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Selection of
Herbaceous Energy Crops
For The
Western Corn Belt

Final Report Part II:
Economic Potentials

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SELECTION OF HERBACEOUS ENERGY CROPS FOR THE WESTERN CORN BELT

**Final Report Part II: Economic Potentials
1988 to 1993**

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Costs of Producing Herbaceous Biomass Crops in Iowa

Introduction

The last decade has seen an increased interest in renewable energy sources. The most prominent is the current emphasis on ethanol produced from corn as a transportation fuel. While biomass, especially in the form of wood fuels, has historically been an important source of heat and steam energy, it is not currently a major component of the energy base. Biomass has the potential to be used both as a raw energy source for co-firing of various electricity and heat generation processes and as the feedstock for other more concentrated processes such as gasification or production of liquid fuels.

The ultimate economic feasibility of biomass depends on its cost of production and on the cost of competing fuels. The purpose of this research project is to evaluate the production costs of several combinations of species and management systems for producing herbaceous biomass for energy use in Iowa. Herbaceous biomass production systems have costs similar to other crop production systems, such as corn, soybean, and forages. Thus, the factors influencing the costs of producing dedicated biomass energy crops include technological factors such as the cultivation system, species, treatments, soil type, and site and economic factors such as input prices and use of fixed resources. In order to investigate how these production alternatives are influenced by soil resources, and climate conditions, two locations in Iowa, Ames and Chariton, with different soil types and slightly different weather patterns were selected for both the agronomic and economic analyses. The Ames site located in central Iowa represents low erosive, highly productive soils while the Chariton site located in southeast Iowa represents more erosive, less productive soils.

Nine crops in thirteen cropping systems were grown at the two sites for five years, from 1988 to 1992 (Tables 1 and 2). Some of the systems had multiple cropping or interplanting, using combinations of cool-season species and warm-season species, in order to meet multiple objectives of maximum biomass, minimal soil loss, reduced nitrogen fertilization or diminished pesticide inputs. Six of the systems use continuous monocropping of herbaceous crops with an emphasis on production. The seven other systems consist of similar crops, but with crop rotation and soil conservation considerations. While the erosion and other off-site effects of these systems is an important consideration in their overall evaluation, this report will concentrate on direct production costs only.

In estimation of the production costs, the practices applied in the agronomic experiments were chosen as much as possible to reflect typical field systems, but in many cases the constraints of experimental work and a desire to collect and analyze specific scientific data led to practices that would not be considered commercially viable. A companion report discusses the agronomic experiments in much greater detail (Anderson et al., 1996).

Seven different species were used for this research. Tables 1 and 2 give the characteristics of the selected energy crop species used, which include their standing life and assumed storage method, and the cropping systems employed, respectively.

The report presents a series of estimates of the net production costs of growing herbaceous biomass based on the yield data obtained from the 13 cropping systems employed in the agronomic research. The production cost estimates are estimates of the costs of producing these crops on a commercial basis in Iowa. The data from the experimental plots was used in conjunction with data on typical management practices and costs of representative Iowa producers. The costs are comparable to the annual cost estimates of the Iowa State University Extension Service for corn, soybean and alfalfa (Duffy and Judd, 1992). The tillage practices assumed in this report are a composite of the ones used in the experiments and the more commonly used commercial alternatives. Some judgment was used in specifying these practices and the margin of error is probably high. This is the standard practice for such technology assessments and gives a "best" estimate of potential production costs. In all cases sensitivity of the estimates to assumptions was analyzed.

Table 1 Characteristics of Selected Energy Crop Species

Species	Growth Habit	Stand Life	Storage Method
Alfalfa	Perennial	5 yrs	Hay
Reed Canarygrass	Perennial	10 yrs	Hay
Switchgrass	Perennial	10 yrs	Hay
Big Bluestem	Perennial	10 yrs	Hay
Sweet Sorghum	Annual	1 yr	Silage
Sorghum x Sudangrass Hybrid	Annual	1 yr	Silage
Rye	Annual	1 yr	Hay
Corn	Annual	1 yr	Grain/Silage
Soybean	Annual	1 yr	Grain

Note: Intercrop sorghums were stored as a hay rather than silage. Corn stover was stored as silage.

Table 2 Cropping Systems

Cropping Systems	Remark
A. Alfalfa	Monocrop
B. Reed canarygrass	Monocrop
C. Switchgrass	Monocrop
D. Big bluestem	Monocrop
E. Sweet sorghum	Monocrop
F. Sorghum x sudangrass hybrid	Monocrop
G. Sweet sorghum/Rye	Double crop
H. Sorghum x sudangrass hybrid/Rye	Double crop
Ka. Sweet sorghum	Rotation ¹
Kb. Sweet sorghum/Rye	Rotation ¹
I. Corn	Rotation ¹
J. Soybean	Rotation ¹
L. Alfalfa/Sweet sorghum	Intercrop
Alfalfa/Sorghum x sudangrass hybrid	
M. Reed canarygrass/Sweet sorghum	Intercrop
Reed canarygrass/Sorghum x sudangrass hybrid	

Note: ¹ The rotation is a three year sequence of corn, soybean and a sweet sorghum (9a) and sweet sorghum/rye (9b) double crop in the third year.

Discussion of the Cropping Systems

Each of the cropping systems is an alternative way to produce biomass on an acre of land. Some discussion of the technical aspects of each system is important. In a broad sense, there are five cropping systems: pure monoculture, monoculture in rotation, double crop, double crop in rotation, and intercrop of annual crop into perennial grasses (Table 2). The purpose of employing different cropping systems is twofold: first, to compare the yields of the different species, and second, to compare the soil conservation potential of different cropping systems.

Of the thirteen cropping systems, the first six systems (A to F) are pure monoculture systems while the systems G and H are double crop systems. Of the first six systems, the first four systems involve the production of pure perennial species. Systems E to H involve annual crops - sweet sorghum, sorghum x sudangrass hybrid, and rye. Each of these first 8 systems are independent of one another in the sense that year after year the same crop is produced on the initially allocated land.

On the other hand, systems K to J are grown as a fixed rotation. The systems comprise three year rotation. Given initially allocated land, corn is produced first, then soybean followed by either sweet sorghum or rye/sweet sorghum depending on the cropping systems within the rotation. The final two systems, systems L and M, represent intercropping of an annual crop into a perennial grass stand.

The first four systems consider perennial crops - two native warm-season grasses, big bluestem and switchgrass; a cool-season introduced grass, reed canarygrass; and a legume, alfalfa - that have been grown mostly for the feeding of animals. These crops provide two advantages. One is that they have excellent soil erosion control properties and can be grown productively on both highly productive land and marginal land that is unsuitable for production of row crops. All of the harvestable material can be removed without creating soil erosion because the permanent root system remains in the field after harvest, thereby protecting the soil from wind and water erosion. A second advantage is that cutting and hauling of these forage crops need not conflict with crop harvests of corn and soybean (Sperling, 1988). Consider then each of the crops in turn.

Alfalfa. Alfalfa is a herbaceous perennial legume, which is one of only a few crops that can be grown in every state in the USA. Alfalfa is regularly produced in the North Central states. Alfalfa is a highly drought tolerant species. It becomes dormant for up to two years, if necessary, during periods of severe drought and resumes growth when moisture conditions become favorable (Barnes and Sheaffer, 1985).

Alfalfa has been produced primarily as a feedstuff for livestock because it possesses the highest feeding values among all commonly grown hay crops. It produces more protein per acre than grain or oil seed crops (Barnes and Sheaffer, 1985). Alfalfa can be harvested for fuel or chemicals, or used in a cropping rotation to provide nitrogen for other crops, thus reducing the need for expensive inputs of fossil fuel derived nitrogen (Barnes and Sheaffer, 1985; Bungay, 1980; Sperling, 1988).

Alfalfa has the potential to be a highly productive crop; however, the success of its production depends on the following factors: a fertile soil, adequate water, and good seedbed preparation at establishment (Barnes and Shaffer 1985, Undersander, et al., 1991). Proper fertility management is the key to optimum economic yields. Proper fertilization of alfalfa allows for good stand establishment and promotes early growth, increases both yield and quality, and improves alfalfa's winter hardiness and stand persistence. Good fertility also improves the ability of alfalfa to compete with weeds and strengthens disease and insect resistance (Undersander, et al., 1991). Alfalfa is sensitive to soil acidity. Thus, soil pH is a critical factor for establishment and maximum production of alfalfa. Soil pH influences symbiotic N fixation and the availability of essential and toxic elements (Barnes and Sheaffer, 1985). Lime application before seeding is important to achieve and maintain proper soil pH, 6.8 or higher, for alfalfa. Benefits of liming alfalfa include: "increased stand establishment and persistence, more activity of nitrogen-fixing Rhizobium bacteria, added calcium and magnesium, improved soil structure and tilth, increased availability

of phosphorus and molybdenum, and decreased manganese, iron and aluminum toxicity" (Undersander, et al., 1991).

