.9	38.0
133.300	50-15	3594	2716	11.2	10.4	.78	.75	2.18	1.19	17	6.2	90.6	76.8	72.9	64.6	66.9	45.9
66,600	50-30	3984	2358	10.8	10.2	.80	.75	2.37	1.24	17	3.8	93.1	79.9	73.2	65.9	68.5	40.3
133,300	75-10	3464	2635	10.0	10.0	.79	.75	2.33	1.38	6	5.0	92.3	82.1	73.2	63.2	57.6	44.2
88,900	75-15	3383	2559	10.8	10.3	.79	.74	2.29	1.23	9	9.1	92.3	81.2	72.8	64.7	59.0	44.1
44,400	75-30	3383	2689	10.3	10.6	.79	.75	2.41	1.38	28	7.0	92.9	85.8	73.2	63.4	57.5	47.8
LSD	(.05)	873	652	1.4	1.1	.02	.02	0.22	0.18	13	2.6	6.4	4.5	2.7	2.2	14.7	10.4
		NS	**	NS	NS	**	**	**	**	**	**	**	**	*	**	NS	**

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

TABLE XIII

MEAN YIELDS FROM TREATMENT EFFECTS

Treatment RW - WRPS - N	Plant Population	Year 1982	1983
cm - cm - kg/ha	plants/ha	kg/ha	
25 - 10 - 0		2732	871
25 - 10 - 90	400,000	3903	1263
25 - 10 - 180		3122	1220
25 - 15 - 0		1561	697
25 - 15 - 90	266,600	4000	1917
25 - 15 - 180		3415	2874
25 - 30 - 0		1463	1045
25 - 30 - 90	133,300	3317	1829
25 - 30 - 180		2634	1742
50 - 10 - 0		2537	1263
50 - 10 - 90	200,000	4049	2396
50 - 10 - 180		3220	2439
50 - 15 - 0		2976	1873
50 - 15 - 90	133,300	3757	2918
50 - 15 - 180		4049	2483
50 - 30 - 0		3464	1263
50 - 30 - 90	66,600	4488	1960
50 - 30 - 180		4000	3092
75 - 10 - 0		2341	1423
75 - 10 - 90	133,300	3935	2643
75 - 10 - 180		4131	2991
75 - 15 - 0		3057	1278
75 - 15 - 90	88,900	3740	2672
75 - 15 - 180		3350	2904
75 - 30 - 0		2667	1394
75 - 30 - 90	44,400	3675	2904
75 - 30 - 180		3805	2904
	LSD (.05)	1513	1008

in 1982 (Tables VII and VIII). The mean effects due to N rate, RW, and WRPS are presented in Tables XIV, XV and XVI. As N rate increased, grain protein increased significantly. This same trend has been reported for other crops as well. There is one trend through, which the results do do support. As a general rule in crop production with N rate being equal, "as yield increases, protein decreases and vice versa" (dilution effect). As already reported grain yield was depressed in 1983 compared to 1982. One would assume that grain would probably be greater in 1983, but the opposite was the result (10.9% in 1982 versus 10.2% in 1983).

TABLE XIV

EFFECT OF NITROGEN RATE ON GRAIN PROTEIN

	Year	
Nitrogen Rate	1982	1983
kg/ha	%	
0	8.6 A	7.4 D
90	10.5 B	11.0 E
180	13.8 C	12.3 F
LSD (.05)	0.8	0.6
Grand Mean	10.9	10.2

TABLE XV

EFFECT OF ROW WIDTH ON GRAIN PROTEIN

	Year	
Row Width	1982	1983
cm	%	
25	11.6 A	10.2
50	10.9 AB	10.1
75	10.4	10.3
LSD (.05)	0.8	NS

TABLE XVI

EFFECT OF WITHIN ROW PLANT SPACING ON GRAIN PROTEIN

	Year	
WRPS	1982	1983
cm	%	
10	11.0	10.2
15	11.1	10.2
30	10.7	10.3
LSD (.05)	NS	NS

In 1982, there was a significant difference in grain protein between the 25 and 75 cm row widths, but not between the 25 and 50 cm widths or the 50 and 75 cm row widths (Table XV). As row width increased, grain protein decreased. This might be explained by the fact that as row width increased grain yield also increased (Table X), and according to the dilution effect a lower grain protein would result. But this effect did not explain the difference in grain protein between years. Also, as a general rule, as row width decreased, plant population increased, but there was no significant effect due to plant population on grain protein (Table XII).

Test Weight

Test weight is a measure of density which is weight per unit volume, here being measured in kilograms per liter (kg/1). In 1982, two main effects and all interactions were significant (Table VII). The main effects were N and RW. The interactions were N X RW, N X WRPS, RW X WRPS, and N X RW X WRPS. It is almost impossible to document and explain precisely the three factor interaction (N X RW X WRPS). It is much more helpful to look individually at each one of the two factor interactions involved. Table XVII presents the mean effects of the N X RW interaction. Figure 4 graphically displays the results. The interaction occured at the 0 N rate, 25 cm RW level. Test weight here was significantly depressed over the 50 and 75 cm RW levels at the 0 N rate. Test weight is a yield component. Generally, test weight is positively correlated with yield, (as test weight increases yield increases). Since grain yield was significantly depressed by the 0 N rate and the 25 cm RW treatments, it is not too surprising to see a corresponding test weight depression here also.

Table XVIII and Figure 5 present the effects of the N X WRPS

TABLE XVII

EFFECT OF NITROGEN RATE X ROW WIDTH
ON TEST WEIGHT FOR 1982

Row Width	Year		
	0	90	180
cm	----------------kg/l----------------		
25	.69	.77	.76
50	.79	.79	.78
75	.78	.80	.79
	LSD (.05) = .02		

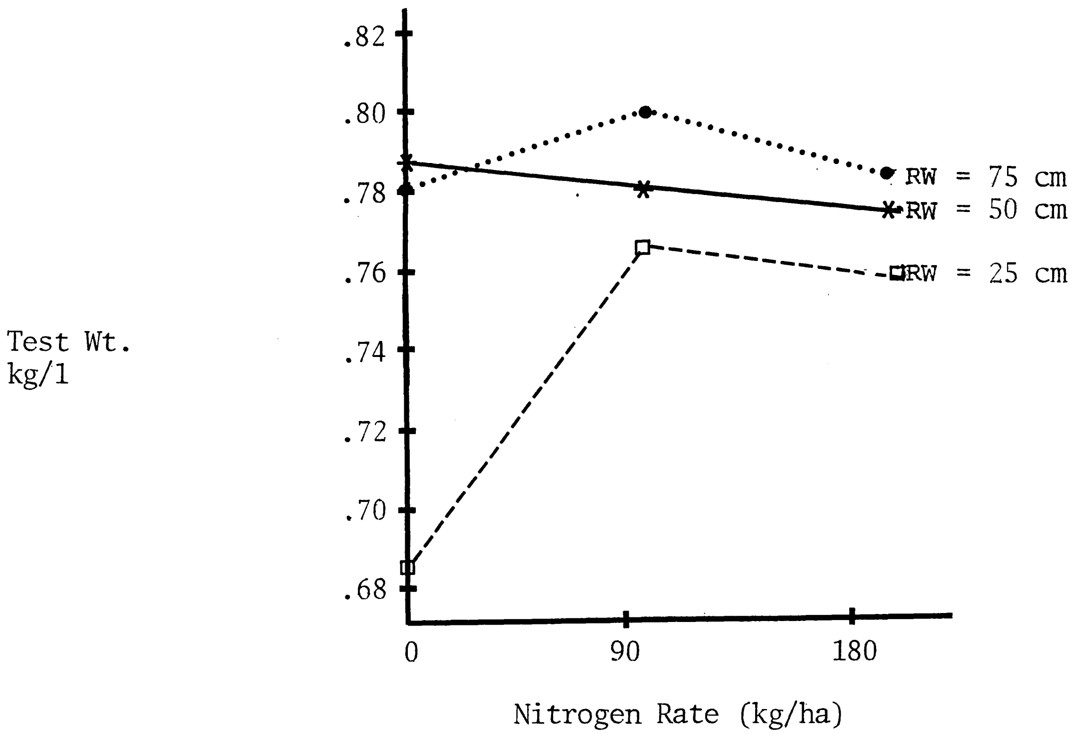

Figure 4. Effect of N X RW on Test Weight for 1982.

