

**INCREASING THE PRODUCTION OF GRAIN SORGHUM
IN ELLSWORTH COUNTY
BY A UNIQUE ROTATION SYSTEM**

by P235

VIRGIL P. CARLSON

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Approved by:


Major Professor

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INTRODUCTION

Wheat, a Historical Grain Crop

The crops produced in this area are largely determined by their dependability of production and economic advantage. Wheat has been the major grain crop of Ellsworth County for many years. It has maintained this position in the past primarily because of its dependability and economic advantage. Wheat also provides somewhat more protection against soil erosion on the sloping fields of Ellsworth County than row crop production of sorghum.

Its economic advantage in the past has been associated with its importance as a major energy food for people of the United States and parts of the world. As the energy requirements of people in the United States have decreased, and our exports to foreign countries have decreased, the demand for wheat also has decreased. This has resulted in a substantial decrease in the price of wheat. The current and foreseeable price is approximately the same as feed grains.

Although wheat is well adapted to the climatic and soil conditions of Kansas, the increase in yields has not increased as in other states and so, has lost its competitive position.

Crosses and selections of dwarf wheats developed from Japanese wheat have produced tremendous increases in yields in some other states and areas of the world. One variety, Gaines, holds a record yield of 216 bushels an acre in the state of Washington. Other dwarf varieties in the corn belt and southern states are yielding from 90 to 100 bushels an acre. Kansas has bred the dwarfing trait into a number of wheats but has not yet found one that will out yield our present varieties.

The yield of wheat, in Ellsworth County, for the past three years, has

averaged 25.4 bushels per acre. The yields for each year follow:

1967 - 23.0 bu., 1968 - 24.2 bu., 1969 - 29.0 bu.^{1/}

Therefore, wheat farmers are now faced with a very serious cost-price squeeze, as costs of production increase, the price of wheat is low, and the yield of wheat has not kept pace with other areas and with other crops.

Grain Sorghum, a Replacement Crop

Wheat farmers are looking for more profitable crops to grow in place of wheat. One crop that shows great promise is grain sorghum. Its dependability is not as great as wheat, as it grows during the summer months and can suffer from lack of moisture during extended periods of hot and dry conditions. However, its average yield, over a period of years, is considerably better than wheat. The yield of grain sorghum, in Ellsworth County, for the past three years, has averaged 38.3 bushels per acre. The yield, being quite variable, is as indicated by the following yearly yields: 1967 - 29 bu., 1968 - 32 bu., 1969 - 54 bu.^{1/}

Development of hybrid grain sorghum has increased yields to give it a competitive advantage over wheat. Highest average yield of grain sorghum, in Kansas history, before hybrids, was 23 bushels an acre in 1950. Each of the last four years, the state average has been at least 46 bushels per acre, according to Brandner (1969).

The demand for grain sorghum as a feed grain has continued to increase, in Ellsworth County, and in Kansas. The increase in livestock feeding, in the county, and the rapid expansion of commercial feedlots in adjacent

^{1/}The 1969 yield is a preliminary estimate and may be revised in the annual statistical bulletin prepared by the Kansas Crop and Livestock Reporting Service.

counties, should maintain the demand for grain sorghums at an increasing level. Therefore, the price outlook is more favorable for grain sorghum than for wheat.

In spite of the apparent economic advantage of grain sorghum over wheat, an increased production of grain sorghum has not happened in Ellsworth County.

As compared to wheat, Ellsworth County farmers have actually decreased grain sorghum acreage since 1960. (Table 1)

Table 1. Comparison of Wheat and Sorghum Production in Ellsworth County^{1/}

Year	Harvested Acres		
	All Sorghum	Grain Sorghum	Wheat
1960	34,000	20,000	110,000
1968	18,400	8,000	117,000

^{1/}Farm Facts 1960-61 and 1968-69. Kansas State Board of Agriculture

Factors that Resist Change

Why are Ellsworth County farmers not changing from wheat to grain sorghum?