Other nutrients commonly recommended for alfalfa production include phosphorus and potassium, which are relatively immobile nutrients when added to soil. Research has shown that maintaining yields, reducing susceptibility to certain diseases, and increasing winter hardiness and stand survival are highly dependent on an adequate potassium supply. It has also been shown that adequate soil phosphorus levels increases seeding success at establishment by encouraging root development (Undersander, et al., 1991; Barnes and Sheaffer, 1985).

Alfalfa typically obtains enough nitrogen from its symbiotic relationship with nitrogen fixing *Rhizobia* bacteria and from soil organic matter-released nitrogen. Thus, nitrogen application is not generally recommended for alfalfa, except when alfalfa is seeded on low-N soils or when alfalfa is seeded with a companion crop (Barnes and Sheaffer, 1985; Undersander, et al., 1991).

Diseases and winter hardiness are the key factors for the persistence of an alfalfa stand. Lack of winter hardiness may result in winter injury or winterkill. Winter injury causes reduced plant density and a lower yield. Diseases may cause seedling death, reduced stand density, lower yield and shortened stand life (Undersander, et al., 1991). Choosing disease resistant cultivars and utilizing proper fertilizer management practices are two widely suggested practices to overcome diseases and lack of winter hardiness (Undersander, et al., 1991; Barnes and Sheaffer, 1985). The expected stand life of alfalfa is up to 10 years (Barnes and Sheaffer, 1985). A five year stand life is assumed in this research.

As shown by Table 3, the most commonly recommended fertilizers - lime, phosphorus, and potassium - mentioned previously were applied in this research. Although some have recommended applying lime 12 months before seeding to get better results (Undersander, et al., 1991), in this experiment,

Table 3 Description of establishment year tillage systems for alfalfa (Systems A and L)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Lime ^a , tons	0	5	
Fertilizers Broadcast			Fall
Phosphorus, lbs P ₂ O ₅	160	160	
Potassium, lbs K ₂ O	625	625	
Chisel Plow			Fall
Tandem Disk			Spring
Harrow			Spring
Herbicide			Spring
Eptom, pt	3	3	
Grain Drill			Spring
Seed, lbs	12	14	
Cultipack			Spring
Harvest (2x in establishment year)			Summer and Fall
Mow-conditioner			
Large round bale			
Haul			

Note: For the establishment year, both monocrop and intercrop alfalfa have the same tillage systems.

^aLimestone

lime was applied in the fall of the year previous to establishment of alfalfa at Chariton. Lime was not applied at Ames because the soil had a pH above 7. Application time for both phosphorus and potassium during establishment is not specified. In this experiment, both phosphorus and potassium are applied only once in the fall of the year previous to the establishment of alfalfa. There was no annual fertilizer application beyond the establishment year.

Fertilizer application rates are usually determined by soil test. In this research, 160 lbs per acre of phosphorus and 625 lbs per acre of potassium were applied at both Ames and Chariton during the establishment year. Lime was applied only at Chariton at a rate of 5 tons per acre.

The time of alfalfa seeding is influenced by the following factors: precipitation patterns, temperature, and cropping patterns (Barnes and Sheaffer, 1985). Alfalfa seeding in the U.S. generally occurs either in the early spring or in the late summer. Adequate moisture and cool temperatures at the time of seedling germination is crucial for the successful establishment. Since alfalfa is extremely cold tolerant at emergence, spring seeding of alfalfa can begin as soon as the potential for damage from spring frosts has passed. This early seeding brings less weed competition and less moisture stress during germination because of cooler temperatures. For the northern states, including Iowa, spring seeding is preferred because of a greater chance of successful stand establishment for the reasons explained above (Undersander, et al., 1991). Recommended seeding dates in Iowa are April for the North and Central Iowa and between the middle of March and April for the Southern Iowa (Undersander, et al., 1991). Alfalfa was seeded in the middle of April at both of the experimental sites, Ames and Chariton.

Optimum seeding depths of alfalfa vary with soil types. Shallower depths may be used when moisture is adequate while the deeper depths should be used for drier soil conditions. In general, alfalfa seed should be planted in a firm seedbed to a depth of 0.52 inches with a cultipacker seeder or with press wheels on a conventional drill in order to obtain good soil-seed contact (Barnes and Sheaffer, 1985; Undersander, et al., 1991).

Optimal seeding rates are influenced by soil conditions, the method of seeding used, and weather conditions. Generally recommended seeding rates are between 12 and 15 pounds per acre (Undersander, et al., 1991). In this research, a grain drill was used to seed alfalfa seed at the rate 12 pounds per acre in Ames and 14 pounds per acre in Chariton, respectively. A cultipacker was used to firm the soil (see Table 3).

Field preparation is important for controlling weeds and smoothing the soil. Controlling the weeds prior to seeding helps ensure a long-lasting, productive stand. As suggested by Undersander, et al. (1991), field preparation began in the fall before spring seeding. In this research, a chisel plow was used to loosen the soil and help control weeds. This was followed in the spring by disking for further weed control, land leveling, and breaking up large soil clods before seeding. Harrowing was practiced as the final tillage in the spring to smooth out soil. Eptam, a preplant incorporated herbicide for controlling annual grasses and broadleaf weeds (Undersander, et al., 1991), was applied in this research at the rate 3 pints per acre. Field preparation activities are illustrated in detail in Table 3.

Harvest schedules are important to provide the highest yield of high quality forage. Optimum harvest schedules for biomass use of alfalfa are different than those used for producing forage for livestock. Research shows that there exists a correlation between yield, forage quality, and harvesting time. Yields increase with longer intervals between cuttings, while forage quality for livestock rapidly declines. It also has been shown that, as the plant matures, the leaf portion, which is more nutritious than stems, decreases and the stem increases in lignin and other fibrous constituents (cellulose and hemicellulose) (Undersander, et al., 1991). Thus, it has been recommended, for livestock, to take an early first cutting, usually early May in Iowa, with 28-33 day-intervals after the first cut (Undersander, et al., 1991). However, in this research, since the goal is to maximize yield and fibrous constituents content, the first cut occurred in June with longer intervals for the cuts than the suggested harvest schedule for livestock. All the following practices were employed in harvesting: mowing, mechanical conditioning, raking, and large round baling. Raking is

assumed to occur on a sporadic basis, as needed depending on rainfall. For the purpose of cost estimation, one raking per year is assumed for the three cut system, with no raking in the establishment year. If alfalfa is harvested only twice each year, no raking is assumed. Mechanical conditioning was practiced to increase the drying rate. Despite the transportation inefficiency of large round bales, they were used because of wide spread use in Iowa. Furthermore, they are easy to store and it can be left near the field on a well-drained site.

Reed Canarygrass. Reed canarygrass is a grass found in temperate portions of all six continents. It is well adapted to the northern half of the U.S. Although its natural habitat is poorly drained and wet areas, it is also drought tolerant. It is very tolerant of flooding and can withstand standing water for up to 35 or more days at any stage of development with no damaging effects (Marten, 1985).

Reed canarygrass is classified as a coarse, cool-season, sod forming grass that spreads underground by short, scaly rhizomes. It forms a heavy sod under well managed conditions but cannot tolerate continued close clipping. It is a vital part of many soil conservation programs, and can be used under irrigation with sewage effluent as a pollution control measure. Reed canarygrass has a high yield capacity with good regrowth throughout the pasture season (Marten, 1985). It tends to be slow in establishment but once established it is very disease resistant and long lived (Carlson, et al., 1978). In this study, the stand life of reed canarygrass is assumed to be 10 years.

As with alfalfa, diseases and winter hardiness are the important factors for the persistence of reed canarygrass. Reed canarygrass has long been identified as a good forage producing species because of its winter hardiness, adaption to a wide range of environmental conditions, good seasonal distribution of high yields, disease resistance, drought tolerance, and persistence under a wide range of management and fertilization systems (Barnhart, 1989; Carlson et al., 1978; Marten, 1985). For these reasons, it has been lately recognized as a good candidate for biomass production.

Reed canarygrass can be seeded either in spring or late summer if sufficient moisture is available (Marten, 1985). As with alfalfa, weed control is a key to establishment because weed competition can cause failure in establishment and at best slow establishment. If seed is planted in the late summer, success is often higher because weeds are less of a problem (Carlson et al., 1978). However, spring seedings are the most common for reed canarygrass, and we planted it in the spring as well. The reason for spring seeding is that reed canarygrass seedlings are more susceptible to killing by cold temperatures than those of most other cool-season grasses (Marten, 1985); thus, plants must be well developed before the start of winter. If reed canarygrass is to be planted in the late summer, timely establishment and favorable soil moisture are very important.