TABLE XVIII

EFFECT OF NITROGEN X WITHIN ROW PLANT SPACING ON TEST WEIGHT FOR 1982

Within Row Plant Spacing	Nitrogen Rate (kg/ha) 0	90	180
cm		kg/1	
10	.78	.78	.77
15	.74	.78	.78
30	.74	.78	.78

LSD (.05) = .02

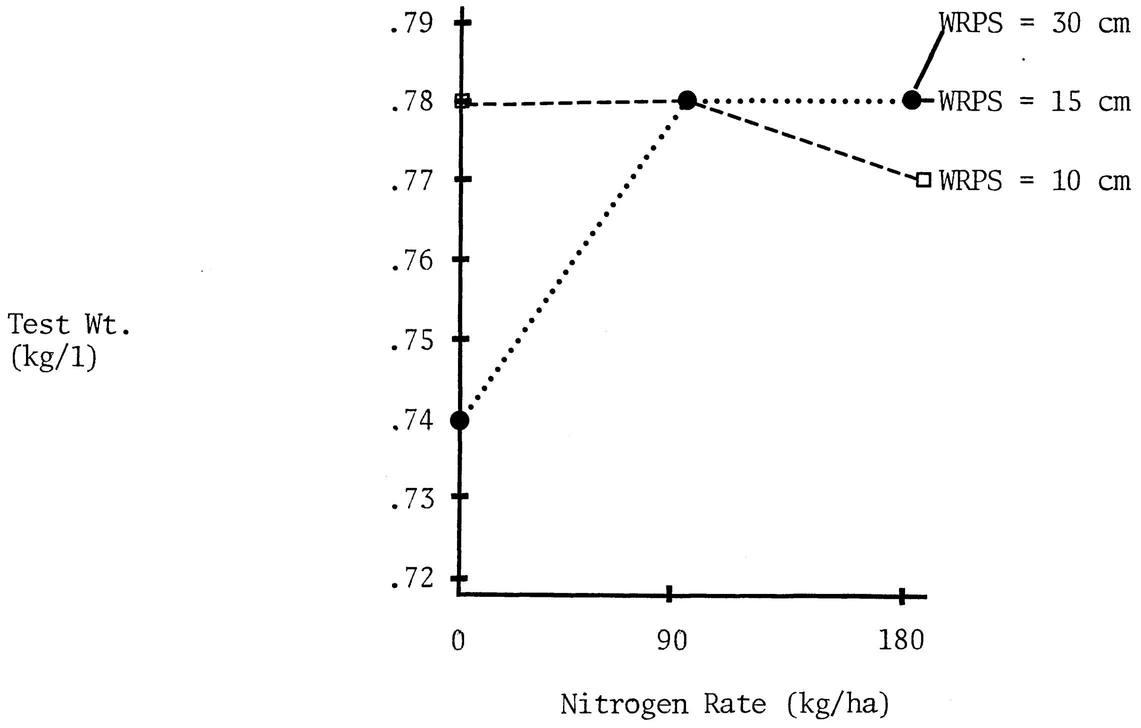

Figure 5. Effect of N X WRPS on Test Weight for 1982.

interaction. The interaction occurred on the 0 N rate level. Test weight is significantly greater at the 10 cm WRPS level compared to the 15 and 30 cm levels. Table XIX and Figure 6 present the results of the RW X WRPS interaction. Here again, test weight is significantly greater at the 25 cm RW and 10 cm WRPS. It is not evident why test weight would be greater for the 10 cm WRPS level at the 25 RW (Table XIX) and 0 N rate treatments (Table XVIII). The opposite effect would have been expected, as the N X RW interaction had a significant test weight depression at these levels (0 N and 25 cm RW). This probably explains the N X RW X WRPS interaction.

In 1982, N rate significantly affected test weight (Table XXI), but not in 1983. Test weight was significantly depressed at the 0 kg/ha N rate compared to the 90 and 180 N kg/ha rates. The interaction for N X RW and R X WRPS also tend to bear out this same trend (Tables XVII and XVIII).

Test weight was significantly affected by RW both years (Table XX). Test weight was significantly depressed at the 25 cm RW compared to the 50 and 75 cm RW levels. This was the only significant effect in 1983. The interactions for N X RW and RW X WRPS for 1982, also tend to bear out this same trend (Tables XVII and XIX). These results for the effect of RW and N rate tend to also correspond with the results for grain yield. Generally speaking, where test weight was significantly suppressed, grain yield was also suppressed, (this trend did not occur in 1983 for N rate).

TABLE XIX

EFFECT OF ROW WIDTH X WITHIN ROW PLANT SPACING ON TEST WEIGHT FOR 1982

Within Row Plant Spacing	Row Width (cm)		
	25	50	75
cm	kg/1		
10	.77	.78	.79
15	.72	.78	.79
30	.74	.80	.79
LSD (.05) = .02			

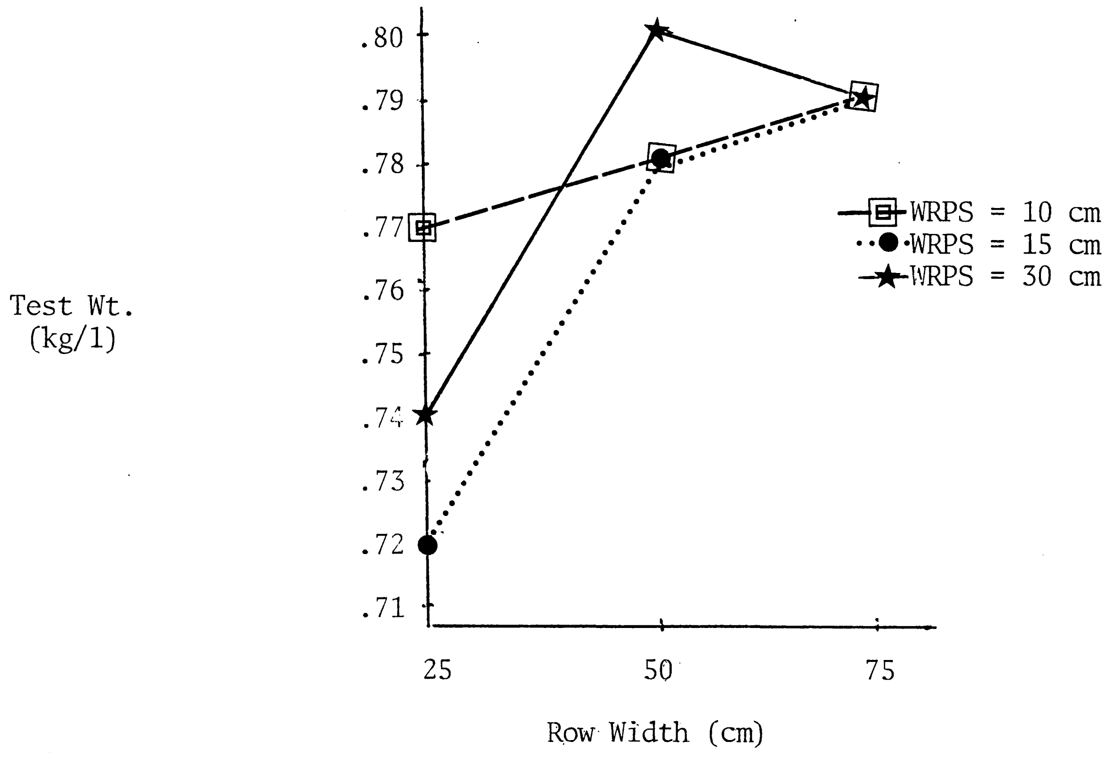

Figure 6. Effect of RW X WRPS on Test Weight for 1982.

