EFFECTS OF ROW SPACING, PLANT POPULATION, AND NITROGEN LEVEL ON GRAIN SORGHUM PRODUCTION UNDER REDUCED TILLAGE SYSTEMS

By

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CHAPTER I

INTRODUCTION

There are many factors which determine the quantity and quality of a crop. Some of these factors, such as choice of an adapted variety, selection of suitable land, fertilizer level, planting date, row spacing, cropping system, and weed control are under the farmer's control, while others such as weather, and outbreak of insect and/or disease are not.

It is well understood that good cultural practices are necessary for high crop production. According to Martin et al. (43) the two most important cultural practices are proper seeding date, and optimum spacings of plants both between-row-spacing (BRS) and within-row-spacing (WRS).

During the last few years, factors such as the increasing cost of fuel and labor, the impact of farm machinery on the soil, the need to control both wind and water erosion, and the need to conserve moisture have brought about emphasis on reduced tillage.

A two year reduced tillage field study on grain sorghum Sorghum bicolor (L). Moench, was undertaken:

1. To determine appropriate BRS, WRS, and nitrogen level with reduced tillage for grain yield.
2. To determine if BRS, WRS, and/or nitrogen level has any effect on protein percentage of the grain.

3. To obtain information on how other agronomic variables, namely: 100-kernel weight, test weight, days to mid-bloom, number of tillers, plant height, panicle length, peduncle exertion, lodging and threshing percent are influenced by BRS, WRS, and nitrogen level.
4. To obtain information on the interrelationship among the agronomic variables due to BRS, WRS, and nitrogen level.

CHAPTER II

LITERATURE REVIEW

Tillage

Tillage is the change of soil conditions for crop production (4). According to Cole and Mathews (21) the three commonly accepted basic reasons for tillage are: to prepare a suitable seedbed, to eliminate competition from weeds, and to improve the physical condition of the soil. As the soil tilth improves, conditions become more favorable for aeration, drainage of water, plant-nutrient availability, and high yields per area (62). The elimination of weeds removes their competition for plant nutrients, water, and sunlight.

Larson (38) states that both too little and too much tillage affect the soil physical condition. Too little tillage results in large clods and large pore spaces. When soil clods are too large the contact between sod and soil is poor, and soils dry out easily. According to him too much tillage produces small soil particles and small pore spaces between the particles. Soil with very small particles tends to be wet, slow to warm up, crusty and tends to retard germination and early growth.

For this review the following definitions are used. Conventional tillage: traditional tillage system, which typically begins with a primary deep tillage operation followed by secondary tillage for seedbed preparation (35), and cultivating to control weeds. Minimun tillage: minimum amount of tillage required to create the proper soil condition for seed germination and plant establishment (61). No tillage: a method of planting crops that involves no seedbed preparation other than opening the soil for the purpose of placing the seed at the intended depth (61). Unger and McCalla (71) refer to no tillage as no-till, till plant, chisel-plant, and rotary tillage.

Tillage helps to control weeds by killing emerging seedlings, burying weeds seeds, and delaying growth of perennial weeds (57). The development of herbicides removed tillage as a reason to control weeds, and brought about the practice of minimum and no tillage (71).

Studies have shown that the physical properties favorable for plant growth can be destroyed by too much tillage (19, 35, 36). Rao et al. (56) studied the effect of minimum tillage on physical properties of soil in corn production. They reported that minimum tillage improved soil physical conditions, including higher rate of infiltration, less soil resistance to water penetration, and less soil compaction. They found fewer weeds, less plant mortality due to cultivation, more root growth, better vegetative development, less lodging, and less corn loss in harvest. But it produced more uneven germination than conventional tillage.

Minimum tillage reduces water loss from the soil (31, 45). Griffith et al. (28) reported that erosion may be decreased by 75 to 90 percent by minimum tillage.

Both equality of yield between minimum tillage and conventional tillage (8, 22, 53, 69) and higher yield through use of minimum tillage (1, 30) have been reported. Doren and Ryder (24) have indicated yield of corn obtained with minimum tillage to be greater in years of low rainfall than high rainfall. Their study also revealed that yield advantage was less apparent on heavy clay soils than on coarse and medium textured soils. Bowers and Bateman (14) indicated an equality of yield on a fine or medium textured soil. Ackerson (1) suggested the largest yield gain for minimum tillage occurred on the fine-textured soil.

Bandel et al. (7) studied the behavior of different nitrogen levels under no tillage versus conventional tillage. They stated that nitrogen deficiency symptoms often were accentuated with no tillage; however, the rate of applied nitrogen required for maximum yield was similar under conventional and no tillage. Moschler and Martens (47) and Moschler et al. (48) reported that utilization by corn of applied phosphorus and potassium was greater for the minimum tillage than for conventional tillage.

An increase of both soil and above-ground insects has been observed under no-tillage (25, 27). Musick and Petty (49) in Ohio, observed that under no-tillage 15 percent of the corn plants were attacked by the black cutworm, *Agrotis ipsilon* (Hufnagel), while under conventionally-tilled fields only 1 percent were attacked. Gregory and Raney (27) have reported that the intensity and frequency of above-ground insects such as armyworms, *Pseudaletia unipuncta* (Haworth) and southwestern corn borer, *Diatraea grandiosella* (Dyar) are common where tillage is minimized.

Yarham and Hirst (78) documented that reduced tillage resulted in more *Septoria* leaf spot on wheat and *Rhynchosporium* scale disease on barley. Obvody and Dunkle (52) have stated that reduced tillage may influence the severity of a fungus *Ramulispora sorghi*, which causes sooty stripe of sorghum. In Nebraska, reduction of stalk rot of sorghum, Fusarium moniliforme (Sheld) has been reported where tillage is minimized (13).

Row Spacing

Dropping seed into holes which are made with a stick, or broadcasting was the seeding method of the earliest farmer. The development of wheeled platners as early as 2800 B.C. in China, and row planters after A.D. 1800 opened the avenue for modern agriculture (40).

In row crops the space between rows depends on factors such as moisture, type of crop, the climate and the variety of a particular crop. For grain sorghum the typical row spacings range from 50-100 cm (44, 76). Results of many investigators (2, 5, 6, 12, 16, 54, 55, 64) indicate that under abundant moisture supply highest yields were obtained from narrow row spacings, whereas under limited moisture supply wider row spacing gave better yields. Arnon (6) postulated that when soil moisture was limited there would be an advantage of increasing the interrow spacing and decreasing the intrarow spacing. According to him intrarow competition would result in smaller plants and in the interrow reservoir of soil moisture would be maintained over a longer portion of the growing season.

The availability of improved herbicides and the development of weed control equipment for narrow rows have generated interest in narrow rows (65). In grain sorghum, yield advantage from rows narrower than 100 cm has been reported (18, 63, 64, 66). Laude et al. (39) at Manhattan, Kansas found that grain sorghum in 50 cm (20 inch) rows produced higher yields than in 100 cm (40 inch), and needed little or no cultivation after planting. A study in Texas has shown that dryland sorghum with narrow row spacing has out-yielded sorghum with conventional row spacing by 15-20 percent (3). Stickler et al. (64) conducted field experiments for 14 years at Manhattan, Kansas to determine the feasibility of growing grain sorghum in narrow rows. Their study showed that the narrow-rows, 50 cm (20 inch) yielded significantly more than the wider-rows, 100 cm (40 inch).

Porter et al. (55) in Texas, studied the relationship of row spacing and plant population to water-use efficiency and grain yield. They reported that irrigated grain sorghum grown in 30 and 50 cm (12 and 20 inch) rows produced significantly higher grain yields than the 75 and 100 cm (30 and 40 inch) rows. The grain yield of narrow row spacing was attributed to a more uniform spacing of plants which resulted in more efficient use of moisture, nutrients, and solar energy.