Seed can be sown with a grain drill, broadcast, or with a band seeder equipped with press wheels. The seedbed should be well prepared and firm. Seed should not be placed deeper than 1.5 cm and should be cultipacked or rolled (Barnhart, 1983). Reed canarygrass can be seeded with or without a companion crop. An oat companion crop can be used for spring seedings. In this study, reed canarygrass is seeded with a grain drill because it is a practice widely used in Iowa for forage production (Table 4). Although reed canarygrass in Iowa is generally seeded with an oat companion crop, it is seeded without a companion crop in this study.

Seeding rates can be influenced by the soil conditions, seeding method applied, weather conditions, soil water available, and the use of a companion crop. The recommended seeding rate falls between 8 to 10 pounds per acre for direct seeded reed canarygrass and between 4 to 5 pounds per acre with a companion crop (Carlson et al., 1978). Reed canarygrass was seeded at a rate of 9 pounds per acre in Ames and 11 pounds in Chariton.

Table 4 Description of establishment year tillage systems for reed canarygrass (Systems B and M)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilizer Broadcast			Fall
Phosphorus, lbs P_2O_5	32	32	
Potassium, lbs K_2O	94	94	
Chisel Plow			Fall
Tandem Disk			Spring
Harrow			Spring
Grain Drill			Spring
Seed, lbs	9	11	
Cultipack			Spring
Fertilizer Broadcast			Late Spring
Nitrogen, lbs	200	200	
Herbicide			Late Spring
2,4-D, pt	2	2	
Harvest			Fall
Mow-conditioning			
Bale			
Haul			

Note: For the establishment year, both monocrop and intercrop reed canarygrass have the same tillage systems.

Management of perennial cool-season grasses for biomass production consists of maximizing economic yield, while fostering persistence of the stand (Cherney et al., 1986). Proper fertility management is the key to optimum economic yield because proper fertilization of reed canarygrass allows for good stand establishment and promotes early growth, increases yield, and improves stand persistence. To maintain high productivity, fertilization with nitrogen, phosphorus, and potassium is recommended, especially nitrogen. Although reed canarygrass responds mainly to nitrogen, increased yield may occur with added potassium and phosphorus (Marten, 1985; Carlson, et al., 1978). As mentioned for alfalfa, an adequate potassium supply is essential for maintaining yields, reducing susceptibility to diseases, and increasing winter hardiness and stand survival. To increase seeding success at establishment, adequate maintenance of phosphorus is important.

Recommended rates for nitrogen range from 80 to 240 pounds per acre, depending on soil conditions and the need for forage. Split application of nitrogen is recommended when nitrogen is applied at over 120 pounds per acre. Split application is also recommended during the growing season to assure more uniform production and to lengthen the productive period (Marten, 1985; Carlson, et al., 1978). As recommended, nitrogen is assumed to be applied twice in this research, once in spring at 100 pounds per acre and again in the summer at 100 pounds per acre, over the stand life. However, it is applied only once in the summer during the establishment year. Rates for phosphorus and potassium are recommended to be based on soil test results (Carlson, et al., 1978). Based on the typical soil test results for Iowa, it is assumed that 32 pounds of phosphorus per acre and 94 pounds of potassium per acre are required, which is three-fourths of the potash applied for alfalfa on an annualized basis.

In this experiment, four levels of nitrogen were applied to the separate plots at the experimental farms. The levels of nitrogen used were 0, 62, 125, and 250 pounds per acre. See Table 4 for phosphorous and potassium rates.

As with alfalfa, field preparation is important for controlling weeds and smoothing the soil. The success of reed canarygrass establishment depends on good field preparation. An adequate seedbed can insure good germination. In this research, field preparation began in the fall before spring seeding. Chisel plowing was practiced in fall to loosen the soil and help control weeds. It was followed by disking in spring for further weed control, and breaking up of large soil clods. To smooth the soil, harrowing was practiced as the final tillage in the spring. See Table 4 for the description of tillage during the establishment year.

Infrequent harvests with high yields are desired. Reed canarygrass stands were unaffected and no great difference in yield was found between a two and four cut harvest system (Marten and Hovin, 1980). Thus, a two cut harvest was practiced in this research. During the establishment year, it was harvested only once in the fall.

Harvest intervals to obtain high reed canarygrass biomass yields assumed in this study are longer than those recommended for livestock forage as explained previously for alfalfa. The first harvest occurred some time in June with longer intervals for the second cut. The practices employed in harvesting were mowing, mechanical conditioning, and large round baling. Mowing is assumed to be done early in the day to allow full day's drying. Mechanical conditioning was practiced to increase drying rate. Large round baling was practiced because of easy of storage and wide spread current use. Raking was not practiced because reed canarygrass was harvested only twice each year.

Perennial Warm-season Grasses

Switchgrass and big bluestem are warm-season grasses, which are native to much of the Central and Lake States of the U.S. (Van Keuren and George, 1985). Switchgrass is a tall, sod forming perennial bunchgrass that grows 3 to 5 feet tall. Big bluestem is an erect, robust, perennial bunchgrass. It grows 3 to 6 feet tall. Big bluestem is a deep rooted grass well adapted to loamy soils and is able to withstand drought conditions (Barnhart and Hintz, 1989).

These warm-season perennial grasses start growing in late spring as air and soil temperatures increase. Maximum growth occurs from June through September. As temperatures cool in fall, growth slows and ceases with the first killing frost (Barnhart and Hintz, 1989).

Switchgrass and big bluestem are winterhardy and will grow in all areas of Iowa. Although they are most productive on fertile and well-drained soils with a good moisture supply where corn grows best, they also grow well on less fertile and droughty soils because they have a greater tolerance to low-available soil water than the cool-season grasses (Barnhart and Hintz, 1989; Jung, et al., 1988); and they also use soil nutrients more efficiently and have lower macronutrient requirements than cool-season grasses (Jung, et al., 1988). These warm season grasses also use nitrogen more efficiently than cool-season grasses (Anderson et al., 1996; Jung, et al. 1988). These properties make them practical choices to grow as biomass crops and for soil conservation on infertile, acid, and droughty soils.

Switchgrass is more tolerant than big bluestem to variability of soil conditions. It persists better in moderately wet soil conditions and occasional flooding. Switchgrass may also be better suited to droughty soils (Barnhart and Hintz, 1989) than big bluestem.

As with the other perennial grasses, seedbed preparation and fertilization are important to have successful establishment. Research has shown that an adequate potassium supply is needed to maintain yields, reduce susceptibility to disease, and increase winter hardiness and stand survival. It also has been shown that keeping adequate phosphorus levels is important to increase seeding success at establishment by encouraging root development (Undersander, et al., 1991; Barnes and Sheaffer, 1985).

Soil deficiencies in lime, phosphorus, and potassium should be corrected before or at seeding time. Application of lime and fertilizer should be based on soil tests. The pH levels should be at least 6.0 (Barnhart and

Hintz, 1989). Soil tests at the both experimental farms indicated that lime application was not needed for these grasses (Anderson et al., 1996). Phosphorus and potassium levels were low so that 32 pounds of phosphorus and 94 pounds of potassium per acre, respectively, were applied at both experimental sites, Ames and Chariton. Suggested phosphorus and potash application rates are at least 60 pounds of each per acre (Barnhart and Hintz, 1989). These fertilizers were assumed to be applied the fall before the spring seeding.

Experience in Iowa suggests not applying nitrogen in the seeding year because even small amounts stimulate weeds and retard warm-season grass establishment. To stimulate more rapid switchgrass establishment, it has been suggested to apply 30 pounds of nitrogen per acre in midsummer if weed control has been good in the seeding year (Barnhart and Hintz, 1989). In our research, nitrogen was not applied during the establishment year; however, nitrogen was applied during production in later years. In estimation of the budgets, 100 pounds per acre of nitrogen was assumed.

As suggested, chisel plow, tandem disk, and harrowing were practiced for field preparation. The first two of these activities are practiced to loosen soil, help weed control, and break up large soil clods in spring before seeding. Harrowing was practiced in spring to smooth out the soil.

These grasses can be seeded alone or as a mixture; however, seeding a single grass species is recommended because mixed species are more difficult to manage (Barnhart and Hintz, 1989). Warm-season grasses can be seeded from late April to mid-June (Barnhart and Hintz, 1989), but better germination, establishment and seedling development often occurs during mid-to-late April or May when precipitation patterns are more favorable. Successful stand establishment is possible with later seeding dates if adequate precipitation occurs, but first year forage yield is reduced (Vassey, et al, 1985). Early seeding provides more time for these grasses to become well established before winter (Barnhart and Hintz, 1989). To take advantage of this, both switchgrass and big bluestem are assumed to be seeded in the early May in this study.