TABLE XX

EFFECT OF ROW WIDTH ON TEST WEIGHT

Row Width	Year 1982	1983
cm	---kg/1---	
25	.76 A	.73
50	.78 B	.74
75	.78 B	.73
LSD (.05)	.01	NS

TABLE XXI

EFFECT OF NITROGEN RATE ON TEST WEIGHT

N rate	Year 1982	1983
kg/ha	---kg/1---	
0	.76 A	.73
90	.78 B	.74
180	.78 B	.73
LSD (.05)	.01	NS

100-Kernel Weight

The 100-kernel weight was significantly affected by N and RW in 1982 and by RW in 1983 (Tables VII and VIII). The results due to the effect of N rate, are presented in Table XXII. In 1982, at the 0 kg/ha N rate, 100-kernel weight was significantly greater. Kernel weight is one of the yield components. Generally speaking, as kernel weight increases (with kernel number being held constant), grain yield increases. In this instance other factors come into play also. As the results of the number of days to midbloom will indicate, at the 0 kg/ha N rate, days to midbloom were significantly greater (Table XXX, Figure 10). At the 0 kg/ha N rate, date of blooming came later in the year. These plots could receive the benefit of later occurring rains, which the 90 and 180 kg/ha N plots were not capable of utilizing. The result was that kernel weight was greater, but kernel number was lower for the 0 kg/ha N rate treatments.

TABLE XXII

EFFECT OF NITROGEN RATE ON 100-KERNEL WEIGHT

Nitrogen Rate	Year 1982	Year 1983
kg/ha	g	g
0	2.43 A	1.15
90	2.07 B	1.22
180	2.05 B	1.22
LSD (.05)	0.13	NS

Table XXIII presents the results for the effect of row width on kernel weight. Compared to the 50 and 75 cm RW levels in 1982, 100-kernel weight was significantly lower for the 25 cm RW. In 1983, 100-kernel weight increased significantly as row width increased. These results for the effect of RW on 100-kernel weight also correspond with the results of RW on grain yield. Where there was a significant yield depression due to RW, there was also a corresponding 100-kernel weight depression. This leads one to the assumption that kernel number per head was not different across RW treatments.

TABLE XXIII

EFFECT OF ROW WIDTH ON 100-KERNEL WEIGHT

Row Width	Year 1982	Year 1983
cm	g	g
25	1.99 A	1.04 C
50	2.22 B	1.22 D
75	2.34 B	1.33 E
LSD (.05)	0.13	0.11

Plant Lodging

In 1982, lodging was significantly affected by N rate, WRPS, and by the N X WRPS interaction (Tables XXIV and XXV). The N X WRPS interaction occurred at the 30 cm WRPS level at the 180 kg/ha N rate (Figure 7).

TABLE XXIV

EFFECT OF NITROGEN RATE X WITHIN ROW PLANT SPACING INTERACTION ON PLANT LODGING FOR 1982

Within Row Plant Spacing	Nitrogen Rate (kg/ha)		
	0	90	180
cm		g	
10	0.2	11.1	16.5
15	0.8	9.7	20.3
30	0.6	14.4	58.3
		LSD (.05) = 13.2	

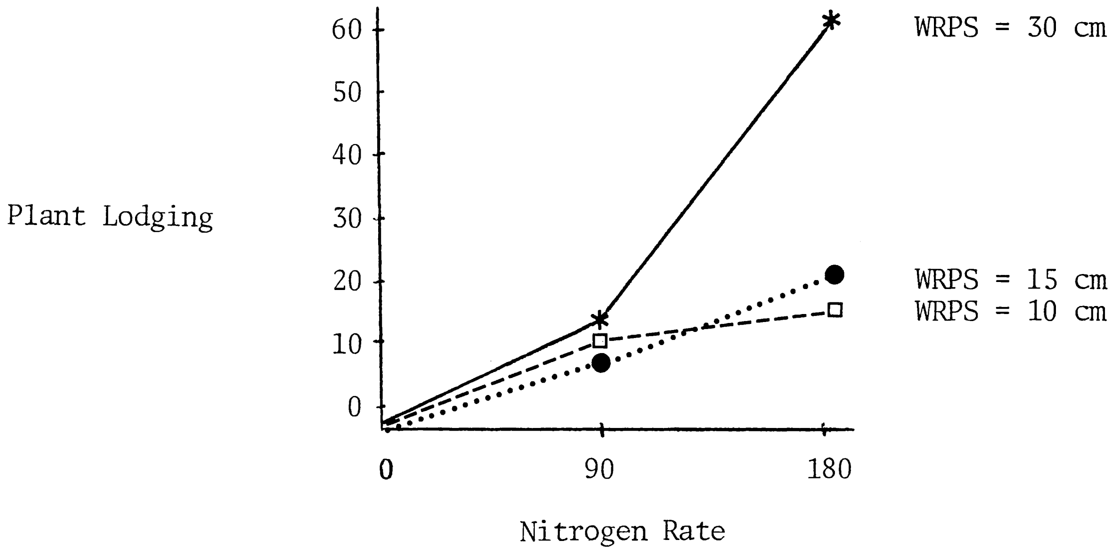

Figure 7. Effect of N X WRPS on Plant Lodging for 1982.

TABLE XXV

TREATMENT EFFECTS ON PLANT LODGING

	Year	
N Rate	1982	1983
kg/ha	%	
0	0.5 A	2.2 C
90	11.8 B	3.6 C
180	31.7 C	6.4 D
LSD (.05)	7.6	2.6

	Year	
Row Width	1982	1983
cm	%	
25	15.4	0.9 A
50	14.4	4.2 B
75	14.2	7.0 C
LSD (.05)	NS	2.6

	Year	
W R P S	1982	1983
cm	%	
10	9.3 A	2.8
15	10.3 A	5.4
30	24.4 B	3.9
LSD (.05)	7.6	NS

In 1983, lodging was significantly affected by N rate and RW (Table XXV). At the 180 kg/ha N rate, lodging was significantly greater compared to the 0 and 90 kg/ha rates. Lodging was significantly affected at all RW levels. As row width increased, lodging increased. This effect did not occur in 1982.

In explaining these effects on lodging for 1982 and 1983, several factors need to be considered:

1. There was a much greater yield potential in 1982 compared to 1983. This is because in 1982 there was a greater amount of precipitation during the late vegetative through early bloom stages of growth (Table III), 5.3 cm for July 1982 versus 0.05 in July of 1983. The late vegetative through the early bloom stages of growth have been noted as the most critical period for drought stress to occur in grain sorghum production (28).