Moldenhauer and Lipscomb (46) indicated that on sandy soils of the Southern Great Plains narrow-row spacing aids in moisture conservation, in controlling wind erosion, and in reducing surface crusting. According to Adams et al. (3) grain sorghum grown at 50 cm row spacing had an average of 2.8 cm less runoff and 3.1 metric tons/ha less soil loss than sorghum grown at 100 cm row spacing.

A study on the effect of narrow-row spacing on evaporation of soil water has suggested that the yield increase with narrow-row spacing might be due to the increased interception of solar radiation. Clegg et al. (20) study has shown that with narrow-row spacings more visible radiation is available for photosynthesis.

The information about the influence of row spacing on sorghum plant height is contradictory. Porter et al. (55) reported that the 30 cm

(12 inch) spacing produced the shorter and the 100 cm (40 inch) spacing the taller plants. Stickler et al.(64) attributes the increase in plant height as row width decreases, to competition for light. They stated that under limited light, elongation of internodes is a common plant response.

Date of mid-bloom has been used as a measure of relative maturity of grain sorghum (15). Niehaus and Pickett (51), and Liang et al. (41) have concluded that grain yield was positively and significantly correlated with half-bloom. It has been reported that row width has no influence on date of mid-bloom when rainfall is adequate, narrow rows increase days to mid-bloom when rainfall is deficient (15).

Incidence of some diseases due to row spacing have been reported. Porter et al. (55) suggested that spacing sorghum plants close to each other may favor the incidence of head smut, caused by the fungus _Sphacelotheca_ _reiliana_. According to Brown et al.(15) charcoal rot, _Macrophomina_ _phaseoil_ was more prevalent in narrow row spacing.

Robinson et al. (58) in Minnesota found that percent lodging was higher in narrow rows, 25, 50, and 75 cm (10, 20, and 30 inch) than in the wider 100 cm (40 inch). In Georgia (15), the increased lodging in the 50 cm (20 inch) row spacing over the 100 cm (40 inch) row spacings was attributed to charcoal rot. In Texas (12), the average number of lodged plants was greater in the wider row, 100 cm (40 inch) than the narrow row 50 cm (20 inch). The increase in lodging was attributed to the increased plant height and the decreased plant diameter in the 100 cm (40 inch) row spacings.

Nelson (50) studied the effect of spacing on protein content of the grain sorghum. He found that spacing did not affect the protein content of the grain sorghum. He found that spacing did not affect the protein content of the grain.

In Texas, a 3-year study has shown that the differences among row spacing on test weight were significant at the 1 percent level (55).

Plant Population

Willey (76, p.201) defined plant population as "the number of plants per unit area of ground." Donald (23) indicated that as the number of plants per unit area increase, competition for growth resources such as nutrients, water, and light increase.

It has been stated that an essential component of plant population is spatial arrangement, which is the pattern of distribution of plants over the ground (76). According to Donald (23), the three components of plant arrangement which have potential of influencing yield are: 1. a square grid, 2. regularity of distribution, and 3. the direction of the rows (north-south or east-west). Willey (76) has indicated that an ideal spatial arrangement is a square grid or equidistance between plants which is often used in perennial tree crops. Practically in annual or row crops the arrangement is rectangular in which the between-row spacing is greater than the within-row spacing. He also indicated that the effect of rectangularity on yield depends upon the flexibility of the individual plants. It has been reported that (5, 29, 37, 64, 67) grain sorghum has a capacity of adjusting to stand differences, by changes in tillering, number of seeds per head, seed weight, and through other yield components.

In grain sorghum, wide ranges of tolerance to plant population have been shown (29, 58, 63). Nelson (50) in Washington found no significant yield difference in populations ranging from 180,000 to 570,000 plants/ha (72,000 to 228,000 plants/acre) on irrigated grain sorghum. According to Grimes and Musick (29), under conditions of abundant moisture the highest grain yield was produced at a population of 250,000 plants/ha (100,000 plants/acre). Yield decline was more rapid when the plant population dropped below 100,000 to 125,000 plants/ha (40,000 to 50,000 plants/acre). Brown and Sharder (16) at Hays, Kansas found that under moderate drought and extreme drought years the highest yields were from populations of 150,000 to 75,000 plants/ha (60,000 and 30,000 plants/acre) respectively. This result was obtained from populations ranging from 38,000 to 300,000 plants/ha (15,000 to 120,000 plants/acre). Porter et al. (55) reported that planting rates which gave average plant populations of 153,000; 270,000; and 380,000 plants/ha (61,000; 108,000; and 152,000 plants/acre) had little effect on grain yield of irrigated grain sorghum. Therefore, plant population needed for maximum grain sorghum yields varies depending upon available moisture (16, 29, 50, 55, 63).

In Australia, Fischer and Wilson (25) studied the effect of plant density on grain sorghum grown at 14,352; 143,520; and 645,836 plants/ha. They obtained a high grain yield of 14,250 kg/ha at 645,836 plants/ha. They indicated that this was as a result of higher dry matter production at the highest plant population.

The effect of plant population on yield components of grain sorghum has shown that high plant populations decrease panicles per plant (32, 64), head size, and seed weight per plant (10). Research has shown that high plant populations have the advantage of reducing the growth of weeds (64, 77).

Nitrogen Fertilizer

Arnon (6) indicated that in regions with summer rainfall, the amount of seasonal precipitation affects the response of dry-land sorghum to fertilizers. Maximum yields were obtained with nitrogen rates of 55 and 100 kg/ha when the annual total precipitation was 393 and 572 mm respectively.

In Oklahoma (70), a five-year grain sorghum fertility study has shown that under dry-land conditions rates of 22 to 44 kg/ha (20 to 40 lb/acre) of nitrogen fertilizer produced economic returns. In New Mexico (42) rates over 112 kg/ha (100 lb/acre) were found to be most profitable under irrigation. According to House (33, P.3) response of grain sorghum to fertilizer varies for different varieties, in that "varieties developed in low fertility and drought situations produce 6 to 10 kg grain per kg applied N, whereas varieties responsive to high levels of fertility produce 20 to 40 kg grain per kg applied N."

In India (60), field trials were conducted at nine locations to compare methods of nitrogen application on grain sorghum. The results of this study indicated that there was no significant difference between single and split application at any location for the 40 kg N/ha rate. At all locations single application was better than split for the 80 kg/ha rate. Nelson (50) found that nitrogen fertilizer at rates of 90 and 180 kg/ha (80 and 160 lb/acre) increase the yield of grain sorghum 0.41 and 0.53 kg/ha (31.4 and 40.7 bu/acre) respectively, over no nitrogen, while heavier application 269 kg/ha (240 lb/acre) gave no further increase in yield.

Interrelationships Among Agronomic Variables Due to Row Spacings, Plant Populations, and Nitrogen Level

Under limited moisture high plant population combined with narrow row spacing decreases grain yield (12, 16). Under irrigation both row spacings and plant population are of minor importance (50, 54). Porter et al. (55) in a three year study at Bushland, Texas showed that yields were significantly greater in narrow rows, and the difference in grain yield among row spacings was not associated with difference in plant population. Grimes and Musick (29) at Kansas conducted a two year test to evaluate the effect of 4 row widths, 18, 36, 54 and 72 cm (7, 14, 21, and 28 inch) all with populations of 140,000; 280,000; 560,000 plants/ha (56,000; 112,000; and 224,000 plants/acre). There was no significant interaction of row width with population.

Nelson (50) at Washington, and Grimes and Musick (29) in Kansas found the interaction of row spacing and nitrogen level to be non-significant. In Texas, at a satisfactory population 56 kg N/ha (50 lb N/acre) was sufficient for maximum yield, but with increasing moisture grain yields increased with 112 kg N/ha (110 lb N/acre) (75). It has been reported that both soil fertility and plant density affect the number of grains per panicle, or panicle weight (55, 58, 66). But neither plant population nor nitrogen level had a significant influence on plant height (55). Blum (9) noted that high soil fertility promoted a longer panicle at both high and low plant populations. His study indicated that the weight per grain was not affected by plant population as much as other components. Wahua and Miller (73) noted a slight increase in weight per seed as population increased.