Switchgrass can be seeded with a grain drill or other standard forage seeding equipment. The use of a grain drill with packing over the row to get better results is recommended. If possible, grasses should be drilled into mulched seedbeds, which helps control erosion and conserve soil water (Barnhart and Hintz, 1989). Switchgrass was seeded with a grain drill at a rate of 8 pounds per acre at both Ames and Chariton.

Big bluestem is difficult to seed without a special grassland drill because big bluestem seeds are light weight and 'bearded'. Seed conditioning equipment has been developed to remove the 'beard' or the long hairy appendages from big bluestem making it free flowing and more easily seeded with standard forage seeders (Barnhart and Hintz, 1989). A grain drill was used to seed big bluestem, and seeding rate was 12 pounds per acre at both Ames and Chariton. To firm the soil, cultipacking is usually used immediately after seeding.

Switchgrass and big bluestem often establish slowly and compete poorly with weeds. When established under heavy weed infestation, plants grow slowly and may take 2 to 3 years for production of good yields (Barnhart and Hintz, 1989). Thus, effective weed control is a key to the success of warm-season grass establishment. There is no herbicide currently registered for use in establishing switchgrass or big bluestem. Old supplies of labeled "atrazine" were used in the field practice of the study and these were applied at about 2 pounds per acre before the germination of summer annual weeds. To control broadleaved weeds, if this is a serious problem, 2,4-D application at about 0.5 pound per acre is suggested. Mowing at a height of 3 to 4 inches in early spring during the seeding year can also reduce competition by weeds (Barnhart and Hintz, 1989).

Summer mowing should be restricted to 6 inches to avoid removing any of the desired grass. Clipping should be discontinued after August 1. 2,4-D can also be used to control broadleaf weeds, once the grasses have reached the 3 to 4 leaf stage (Barnhart and Hintz, 1989).

Activities employed in harvesting were the same as for alfalfa and reed canarygrass.

Table 5 Description of establishment year tillage systems for switchgrass (System C)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilizer Broadcast			Fall
Phosphorus, lbs P_2O_5	32	32	
Potassium, lbs K_2O	94	94	
Chisel Plow			Fall
Tandem Disk			Spring
Harrow			Spring
Grain Drill			Spring
Seed, lbs	8	8	
Cultipack			Spring
Herbicide			Late Spring
Atrazine 4L, pt	2.5	2.5	
Harvest			Fall
Mow-conditioning			
Bale			
Haul			

Table 6 Description of establishment year tillage systems for big bluestem (System D)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilizer Broadcast			Fall
Phosphorus, lbs P_2O_5	32	32	
Potassium, lbs K_2O	94	94	
Chisel Plow			Fall
Tandem Disk			Spring
Harrow			Spring
Grain Drill			Spring
Seed, lbs	12	12	
Cultipack			Spring
Herbicide			Late Spring
Atrazine 4L, pt	2.5	2.5	
Harvest			Fall
Mow-conditioning			
Bale			
Haul			

Sorghum. Sorghums have been used primarily for forage or grain in the U.S.; however, there has been increased interest in production of sorghum for biomass. Sorghum production is concentrated in the Southwestern U.S. Sorghum is a coarse, erect grass. Although sorghums grow better with more adequate moisture, sorghums are known to be more drought tolerant than corn and soybeans. During the drought period, sorghum has the capability to become dormant, then resume growth when water becomes available.

The drought-tolerance capability of sorghum and its versatility make it a practical choice in conventional crop rotations and conservation-tillage programs (Duncan, 1985; Fribourg, 1985). This characteristic may be useful for production in southern Iowa during relatively dry summers.

Recommended seeding temperatures for sorghums are soil temperatures of 65 to 70 F because adequate germination of sorghums takes place at this level (Duncan, 1985; Fribourg, 1985). If sorghum must be planted before the soil temperature reaches 65 F, use of a starter fertilizer is recommended to provide critically needed N and P and to enhance early season growth (Duncan, 1985).

Planting depth of sorghum depends on the soil type. The planting depth is important because the sorghum seedling does not emerge from the soil as easily as a corn seedling. Planting depth in general should not exceed 1 to 2 inches. For good emergence, the recommended depth is 3/4 to 1 inch in clay soils and 1.5 to 2 inches in sandy soils. Although sorghum can be planted in a dry soil if rain is expected or if irrigation water can be applied within two weeks after planting, sorghum growth and seedling development are usually better when the seed is planted in a moist soil (Duncan, 1985).

Seeding rates of sorghum are extremely important for economical yields. If plant populations are too high, the plants tend to compete with each other for nutrients and moisture. In addition, high population often result in slender and weak stalks (Duncan, 1985). The recommended normal seeding rates for silage are 6 to 8 pounds per acre (Duncan, 1985). Seeding rates used in this research are 7 pounds per acre for all sorghum cropping systems.

Sorghums can be drilled, broadcast, or sown in rows (Fribourg, 1985). Narrow rows, 30 inches or less, are suggested because weed control and moisture conservation may be more difficult in wider rows. With wider row spacing, sorghum has difficulty producing a closed canopy that will help control weeds and reduce water losses caused by evaporation (Duncan, 1985). A 30-inch narrow row planter was assumed to be used for this study.

Although sorghums will grow on low-fertility and/or moderately acid soils, good fertility management is necessary for optimum yields in sorghum. The fertility program should be based on soil test results. The recommended fertilization is as follows: 80 to 100 pounds of N per acre for dry land and 100 to 120 pounds of nitrogen per acre for irrigated land; 60, 40, 0 pounds of P per acre for low, medium, high levels of P containing soil, respectively and 80, 60, 0 pounds of K per acre for low, medium, high levels of K containing soil, respectively (Duncan, 1985).

Phosphorus should be applied preplant or at planting while potassium may be applied before or after planting. Nitrogen should generally be applied in split applications, with about a third of the requirement applied as a preplant or starter fertilizer. The remainder should be applied in one application approximately 20-25 days after emergence (about a month after planting) or at 10-inch plant height (Duncan, 1985).

Relative to other major row crops such as corn or soybean, chemical weed control choices for sorghum are somewhat limited. The herbicide most widely used for sorghum production in Iowa and elsewhere in the U.S. is Dual. Dual is registered for application to sorghum either as a preplant soil incorporated treatment or a preemergence treatment. Dual is recommended for use on sorghum grown from "Concep" treated seed. Concep acts as a safener, herbicide antidote, which reduces the potential for Dual injury to the crop. Suggested application rates are 1.5 to 2 pt per acre. For the double crop sorghums, paraquat provides good to excellent control of both the annual grass in the doublecrop and broadleaf weeds. The recommended application rates depend on the height of the grass or broadleaf weeds. For control of grass and broadleaf weeds 2 inches in height or less, 1 pt per acre is suggested. For control of grass and broadleaf weeds 2 to 3 inches in height, 2 pts per acre are suggested (Duncan, 1985).

In this research, the dry matter yield of sorghums was investigated under different cropping systems. Two sorghum cultivars, sweet sorghum and a sorghum x sudangrass hybrid were planted. The cropping systems used for sorghums are as follows: monocrop, doublecrop with winter rye, rotation following corn

and soybeans, double cropping with winter rye following corn and soybean rotation, and intercrop with alfalfa or reed canarygrass.

Monocrop Sorghums. Monocrop sorghum systems were fertilized before planting in the middle of May. Both sites, Ames and Chariton, received 58 pounds of phosphorus, 47 pounds of potassium, and 100 pounds of nitrogen.

Monocrop sorghum fields were disked followed by field cultivation and harrowing in the middle of the spring to control weeds, break up large soil clods, and smooth the soil. A narrow-row planter was used to plant sorghum seeds in the spring. Post-planting cultivation was practiced to control weeds in summer. For weed control, Dual was applied at the rate 2 pt per acre at the time of disking in spring.

Monocrop sorghums were harvested with a silage harvester in the late fall. Table 7 describes the tillage systems for monocrop sorghums.

Table 7 Description of tillage systems for monocrop sweet sorghum silage and sorghum sudangrass (Systems E and F)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilizer Application			Spring
Phosphorus, lbs P_2O_5	58	58	
Potassium, lbs K_2O	47	47	
Anhydrous Ammonia, lbs	100	100	
Disk and Herbicide			Spring
Dual, pt	2	2	
Field Cultivate			Spring
Harrow			Spring
Plant			Spring
Seed, lbs	7	7	
Cultivate			Summer
Harvest			Fall
Haul			
Forage Blower			

Note: Sorghum was harvested for silage.