2. Fusarium stalk rot, Fusarium monoiliforme, was severe in 1982, but was not noted in 1983. This could have been due to the greater yield potential for 1982, which resulted in a greater drain of plant moisture reserves during the grain filling period, leaving the plant in a weakened condition. Drought stress was severe in August both years, but especially so in 1982 when 0.8 cm precipitation occurred versus 2.4 cm precipitation in August of 1983. Supporting this, was the observation that at harvest, 1982, the plant stalks and leaves from the 90 and 180 kg/ha plots were brown and dead, whereas in 1983, the plant stalks and leaves were green and still alive.

3. In 1983, there was a severe wind storm shortly before harvest causing most, if not all, of the plant lodging.

The picture for plant lodging in 1982 can thus be described. As nitrogen rate increased from 0 to 90 and from 90 to 180 kg/ha N, the susceptibility to fusarium stalk rot increased the incidence of plant lodging. The increased lodging rate at 180 kg/ha N rate was not due to increased yield as yield tended (but not significantly) to be suppressed over the 90 kg/ha N rate. At the same time, as WRPS increased (especially at the 180 kg/ha N rate), plant lodging was significantly increased. As WRPS increased, plant population tended to decrease, so the increased lodging incidence was also the result of increased head size and weight, which increased the plants susceptibility to fusarium stalk rot.

The picture for 1983 was somewhat different. A severe wind storm was the major factor. As the distance between rows increased, wind damage resulted in increased lodging. Here too, plant populations tend to be lower as RW increases. Also in 1983, the grain yield trend was greater for the 75 cm RW (not significantly over the 50 cm RW). With this in mind, as RW increased and plant population decreased, head size and weight per plant increased, increasing the susceptibility to wind damage and plant lodging. Additionally, the supporting factor of the adjoining rows decreased as RW increased which also increased the plants susceptibility to wind damage and subsequent lodging.

Plant Height

In 1982, plant height was significantly affected by RW and by the N X RW interaction (Table VII). In 1983, plant height was significantly affected by N rate, RW and WRPS (Table VIII). The N X RW interaction occurred at the 0 N rate, 25 cm RW level (Table XXVI, Figure 8). Plant height was significantly shorter compared to the 50 and 75 cm RW treatments. RW significantly affected plant height both years (Table XXVII).

TABLE XXVI

EFFECT OF NITROGEN RATE X ROW WIDTH INTERACTION ON PLANT HEIGHT FOR 1982

	Nitrogen Rate (kg/ha)		
Row Width	0	90	180
cm		cm	
25	75.6	89.8	93.8
50	92.0	90.9	89.2
75	94.0	93.1	90.3

LSD (.05) - 6.4)

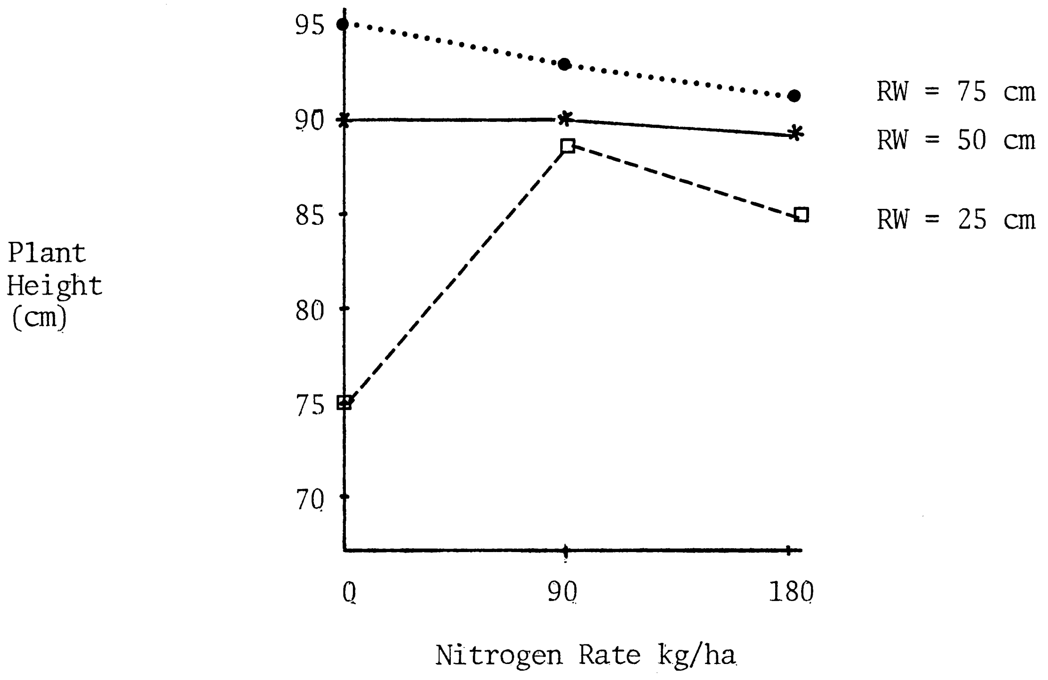

Figure 8. Effect of N X RW on Plant Height for 1982.

TABLE XXVII

TREATMENT EFFECTS ON PLANT HEIGHT

	Year	
N Rate	1982	1983
kg/ha	cm	
0	87.2	76.6 C
90	91.3	74.3 CD
180	87.8	72.4 D
LSD (.05)	NS	2.6

	Year	
Row Width	1982	1983
cm	cm	
25	83.1 A	64.2 C
50	90.7 B	76.4 D
75	92.5 B	83.1 E
LSD (.05)	3.7	2.6

	Year	
WRPS	1982	1983
cm	cm	
10	88.6	71.8 A
15	87.6	74.0 A
30	90.0	77.8 B
LSD (.05)	NS	2.6

In 1982, there was a significant decrease in plant height at the 25 cm RW level compared to the 50 and 75 cm RW levels. In 1983, plant height was significantly different at all RW levels. As RW increased, plant height was significantly greater. The effect of WRPS on plant height is also somewhat similar (Table XXVII). In 1983, plant height was significantly greater at the 30 cm RW level compared to the 10 and 15 cm RW levels. In 1982, the trend is somewhat similar, but not significant. At the wider RW treatments and at the 30 cm WRPS level, plant populations (44,000 to 133,000 plt/ha) are much lower compared to the narrower RW and WRPS levels. As a result, plant competition for limited moisture reserves was decreased during the latter vegetative stages of growth, resulting in increased plant height for the lower plant populations. Plant height was also significantly greater in 1982 (approximately 89 cm versus 74 cm in 1983) due to increased drought stress which occurred in July of 1983, during the latter vegetative stages of plant growth (Table III).

The effect of N rate on plant height is presented in Table XXVII. In 1983 at the 180 kg/ha N rate, plant height was significantly shorter compared to the 0 kg/ha N rate. The decrease in plant height might be related to the effect of N on plant maturity. Nitrogen significantly decreased the number of days to midbloom (Table XXX); and as maturity class shortens, plant height generally is shorter.