The writer suggests the following reasons:

1. Wheat has been the traditional and dependable cash grain crop. Many landlords require their renters to plant the full wheat allotment.
2. Ellsworth County has a limited number of feed-grain consuming live-stock programs. The major livestock programs are beef cow-herds and backgrounding programs which utilize the large acreage of native grasses and harvested roughages. Therefore, many individual farmers have limited need for a feed-grain crop.
3. Methods of grain sorghum production are changing more rapidly than

with wheat. Therefore, some farmers would prefer to produce wheat, than to adopt the newer methods of weed control, fertilization, tillage, planting, insect control, and harvesting that has developed in the production of grain sorghum.

4. The production of grain sorghum under the conventional method of clean cultivation, results in more soil erosion on sloping land as compared to wheat production.
5. Class III land that has been terraced is usually divided into many small fields of varying shapes. These fields are difficult to farm with the clean cultivation method of row crop production.
6. Many Ellsworth County farmers rent land at different locations from different landlords. Many of these farms have no feed-grain base under the government production control program. If the farm has a small feed-grain base, it has been more practical to divert the entire base or substitute wheat for feed-grain rather than transport machinery to produce a small acreage of grain sorghum.
7. It is difficult for many growers to realize that the world supply of wheat could change so rapidly from a call to produce more wheat for the world's starving to a price depressing world surplus in a period of only two years.

Under the present price and yield relationships between wheat and grain sorghum, it is quite obvious that grain sorghum production should increase very sharply and wheat production decline. The purpose of this report is, therefore, to review one of the latest methods of grain sorghum production which should bring higher net income per crop acre and also be a base for expanding livestock programs.

DEVELOPMENT OF UNIQUE ROTATION SYSTEM

The wheat, sorghum, fallow rotation is a cropping sequence that has been followed for a number of years in the Great Plains area. The principal feature of the rotation is that the land is kept free of growing crops and weeds for many months between crops to allow for storage of soil moisture. Inadequate moisture is generally the most limiting factor in crop production in this area.

As the area is subject to violent rain and wind storms, precautions are necessary to preserve crop residues on the soil surface during the fallow period. This is desirable so as to reduce wind and water erosion, and increase the intake and infiltration of water into the soil profile.

Development of the large V-blade undercutter and rod-weed chisel implements provides the best tools to control growing vegetation and still preserve the protective cover of crop residues.

Control of the moisture robbing broadleaf and grassy weeds often requires six to eight cultivations during the fallow period. Each tillage operation incorporates and reduces the effectiveness of the stubble mulch.

Early Research Work

When modern herbicides were developed, several research workers began experimenting with chemical fallow. This type of work was initiated in 1958, at the Fort Hays Branch, Kansas Agricultural Experiment Station, Hays, Kansas. The study was to determine the long time effect of replacing part, or in some cases, nearly all of the mechanical cultivations in a wheat, sorghum, fallow rotation, with herbicide treatments. Factors being studied included weed control, moisture storage, yield of crops, and soil tilth as affected by minimum tillage.

The initial work during 1961, and 1962, was a comparison between conventional stubble mulch tillage and application of 3 pounds of 2-chloro-4-isopropylamino-6-ethylamino-s-triazine (atrazine) and 1 pound of butoxyethanial ester of 2, 4-dichlorophenoxyacetic acid (2, 4-D) in 20 gallons of water per acre, to wheat stubble in July. No tillage operations were performed at any time, except the planting operation by a disc-type furrow-opener planter.

The no-tillage chemical treatment was not consistent in satisfactory weed control.

There was a very slight advantage for the chemical treated plots in the percent of soil moisture in the soil profile at the end of the growing season; a period of about 3 1/2 months.

The chemical treated plots had better soil tilth and the sorghum stands were rated satisfactory, while the stands were rated poor on the cultivated plots. This was in the dry spring of 1962.

Modified System

After the no-tillage concept did not give consistently grassy weed control, the research studies were changed in 1964. The studies were to determine how herbicides applied to wheat stubble could best be supplemented but still retain these basic advantages: (a) preserve crop residues to reduce erosion hazards; (b) control unwanted vegetation during the fallow period between harvesting wheat and planting sorghum; (c) provide a satisfactory sorghum seedbed; (d) give acceptable weed control in the crop; and (e) minimize herbicides residues in the soil. A brief review of the Hays research project from 1965-1968 follows.