Wanjari and Patil (74) studied the relationship of plant height and panicle length to grain yield in sorghum. They stated that plant height had a sizable direct effect on grain yield, and panicle length was significantly correlated with grain production. Burnside and Wicks (17) stated that sorghum yields were positively correlated with heads per plant, seed weight per head, and weight per 1000 seeds.

CHAPTER III

METHODS AND MATERIALS

The effect of between- and within-row spacing, and rates of nitrogen fertilizer on production of grain sorghum under reduced tillage systems were studied. The experiment was conducted on a Teller loam soil at the Agronomy Research Station, Perkins, Oklahoma.

A seedbed was prepared in a manner similar to conventional tillage. A grain sorghum hybrid 'Acco BR-Y93' was planted on 8 June 1981 and 9 June 1982 at a rate of 8 kg/ha with a 10-inch John Deere drill. day after planting propazine [2-chloro-4, 6-bis (isopropylamina)-5-triazine] and propachlor [2-chloro-N-isopropylacetanilide] were applied at rates of 1.12 and 1.62 kg/ha active ingredient, respectively.

Experimental factors were 3 between-row-spacings (25, 50, and 75 cm), 3 within-row-spacings (10, 15, and 30 cm), and 3 levels of nitrogen fertilizer (0, 90, and 180 kg/ha). The experimental design was a randomized complete block with 3 relications. Each replication consisted of 27 treatments (Table I). The plot size for each treatment was 5 x 12 m. In both years, the same plots were used on 2 of the 3 replications.

As soon as emergence was complete the desired between-and-within-row spacings were established by pulling the unwanted plants. The intended plant populations from the combination of between-row and within-row plant spacing were 400,000; 266,667; 200,000; 133,333;

TABLE I

EXPERIMENTAL FACTORS

Between Row Spacing (cm)	Within Row Spacing (cm)	Plants Per Hectare (Plants/ha)	Nitrogen Level (kg/ha)
25	10	400,000	0 90 180
	15	266,667	0 90 180
	30	133,333	0 90 180
50	10	200,000	0 90 180
	15	133,333	0 90 180
	30	66,666	0 90 180
75	10	133,333	0 90 180
	15	88,889	0 90 180
	30	44,444	0 90 180

88,889; 66,667; and 44,444 plants per hectare (Table I). After thinning nitrogen fertilizer was applied over the plots according to the treatment, using ammonium nitrate (NH_4NO_3) as the carrier wih a Barber Fertilizer Spreader in 1981, and with a Cyclone Speed Spreader in 1982. The soil test result showed that application of potassium and phosphorus was not needed.

Bloom notes were taken, and days to mid-bloom were computed using the following formula:

$$\text{Days to mid-bloom} = \frac{\left(\begin{array}{c}\text{Number of days from}\\ \text{date of planting to}\\ \text{date of first bloom}\end{array}\right) + \left(\begin{array}{c}\text{Number of days from}\\ \text{date of planting to}\\ \text{date of all-bloom}\end{array}\right)}{2}$$

Prior to harvest, from each plot 6 m of a middle row were marked for data collection. Ten random plants were used to obtain number of tillers per plant, plant height, panicle length (length from the base of the ear to the tip), peduncle exsertion (length from the ligule of the flag leaf to the base of the panicle). Means of these variables were recorded. Plots were harvested using hand pruning shears, at the same time the total number of plants and those which lodged were recorded. In the 6 m plot, the average number of plants over the 3 replications differed from the intended value in 1 to 2 plants in 1981, and in 1 to 3 plants in 1982. A deviation this small is probably of no real agronomic importance. A small vogel-type plant-head thresher was used to thresh. A dial type spring scale was used to obtain plot head and grain weight. A Toledo scale was used to obtain test weight. The grain weight was divided by the plot head weight in order to obtain the threshing percentage. Grain yield was obtained by multiplying grain weight by a factor to get kg/ha. The factors were, 6667, 3333, and 2222 for 25, 50, and 75 cm BRS respectively. In the laboratory, portein percentage was obtained by the Udy dye binding procedure (34). Mettler electronic balance was used to weigh 100 kernels in grams. All measurements except the 100-kernel weight were made using English units.

During the analysis English units were converted to International System of Units (SI units).

CHAPTER IV

RESULTS AND DISCUSSION

The analyses of variance for grain yield, protein percentage, 100-kernel weight, test weight, and other agronomic variables are presented in Tables II and III for 1981 and 1982, respectively. Table II shows that a significant difference exists due to between-row-spacing (BRS) for all variables except protein percentage, and 100-kernel weight. The only significant effect due to within-row-spacing (WRS) was for plant height. The effect of nitrogen (N) was significant for grain yield, protein percentage, test weight, plant height, peduncle exsertion, loding and threshing percent. The interactions which showed significant effects were BRS x WRS and BRS x N for days to mid-bloom and protein percentage, respectively in 1981.

In 1982, significant effects were found due to BRS on test weight, days to mid-bloom, plant height, panicle length, loding and threshing percent (Table III). Within-row-spacing had a significant effect on nubmer of tillers, loding and threshing percent. Number of tillers were significantly different due to the BRS x WRS interaction. Nitrogen fertilizer has shown a significant effect on all variables except number of tillers. Significant BRS x N interactions were found for days to mid-bloom, plant height, and panicle length. The only effect of WRS x N interaction was on test weight.

TABLE II

MEAN SQUARES FOR THE AGRONOMIC VARIABLES, FROM THE ANALYSIS OF VARIANCE (1981)

Source of Variation	d f	Grain Yield (kg/ha)	Protein Percentage	100-Kernel Weight (g)	Test Weight (kg/L)	Days to mid-bloom	Number of Tillers	Plant Height (cm)	Panicle Length (cm)	Peduncle Exsertion (cm)	Lodging Percent	Threshing Percent
BRS	2	10401245.78**	1.90	0.09	0.0212**	65.35**	2.38**	252.65**	69.65**	262.84**	4435.35**	282.41**
WRS	2	211132.89	0.03	0.05	0.0001	3.20	0.26	65.07*	4.49	12.38	328.68	97.31
BRS x WRS	4	1064211.00	2.66	0.05	.0015	11.81**	0.10	33.89	7.97	2.13	776.62	12.44
N	2	3152197.05**	120.36**	0.07	.0289**	0.61	0.04	98.53*	1.27	20.67*	5312.24**	164.92*
BRS x N	4	1170281.35	8.49**	0.04	.0044	1.11	0.04	11.07	0.54	5.23	978.27	74.51
WRS x N	4	1203502.79	0.90	0.04	.0016	0.90	0.10	7.37	4.69	9.27	364.38	49.54
BRS x WRS x N	8	388731.32	2.21	0.03	.0012	1.68	0.09	9.52	3.50	6.71	596.42	94.44
Error	52	860146.24	1.50	0.05	.0024	2.39	0.11	21.20	4.73	5.53	702.87	49.52

* Significant at the 0.05 level of probability
** Significant at the 0.01 level of probability

TABLE III

MEAN SQUARES FOR THE AGRONOMIC VARIABLES, FROM THE ANALYSIS OF VARIANCE (1982)

Source of Variation	d f	Grain Yield (kg/ha)	Protein Percentage	100-Kernel Weight (g)	Test Weight (kg/L)	Days to mid-bloom	Number of Tillers	Plant Height (cm)	Panicle Length (cm)	Peduncle Exsertion (cm)	Lodging Percent	Threshing Percent
BRS	2	122119.73	0.14	0.13	0.0033*	64.53*	0.01	385.18*	178.10*	18.16	2904.09*	420.60**
WRS	2	119907.20	0.72	0.13	0.0013	2.68	0.03**	19.36	8.20	13.62	1662.46*	402.20**
BRS x WRS	4	246899.69	1.85	0.11	0.0005	5.74	0.02*	35.01	3.78	11.35	276.36	80.89
N	2	2812060.71**	381.99**	6.87**	0.0139**	414.27**	0.01	1638.95**	250.02**	173.72**	7624.38**	726.88**
BRS x N	4	678719.19	2.26	0.11	.0005	26.77**	0.01	253.17**	26.60**	2.99	876.57	86.66
WRS x N	4	139775.82	2.80	0.07	.0023**	3.75	0.01	78.38	1.87	3.82	1046.27	49.26
BRS x WRS x N	8	522620.81	0.42	0.04	.0007	4.84	0.01	40.26	7.85	6.21	390.85	65.78
Error	52	458396.19	1.35	0.06	.0009	5.06	0.01	36.88	5.02	5.60	437.54	68.70