Double Crop Sorghums with Rye. Phosphorus and potassium were applied in the fall before planting winter rye. Both sites, Ames and Chariton, received 58 pounds per acre of phosphorus and 47 pounds per acre of potassium. A split application of nitrogen was used. About one-third of the nitrogen was applied in the late March for the double crop rye/sorghum systems. The remainder was applied at the time of sorghum planting, late May.

The double crop sorghum/winter rye systems were disked followed by harrowing in the fall before planting the winter rye. Rye was planted by grain drill in the winter and the sorghum was planted no-till into the rye stubble immediately after the rye was harvested as forage in May. Winter rye was seeded at 100 pounds per acre in Ames and 120 pounds per acre in Chariton, respectively. Sorghum was seeded at 7 pounds per acre in both sites.

Winter rye was harvested as hay in late May while sorghums were harvested as silage in the fall. See Table 8 for a description of the tillage systems.

Table 8 Description of tillage systems for doublecrop rye/sweet sorghum and sorghum x sudangrass hybrid (Systems G and H)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilizer Application			Fall
Phosphorus, lbs P ₂ O ₅	58	58	
Potassium, lbs K ₂ O	47	47	
Tandem Disk			Fall
Harrow			Fall
Grain Drill			Fall
Rye Seed, lbs	100	120	
Anhydrous Nitrogen, lbs	63	63	Spring
Harvest Rye			Spring
Mow-condition			
Large round bale			
Haul			
Plant			Spring
Sorghum seed, lbs	7	7	
Anhydrous Nitrogen, lbs	100	100	Spring
Herbicide			Spring
Paraquat, pt	2	2	
Harvest			Fall
Haul			
Forage Blower			

Note: Sorghum was harvested as silage.

Sweet Sorghum and Sweet Sorghum/Rye in Rotation. These systems are very much like the other sorghum systems except for the use of nitrogen. For the sorghum/rye in rotation with corn and soybean, no nitrogen was applied in the early spring because soybean is a nitrogen fixer. Nitrogen was applied only once in late spring, at the time of sorghum planting.

Monocrop sweet sorghum in rotation with corn and soybean was fertilized in the spring. The amount of phosphorus and potassium applied for this system was the same as the amount used for the other systems involved with sorghum, except the intercrop sorghum systems. Nitrogen applied for this system was less than for the other systems involved with sorghum because sweet sorghum in this system was planted after soybean, which is a nitrogen fixer. Nitrogen was applied at 50 pounds per acre in spring before the sorghum planting.

Tables 9 and 10 give the tillage systems practiced for the sorghums in rotation with corn-soybean.

Table 9 Description of tillage systems for sweet sorghum in rotation with corn-soybean (System K)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilizer Application			Spring
Phosphorus, lbs P_2O_5	58	58	
Potassium, lbs K_2O	47	47	
Anhydrous Ammonia, lbs	50	50	
Disk and Herbicide			Spring
Dual, pt	2	2	
Harrow			Spring
Plant			Spring
Seed, lbs	7	7	
Harvest			Fall
Haul			
Forage Blower			

Note: Sorghum was harvested for silage.

Table 10 Description of tillage systems for double crop sweet sorghum/rye in rotation with corn-soybeans. (System K)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilizer Application			Fall
Phosphorus, lbs P_2O_5	58	58	
Potassium, lbs K_2O	47	47	
Tandem Disk			Fall
Harrow			Fall
Grain Drill			Fall
Rye seed, lbs	100	100	
Harvest			Spring
Mow-condition			
Large round bale			
Haul			
Plant			Spring
Sorghum seed, lbs	7	7	
Fertilization			Spring
Anhydrous Ammonia, lbs	50	50	
Harvest			Fall
Silage harvester			
Haul			
Forage Blower			

Note: Sorghum was harvested for silage.

Intercrop Sorghum/Alfalfa Systems. For the establishment year, the intercrop sweet sorghum/alfalfa and sorghum x sudangrass hybrid/alfalfa systems have the same tillage practices as for monocrop alfalfa. The difference in tillage practices appears only during the production years of alfalfa following the establishment year. During the standing years, sorghums are intercropped into the established alfalfa. Sorghums, both sweet sorghum and sorghum x sudangrass hybrid, are planted in the late spring right after the first harvest of alfalfa. A custom made "slot tiller" was used at the experimental farm to till the soil for the sorghum rows in the established alfalfa before planting the sorghum into alfalfa. However, in description of tillage systems and estimation of production costs, use of a no-till planter was assumed since a "slot tiller" is not commercialized. As with all other sorghum systems, sorghum seeding rates were 7 pounds per acre at both Ames and Chariton.

After planting the sorghum and before emergence each year, Paraquat was sprayed at a rate of 0.4 pt per acre around sorghum slots to suppress the foliage of established alfalfa to reduce competition for the emerging sorghum.

For the description of the tillage systems, see Table 11. This is the tillage systems for both sweet sorghum/alfalfa and sorghum x sudangrass hybrid/alfalfa.

Table 11 Description of tillage systems for intercrop crop sorghum/alfalfa (System L)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Harvest (Alfalfa)			Spring
Mow-conditioning			
Rake			
Large round bale			
Haul			
No-till Plant			Spring
Sorghum seeds, lbs	7	7	
Herbicide			Spring
Paraquat, pt	0.4	0.4	
Harvest (Sorghum/Alfalfa)			Summer
Mow-conditioning			
Large round bale			
Haul			
Harvest (Sorghum/Alfalfa)			Fall
Mow-conditioning			
Large round bale			
Haul			

Intercrop Sorghum/Reed Canarygrass System. For the establishment year, this system has the same tillage practices as for the monocrop reed canarygrass. Both sweet sorghum and sorghum x sudangrass are interplanted into the established reed canarygrass.

In the fall of each year, maintenance rates of phosphorus and potassium were applied to the both of experimental sites at a rate of 32 pounds per acre and 94 pounds per acre, respectively. This intercrop system received half of the nitrogen in mid April with the remainder applied in late July before the second harvest.

As for the intercrop sorghum/alfalfa, a slot tiller was used to till the soil to plant the sorghum into established reed canarygrass. Sorghum was planted with a no-till planter in early June after the first harvest of reed canarygrass. Seeding rates were the same as monocrop sorghum systems, 7 pounds per acre. Each year, Paraquat was applied at a rate of 0.4 pt per acre to the foliage of established reed canarygrass to reduce competition for the emerging sorghum after planting and before emergence in the middle of June.

Table 12 illustrates in detail the tillage schedule and the tillage practice for this system.

Table 12 Description of tillage systems for intercrop crop sorghum/reed canarygrass (System M)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilization			Fall
Phosphorus, lbs P_2O_5	32	32	
Potassium, lbs K_2O	94	94	
Nitrogen, lbs	100	100	
Harvest			Spring
Mow-conditioning			
Large round bale			
Haul			
No-till Plant			Spring
Sorghum seeds, lbs	7	7	
Herbicide			Spring
Paraquat, pt	0.4	0.4	
Fertilization			Summer
Nitrogen, lbs	100	100	
Harvest			Summer
Mow-conditioning			
Large round bale			
Haul			
Harvest			Fall
Mow-conditioning			
Large round bale			
Haul			

Corn and Soybean Rotation. The primary purpose of producing corn and soybean in this research was to compare sorghum yields in a crop rotation system with the sorghum yields in the other systems. An additional purpose was to consider the effects of growing biomass on farms where corn and soybean are the major crops.

For corn production in Iowa, the conventional tillage systems typically include the following activities: chisel plow, tandem disk, N application, field cultivation, planting, cultivation, and spraying. Chisel plowing is usually omitted for the crop rotation systems such as corn following soybeans (Duffy and Judd, 1992). As indicated by the short description of tillage systems above, fertilizers are applied before planting while herbicides are applied after sufficient growth of corn.

As shown in Table 13, the tillage systems practiced in this research are somewhat different than what has been conventionally practiced in Iowa for corn production. Chisel plowing and field cultivation activities

were not practiced in this research because the soil was loose enough even without plowing, and preplant herbicides were applied instead of field cultivation. Thus, the field was tandem disked followed by harrowing.

To control weeds during field preparation, herbicides were applied before planting in the spring. By attaching the sprayer on the tandem disk, disking and herbicide application activities were practiced simultaneously. The post-planting weed problems were controlled entirely by the cultivation in the summer.

Fertilizers were applied in the spring before planting. Both sites, Ames and Chariton, received the same amount of P and K, 58 pounds of P per acre and 47 pounds of K per acre, respectively. Four levels of fertilizer nitrogen, 0, 62, 125, and 250 pounds per acre, were applied to subplots at both sites. However, in estimating net production costs, 125 pounds of N per acre was chosen. Although yields increased as more N was applied, the highest net return was obtained at this level of N.