Materials and Methods

The soil in the experimental area was a silty clay loam topsoil and a clay

loam subsoil. The organic matter was approximately 1.7% and the topsoil had a pH of 7.5. The soil was classified as a Harney silty clay loam.

The plots were repeated three times in a randomized block design each year and were of sufficient size so that all operations could be done with normal size field equipment. Ten systems were started but only five systems were completed all four years (1965, 1966, 1967, and 1968). The other systems were dropped or modified when it became apparent they were not meeting the objectives of the study. Two other systems were added in 1966, and continued for the next 3 years. The systems are described in Table 2.

Table 2. Systems used in comparing conventional tillage, no tillage, and minimum tillage for sorghum production, 1965-68.

System	Operation		
	Year of wheat harvest	Sorghum year	
		Preplanting or immediately after planting	After emergence of crop
1.	Ordinary	Ordinary tillage	Cultivation
2.	3 lb./A atrazine	None	None ^a
3.	3 lb./A atrazine, then undercut immediately	None	One cultivation, if needed
4.	3 lb./A atrazine, then undercut immediately	One tillage	None
5.	2 lb./A atrazine, then undercut immediately	1 lb./A atrazine after planting	One cultivation, if needed
6.	Undercut immediately, then 3 lb./A atrazine	One tillage	None
7.	2 lb./A atrazine, then undercut immediately	One tillage, 1 lb./A atrazine after planting	None

^a Received one cultivation after emergence of the crop in 1968

The first tillage and atrazine applications were done soon after wheat harvest, varying from June 26 to August 8. Frequent rain and wet soil in 1967, delayed wheat harvest about one month. All tillage operations during the summer

and fall of the first year of the rotation were done with a 5 1/2' sweep-type implement. The blade was operated 4 to 6 inches below the soil surface, which does not turn or mix the soil to any appreciable extent. Tillage in the spring, prior to planting sorghum, was with a duckfoot cultivator or mulch treader. Sorghum planting date was determined by weather and soil conditions in May and early June. The crop was seeded in 40-inch rows with either a surface planter or a disk furrow-opener planter at the same seeding rate. Sorghum stands were determined by counting emerged plants in 400 ft. of row. A conventional row crop cultivator was used for mechanical weed control. Plots were trimmed to eliminate possible border effect and grain yield was determined by harvesting the entire remaining plot area. Visual estimates of weed infestations were recorded each time an operation was performed.

Results and Discussion

Weed control: The systems which combined 3 lb./A atrazine and one undercutting tillage operation after wheat harvest, combined with one tillage before planting sorghum, controlled weeds during the fallow period and in the growing crop. If grassy weeds were growing in the wheat stubble when atrazine was applied, one tillage was needed to insure control. Weed control did not differ significantly when atrazine was applied before or after the undercutting tillage. One tillage just before planting eliminated most grassy weeds that emerged in the spring. In no case were annual broadleaf weeds a problem on plots treated with atrazine.

In the systems of 3 lb./A atrazine and no tillage, the grassy weeds were not controlled. The primary ones were foxtails (*Setaria* spp.).

In the system of a split application of atrazine, 2 lb. when undercut and 1 lb. at planting, weed control was improved by spring tillage as compared to

no spring tillage. Except for the 1966 crop year, the split application and tillage gave no better weed control than 3 lb./A atrazine combined with summer and spring tillage. Some volunteer wheat became established on the plots treated with 2 lb./A atrazine, compared to complete control at the 3 lb. rate. It was concluded by Phillips that there was no consistent advantage for using a split application of atrazine.

In the conventional tillage plots, five to seven tillage operations were necessary to control weeds and volunteer wheat between wheat harvest and planting of the sorghum. After crop emergence, the plots were cultivated as many times as needed to control the weeds.

In summary, conventional tillage and all combinations of atrazine and two tillage operations resulted in essentially weed-free grain sorghum. When the plots previously treated with atrazine were not tilled prior to seeding of sorghum, one post-emergence cultivation was needed to insure weed control. The atrazine, no tillage system, could not be relied upon to control grassy weeds.

Sorghum Stands: In each year, sorghum emergence on plots receiving atrazine and minimum tillage was significantly greater than on conventional tillage plots. In 3 of the 4 years the poorest stands were on the atrazine no-tillage system.