* Significant at the 0.05 level of probability

* * Significant at the 0.01 level of probability

Grain Yield

In 1981, the highest yield was obtained from the 25 cm BRS (Table XIII, Appendix). The 75 cm BRS yielded about 600 and 1200 kg/ha less than the 50 and 25 cm, respectively. This kind of yield advantage due to the narrow row spacing could be because of more efficient use of moisture, nutrients, and solar energy. Other researchers have also found significant differences in grain yield among different row spacings (50, 55). Table XIV (Appendix) shows that in 1981 N-rate had a significant effect on grain yield. There was a significant difference in yield between 90 and 180, and between 0 and 180 kg N/ha. The decrease in yield at 180 kg N/ha could be due to excess N which accumulated from the previous years legume crop, peanuts, <u>Arachis hypogaea</u>. It is well documented that an excess of fertilizer decreases yield (50, 68). The data for the effect of plant population on grain yield are given on Table XV (Appendix). This table shows that the lowest yield was obtained from 44,000 plants/ha. The 267,000 plants/ha and the 133,000 plants/ha (at 25 cm BRS and 30 cm WRS) gave the highest yield.

In 1982 N-rate was the only factor which significantly affected yield (Table III). The data (Table XVI Appendix) show that the average yield was 2611, 3202, and 3131 kg/ha for 0, 90, and 180 kg N/ha respectively. Differences among 0 and 90, and 0 and 180 kg N/ha were significant, indicating the increase in yield was due to N fertilizer. The difference between 90 and 180 N-rate was not significant. As the data in Table XVII (Appendix) show, in 1982 the yield from the highest population (400,000 plants/ha) was the lowest of all, while the population with 67,000 plants/ha gave the highest yield.

Plant populations of 133,000 were obtained at 25 cm BRS by 30 cm WRS, at 50 cm BRS by 15 cm WRS, and at 75 cm BRS by 10 cm WRS (Table I). Of these three, the 25 cm BRS by 30 cm WRS gave the best yield in both years (Tables XV and XVII, Appendix). This follows Donald's and Willey's principle of square grid and rectangularity (23, 76).

In both years yield was significantly influenced by N level, but the effect was somewhat contradictory. In 1981 application of N decreased the yield; whereas, in 1982 there was a yield advantage due to N application. Between-row-spacing showed a significant effect on yield in 1981, but not in 1982 (Tables XIII and XVIII). This indicates that the narrow row was superior in yield under abundant moisture.

Protein Percentage

In 1981, protein percentage was significantly influenced by N, and BRS x N interaction (Table II). The lowest protein percentage was obtained from the lowest N level (Table XIV, Appendix). The significant BRS x N interaction can be explained by examining the data in Table IV. At the 0 kg N/ha, there was a significant increase in protein percentage as the BRS increased from 25 cm to 50 cm, indicating that more N was available to individual plants at the wider rows than at the narrow rows. At the 90 kg N/ha the increase in protein percentage as BRS increased was not significant. At the 180 kg N/ha, there was a significant increase in protein percentage as BRS decreased from the 50 to 25 cm, indicating that the added N was more efficiently used at the 25 cm compared to other BRS. At the 25 cm BRS there was a significant increase of this variable as N increased from 0 to 90, and from 90 to 180 kg/ha. At the 50 and 75 cm, there was a significant increase in

TABLE IV

AVERAGE EFFECT OF BETWEEN ROW SPACING AND NITROGEN ON PROTEIN PERCENTAGE (1981)

Between Row Spacing (cm)	Nitrogen (kg/ha) 0	90	180
	---------Protein Percentage----------		
25	7.78	11.82	14.09
50	9.26	11.84	12.19
75	9.83	12.17	12.82

LSD 0.05 = 1.16

0.01 = 1.54

protein percentage as N increased from 0 to 90 kg/ha, while the increase in this variable was not significant as N increased from 90 to 180 kg/ha. The effect of plant population on this variable was not significant in 1981 (Table XV, Appendix).

In 1982, N-rate was the only factor which showed a significant effect on protein percentage (Table III). The data (Table XVI, Appendix) show significant differences between all rates of N. This kind of direct relationship between N level and protein percentage has been reported previously (50, 72). The effect of plant population on this variable was not significant in 1982 (Table XVII, Appendix).

In both years protein percentage was significantly increased due to N level. There was no significant effect on this variable due to other factors.

100-Kernel Weight

In 1981, 100-kernel weight was not significantly affected by any of the factors and/or their interaction (Table II), and by plant population (Table XV, Appendix).

In 1982, N-rate was the only factor which showed a significant effect on weight of 100-kernels (Table III). Differences among 100-kernel weight means were significant at all rates of N, and application of N significantly decreased the weight of kernels (Table XVI, Appendix). The average data of 100-kernel weight tends to be inversely related to N-rate but directly related to WRS (Table XVI and XIX, Appendix). The data in Table XVII (Appendix) shows that at the 44,000 plants/ha weight of 100 kernels was significantly higher than the 400,000; 200,000; and 133,000 (at the 25 cm BRS by 30 cm WRS, and at the 50 cm BRS by 15 cm

WRS) plants/ha.

In both years, the average data (Tables XIV and XVI, Appendix) of 100-kernel weight decreased as the N level increased; however, in 1981 the difference between means was not significant, in 1982 it was significant.

Test Weight

In 1981, test weight was significantly influenced by BRS and N (Table II). The wider rows (50 and 75 cm) produced grain of greater weight than the narrow row spacing (Table XIII, Appendix). The data in Table XIV (Appendix) show that test weight was significantly reduced by application of 90 and 180 kg N/ha indicating an inverse relation of test weight to N rate. Test weight was significantly higher at the lowest (44,000 plants/ha) plant population than at the highest (400,000 plants/ha) plant population in 1981 (Table XV, Appendix).

In 1982, BRS, N level, and the WRS x N itneraction were the factors which showed significant effects on test weight (Table III). Test weight in the narrow rows (25 cm) was significantly lower than the wider rows (Table XVIII, Appendix). Differences among test weight means were significant at all rates of N, and application of N significantly decreased test weight (Table XVI, Appendix). The significant WRS x N interaction can be explained by examining the data in Table V. At the 30 cm WRS, test weight was significantly reduced as N level increased from 0 to 90 kg/ha. At the 180 kg/ha, test weight was significantly increased as WRS increased from 10 to 15 cm. The other WRS and N are not significant. This variable was significantly higher at the lowest plant population in 1982 (Table XVII, Appendix).

TABLE V

AVERAGE EFFECT OF WITHIN ROW SPACING AND NITROGEN ON TEST WEIGHT (1982)

Within Row Spacing (cm)	Nitrogen (kg/ha)		
	0	90	180
	----------test weight (kg/L)----------		
10	0.707	0.691	0.639
15	0.705	0.689	0.669
30	0.718	0.675	0.685

LSD 0.05 = 0.028 kg/L

0.01 = 0.037 kg/L

In both years, test weight was significantly low due to the narrow rows and added N, and it was higher at the lowest plant population.