Days to Midbloom

Days to midbloom was significantly affected by N rate and RW both years, and in 1983, by the N X RW and RW X WRPS interactions (Tables VII and VIII). The N X RW interaction (Table XXVIII, Figure 9), occurred on the O N rate, 25 cm RW level. Here, the number of days to midbloom

TABLE XXVIII

EFFECT OF NITROGEN X ROW WIDTH INTERACTION ON DAYS TO MIDBLOOM FOR 1983

Row Width	Nitrogen Rate (kg/ha) 0	90	180
cm	days		
25	84.6	66.2	64.7
50	73.4	62.8	61.0
75	69.8	61.3	60.8
LSD (.05) = 2.2			

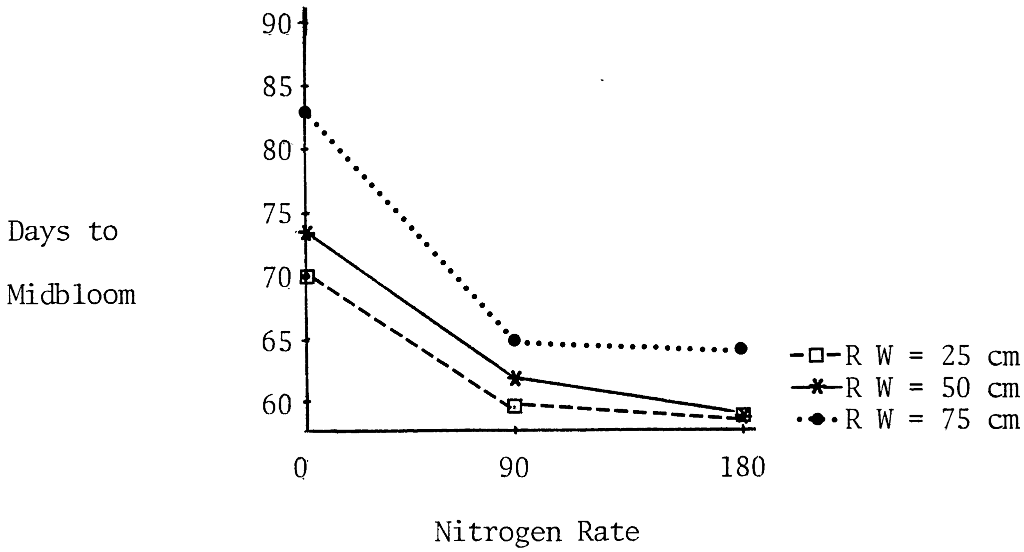

Figure 9. Effect of N X RW on Days to Midbloom for 1983.

is significantly greater compared to the 50 and 75 cm RW levels. The RW X WRPS interaction (Table XXIX, Figure 10), seems to occur also at the 25 cm RW level. Here, the number of days to midbloom is significantly shorter at the 30 cm WRPS level compared to the 10 and 15 cm WRPS levels. Overall, N rate and RW significantly affected days to midbloom both years. At the 0 N rate (Table XXX), the number of days to midbloom is significantly greater compared to the 90 or 180 kg/ha N rates. At the 25 cm RW level Table XXX), days to midbloom is significantly greater compared to 50 or 75 cm RW levels in 1982, and in 1983, as RW increased the number of days to midbloom significantly decreases across all RW levels. For this study, both the narrow 25 cm RW and the 0 N rate, significantly increased the number of days to midbloom.

Nitrogen Removed in Grain

The amount of N removed by the grain was calculated by dividing plant protein by 6.25 (an average value for N contained in protein is (6.25%). This value was then multiplied by grain yield to arrive at the amount of N removed in the grain. Grain N removal was significantly increased as N increased. The effect of RW on the amount of N removed by the grain is also presented in Table XXXI. In 1983, there was a significant decrease in the amount of N removed at the narrower 25 cm RW compared to the 50 and 75 cm RW levels. This effect is closely related to the effect of RW on grain yield, which was significantly depressed at the 25 cm RW level. Similarly, the effect of N rate on N removed reflects the effect of N rate on grain protein and yield. As N rate increased, protein increased, and grain yield was significantly depressed at the 25 cm RW level. As N rate increased, protein increased, and grain yield was significantly depressed at the 0 N rate. This is

TABLE XXIX

EFFECT OF ROW WIDTH X WITHIN ROW PLANT SPACING ON DAYS TO MIDBLOOM FOR 1983

Within Row Plant Spacing	Row Width (cm)		
	25	50	75
cm	days		
10	73.4	66.3	63.4
15	72.3	64.8	64.9
30	69.8	66.1	63.6
	LSD (.05) = 2.2		

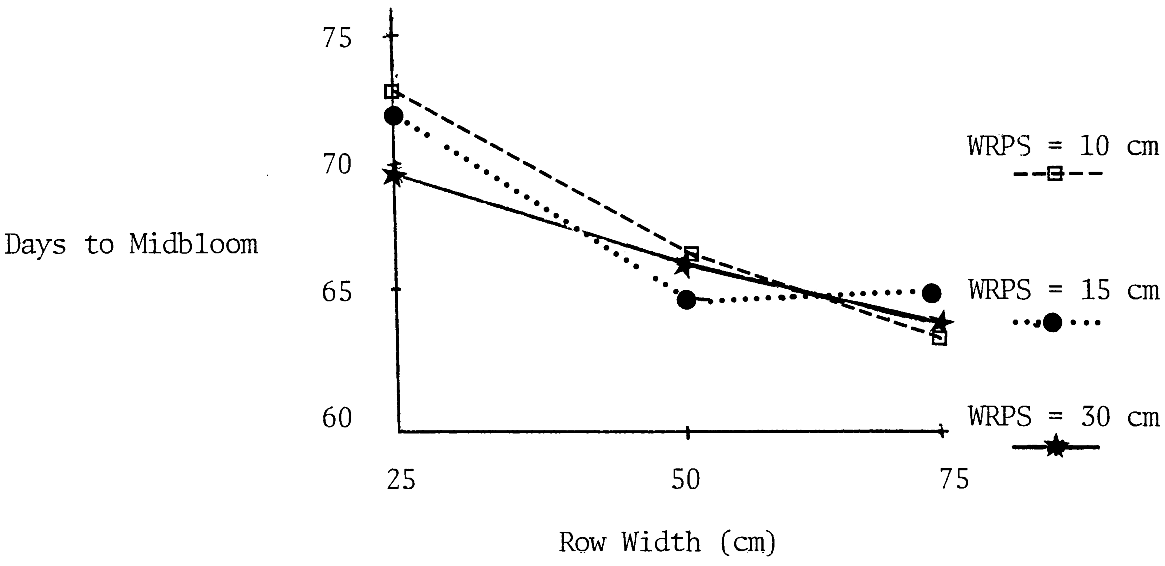

Figure 10. Effect of RW X WRPS on Days to Midbloom for 1983.

TABLE XXX

SIGNIFICANT TREATMENT EFFECTS ON DAYS TO MIDBLOOM

	Year	
N Rate	1982	1983
kg/ha	----------------days----------------	
0	77.4 A	75.7 C
90	72.8 B	63.2 D
180	72.0 B	62.0 D
LSD (.05)	1.6	1.3

	Year	
Row Width	1982	1983
cm	----------------days----------------	
25	75.7 A	76.6 C
50	73.4 B	65.5 D
75	73.0 B	63.8 E
LSD (.05)	1.6	1.3

no surprise though as the amount of N removed by the grain is a function of grain yield and grain protein. Table XXXII presents the means of the treatment effects on grain yield, grain protein, and the amount of N removed in the grain for both years.

To measure total N uptake by the plant for each treatment, forage yeild and forage protein measurements should have been taken. This was not done.