Corn was planted with a John Deere Maxemerge2 planter in early May. The seeding rate was 30,000 kernels per acre. This rate allows an approximate final population of 26,506 plants per acre.

Grain and stover were harvested separately. Grain was harvested first. A corn head was attached to the combine to harvest corn grain. Stover was harvested by a flail chopper. Then, raking, large round baling, and hauling activities were followed in order on the stover.

Table 13 Description of tillage systems for corn (System I)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilization			Spring
Phosphorus, lbs P_2O_5	58	58	
Potassium, lbs K_2O	47	47	
Nitrogen, lbs	125	125	
Tandem Disk and Herbicide			Spring
Bladex 4L, pt	5	5	
Lasso, pt	5	5	
Harrow			Spring
Plant			Spring
Corn seed, thou k	30	30	
Cultivator			Summer
Harvest			Fall
Combine with corn head			
Flail chopper			
Rake			
Large round bale			
Haul stover			

Field preparation activities for soybean in Iowa include chisel plow, tandem disk, and field cultivation. Field preparation is practiced in the spring before planting. Soybean planting is done in the spring at a rate of 60 pounds per acre. After sufficient growth of the soybean, cultivation and herbicide applications are used to control weeds. Harvesting was done by combining in the fall (Duffy and Judd, 1992).

Fertilizers were applied in the early spring. Phosphorus was applied at a rate of 40 pounds per acre, and potassium was applied at a rate of 75 pounds per acre in both sites. Nitrogen was not used because soybeans are a nitrogen fixer. The field was harrowed and then tandem disked in the spring. By attaching a sprayer to the tandem disk, disking and herbicide application were done simultaneously. Lasso was applied at a rate of 6 pt per acre in both sites to control weeds.

Soybean was planted with a John Deere MaxEmerge2 planter in the Spring at a rate of 60 pounds per acre. After sufficient growth of soybeans, cultivation was practiced to control weeds in the summer. Soybeans were harvested using a combine with a soybean platform in the fall.

Table 14 Description of tillage systems for soybean (System J)

Field Operation	Rate/Acre		Time of Year
	Ames	Chariton	
Fertilization			Spring
Phosphorus, lbs P ₂ O ₅	40	40	
Potassium, lbs K ₂ O	75	75	
Tandem Disk and Herbicide			Spring
Lasso, pt	6	6	
Harrow			Spring
Plant			Spring
Soybean seed, unit	1	1	
Cultivator			Summer
Harvest			Fall
Combine with soybean platform			

Discussion on Yield

Average total dry matter yield and yield response to nitrogen treatments in the experiments are shown in Tables 15 through 21. These are the average of dry matter yields under various nitrogen treatments over the experimental period, 1988-1992.

Most cropping systems were treated with four different levels of nitrogen (0, 62, 125, 250 pounds per acre) to compare yield response to nitrogen. Sorghum intercropped with alfalfa and reed canarygrass, and sweet sorghum and sweet sorghum/rye systems in rotation with corn and soybean had only two different levels of nitrogen treatments (62 and 125 pounds per acre). Monocrop alfalfa and soybean received no nitrogen treatments.

It is generally believed that yields on productive land are higher than those on marginal land under the same management systems. As shown by the data from the Iowa experiment on biomass production, this research reaches the same conclusion with a few noticeable exceptions. For example, reed canarygrass yields on marginal land in Chariton are higher than on productive land in Ames, as shown by Table 15. Yields of the pure monocrop sorghum and sweet sorghum in rotation with corn and soybean are also higher in Chariton than in Ames. This may be due to regional difference in weather conditions during the experimental periods, 1988 to 1992. Chariton is located in the Southern Iowa so that it is usually warmer than Ames which is located in the Central Iowa. In general, reed canarygrass grows better under cool and

moist weather conditions (Marten, 1985), while sorghum is a warm-season crop (Doggett, 1988). Thus, the warmer conditions in Chariton might be a reason for the higher yields.

Yield response to nitrogen use is measured by comparing the marginal productivity of nitrogen, which is defined as the change in yield in response to a small change in nitrogen. In this study, the highest rate of yield increase response was achieved at a rate of 62.5 lbs per acre with very few exceptions. Although total yield increases at nitrogen rates above 62.5 lbs per acre, the yield increases at a decreasing rate.

Perennial Forages

As mentioned before, alfalfa had two harvesting systems, two cuts and three cuts per year. Reed canarygrass was harvested twice per year. Switchgrass and big bluestem were harvested once per year. Table 15 shows the yield response of the perennials at both Ames and Chariton to different levels of nitrogen use. These yield are based on data reported in Anderson et al. (1996) and are converted from Mg per ha to dry tons per acre and then allow for a 10% loss of dry matter. This is also true of the yields in tables 16 to 21.

For alfalfa, the three cut system had higher yields than the two cut system at both locations. However, not much yield improvement was achieved by the three cut system at Chariton as compared to Ames.

Reed canarygrass at Ames showed consistent improvement in yield in response to increases in nitrogen use compared to the yield response at Chariton. The highest yield response is observed at 125 lbs of nitrogen per acre at Ames and 62.5 pounds per acre at Chariton, respectively.

Switchgrass produced more dry matter on average per year than the other perennial forages selected for this research in both experiment sites, Ames and Chariton (Table 15). The largest increase in yield is observed at the nitrogen level 62.5 pounds per acre at Ames and 125 pounds per acre at Chariton, respectively. Switchgrass yield at Ames shows almost no response to the additional nitrogen use beyond 62 pounds per acre.

Big bluestem shows the largest yield response to nitrogen use at 62.5 pounds per acre at both Ames and Chariton. The yield response at Chariton at this level is much larger than at Ames.

In short, the maximum yield responses to nitrogen are observed at the nitrogen level 62.5 pounds per acre, except reed canarygrass at Ames and switchgrass at Chariton. Among the perennial grasses, switchgrass is the highest dry matter producing energy crop. This finding is consistent with other experimental findings (Turhollow, 1994; Wright, 1994).

Table 15 Average dry matter yield 1989 to 1992 for monocrop perennial grasses and yield response to nitrogen fertilization (Systems A, B, C, and D)

Cropping System	Yield	Change in yield	Yield	Change in yield
		(ton/acre)		
		<u>Ames</u>	<u>Chariton</u>	
Alfalfa				
2 cut	4.12		3.35	
3 cut	4.40		3.47	
Reed canarygrass				
0 lbs N/a	1.65		2.47†	
62.5 lbs N/a	2.47	0.82	3.64†	1.17*
125 lbs N/a	3.33	0.86*	4.41†	0.77
250 lbs N/a	4.58	1.25	4.73†	0.32
Switchgrass				
0 lbs N/a	2.46		3.14†	
62.5 lbs N/a	4.50	2.04*	3.76†	0.62
125 lbs N/a	4.50	0.00	4.69†	0.93*
250 lbs N/a	4.73	0.23	4.92†	0.23
Big bluestem				
0 lbs N/a	3.30		2.20	
62.5 lbs N/a	3.74	0.44*	3.29	1.09*
125 lbs N/a	3.84	0.10	3.55	0.26
250 lbs N/a	4.17	0.33	3.74	0.19

Note: * indicates the highest yield response to nitrogen use.

[†]Yields are 1990 to 1992 average

Sweet Sorghum and Sorghum x Sudangrass Hybrid

The sorghums are high yielding annual crops. Table 16 shows the yields of the sorghum crops used in this study at different levels of nitrogen.

Sweet sorghum produced more dry matter than sorghum x sudangrass hybrid at both locations for all nitrogen levels. The yields of sweet sorghum ranged from 5.04 to 7.08 tons per acre at Ames and from 5.92 to 7.29 tons per acre at Chariton for different nitrogen levels. The yields of sorghum x sudangrass hybrid ranged from 5.03 to 6.48 tons per acre at Ames and from 5.62 to 6.97 tons per acre at Chariton.

Sweet sorghum produced about 15% more dry matter at Ames and about 11% more at Chariton, respectively, than sorghum x sudangrass hybrid at the 62.5 pounds nitrogen level per acre. At 125 pounds nitrogen per acre, it produced about 9% more at Ames and about 15% more at Chariton, respectively. At 250 pounds per acre, it produced about 5% more at Ames and about 3% more at Chariton.

The largest yield response to nitrogen was achieved at the rate of 62.5 pound per acre for both sorghums at both sites. Dry matter yield for sweet sorghum at Ames increased by about 33% per acre and that at Chariton increased by about 20% per acre when nitrogen input use changed from 0 to 62.5 pounds per acre.