Days to Mid-bloom

In 1981, there was a significant difference due to BRS and BRS x WRS itneraction on days to mid-bloom (Table II). The data in Table XIII, (Appendix) show a significant difference between 25 and 50, and 25 and 75 cm BRS, indicating that narrow rows delay maturity. The BRS x WRS interaction can be explained by examining the data in Table VI. At the narrow rows (25 cm), days to mid-bloom significantly increased as WRS increased from 10 to 15 cm, but significantly decreased as WRS increases from 15 to 30 cm. At the 50 cm BRS, there was no significant difference between 10 and 15 cm WRS, whereas there was a significant decrease in days to mid-bloom as WRS increases from 15 to 30 cm. At the 75 cm BRS, days to mid-bloom was significantly decreased as WRS increased from 10 to 15 cm, but significantly decreased as WRS increases from 15 to 30 cm. At the 10 cm WRS the narrow rows (25 cm) significantly delay maturity. At the 15 and 30 cm WRS, there was a significant increase in days to mid-bloom as each BRS decreased. The interaction came about because of the varied maturity at WRS of 15 cm. Plant population had a significant effect on days to mid-bloom (Table XV, Appendix). At the 267,000 and the 133,000 (at 25 cm BRS by 30 cm WRS) plants/ha, maturity was delayed significantly.

In 1982, the effect of BRS, N, and BRS x N interaction were significant (Table III). Narrow rows significantly delayed maturity (Table XVIII, Appendix). Application of N enhanced early maturity (Table XVI, Appendix). The data for BRS x N interaction (Table VII) show that at

TABLE VI

AVERAGE EFFECT OF BETWEEN ROW SPACING AND WITHIN ROW SPACING ON DAYS TO MID-BLOOM (1981)

Between Row Spacing (cm)	Within Row Spacing (cm)		
	10	15	30
	--------- days to mid-bloom ----------		
25	58	61	59
50	57	57	58
75	57	56	57

LSD 0.05 = 1 day

0.01 = 2 days

TABLE VII

AVERAGE EFFECT OF BETWEEN ROW SPACING AND NITROGEN ON DAYS TO MID-BLOOM (1982)

Between Row Spacing (cm)	Nitrogen (kg/ha)		
	0	90	180
	-----------days to mid-bloom----------		
25	75	65	65
50	70	64	64
75	68	65	63

LSD 0.05 = 2 days

0.01 = 3 days

all BRS, maturity was significantly delayed at 0 kg N/ha compared to 90 kg N/ha. At the 75 cm BRS, 90 kg N/ha significantly delayed maturity compared to 180 kg N/ha. At the 0 kg N/ha, days to mid-bloom significantly decreased as all BRS increased. At the 90 and 180 kg N/ha, there was no significant effect on days to mid-bloom due to BRS. This indicates that application of N enhances maturity and the effect of N could be influenced by the rate of application and the BRS. Table XVII (Appendix) shows that the significant effects of plant population on days to mid-bloom is related to BRS. Wider rows and low plant population enhance maturity.

In both years, the narrow row spacing significantly increased days to mid-bloom. In 1981, the effect of N was not significant. In 1982, added N significantly enhanced early maturity.

Number of Tillers

Number of tillers were significantly influenced due to BRS (Table II). The significant increase of tiller number as the distance between rows increased (Table XIII, Appendix) may be due to an increase in the amount of light penetrating to the lower leaves. Light is one of the factors which has an influence on the developmetn of tillers (68). In 1981, (Table XV, Appendix) there were significantly more tillers at the lower plant populations (133,000; 89,000; 67,000; and 44,000) than at the higher populations (400,000 and 267,000).

The analysis of variance for 1982 (Table III) shows that the effect of WRS, and BRS x WRS interaction was significant on number of tillers. Significantly fewer tillers were developed at the 10 cm than at the 15 cm and 30 cm WRS (Table XIX, Appendix), indicating a decrease in number of tillers as the space between plants within-row decreases. The data for BRS x WRS interaction (Table VIII) show that the only significant increase in number of tillers was at the 75 cm BRS by 30 cm WRS. This indicates an increase in number of tillers as the space between plants increases. Significantly more tillers were developed at the lowest plant population (Table XVII, Appendix).

In both years the development of tillers was significant due to either BRS in 1981 or WRS in 1982. This indicates that the space between plants (in either direction) has an effect on number of tillers. The results of two years data indicate that as the plant population increases there is a reduction in the number of tillers.

Plant Height

Between-row-spacings, WRS, and N had a significant influence on plant height in 1981 (Table II). Plants at the 25 cm BRS were significantly taller than the 75 cm (Table XIII, Appendix). Plants at the 10 cm WRS were significantly taller than the 30 cm (Table XX, Appendix). The increase in plant height as BRS and WRS decrease could be attributed to competition for light, indicating elongation of internodes under limited light conditions (54). The data in Table XIV (Appendix) shows a significant decrease in plant height due to the 180 kg N/ha compared to other N levels. This might be due to an excess N from the previous legume crop. Table XV (Appendix) shows that plant height increases as the population increased.

In 1982, plant height was significantly influenced by BRS, N, and BRS x N interaction (Table III). There was a significant increase in plant height as the distance between rows exceeded 25 cm (Table XVIII,

TABLE VIII

AVERAGE EFFECT OF BETWEEN ROW SPACING AND WITHIN ROW SPACING ON NUMBER OF TILLERS (1982)

Between Row Spacing (cm)	Within Row Spacing (cm)		
	10	15	30
	----------Number of Tillers-----------		
25	0.00	0.00	0.02
50	0.01	0.02	0.03
75	0.00	0.00	0.14

LS 0.05 = 0.04 tillers

0.01 = 0.05 tillers

Appendix). This could be attributed to competition for moisture when rows are narrow. Application of N increased plant height significantly, indicating that N encourages vegetative growth (Table XVI, Appendix). The data for BRS x N interaction (Table IX) show that at all BRS, plant height was significantly increased due to the application of 90 kg/ha of N. There was no significant increase in plant height due to 180 kg N/ha At the 0 kg N/ha plants were significantly shorter at the 25 cm BRS. This indicates that narrow rows (25 cm) and the lowest level of N significantly reduced plant height. Plants were significantly shorter at 400,000 and 267,000 plants/ha compared to all other populations (Table XVII, Appendix).

In both years, BRS had a significant effect on height, however the results from the two years are contradictory. In 1981 plants were significantly taller at the narrow row spacing, indicating elongation of internodes under limited light conditions. In 1982 plants were significantly shorter at the narrow row spacing, indicating under limited moisture condition there might be competition for moisture at the narrow rows. Application of N significantly increased plant height in 1982. In 1981 plants were significantly shorter at the highest N level, probably because of excess N from the previous years legume crop.

Panicle Length

In 1981, the only factor which had a significant effect on panicle length was BRS (Table II). The panicles were significantly longer as the space between rows increased from 25 to 50 cm. There was no significant difference between 50 and 75 cm BRS (Table XIII, Appendix). Panicles were significantly shorter at the 400,000 and 267,000 plant/ha

TABLE IX

AVERAGE EFFECT OF BETWEEN ROW SPAING AND NITROGEN ON PLANT HEIGHT (1982)

Between Row Spacing (cm)	Nitrogen (kg/ha		
	0	90	180
	------------Plant height (cm)-------------		
25	74	97	99
50	91	98	100
75	91	99	101

LSD 0.05 = 3 cm

0.01 = 4 cm

than at most other populations in 1981 (Table XV, Appendix). The increased panicle length at the wider row and lower plant population could be due to less competition for nutrients and light.

In 1982, Panicle length was significantly influenced by BRS, N, and BRS x N interaction (Table III). Table XVIII (Appendix) shows that panicle length increased significantly with each increase in BRS. The 90 and 180 kg N/ha produced significantly longer panicles (Table XVI, Appendix), compared to the 0 kg N/ha indicating that N encourages panicle length. The data for the effect of BRS x N interaction is given in Table X. At all BRS, application of 90 kg N/ha significantly increased panicle length over the 0 kg N/ha. At the 50 cm BRS the 180 kg N/ha significantly decreased panicle length over the 0 kg N/ha. At all levels of N panicles were significantly taller as the space beween rows increased. This indicates that, in general N application and wider rows have the effect of increasing panicle length. The data in Table XVII (Appendix) show panicle length was significantly reduced at the 400,000; 267,000, and 133,000 (at 25 cm BRS by 30 cm WRS) plants/ha.