TABLE XXXI

SIGNIFICANT TREATMENT EFFECTS ON AMOUNTS OF NITROGEN REMOVED BY THE GRAIN

	Year	
Nitrogen Rate	1982	1983
kg/ha	kg/ha	
0	36.78 A	16.86 C
90	63.81 B	44.28 D
180	76.29 C	54.18 E
LSD (.05)	8.5	6.0

	Year	
Row Width	1982	1983
cm	kg/ha	
25	55.08	28.55 A
50	63.78	41.41 B
75	58.03	45.35 B
LSD (.05)	NS	6.0

TABLE XXXII

TREATMENT EFFECTS ON GRAIN YIELD, GRAIN PROTEIN AND NITROGEN REMOVED BY THE GRAIN

Treatment Effect	Grain Yield Year		Protein Year		N in Grain Year	
RW-WRPS-N	1982	1983	1982	1983	1982	1983
cm-cm-kg/ha	----kg/ha----		-------%-------		----kg/ha----	
25-10-0	2732	871	9.2	7.0	39.4	10.2
25-10-90	3903	1263	12.9	12.4	81.2	27.5
25-10-180	3133	1220	15.5	12.9	77.2	28.3
25-15-0	1561	697	9.9	7.0	25.6	8.8
25-15-90	4000	1917	9.9	10.6	63.0	37.8
25-15-180	3415	2874	14.2	11.9	75.1	57.4
25-30-0	1463	1045	6.9	6.2	17.0	11.6
25-30-90	3317	1829	11.0	10.8	54.3	35.6
25-30-180	2634	1742	15.1	13.0	63.0	39.8
50-10-0	2537	1263	7.7	6.4	34.3	15.6
50-10-90	4049	2396	10.5	10.2	64.4	44.0
50-10-180	3220	2439	13.8	12.5	71.2	54.4
50-15-0	2976	1873	9.3	8.0	48.4	27.8
50-15-90	3757	2918	10.5	10.8	62.2	55.6
50-15-180	4049	2483	13.9	12.3	90.1	54.3
50-30-0	3464	1263	9.4	8.0	52.5	17.4
50-30-90	4488	1960	10.0	10.7	71.0	36.6
50-30-180	4000	3062	13.0	12.1	82.0	70.0
75-10-0	2341	1423	7.3	7.6	28.5	20.0
75-10-90	3935	2643	10.9	11.2	66.1	52.3
75-10-180	4131	2991	12.0	11.3	78.3	60.1
75-15-0	3057	1278	9.3	8.1	47.5	19.0
75-15-90	3740	2672	9.7	10.8	57.9	51.1
75-15-180	3350	2904	13.4	12.0	71.5	62.4
75-30-0	2667	1394	8.3	8.4	37.9	21.3
75-30-90	3675	2904	9.7	11.2	56.3	58.2
75-30-180	3805	2904	13.0	12.3	78.2	63.8
LSD (.05)	1513	1008	2.5	1.8	25.4	18.0

Soil Fertility Data

The soil test data were analyzed for the three main effects of N rate, RW, and WRPS, plus the effects of year and depth. This analysis was used for pH, soil nitrate (NO_3^- - N), phosphorous (P), and potassium (K). Since there was approximately a three month difference in the soil sampling date after harvest in 1982 compared to 1983 (February 1982, for 1982 harvest versus February 1983, for the 1983 harvest), it is questionable that the difference in the soil NO_3^- - N data for 1982 versus 1983 is really a true measure of the amount of NO_3^- - N left in the soil after harvest. With this in mind, soil NO_3^- - N was also analyzed for the main effects plus depth for 1983, disregarding the data for 1982.

Table XXXIII presents the results of the analysis of variance for the soil test by treatments, depth (D) and year (Y). In this analysis, only soil NO_3^- - N, P, and K were significantly affected by year. The effect of depth was significant for pH, P, and K. Significant interactions were year X depth for pH and NO_3^- - N.

Soil Phosphorous, Potassium and pH

Phosphorous, potassium and pH were significantly affected by year and depth (Table XXXIII). Table XXXIV presents the mean effects for these variables due to year and depth. Although P and K are both significantly greater in the 0-15 cm surface layer than in the 15-30 layer, these differences are not due to this no-till study. The year previous to this study, the state and federal sorghum purity trials were held. In the years previous to that, peanut trials were grown on this site. Over the years adequate amounts of P_2O_5 and K_2O were applied to ensure ample fertility for peanut production. Along with this, over the years tillage

TABLE XXXIII

ANALYSIS OF FERTILITY DATA INCLUDING YEAR AND DEPTH

Source	DF	pH		$NO_3^- - N$		Phosphorous		Potassium	
		SS	F	SS	F	SS	F	SS	F
Replication	2	2.134	*11.13	18.65	2.03	27965	*36.67	181004	*34.08
Row Width	2	0.336	1.75	34.17	**3.72	1842	2.42	2504	0.47
Within Row Plant Spacing	2	0.436	2.27	5.65	0.62	168	0.22	518	0.10
RWXWRPS	4	0.010	0.26	19.16	1.04	1656	1.09	7840	0.74
Nitrogen	2	0.479	2.50	56.05	*6.11	84	0.11	5407	1.02
NXRW	4	0.340	0.89	11.03	0.60	1762	1.16	12328	1.16
NXWRPS	4	0.337	0.88	9.23	0.50	393	0.26	21673	2.04
NXRWXWRPS	8	0.671	0.87	35.09	0.96	4466	1.46	12326	0.58
$Error_1$	52	4.983		238.54		19829		138078	
Year (Y)	1	4.203	*79.19	596.17	*228.80	3838	*13.19	169168	*73.22
Depth (D)	1	0.701	*14.34	10.06	3.86	76702	*263.65	564298	*244.23
YXD	1	0.452	*8.52	21.73	*8.34	684	2.35	6395	2.77
RWXY	2	0.195	1.84	13.67	2.62	2573	**4.42	12593	2.73
RWXD	2	0.113	1.06	4.83	0.93	142	0.24	1893	0.41
RWXYXD	2	0.222	2.09	0.83	0.16	331	0.57	1890	0.41
WRPSXY	2	0.036	0.34	7.66	1.47	334	0.57	536	0.12
WRPSXD	2	0.015	0.14	0.90	0.17	235	0.40	682	0.15
WRPSXYXD	2	0.082	0.77	1.46	0.28	1021	1.75	673	0.15
NXY	2	0.029	0.27	9.34	1.79	445	0.76	1809	0.39
NXD	2	0.187	1.76	0.21	0.96	243	0.42	1588	0.34
NXYXD	2	0.039	0.37	1.13	0.22	108	0.19	1058	0.23
NXRWXWRPSXYXD	60	2.684	0.84	164.46	1.05	9831	0.56	108005	0.78
$Error_2$	162	8.597		422.12		47130		374297	
C.V.		3.59		60.32		22.39		17.95	

**Indicates significance at the .01 level of probability.

*Indicates significance at the .05 level of probability.

TABLE XXXIV

EFFECT OF YEAR AND DEPTH ON SOIL PHOSPHOROUS, POTASSIUM AND pH

Year	Phosphorous		Potassium		pH	
	------------kg/ha------------					
1982	71.7	A	290.6	C	6.52	E
1983	78.6	B	244.9	D	6.29	F
LSD (.05)	3.7		10.5		0.05	
Depth	**Phosphorous**		**Potassium**		**pH**	
cm	------------kg/ha------------					
0-15	90.5	A	309.5	C	6.36	E
15-30	59.7	B	226.0	D	6.46	F
LSD (.05)	3.7		10.5		0.07	

depth on this site has been approximately 15 cm. It was observed in taking the soil tests, that a distinct soil hard pan layer existed at approximately the 15 cm depth. Once this layer was penetrated, the soil test probe penetrated the deeper depths much easier. With this in mind, the P_2O_5 and K_2O applied to this site over the years have primarily been mixed into the top 15 cm of the soil depth. With phosphorous and potassium being essentially immobile soil nutrients, this accounts for their increased concentration in the upper 15 cm of the soil profile tested. The overall increase in P in 1983 compared to 1982, could be the result of applying 50.4 kg/ha P_2O_5 before planting in 1983.