Decreased sorghum emergence on the conventional tillage plots was believed to result from two main factors. First, mechanical operations necessary to control weeds ahead of planting loosened the top few inches of soil so that moisture was lost from the soil surface. Probably equally important, repeated tillage destroyed wheat stubble residues thus leaving the soil surface nearly bare and subject to crusting.

Previous work, at the Fort Hays Station, reported by Phillips and Ross (1964)

showed that pre-emergence applications of atrazine may reduce sorghum stands. In this work, there was no evidence of atrazine toxicity following applications made several months prior to seeding the crop.

Table 3. Sorghum stands following systems of conventional tillage, no tillage, and minimum tillage between wheat harvest and sorghum planting.^{1/}

System ^{2/}	Sorghum stands: 1,000 plants/A				
	1965	1966	1967	1968	4-Year Average
1. ... Conventional tillage	9.3 ^b	8.8 ^c	18.6 ^c	10.2 ^b	11.7 ^b
2. ... 3 lb./A atrazine, no tillage	7.6 ^b	14.3 ^a	16.0 ^d	6.3 ^c	11.0 ^b
3. ... 3 lb./A atrazine, summer tillage	13.0 ^a	13.9 ^a	22.9 ^a	11.6 ^{ab}	15.4 ^a
4. ... 3 lb./A atrazine, summer and spring tillage	13.1 ^a	12.0 ^{ab}	22.0 ^a	12.4 ^{ab}	14.9 ^a
5. ... 2 lb./A atrazine, summer tillage, 1 lb./A atrazine at planting	13.3 ^a	13.9 ^a	21.1 ^{ab}	11.4 ^{ab}	14.9 ^a
6. ... 3 lb./A atrazine, summer and spring tillage	----	9.7 ^{bc}	21.3 ^{ab}	12.7 ^a	----
7. ... 2 lb./A atrazine, summer and spring tillage, 1 lb./A atrazine, at planting	----	12.4 ^a	19.2 ^{bc}	13.1 ^a	----

^{1/} Data are averages of three replications. Means within columns followed by the same letter are not significantly different at the 5% level.

^{2/} Plots of system 1 were cultivated as needed after crop emergence. Plots of systems 3 and 5 were cultivated once, if needed.

Atrazine, applied shortly after wheat harvest combined with one or two tillage operations resulted in sorghum yields markedly above those recorded for conventional tillage or for atrazine no-tillage treatments. The large yield differences are not understood as good to excellent weed control was obtained on the conventional tillage plots. Root pruning may have affected sorghum growth.

Visual estimates indicated that the most severe weed competition occurred in the atrazine no-tillage plots. Thus, yield differences between atrazine minimum tillage and atrazine no-tillage treatments seem readily explainable on the basis of reduced weed competition. However, competition on the atrazine no-tillage plots did not reduce yields below the conventional tillage plot in 3 of the 4 years.

Table 4. Grain sorghum yield from systems of conventional tillage, no-tillage, and minimum tillage between wheat harvest and sorghum planting^{1/}

System ^{2/}	Yield: lb./A				4-Year	4-Year
	1965	1966	1967	1968	Avg.	Avg.bu.
1. ... Conventional tillage	1190 ^b	1990 ^d	2930 ^b	2080 ^{ab}	2050 ^b	36.6
2. ... 3 lb./A atrazine, no tillage	1630 ^b	2290 ^{cd}	2900 ^b	1730 ^b	2140 ^b	38.2
3. ... 3 lb./A atrazine, summer tillage	2890 ^a	4110 ^a	3930 ^a	2540 ^a	3370 ^a	60.2
4. ... 3 lb./A atrazine, summer and spring tillage	3550 ^a	3480 ^{ab}	3680 ^{ab}	2560 ^a	3320 ^a	57.4
5. ... 2 lb./A atrazine, summer tillage, 1 lb./A atrazine, at planting	3080 ^a	4060 ^a	3800 ^{ab}	2620 ^a	3390 ^a	60.5
6. ... Summer tillage, 3 lb./A atrazine, spring tillage	----	3130 ^c	3320 ^{ab}	2590 ^a	3010	53.7
7. ... 2 lb./A atrazine, summer and spring, 1 lb./A atrazine, at planting	----	3340 ^{ab}	3500 ^{ab}	2660 ^a	3166	56.5

^{1/} Data are averages of three replications. Means within columns followed by the same letter are not significantly different at the 5% level.