In both years BRS had a significant effect on panicle length. The panicles were longer at the wider row than at the narrow row spacing. In 1982, a significant increase in panicle length has been shown due to added N, whereas, there was no such effect in 1981.

Peduncle Exsertion

Peduncle exsertion was significantly influenced by BRS and N (Table II) in 1981. Exsertion tends to be inversely related to BRS and N (Tables XIII and XIV, Appendix). The increase in peduncle exsertion as the space between row decreases could be due to the elongation of

TABLE X

AVERAGE EFFECT OF BETWEEN ROW SPACING AND NITROGEN ON PANICLE LENGTH (1982)

Between Row Spacing (cm)	Nitrogen (kg/ha)		
	0	90	180
	--------- Panicle length (cm) -----------		
25	16	25	25
50	23	27	26
75	25	28	28

LSD 0.05 - 1 cm

0.01 = 2 cm

internodes, which occurs under limited light conditions such as narrow row spacing (64). A significant decrease in peduncle exsertion occurred at the highest nitrogen rate (Table XIV, Appendix). Exsertion was significantly reduced when the population was less than 267,000 in 1981 (Table XV, Appendix).

In 1982 N was the only factor which had a significant effect on peduncle exsertion (Table III). Average peduncle exsertion was inversely related to nitrogen rate (Table XVI, Appendix). A significant difference occurred between the plots with and without nitrogen fertilizer. The peduncles were exserted more at the 267,000 plants/ha than at all other populations in 1982 (Table XVII, Appendix).

In both years, peduncle exsertion tended to be inversely related to BRS and N. In 1981, both factors (BRS and N) had a significant effect on exsertion, whereas in the following year, the only significant effect was due to N, this could be attributed to the difference in precipitation in these years.

Lodging Percent

In 1981, this variable was significantly influenced by BRS and N (Table II). Even though fusarium wilt, Fusarium moniliforme, a stalk rot organism was accounted for lodging, more plants lodged at the 25 cm BRS and at the higher rate of N (Tables XIII and XIV, Appendix). The increase in lodging at the narrow rows could be due to the limited light condition which caused thin and weak cell walls of the stems (40). Significantly more plants lodged due to N application (Table XIV, Appendix), indicating that N produces a lush growth which leads to increased lodging (40). Significantly more plants lodged at the highest

(400,000 plants/ha) plant population than most other populations in 1981 (Table XV, Appendix).

In 1982, lodging percent was significantly influenced by BRS, WRS, and N (Table III). The data in Table XVII and XIX (Appendix) show how percent lodging significantly increased as both BRS and WRS reduced, indicating the effect of limited light competition and stress, which might be one of the causes for the susceptibility to fusarium wilt. Also in 1982, N application significantly icnreased lodging percent (Table XVI, Appendix). Significantly more plants lodged at the 400,000; 267,000; and 200,000 plants/ha, than at any other plant populations in 1982 (Table XVII, Appendix). The increase in lodging at the higher plant population could be due to plant competition stress.

In both years, more plants lodged due to the narrow row spacing, added N, and higher plant population.

Threshing Percent

In 1981, this variable was significantly influenced by BRS and N (Table II). Threshing percent was significantly higher in the wider rows (50 and 75 cm BRS) compared to the narrow rows (25 cm) (Table XIII, Appendix). The significant difference between 0 and 180, and 90 and 180 kg N/ha show that plots which received 180 kg N/ah did not thresh well (Table XIV, Appendix). At 267,000 plants/ha, this variable was significantly lower than some other plant populations in 1981 (Table XV, Appendix).

The effect of BRS, WRS and N level was significant on threshing in 1982 (Table III). As the data in Tables XVIII and XIX (Appendix) show, threshing percent increased as the BRS and WRS increased. This could be due to the increased ratio of grain weight to plot head weight at the wider row spacing. The sorghum threshed significantly better without the application of N fertilizer (Table XVI, Appendix). Threshing percent was significantly lower at the highest plant population than at most other plant populations in 1982 (Table XVII, Appendix).

In both years, the lowest thresing percent was due to the 25 cm BRS and 180 kg N/ha. This indicates that ease of threshing was due to the effect of wider rows and with lower level of N.

Agronomic Variables Interrelationship

The coefficients of correlation of the agronomic variables are presented in Tables XI and XII for 1981 and 1982, respectively.

Grain Yield

In 1981, grain yield was positively and significantly correlated with 100-kernel weight, plant height, panicle length, and threshing percent (Table XI). There was a negative and significant correlation between grain yield and days to mid-bloom, indicating that there might be unfavorable environmental condition which brought this type of correlation (it is an established fact that late maturity and high grain yield are positively correlated). In 1982, grain yield was significantly affected because of lodging (Table XII). The negative and significant correlation between grain yield and protein indicates an established fact that these two variables are inversely related. In both years, yield was positively and significantly correlated with 100-kernel weight and threshing percent, indicating that the heavier the kernel, and the higher the ratio of the grain weight to the plot head weight the higher

TABLE XI

COEFFICIENTS OF CORRELATION OF AGRONOMIC VARIABLES (1981)

	Protein Percentage	100-Kernel (g)	Test Weight (kg/L)	Days to Mid-Bloom	Number of Tillers	Plant Height (cm)	Panicle Length (cm)	Peduncle Exsertion (cm)	Lodging Percent	Threshing Percent
Grain Yield (kg/ha)	-0.161	0.492**	0.192	-0.401**	0.042	0.386**	0.346**	0.008	-0.196	0.461**
Protein Percentage		-0.186	-0.288*	0.199	0.095	-0.140	-0.042	-0.336**	0.496**	-0.010
100-Kernel Weight (g)			0.271*	-0.388**	0.293*	0.207	0.007	0.072	-0.260	0.239
Test Weight (kg/L)				-0.386**	0.126	0.357**	0.344**	0.104	-0.675**	0.169
Days to Mid-Bloom					0.031	-0.514**	-0.188	-0.287*	0.315*	-0.318*
Number of Tillers						-0.157	-0.144	-0.096	0.152	-0.206
Plant Height (cm)							0.403**	0.173	-0.108	0.159
Panicle Length (cm)								-0.489**	-0.283*	0.181
Peduncle Exsertion (cm)									-0.108	0.042
Lodging Percent										-0.263

*Significant at the 0.05 level of probability
**Significant at the 0.01 level of probability

TABLE XII

COEFFICIENTS OF CORRELATION OF AGRONOMIC VARIABLES (1982)

	Protein Percentage	100-Kernel (g)	Test Weight (kg/L)	Days to Mid-Bloom	Number of Tillers	Plant Height (cm)	Panicle Length (cm)	Peduncle Exsertion (cm)	Lodging Percent	Threshing Percent
Grain Yield (kg/ha)	-0.379**	0.444**	0.260	-0.236	-0.049	0.240	-0.038	0.094	-0.385**	0.608**
Protein Percentage		-0.460*	-0.229	-0.043	0.007	-0.061	-0.131	-0.256	0.271*	-0.297*
100-Kernel Weight (g)			0.221	0.049	0.026	0.158	-0.046	0.495**	-0.303*	0.304*
Test Weight (kg/L)				-0.170	-0.086	0.049	0.105	0.125	-0.224	0.287*
Days to Mid-Bloom					0.010	-0.631**	-0.291*	-0.139	0.035	-0.140
Number of Tillers						-0.212	-0.018	-0.161	-0.024	0.029
Plant Height (cm)							0.340**	0.342**	0.250	0.159
Panicle Length (cm)								0.051	0.042	0.105
Peduncle Exsertion (cm)									0.091	0.204
Lodging Percent										-0.166

*Significant at the 0.05 level of probability
**Significant at the 0.01 level of probability

the grain yield is.

Protein Percentage

In both years, protein percentage was positively and significantly correlated with lodging percent. This might be due to the development of small seeds. In both years protein percentage was negatively and significantly correlated with those variables which are positively correlated with grain yield, indicating the inverse relationship of protein percentage to grain yield and variables which have a direct relationship with grain yield.