Soil pH was significantly influenced by year, depth and the interaction of Y X D (Table XXXIII). The year 1983 shows a significant drop in pH overall treatments compared to 1982 (Table XXXIV). The effect of depth indicates the rate of pH drop was significantly greater for the top 15 cm of the soil profile tested. The interaction of Y X D (Table XXXV), showed no significant difference due to depth at the end of the one cropping year, but at the end of two years there was a significant drop in pH in the 0-15 cm layer and it was a more rapid drop than the 15-30 cm layer. Other research has also noted a more rapid pH drop for the soil surface depth compared to the subsurface depths under no-till conditions (36). Ideally though, to more accurately monitor the effect of pH, P and K due to depth under a no-till setting, the soil profile should have been tested every 5-6 cm of soil depth to a total soil profile depth of 25-30 cm. Under no-till, one could conceiveably have a serious pH drop at the soil surface and not pick it up if the surface layer is mixed in with the whole soil profile at the time of soil testing. Under continuous no-till, results indicate a greater frequency of liming is needed (but not necessarily a greater amount), to keep the soil surface pH at optimal levels for seedling growth and vigor and optimal herbicide activity.

TABLE XXXV

EFFECT OF YEAR X DEPTH ON pH

Depth	Year	
	1982	1983
cm	pH	
0-15	6.51	6.21
15-30	6.53	6.38
LSD (.05) = .07		

Soil Nitrate

The data for the amount of soil nitrate (NO_3^- - N) contained in the soil after harvest was analyzed two ways. In the analysis including year and depth (Table XXXIII), soil NO_3^- - N was significantly affected by RW, N rate, year, and year x depth. The second analysis just looked at the amount of soil NO_3^- - N left in the soil for 1983, after two years of continuous no-till grain sorghum production. The only significant effect in this analysis was due to depth. The treatment means due to these different effects for these two analyses are presented in Tables XXXVI and

XXXVII. Over both years there was a significant decrease in the amount of soil NO_3^- - N for the 50 cm RW compared to the 75 cm RW level (Table XXXVI). Also, the 180 kg/ha N rate had a significant increase in soil NO_3^- - N over the 0 and 90 kg/ha N rates. While these numbers may be statistically significant, it is doubtful that they have any practical significance. The same may also be said for the effects of year and year x depth over both years or the effect of depth in 1983 (Table XXXVII). Approximately 4 kg/ha in 1982 versus 1.3 kg/ha in 1983 is of little practical significance. This difference could also be due to the extra three month longer time interval before soil testing after the 1982 harvest. Also in 1983, there was a significant decrease in soil NO_3^- - N due to depth which did not seemingly occur in 1982. The only significant statement which can be made involving soil NO_3^- - N in this study is that after two years of continuous monocrop no-till grain sorghum production, soil test NO_3^- - N in the top 30 cm of the soil profile measured 1.2, 0.9, and 1.9 kg/ha NO_3^- - N from the 0, 90 and 180 kg/ha N rates respectively (TableXXXVI), and that in 1983, none of the main treatment effects significantly affected soil NO_3^- - N.

TABLE XXXVI

EFFECT OF ROW WIDTH AND NITROGEN RATE ON SOIL NO_3^- - N

Row Width	Year 1982	Year 1983	Year 1982-1983
cm	kg/ha		
25	4.06	1.43	2.75 A B
50	3.87	0.62	2.25 B
75	4.16	1.91	3.04 A
LSD (.05)	NS	NS	0.6

Nitrogen Rate	Year 1982	Year 1983	Year 1982-1983
kg/ha	kg/ha		
0	3.50 A	1.18	2.34 D
90	3.99 B	0.85	2.42 D
180	4.60 C	1.93	3.26 E
LSD (.05)	0.42	NS	0.6

TABLE XXXVII

EFFECT OF YEAR X DEPTH ON SOIL NO_3^- - N

Depth	Year 1982	Year 1983
cm	kg/ha	
0-15	3.95	1.75
15-30	4.12	0.88
LSD (.05) = 0.50		

CHAPTER V

SUMMARY AND CONCLUSIONS

A two year field experiment was conducted at the Agronomy Research Station, Perkins, Oklahoma during the cropping seasons of 1982 and 1983. The main objective of this study was to gather additional data to help in determining optimal row width and plant population at differing levels of nitrogen, for a continuous monocrop dryland no-till grain sorghum production system.

The experimental design was a randomized complete block with three replications. The treatments consisted of three row widths {(RW) 25, 50, and 75 cm }, three within row plant spacing {(WRPS) 10, 15 and 30 cm }, and three nitrogen rates {(N) 0, 90, and 180 kg/ha }. This resulted in a 3 x 3 x 3 factorial arrangement of treatment factors. The three RW and three WRPS resulted in seven different plant populations levels ranging from a high of 400,000 plants/ha to a low of 44,000 plants/ha.

Data were collected for eight different yield response variables, four soil fertility variables, and for soil temperature randomly selected from the 90 kg/ha N level. Yield response variables included grain yield, grain protein, nitrogen removed by the grain, test weight, 100-kernel weight, plant height, days to midbloom,and plant lodging. Soil test fertility variables included pH, soil NO_3^- - N, P, and K.

In 1982, RW significantly affected all yield variables except plant lodging and the amount of nitrogen removed by the grain. The only significant effect due to WRPS was for plant lodging. The effect of N rate was significant for all variables except plant height. Significant interactions included: N X RW for test weight and plant height, N X WRPS for test weight and plant height, NW X WRPS for test weight and the amount of nitrogen removed in the grain, and a N X RW X WRPS interaction for test weight. Also in 1982, the effect of plant population was significant for test weight, 100-kernel weight, plant lodging, plant height and days to midbloom.

In 1983, RW significantly affected all yield variables except grain protein. The only significant effect due to WRPS was for plant height. The effect of N rate was significant for all variables except test weight and 100-kernel weight. Significant interactions were N X RW and RW X WRPS for days to midbloom. Also in 1983, the effect of plant population was significant for all variables except for grain protein.

While there was a significant effect due to plant population both years for most variables, the effect of plant population can best be explained by looking at the effect of RW. As a general rule, as RW increased plant population decreased or vice versa. The only places RW did not explain the effect of plant population was for plant lodging in 1982 and for plant height in 1983. Here, as WRPS increased, lodging and plant height increased.

For both years, there was a significant depression at the narrow 25 cm RW compared to the wider 50 and 75 cm RW for grain yield and test weight. The same effect occurred for the amount of nitrogen contained in the grain for 1983 and for 100-kernel weight in 1982. In 1983, lodging and 100-kernel weight increased across all RW levels as RW increased. For both years, as RW increased, plant height increased and days to midbloom decreased.

For both years there was a significant depression in grain yield and test weight at the 0 kg/ha N rate compared to the 90 and 180 kg/ha rates. There was no significant difference in yield and test weight between the 90 and 180 kg/ha rates either year. Grain protein significantly increased across all N levels. As N rate increased; grain protein increased, the amount of nitrogen contained in the grain increased, plant lodging increased, and plant height increased in 1983. In 1982, there was a significant increase in 100-kernel weight at the 0 kg/ha N rate compared to the 90 and 180 kg/ha N rates, and for both years, the same effect occurred for days to midbloom.

Across both years test weight, 100-kernel weight, and grain yield were all significantly and positively correlated.

In 1982, the greatest grain yield, due to plant population came from the 50 cm RW x 30 cm WRPS treatment at the 66,000 plants/ha level. In 1983, the greatest yield came from the 50 cm RW x 15 cm WRPS treatment at the 133,000 plants/ha level. In both years, the treatment with the greatest mean grain yield came from the 50 cm RW x 30 cm WRPS x 90 kg/ha N rate in 1982 and the 180 kg/ha N rate in 1983, at the 66,000 plants/ha population level.