^{2/} Plots of system 1 were cultivated as needed after crop emergence. Plots of systems 3 and 5 were cultivated once if needed.

Summary: Phillips concluded that 3 lb./A atrazine, applied shortly after wheat harvest, either preceding or following tillage, combined with one mechanical operation just before seeding sorghum the following spring is a practical approach to sorghum production in a wheat-sorghum-fallow rotation. The system

overcomes many of the disadvantages of pre-emergence treatments with herbicides, yet it preserves many advantages of the no-tillage concept. No adverse effect on wheat production has been noted when conventional tillage was used during the remainder of the 3-year rotation.

One caution was expressed by Phillips (1969) as his report stated:

"Results presented may be applicable only when soil types are similar to those described. Field experience indicates failure may be expected on coarse-textured soils."

ADVANTAGES OF THE SYSTEM

Economic Advantage

The prospect of an increase in yield of 56% or 20.8 bu. per acre (4 years results at Fort Hays) is the major incentive to adopt this system of grain sorghum production. The cost of weed control is approximately \$2.00 per acre more than conventional tillage, and approximately \$1.00 less than conventional tillage up to planting and then applying a herbicide to control broadleaf and grassy weeds on a complete area coverage.

The adoption of this rotation would mean that the average producer would produce more grain sorghum and less wheat. The rotation, when applied to certain numbers of cropland acres, would mean that 1/3 of the acres would be in grain sorghum, 1/3 in wheat, and 1/3 fallow. This is 2 crops every 3 years which is an economic advantage over a wheat fallow rotation. The higher yield potential of grain sorghum and the present price relation between grain sorghum and wheat, gives an economic advantage to this rotation as compared to wheat production.

Spreading of the risk factor of producing two crops that differ in disease, insects, and in time of weather hazards, would be an economic advantage. Also, there would be a spreading of the work load in crop production when producing

an equal acreage of wheat and grain sorghum.

The production of more grain sorghum, in Ellsworth County, would provide a basis for expanding livestock programs. Using a "multiplier effect" of 3.5 for grain sorghum fed to livestock as compared to 1.7 when sold rather than fed, could result in an increased economic activity in the county of \$180,000 for every 100,000 bushels fed.

Agronomic Advantages

Several of the most important agronomic advantages of the Minimum Tillage, Stubble Mulch, Chemical Weed Control in a Wheat, Sorghum, Fallow Rotation would be under the general heading of "Conservation."

Soil Conservation

Soil conservation would be enhanced by the fact that nearly all tillage operations would be done by tools that would keep the maximum amount of crop residue on the soil surface during the entire three year rotation. Residue management that leaves a surface mulch of plant residues will reduce the beating action of the rain, maintain the water infiltration rate, reduce runoff and thereby reduce soil erosion by water.

An Ellsworth County Soil Class and Needs Inventory shows that the county has 77,594 acres of Class II cropland, of which 40,374 acres need stubble mulch practices. There are 38,069 acres of Class III cropland that need terraces and waterways, contour farming, and stubble mulch practices. This system of minimum tillage and stubble mulch management should reduce the soil erosion and water runoff problem when supported by the recommended structures and practices.

Wind erosion is an ever present menace to dryland farming, especially during fallow periods when no crop is growing on the land. Anchoring the

stubble and trash on the surface of the soil not only reduces wind velocity very markedly at the ground level, but also traps any flying soil particles. Bennett (1940) has shown that leaving the plant residue on top reduces evaporation. This may also reduce erosion because moist soils do not blow.

Moisture Conservation

In the Great Plains Region, moisture stored in the soil profile is the means by which increased crop yields are attained. Ellsworth County, being a part of the Great Plains Region, often receives less rainfall during the growing period than is needed to produce profitable crop yields. The only way to overcome this moisture deficiency is to store moisture in the soil profile during non-crop growing periods and keep it there for the subsequent crop. Control of weeds and volunteer crop growth is essential to the success of this fallow practice.