100-kernel Weight

In 1981, the weight of 100 kernels was positively and significantly correlated with grain yield, test weight, and number of tillers, indicating the direct relationship of 100-kernel weight and these variables. This variable was negatively and significantly correlated with days to mid-bloom (Table XI). In 1982, grain yield, peduncle exsertion, and threshing percent were the variables which showed a positive and significant correlation with 100-kernel weight. There was a negative and significant correlation of 100-kernel weight to protein percentage and lodging percent (Table XII).

Test Weight

In 1981, test weight was positively and significantly correlated with 100-kernel weight, plant height, and panicle length; whereas it was negatively and significantly correlated with protein percentage, days to mid-bloom, and lodging percent. The negative correlation of test weight with lodging percent might be due to the occurrence of lodging before physiological maturity (Table XI). In 1982, the only variable which showed a significant correlation with test weight was threshing percent (Table XII).

Number of Tillers

In 1981, this variable was positively and significantly correlated to 100-kernel weight (Table XI) whereas in 1982, it was not significantly correlated with any of the variables (Table XII).

Plant Height

In 1981, plant height was positively and significantly correlated with grain yield, test weight, and panicle length. This agrees with a well established fact that the increase in height and yield has a direct relationship (Table XI). The correlation of plant height with days to mid-bloom was negative and significant. In 1982, there was a positive and significant correlation with panicle length and peduncle exsertion, which its correlation with days to mid-bloom was negative and significant. (Table XII).

Panicle Length

In 1981, this variable was positively and significantly correlated with grain yield, test weight, and plant height, indicating that the increase of these variables was associated with panicle length. The length of panicle was negatively and significantly correlated with peduncle exsertion and lodging percent (Table XI). In 1982 this variable was positively and significantly correlated with plant height, and negatively and significantly correlated with days to mid-bloom. In both years this variable was directly related to plant height, this might be because the plant height was measured from the base of the plant to the tip of the panicle.

Peduncle Exsertion

In 1981 this variable was negatively and significantly correlated with protein percentage, days to mid-bloom, and panicle length (Table XI). In 1982, peduncle exsertion was positively and significantly correlated with 100-kernel weight and plant height (Table XII). The positive correlation of peduncle exsertion with plant height could be attributed to the fact that both of them depend on the length of the internode.

Lodging Percent

In 1981 this variable was directly and significantly related with protein percentage and days to mid-bloom, whereas it correlation with test weight and panicle length was negative and significant (Table XI). In 1982, the correlation of this variable with grain yield and 100-kernel weight was negative and significant, indicating a well established fact that lodging of plants affect grain yield (Table XII). Also in 1982, this variable was positively and significantly correlated with protein percentage.

Threshing Percent

In 1981 there was a positive and significant correlation between this variable and grain yield. Days to mid-bloom was found to be negatively and significantly correlated with threshing percent (Table XI).

In 1982 grain yield, 100-kernel weight, and test weight showed a positive and significant correlation with threshing percent but there was a negative and a significant correlation between threshing percent and protein percentage (Table XII). As it is described in Chapter III (Methods and Materials), one of the variables used to obtain grain yield and threshing percent was grain weight, this could be (having a common variable) why these variables are directly and significantly correlated in both years.

CHAPTER V

SUMMARY AND CONCLUSIONS

A two year field experiement was conducted at the Agronomy Research Station, Perkins, Oklahoma during the crop seasons of 1981 and 1982. The main objective of this study was to determine the appropriate between-row-spacing (BRS), within-row-spacing (WRS), and N- level with a reduced tillage farming system for grain sorghum production.

The treatments were in a 3x3x3 factorial where the treatments consist of three BRS (25, 50, and 75 cm), three WRS (10, 15, and 30 cm), and three N levels (0, 90, and 180 kg/ha). The combination of these BRS and WRS gave seven plant populations, (400,000; 267,000; 200,000; 133,000; 89,000; 67,000; and 44,000 plants/ha). A randomized complete block design with three replication was used. In the laboratory, protein percentage was obtained by the Udy dye binding procedure.

Data was obtained for eleven agronomic variables, namely: grain yield, protein percentage, 100-kernel weight, test weight, days to midbloom, number of tillers per plant, plant height, panicle length, peduncle exsertion, lodging percent, and threshing percent.

In 1981, there was a significant difference due to between-row-spacing (BRS) for all variables except protein percentage, and 100-kernel weight. The only significant effect due to within-row-spacing (WRS) was for plant height. The effect of nitrogen (N) was significant for grain yield, protein percentage, test weight, plant height, peduncle exsertion, lodging and threshing percent. The interactions which showed significant effects were BRS x WRS and BRS x N for days to mid-bloom and protein percentage, respectively. Effect of plant population was significant on all variables except protein percentage, and 100-kernel weight.

In 1982 a significant effect was found due to BRS on test weight, days to mid-bloom, plant height, panicle length, lodging and threshing percent. Within-row-spacing had significant effect on number of tillers, lodging, and threshing percent. Number of tillers were significant due to BRS x WRS itneraction. Nitrogen had a significant effect on all variables, except number of tillers. There was significant BRS x N interactions for days to mid-bloom, plant height, and panicle length. The only effect of WRS x N interaction was on test weight. The effect of plant population was significant on all variables except protein percentage.

In 1981, the yield advantage of narrow rows over the wider rows could be attributed to adequate and proper distribution of moisture. In both years, yield was significantly influenced by N level. In 1981 the highest fertilizer rate decreased the yield. This might have been due to N, which was accumulated from the previous years legume crop. In 1982 application of N significantly increased yield. In general, yields were higher at the 133,000 and 67,000 plants/ha in 1981 and in 1982, respectively.

Protein percent was significantly increased due to the application of nitrogen in both years. In 1982, N application significantly decreased the weight of 100-kernel. Test weight was significantly lower due to narrow row and nitrogen application during both years. Days to mid-bloom were significantly increased due to BRS in both years, indicating that narrow rows delay maturity. In 1982, application of nitrogen significantly enhanced early maturity.

Significantly more tillers were developed as BRS and WRS increased in 1981 and 1982, respectively. This indicates the development of tillers depended on the space between plants in either direction.

In 1981, plants were significantly taller in the 25 cm BRS and 10 cm WRS, indicating elongation of internodes under limited light condition. But in 1982 plants were taller in the wider rows. Application of N signficantly increased plant height in 1982, but in 1981 plants were significantly shorter at the highest fertilizer level, probably because of excess N from the previous legume crop.

In both years, more plants lodged due to the narrow row spacing and added N.

The lowest threshing percent, in both years was due to the 25 cm BRS, and the 180 kg N/ha, indicating ease of threshing due to the effect of wider rows and lower rate of N.

In both years, there was a positive and significant correlation between grain yield and 100-kernel weight, yield and threshing percent, protein percentage, and lodging percent, plant height, and panicle length; whereas a negative and significant correlation occurred between days to mid-bloom and plant height.