While there was no significant difference between the 50 and 75 cm RW levels and the 90 and 180 kg/ha N rates, the results from this experiment and from other research (1, 8, 9, 10, 34) would tend to favor the medium 50 cm RW level and the 90 kg/ha N rate, at a plant population somewhere between 66,000 to 133,000 plants/ha under a dryland grain sorghum production system.

There was little significance if any, due to any of the treatment main effects on any of the soil test fertility variables. There was a significant effect due to depth by the end of the second year for pH. At the 0-15 cm soil depth, pH was significantly decreased compared to the 15-30 cm soil depth. At the end of the first year there was no significant difference in pH at either soil depth. At the end of two cropping seasons under monocrop no-till conditions, the top 30 cm of the soil profile tested 1.2, 0.9, and 1.9 kg/ha NO_3^- - N from the 0, 90, and 180 kg/ha N rate treatments, respectively.

In conclusion, under dryland no-till grain sorghum production conditions, optimal row width would seem to be somewhere in the range of 50 to 75 cm, with a corresponding plant population ranging from 66,000 to 133,000 plants per hectare. Basically, the same row widths and plant populations which have generally been considered optimal under conventional tillage conditions.

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APPENDIX

TABLE XXXVIII

CORRELATION COEFFICIENTS OF RESPONSE VARIABLES ACROSS BOTH YEARS

	pH	NO_3^--N	P	K	Test Weight	100 Kernel Weight	Grain Yield	Protein	Plant Height	Plant Lodging	Days to Midbloom	Nitrogen in Grain
pH	1.00	.027	**-.370	**-.215	.073	.372	.077	**-.228	*.115	.052	**.431	-.010
NO_3		1.00	.061	**.336	**.315	**.475	**.384	**.265	**.441	**.255	**.171	**.420
P_2O_5			1.00	**.664	-.002	*-.137	-.024	**.182	.052	.003	**-.225	.055
K_2O				1.00	**.147	**.258	**.156	**.194	**.256	**.158	.090	**.209
Test Weight					1.00	**.538	**.649	*.137	**.697	**.269	-.072	**.550
100-Kernel Weight						1.00	**.432	-.014	**.619	**.189	**.406	**.332
Grain Yield							1.00	**.314	**.644	**.286	**-.297	**.884
Grain Protein								1.00	.034	**.458	**-.430	**.683
Plant Height									1.00	.279	.023	**.525
Plant Lodging										1.00	-.043	**.468
Days to Midbloom											1.00	**-.360
Nitrogen in Grain												1.00

*Indicates significance at the .05 level of probability.

**Indicates significance at the .01 level of probability.

TABLE XXXIX

AVERAGE EFFECT OF NITROGEN LEVEL
ON YIELD DATA FOR 1982

Yield Variable	Nitrogen Level (kg/ha)			LSD	
	0	90	180	.05	.01
Grain Yield (kg/ha)	2533	3874	3525	504	672
Grain Protein (%)	8.59	10.55	13.76	.83	1.10
Grain Nitrogen (kg/ha)	36.8	63.8	76.3	8.5	11.3
Test weight (kg/l)	.755	.785	.779	.012	.016
100 Kernel weight (g)	2.43	2.07	2.05	.13	.17
Plant Height (cm)	87.2	91.3	87.8	3.7	4.9
Plant Lodging (%)	0.5	11.8	31.7	7.6	10.1
Days to Midbloom	77.4	72.8	72.0	1.6	2.1

TABLE XXXX

AVERAGE EFFECT OF ROW WIDTH ON
YIELD DATA FOR 1982

Yield Variable	Row Width (cm)			LSD	
	25	50	180	.05	.01
Grain Yield (kg/ha)	2905	3616	3411	504	672
Grain Protein (%)	11.60	10.90	10.39	.83	1.10
Grain Nitrogen (kg/ha)	55.1	63.8	58.0	8.5	11.3
Test Weight (kg/l)	.741	.788	.789	.012	.016
100 Kernel weight (g)	1.99	2.21	2.34	.13	.17
Plant Height (cm)	83.1	90.7	92.5	3.7	4.9
Plant Lodging (%)	15.4	14.4	14.2	7.6	10.1
Days to Midbloom	75.7	73.4	73.0	1.6	2.1

TABLE XXXXI

AVERAGE EFFECT OF WITHIN ROW PLANT SPACING ON YIELD DATA FOR 1982

Yield Variable	Within Row Plant Spacing (cm)			LSD	
	10	15	30	.05	.01
Grain Yield (kg/ha)	3330	3323	3279	504	672
Grain Protein (%)	11.08	11.11	10.70	.83	1.10
Grain Nitrogen (kg/ha)	59.8	60.1	56.9	8.5	11.3
Test Weight (kg/l)	.779	.766	.774	.012	.016
100 Kernel Weight (g)	2.14	2.16	2.24	.13	.17
Plant Height (cm)	88.6	87.6	90.0	3.7	4.9
Plant Lodging (%)	9.3	10.3	24.4	7.6	10.1
Days to Midbloom	74.7	73.8	73.6	1.6	2.1

TABLE XXXXII

AVERAGE EFFECT OF NITROGEN LEVEL ON YIELD DATA FOR 1983

	Nitrogen Level (kg/h)			LSD	
Yield Variable	0	90	180	.05	.01
Grain Yield (kg/ha)	1382	2551	2819	376	502
Grain Protein (%)	7.4	11.0	12.3	0.6	0.8
Grain Nitrogen (kg/ha)	16.8	44.3	54.2	6.0	8.0
Test Weight (kg/l)	.728	.735	.731	.013	.018
100 Kernel Weight (g)	1.15	1.22	1.22	.11	.14
Plant Height (cm)	76.9	74.3	72.4	2.6	3.5
Plant Lodging (%)	2.2	3.6	6.4	2.6	3.5
Days to Midbloom	75.7	63.2	62.0	1.3	1.7

TABLE XXXXIII

AVERAGE EFFECT OF ROW WIDTH ON YIELD DATA FOR 1983

Yield Variable	Row Width (cm) 25	50	75	LSD .05	.01
Grain Yield (kg/ha)	1675	2450	2627	376	502
Grain Protein (%)	10.2	10.1	10.3	0.6	0.8
Grain Nitrogen (kg/ha)	28.5	41.4	45.3	6.0	8.0
Test Weight (kg/l)	.694	.751	.747	.013	.018
100 Kernel Weight (g)	1.04	1.22	1.33	.11	.14
Plant Height (cm)	64.2	76.4	83.1	2.6	3.5
Plant Lodging (%)	0.9	4.2	7.0	2.6	3.5
Days to Midbloom	71.6	65.5	63.8	1.3	1.7

TABLE XXXXIV

AVERAGE EFFECT OF WITHIN ROW PLANT SPACING ON YIELD DATA FOR 1983

Yield Variable	Within Row Plant Spacing (cm)			LSD	
	10	15	30	.05	.01
Grain Yield (kg/ha)	2054	2441	2256	376	502
Grain Protein (%)	10.2	10.2	10.3	0.6	0.8
Grain Nitrogen (kg/ha)	34.7	41.6	39.0	6.0	8.0
Test Weight (kg/l)	.729	.729	.734	.013	.018
100 Kernel Weight (g)	1.20	1.15	1.24	.11	.14
Plant Height (cm)	71.8	74.0	77.8	2.6	3.5
Plant Lodging (%)	2.8	5.4	3.9	2.6	3.5
Days to Midbloom	67.5	67.2	66.3	1.3	1.7

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