Reference to the wheat, sorghum, fallow rotation is somewhat misleading as the rotation includes two fallow periods. The longest fallow period is between the crop of wheat and the planting of the sorghum crop. This is usually an 11 month period. The other fallow period from sorghum harvest to wheat planting is about a 10 1/2 month period. Both wheat and sorghum respond favorably to the fallow practice, as both have roots systems that penetrate deep into the soil profile. Grain sorghum can yield well with little rainfall during the growing season if the soil holds enough water at planting time. Water conservation practices that increase moisture storage go a long way toward assuring good yields in semiarid areas.

Most Ellsworth County soils have adequate water holding capacity for a successful fallow program, providing enough water enters the soil profile. As most all the moisture must enter from the top, the surface condition of the

soil will influence the efficiency of moisture storage. Any tillage method that loosens and roughens the soil surface and still leaves a surface mulch of plant residues to reduce water runoff and soil dispersal will increase infiltration. Jones, Moody, and Lilland (1969) found that on sloping land, wheat straw mulch increased infiltration. Runoff measured during 1965 and 1966 represented a loss of approximately 27% of the precipitation on the unmulched plots and only 4.5% on the mulch plots. This is important in Kansas, as many of the summer rains are often hard rains of short duration. Rains that are gentle and of long duration are most effective in moisture storage. Effective rains need to soak the soil below the zone from which evaporation losses are rapid. Stubble mulch will slow down the rate of evaporation from the soil surface by shading and reducing the wind velocity and soil temperature. This should allow more moisture from frequent small showers to be added to permanent storage.

Organic Matter Conservation

Organic matter of the soil is related to the erodibility of the soil and its natural fertility. Farming practices which destroy organic matter are tillage operations which expose the soil to the oxidation forces of the sun and air, crop removal, and burning of plant residues. Also, water and wind erosion can carry away the organic matter of the soil. Daniel and Langham (1936) studied the effects of wind erosion and cropping on the nitrogen and organic matter content of soils in the southern high plains. A summary of their study is given in Table 5.

Table 5. Mean total nitrogen and organic matter content of virgin, cropped and drifted soils.

Kind of Soil	No. of Samples Analyzed	Nitrogen		Organic Matter	
		Percent in Soil	Loss in % of Virgin Soil	% in Soil	Loss in % of Virgin Soil
Virgin surface	61	0.100		2.33	
Cropped surface	61	0.085	-15.0	1.91	-18.0
Drifted soil	61	0.072	-28.0	1.71	-24.5

The system of minimum tillage, stubble mulch, and chemical weed control in a wheat, sorghum, fallow rotation should reduce to a minimum the destructive forces that destroy the organic matter of the soil. It probably would increase the organic matter contents of many Ellsworth County soils that have been exposed to these destructive forces for many years; especially with a balanced fertilizer program which would result in greater amounts of plant residues to be returned to the soil.

The system allows sufficient time between crops for plant residues to decay or be broken down so that the need of burning wheat stubble is never warranted. Studies by Smika, Black, and Greb (1969) in a wheat fallow rotation, showed that wheat straw mulch did cause some differences in time of soil NO_3N release within the fallow period. The greatest increase of release occurred in late May and June in all treatments with the sharpest increase in bare soil. The bare soil stopped releasing nitrogen in late July while the mulched soil continued to release nitrogen until September, at which time the bare soil and the mulch soil had approximately the same NO_3N level. As the greatest demand for nitrogen of the sorghum crop comes in late July, August, and September, the release of nitrogen should be in time with the demand.

Weed Control

The wheat, sorghum, fallow rotation, combined with the herbicide should

give almost 100% control of all annual weeds. This should eventually result in very few weed seeds in the soil. Control of perennial weed plants such as field and hedge bindweed could be done during the fallow periods with herbicides (2, 4-D) or by tillage operations with a duckfoot or undercutting implement.

Wicks, Fenster, and Burnside (1969) found that wheat yields were often increased with the use of herbicides for weed control in sorghum, due to the better weed control during the fallow season between sorghum harvest and planting of the wheat. This could mean fewer tillage operations during this fallow period. Shatter cane is often a problem on land that is in continuous sorghum production. This three year rotation would not contribute to this problem.