Sorghum x sudangrass hybrid had the most yield response to nitrogen at 62.5 pounds per acre at both sites. Sorghum x sudangrass hybrid at Ames produced about 15% more dry matter at 62.5 pounds nitrogen

per acre than 0 pound per acre. At Chariton, yields increased about 13% at 62.5 pounds nitrogen per acre as compared to 0 pound per acre.

Two things should be noted from Table 16. First, contrary to general notion that yield on productive land is higher, dry matter yield was higher on the marginal land in Chariton than on the productive land in Ames. As explained in the beginning of this section, this may be primarily due to the regional difference in weather conditions during the experimental period. Secondly, sweet sorghum showed negative yield response to nitrogen at 250 pounds per acre at both locations. Reasons for this are not totally obvious given that the dry matter yield of double cropped sweet sorghum with winter rye (Table 18) shows a continuous increase in total yield as more nitrogen is applied. One possible explanation for the negative response of monocrop sweet sorghum to nitrogen at 250 pounds per acre is higher crop losses during harvest.

Table 16 Average dry matter yield 1988 to 1992 for monocrop sorghum and yield response to nitrogen fertilization (Systems E and F)

Cropping System	Yield	Change in yield	Yield	Change in yield
		(ton/acre)		
	<u>Ames</u>		<u>Chariton</u>	
Sweet sorghum				
0 lbs N/a	5.04		5.92	
62.5 lbs N/a	6.68	1.64*	7.07	1.16*
125 lbs N/a	7.08	0.40	7.29	0.22
250 lbs N/a	6.81	-0.27	7.18	-0.11
Sorghum x sudangrass				
0 lbs N/a	5.03		5.62	
62.5 lbs N/a	5.79	0.76*	6.35	0.73*
125 lbs N/a	6.47	0.68	6.36	0.01
250 lbs N/a	6.48	0.01	6.97	0.61

Note: * indicates the highest yield response to nitrogen.

Sorghum Interseeded with Alfalfa or Reed Canarygrass

These systems were harvested three times per year. Sorghum in this system was harvested together with the perennial grasses. As a result, sorghum in this system is assumed to be harvested as hay.

Sorghum intercropped into the reed canarygrass system was not initiated at Chariton because of the weather conditions in 1988. Reed canarygrass was seeded on 13 April, 1988 at Chariton; however, the reed canarygrass did not establish and reseeding was done in late August. The reed canarygrass emerged but winter killed when unusually warm weather initiated growth and then an arctic cold front dropped temperatures below 30 degree F, killing the grass. Reseeding was done in April 1989 without tillage of the plots and establishment was weak but successful and no harvest was taken until 1990. As a result, the sorghum/reed canarygrass systems was not initiated at Chariton.

As shown by Table 17, sorghum intercropped into alfalfa at Ames produced much higher dry matter yield than sorghum intercropped into reed canarygrass. Sweet sorghum/alfalfa produced about 82% more dry matter at the nitrogen rate 62.5 pounds per acre and about 40% more at 125 pounds per acre, respectively, than sweet sorghum/reed canarygrass at the same levels of nitrogen. Sorghum x sudangrass

hybrid/alfalfa produced about 63% more at 62.5 pounds per acre and about 34% more at 125 pounds per acre than sorghum x sudangrass hybrid/reed canarygrass.

As expected, dry matter yield was higher on the productive land in Ames for both sorghums intercropped into alfalfa. At 62.5 pounds per acre of nitrogen, yields at Ames were about 18% higher for sweet sorghum/alfalfa and about 15% higher for sorghum x sudangrass hybrid/alfalfa, respectively, than at Chariton.

Table 17 Average dry matter yield for intercrop systems and yield response to nitrogen fertilization (Systems L and M)

Cropping System	Ames (1989-1992)		Chariton (1989-1990)	
	Yield	Change in yield (ton/acre)	Yield	Change in yield
Sweet sorghum/Alfalfa				
62.5 lbs N/a	6.11		4.29	
125 lbs N/a	6.19	0.08	4.71	0.42
Sorghum x Sudangrass/Alfalfa				
62.5 lbs N/a	5.60		4.86	
125 lbs N/a	6.03	0.43	5.16	0.30
Sweet sorghum/Reed Canarygrass				
62.5 lbs N/a	3.36			
125 lbs N/a	4.41	1.05		
Sorghum x sudangrass/Reed canarygrass				
62.5 lbs N/a	3.44			
125 lbs N/a	4.49	1.05		

By comparing Table 17 to Tables 15 and 16, we observe that the dry matter yield of these systems is greater than the monocrop alfalfa and reed canarygrass systems, but lower than the monocrop sorghum systems. The same results have been observed by other experiments (Turhollow, 1994; Wright, 1994).

In short, under the same management systems, sorghum intercropped into alfalfa is more suitable for energy crop production because this system has higher yields than sorghum intercropped into reed canarygrass.

Sorghum Doublecropped with Winter Rye

Table 18 shows average dry matter yields and yield response to nitrogen fertilization for sorghum doublecropped with winter rye.

Rye dry matter yields were much lower than other crops in this research. Rye yields were influenced by previous nitrogen applications to sorghum with consistent yield increases in response to nitrogen fertilizer although the response at Chariton was small beyond 62.5 pounds per acre. Rye dry matter yields responded the most to nitrogen fertilizer application at 62.5 pounds per acre at both sites. At this level, dry matter yield increased by more than 40% except the rye doublecropped with sweet sorghum, which showed about a 15% increase at Chariton.

Like monocrop sweet sorghum, sweet sorghum doublecropped with rye produced, overall, slightly higher dry matter yield than the sorghum x sudangrass hybrid at both locations. As expected, dry matter yield was lower on the marginal land. Unlike monocrop sorghum, consistent yield increases with nitrogen application was evident at both sites.

Noticeable differences in yield between monocrop sorghum and doublecropped sorghum was observed. Dry matter yield of doublecrop sorghum was much lower than that of monocrop sorghum. Even total dry matter yield of doublecropped sorghum, which is the sum of the dry matter yield of sorghum and rye, was overall lower than the yield of monocrop sorghum. Thus, the double crops must find their advantage, if any, in soil conservation properties, not yields.

Table 18 Average dry matter yield 1988 to 1991 for double crop sorghum/rye and yield response to nitrogen fertilization (Systems G and H)

Cropping System	Yield	Change in yield	Yield	Change in yield
		(ton/acre)		
		Ames	Chariton	
Sweet sorghum/Rye				
Sweet sorghum				
0 lbs N/a	3.26		2.97	
62.5 lbs N/a	4.25	0.99*	3.73	0.76*
125 lbs N/a	5.22	0.97	4.48	0.75
250 lbs N/a	5.53	0.31	5.49	1.01
Rye				
0 lbs N/a	1.19		1.50	
62.5 lbs N/a	1.80	0.61*	1.72	0.22*
125 lbs N/a	2.12	0.32	1.85	0.13
250 lbs N/a	2.40	0.27	1.92	0.07
Total				
0 lbs N/a	4.22		4.47	
62.5 lbs N/a	5.69	1.47*	5.45	0.98*
125 lbs N/a	6.92	1.23	6.33	0.88
250 lbs N/a	7.45	0.53	7.41	1.08
Sorghum x sudangrass/Rye				
Sorghum x sudangrass				
0 lbs N/a	2.78		2.94	
62.5 lbs N/a	4.15	1.38*	3.66	0.72
125 lbs N/a	4.89	0.74	4.47	0.81*
250 lbs N/a	6.06	1.17	5.20	0.73
Rye				
0 lbs N/a	1.11		1.17	
62.5 lbs N/a	1.59	0.48*	1.72	0.55*
125 lbs N/a	1.90	0.31	1.80	0.09
250 lbs N/a	2.20	0.29	2.03	0.23
Total				
0 lbs N/a	3.67		4.10	
62.5 lbs N/a	5.42	1.76*	5.37	1.27*
125 lbs N/a	6.41	0.99	6.27	0.90
250 lbs N/a	7.82	1.41	7.23	0.96

Note: * indicates the highest yield response to nitrogen use.

Sweet Sorghum in Rotation with Corn and Soybean

Two rotation systems were employed. One was sweet sorghum following corn and soybean and the other was sweet sorghum/rye doublecrop following corn and soybean. Both are in a three year rotation.

As shown by Table 19, sweet sorghum in rotation with corn and soybean produced higher dry matter yield than sweet sorghum/rye in rotation if we compare just the dry matter yield of sorghum itself. However, if we compare the total dry matter yield of sweet sorghum/rye, which is the sum of the yield of both sorghum and rye, to sorghum in rotation, sweet sorghum/rye in rotation produced higher dry matter yield.

As with the monocrop sorghum in Table 16, the dry matter yield of sorghum in rotation on the marginal land was higher than that on the productive land. As explained before, this is probably due to climate differences.