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APPENDIX

TABLE XIII

AVERAGE EFFECT OF BRS ON AGRONOMIC VARIABLES (1981)

	Between Row Spacing (cm)			LSD	
Variables	25	50	75	0.05	0.01
Grain yield (kg/ha)	4890.31	4250.56	3649.17	506.45	675.06
Protein percent	11.23	11.10	11.61	0.67	0.89
100-kernel weight (gm)	1.83	1.82	1.92	0.12	0.16
Test weight (kg/L)	0.66	0.70	0.72	0.02	0.03
Days to mid-bloom	59.44	56.89	56.63	0.84	1.13
Number of tilelrs	0.10	0.43	0.69	0.18	0.24
Plant height (cm)	110.07	105.55	104.23	2.51	3.35
Panicle length (cm)	23.69	25.96	26.79	1.19	1.58
Peduncle exsertion (cm)	9.99	5.56	3.97	1.25	1.67
Lodging percent	53.30	33.70	29.19	14.48	19.30
Threshing percent	62.17	68.49	66.52	3.84	5.12

TABLE XIV

AVERAGE EFFECT OF N-RATE ON AGRONOMIC VARIABLES (1981)

	Nitrogen Rate kg/ha			LSD	
Variables	0	90	180	0.05	0.01
Grain yield (kg/ha	4459.70	4461.53	3868.80	506.45	675.06
Protein Percentage	8.96	11.94	13.03	0.67	0.89
100-kernel weight (gm)	1.91	1.84	1.81	0.12	0.16
Test weight (kg/L)	0.73	0.69	0.67	0.02	0.03
Days to mid-bloom	57.74	57.48	57.74	0.84	1.13
Number of tillers	0.44	0.37	0.41	0.18	0.24
Plant height (cm)	107.90	107.53	104.42	2.51	3.35
Panicle length (cm)	25.26	25.48	25.69	1.19	1.58
Peduncle exsertion (cm)	7.38	6.50	5.64	1.25	1.67
Lodging percent	22.81	41.30	44.07	14.48	19.30
Threshing percent	67.25	67.05	62.88	3.84	5.12

TABLE XV

AVERAGE EFFECT OF PLANT POPULATION ON AGRONOMIC VARIABLES (1981)

Plants Per Hectare (1000)	Between Row Spacing (cm)	Within Row Spacing (cm)	Grain Yield (kg/ha)	Protein Percentage	100-Kernel Weight (g)	Test Weight (kg/L)	Days to Mid-Bloom	Number of Tillers	Plant Height (cm)	Panicle Length (cm)	Peduncle Exsertion (cm)	Lodging Percent	Threshing Percent
400	25	10	4619	11.43	1.76	0.65	58	0.11	111	24	10	69	63
267	25	15	5010	11.63	1.78	0.66	61	0.04	108	22	11	45	59
200	50	10	4603	10.81	1.89	0.70	57	0.46	108	25	6	32	69
133	25	30	5042	10.62	1.94	0.68	59	0.14	111	25	9	45	65
133	50	15	3985	10.74	1.74	0.70	57	0.26	106	27	5	36	67
133	75	10	3772	11.58	1.91	0.73	57	0.53	106	27	4	26	65
89	75	15	3891	11.66	1.92	0.73	56	0.70	106	27	5	27	65
67	50	30	4164	11.73	1.82	0.70	57	0.57	104	26	5	33	69
44	75	30	3284	11.59	1.93	0.71	57	0.84	101	27	3	33	69
	LSD	0.05	877	NS	NS	0.04	1	0.31	4	2	2	25	6

TABLE XVI

AVERAGE EFFECT OF N-RATE ON AGRONOMIC VARIABLES (1982)

	Nitrogen Rate kg/ha			LSD	
Variables	0	90	180	0.05	0.01
Grain yield (kg/ha)	2611.09	3201.96	3131.47	369.74	492.81
Protein Percentage	6.89	12.49	14.05	0.63	0.85
100-kernel weight (gm)	2.72	1.93	1.78	0.14	0.18
Test weight (kg/L)	0.710	0.685	0.664	0.016	0.021
Days to mid-bloom	71.22	64.93	64.04	1.23	1.64
Number of tilelrs	0.013	0.041	0.012	0.038	0.052
Plant height (cm)	85.61	98.12	99.91	3.32	4.42
Panicle length (cm)	21.07	26.43	26.25	1.22	1.63
Peduncle exsertion (cm)	7.71	3.57	3.10	1.29	1.72
Lodging Percent	0.59	25.41	32.63	11.42	15.23
Threshing Percent	69.11	61.04	59.42	4.53	6.03

TABLE XVII

AVERAGE EFFECT OF PLANT POPULATION ON AGRONOMIC VARIABLES (1982)

Plants Per Hectare (1000)	Between Row Spacing (cm)	Within Row Spacing (cm)	Grain Yield (kg/ha)	Protein Percentage	100-Kernel Weight (g)	Test Weight (kg/L)	Days to Mid-Bloom	Number of Tillers	Plant Height (cm)	Panicle Length (cm)	Peduncle Exsertion (cm)	Lodging Percent	Threshing Percent
400	25	10	2602	11.76	2.00	0.66	68	0.00	92	21	5	40	53
267	25	15	2928	10.70	2.26	0.68	68	0.00	90	20	8	34	60
200	50	10	2879	11.26	2.02	0.69	67	0.01	97	25	5	29	59
133	25	30	3188	10.73	2.06	0.69	69	0.02	88	23	5	17	67
133	50	15	2814	11.43	2.07	0.69	66	0.02	98	25	5	17	61
133	75	10	2850	10.97	2.18	0.69	66	0.00	97	26	5	12	67
89	75	15	3165	11.18	2.14	0.70	66	0.00	96	27	4	8	67
67	50	30	3318	10.88	2.21	0.69	66	0.03	94	25	3	10	67
44	75	30	3089	11.41	2.34	0.70	64	0.14	99	28	4	7	68
	LSD	0.05	641	NS	0.23	0.03	2	0.07	6	2	2	20	8

TABLE XVIII

AVERAGE EFFECT OF BRS ON AGRONOMIC VARIABLES (1982)

	Between Row Spacing (cm)			LSD	
Variables	25	50	75	0.05	0.01
Grain yield (kg/ha)	2905.99	3003.58	3034.95	369.72	492.81
Protein Percentage	11.06	11.19	11.19	0.63	0.85
100-kernel weight (gm)	2.10	2.10	2.22	0.14	0.18
Test weight (kg/L)	0.675	0.688	0.697	0.016	0.021
Days to mid-bloom	68.44	66.30	65.44	1.23	1.64
Number of tillers	0.012	0.021	0.053	0.038	0.052
Plant height (cm)	90.22	96.24	97.18	3.32	4.42
Panicle length (cm)	21.83	25.02	26.91	1.22	1.63
Peduncle exsertion (cm)	5.74	4.42	4.23	1.29	1.72
Threshing percent	59.94	62.05	67.58	4.53	6.03

TABLE XIX

AVERAGE EFFECT OF WRS ON AGRONOMIC VARIABLES (1982)

	Within Row Spacing (cm)			LSD	
Variables	10	15	30	0.05	0.01
Grain yield (kg/ha)	2777.32	2968.84	3198.37	369.72	492.81
Protein Percentage	11.33	11.10	11.01	0.63	0.85
100-kernel weight (gm)	2.07	2.16	2.20	0.14	0.18
Test weight (kg/L)	0.679	0.688	0.693	0.016	0.021
Days to mid-bloom	66.96	66.85	66.37	1.23	1.64
Number of tillers	0.003	0.007	0.067	0.038	0.052
Plant height (cm)	95.39	94.54	93.70	3.32	4.42
Panicle length (cm)	24.18	24.37	25.21	1.22	1.63
Peduncle exsertion (cm)	4.89	5.46	4.05	1.29	1.72
Lodging percent	27.11	20.07	11.44	11.42	15.23
Threshing percent	59.68	62.57	67.32	4.53	6.03

TABLE XX

AVERAGE EFFECT OF WRS ON AGRONOMIC VARIABLES (1981)

	Within Row Spacing (cm)			LSD	
Variables	10	15	30	0.05	0.01
Grain yield (kg/ha)	4331.40	4295.24	4163.39	506.45	675.06
Protein Percentage	11.27	11.34	11.31	0.67	0.89
100-kernel weight (gm)	1.85	1.81	1.90	0.12	0.16
Test weight (kg/L)	0.69	0.70	0.69	0.02	0.03
Days to mid-bloom	57.37	58.04	57.56	0.84	1.13
Number of tillers	0.37	0.33	0.51	0.18	0.24
Plant height (cm)	108.19	106.59	105.08	2.51	3.35
Panicle length (cm)	25.30	25.19	25.95	1.19	1.58
Peduncle exsertion (cm)	6.69	7.07	5.76	1.25	1.67
Lodging Percent	42.74	36.41	37.04	14.48	19.30
Threshing Percent	65.64	63.87	67.67	3.84	5.12

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