Diseases and Insects

Many of our disease and insect problems of wheat are associated with volunteer wheat. These include wheat streak mosaic, fall rust, hessian fly, grasshoppers, cutworm, and fall armyworms. The application of 3 lb./A atrazine after wheat harvest controls the growth of volunteer wheat. This should reduce the buildup of these diseases and insects, which could attack or infect nearby seeded wheat.

Chemical Residues

Applying 3 lb./A atrazine after wheat harvests allows a period of 25 to 26 months for the chemical to be degraded. Soil residues of atrazine have, until recently, been considered a problem only in the topsoil. Leaching into the lower soil profile has now been shown to be a means of atrazine dissipation. Burnside, Fenster, Wicks, and Drew (1969) found 0.8 ppmw atrazine at the 18 to 24 inch depth of a loam soil and 0.2 ppmw at the 12 to 18 inch depth of a silty clay loam soil, 16 months after a 2 1/2 lb./A treatment. Atrazine degradation decreases with increasing soil depth as a process of biological and non-bio-

logical breakdown of herbicides decreases with lower soil temperature, photodecomposition, and volatilization. Soil carryover of herbicide residues was greater in coarse-textured (sandy) soil and in the drier regions of western than in eastern Nebraska. Soils showing the greatest to least herbicide residue were sandy loam, silt loam, and silty clay loams. Soil texture differences had a greater influence on herbicide residue carryover than did climatic differences.

The use of a herbicide for weed control on the total land area gives a greater degree of flexibility in row spacing. Research work in Kansas, on row spacing and stand densities, compiled by Stickler (1964) showed that narrower row spacing with 240 sq. in. per plant gave the highest average yield in 20 trials, in Central Kansas. See Figure 1, page 20.

Also, the response of 20 and 40 inch rows to differences in stand density was similar in most trials. This means that the best seeding rate in any given situation depends very little on row width. That is, the same number of plants per acre should be used when different row widths are employed. It was observed that stand density and/or row width often affects several important agronomic characteristics in addition to yield. One is maturity. Thinner stands that tiller more frequently, mature later, and moisture content of the grain is higher than in stands thick enough to tiller little or not at all.

Lodging, due to charcoal rot, which is associated with stress from drought and/or high temperatures, is usually higher in narrow rows and/or high stand densities. This is because the moisture demands (of transpiration) become greater with increased stand and narrow rows. However, root lodging from wind and rain is greater in the wider rows.

Increasing the stand density and decreasing the row width increases plant height under favorable growing conditions or under irrigation. Tall plants

lodge more and are generally more difficult to harvest.

Narrow rows reduce evaporation from the soil surface. With some rainfall patterns, this could increase yields.

Stand density and narrow rows influence weed control. Burnside and Wicks, (1969) found that sorghum grown in 20 in. rows had higher grain and stover yields and lower weed yields than 40 in. rows. Weed competition had a more marked effect on sorghum grain yields than did row spacing or sorghum population. In hand weeded plots, sorghum yields were reduced 4, 12, and 18% by delaying weeding of the plots 3, 4, and 5 weeks as compared with 2 weeks after planting. Weeds that did not emerge until 4 weeks after planting did not reduce sorghum yields.

Probably the most important finding of plant population studies is that yield tends to vary little over a wide range of stand density. Hybrid grain sorghum will compensate for low stand density by tillering and increasing head size.

One of the best aids for producers use, is the slide rule "Seeding Guide for Sorghum and Corn," developed by Engineers Floyd N. Reece and Russell L. Herpich, Extension Service, of Kansas State University. This guide is available from County Extension Agricultural Agents. For dryland production, plant population is based on 20,000 plants per acre with 20 inches or less of annual rainfall and an increase of 1,000 plants per acre for each inch of rainfall over 20 inches.

For Ellsworth County, the recommendation would be 26,000 plants per acre. The guide shows that for an estimate field germination of 75%, and a row spacing of 20 inches, thirteen seeds should be planted to every 10 ft. of row. In 40 inch rows, 26 seeds should be planted for every 10 ft. of row.