Table 19 Average dry matter yield 1989 to 1992 for sorghum and sorghum/rye in rotation and yield response to nitrogen fertilization (System K)

Cropping System	Yield	Change in yield	Yield	Change in yield
		(ton/acre)		
	<u>Ames</u>		<u>Chariton</u>	
Sweet sorghum				
62.5 lbs N/a	6.68		7.15	
125 lbs N/a	7.18	0.51	7.32	0.17
Sweet Sorghum/Rye				
Sweet sorghum				
62.5 lbs N/a	5.46		5.61	
125 lbs N/a	5.76	0.31	6.85	1.23
Rye				
62.5 lbs N/a	2.32		1.93	
125 lbs N/a	2.35	0.03	1.98	0.05
Total				
62.5 lbs N/a	7.31		7.55	
125 lbs N/a	7.64	0.33	8.83	1.28

Corn and Soybean

As shown in Table 20, corn yield responds positively to nitrogen use. The largest corn grain yield response to nitrogen occurs at 62.5 pounds per acre of nitrogen at both Ames and Chariton. As the nitrogen level increases beyond 62.5 pounds per acre while all other inputs levels stay at the same, additional yields on corn grain increased at a decreasing rate. At Chariton, no yield response to nitrogen is observed at 250 pounds per acre. Corn grain yields of this rotation system are slightly higher than the estimated grain yields of corn following soybean in Iowa under a similar management system as suggested by extension service budgets. It is also slightly higher than the actual average annual corn grain yields in Iowa from 1988 through 1991. Estimated yields of corn grain in Iowa are 115 bushels per acre with 138 pounds per acre of nitrogen using extension budgets (Duffy and Judd, 1992) while the actual average annual corn grain yields in Iowa are 111 bushels per acre (Iowa Department of Agriculture, 1992). The average yield in the experiments was 118 bushels per acre at a nitrogen level 125 pounds per acre.

As expected, yields on corn stover steadily increase as the level of nitrogen use increases. Unlike corn grain, however, the largest yield response to nitrogen is observed at 125 pounds per acre of nitrogen at both Ames and Chariton. One thing should be noticed is that yield of stover decreased at nitrogen level 62.5 pounds per acre at Chariton compared to the yield with no nitrogen use. This inconsistency in stover yields on nitrogen use might have been caused by harvest loss.

No nitrogen was used in soybean production since soybean is a nitrogen fixer. Yields of soybean are shown in Table 21. Compared to the estimated yields of soybean in rotation with corn, 50 bushel per acre, for a similar management system in Iowa (Duffy and Judd, 1992), soybean yields, 28 bushels per acre in Ames and 40 bushels per acre in Chariton, in our experiment are much lower.

Actual average annual yields for soybean in Iowa during the 1988-1991 time period was 38 bushels per acre (Iowa Department of Agriculture, 1992). This was higher than the yields at Ames, but lower than the yields at Chariton.

Table 20 Average dry matter yield for corn and yield response to nitrogen fertilization (System I)

Cropping System	Ames		Chariton	
	Yield	Change in yield	Yield	Change in yield
	(ton/acre)			
Corn				
Grain				
0 lbs N/a	1.37		1.83	
62.5 lbs N/a	2.45	1.08*	2.09	0.26*
125 lbs N/a	3.00	0.55	2.23	0.14
250 lbs N/a	3.31	0.31	2.23	0.00
Stover				
0 lbs N/a	2.41		2.29	
62.5 lbs N/a	2.70	0.28	2.24	-0.05
125 lbs N/a	3.16	0.47*	2.69	0.45*
250 lbs N/a	3.38	0.21	2.87	0.18
Total				
0 lbs N/a	3.78		4.12	
62.5 lbs N/a	5.15	1.37*	4.33	0.21
125 lbs N/a	6.17	1.02	4.91	0.58*
250 lbs N/a	6.69	0.52	5.09	0.18

Note: * indicates the highest yield response to nitrogen use.

Table 21 Average dry matter yield for soybean (System J)

Cropping System	Ames	Chariton
	(ton/acre)	
Soybean		
Grain	0.76	1.10
Stover	0.60	0.99
Total	1.36	2.09

Summary of Yield Responses. Overall, sweet sorghum and sorghum x sudangrass hybrids in different cropping systems produced higher yields than any other annual and perennial species grown in this experiment.

As shown in Tables 16 through 19, among the cropping systems involved with sorghum, sweet sorghum in both the pure monocrop system and monoculture in the rotation system produced the highest dry matter. When we just compare sorghum yield itself in the mixed cropping systems to the monocrop sorghum systems, including sweet sorghum in rotation, sorghum yield in the mixed cropping systems is lower than that of monocrop sorghum. However, if we compare the total yield of the mixed systems themselves - for example, sorghum/rye in doublecrop or in double crop rotation, to the monocrop systems, there is not much difference in dry matter yields.

Sorghum intercropped into the perennial forages, alfalfa and reed canarygrass, also produced lower dry matter yields than the monocrop sorghum systems. However, if we consider the objective of soil conservation, sorghum/alfalfa intercrop system might be a good system to consider as energy crop production system since it has relatively high dry matter yields.

Among the perennial grasses, switchgrass produced the highest dry matter yields at both Ames and Chariton. In Ames, big bluestem produced relatively higher dry matter yields than reed canarygrass. On the other hand, big bluestem was less productive than reed canarygrass in Chariton.

Given the objective to find a biomass crop(s) and a biomass production system(s) that has sustainable high productivity and serves conservation purposes, the results are encouraging.

Recent research shows that sorghum yields may decrease if continuous production of sorghum is practiced on the same land (Wright, 1994). This is the problem inherent in monoculture and double cropped sorghum (Wright, 1994). Pure monoculture sorghum also has a soil erosion problem because it has no ground cover after harvest. However, by practicing the crop rotation system over continuous cropping of a monoculture sorghum, we can avoid some pest and disease problems (Wright, 1994), which will result less use of chemicals, and soil erosion problem without losing high productivity. Thus, the intercropped sorghums show some promise as an environment friendly biomass crop.

Switchgrass is another excellent choice as an biomass energy crop in Iowa, particularly, where soil erosion is an important concern. Although its yield is lower than sorghum, it is the most productive among the perennial grasses and once established, it provides good soil control (Wright, 1994).

So far we have discussed yields of each species and cropping system and their response to the nitrogen use. We have also looked at the most productive nitrogen level for each species. Furthermore, we have identified the most productive cropping systems within the perennial grasses and the annuals and among the different systems. Now we turn to the production costs of each cropping systems. This will help in selecting economically feasible biomass cropping system(s).

Assumptions Used in Estimating Production Costs for the Biomass Systems

Production of the biomass crops considered in this study is most likely to occur on farms that are already producing forage since production of biomass crops involves high fixed costs to own and maintain forage machinery. In some areas, an active custom market for forage operations may allow producers to add these biomass crops at a reasonable cost even without machinery ownership.

Two types of cost estimates are developed in this study. One type is a good approximations of the costs for producers who custom hire the planting and harvesting operations or for those who already own and effectively utilize forage equipment. For producers who already grow other forages, if the biomass crops provide a better return to the fixed machinery and labor resources, the biomass crops can be easily substituted for the currently grown forage crops. The other set of costs are based on lower annual use of

forage equipment by farmers who primarily grow row crops such as corn and soybean and are considering adding biomass crops.

The net production costs presented in this report provide a detailed break down of variable production costs for both marginal and high productivity land. The Mississippi State Budget Generator (MSBG) is used as a tool to estimate the net production costs for the each of the cropping systems with modification on input data to incorporate Iowa conditions and these specific crops.

Equipment and Annual Hours of Use

It is assumed that the equipment required to perform the various tillage, planting, and harvest operations are owned by the farm operator. Table 22 presents the annual hours of use and performance rate for each piece of equipment used in the production of the biomass crops in this research. The performance rate is the rate at which an implement performs its primary function; for example, the number of acres that can be plowed per hour. The implied annual hours of use for each implement is estimated by dividing a number of acres land used in crop production by the performance rate.

Two sets of the annual hours of use for each implement are listed under annual use column (A) and (B) in Table 22. The first one (A) assumes that only 160 acres of farm land is allocated to the production of energy crops. Only those implements used in the forage production are in this set. Thus, the annual use of the forage equipment is rather low. The second set (B) is based on the average annual hours of use of implements by Iowa farmers. This set is from survey data collected by Iowa State University Extension Service. Although the first set is estimated by assuming that 160 acres of land is allocated for the biomass production, this does not necessarily mean that the 160 acres represents total farm land devoted to energy crop production. It is a just yard-stick. For example, if a representative farmer decides to allocate 320 acres for production of energy crops - 160 acres for switchgrass and 160 acres for sweet sorghum - and a bulk fertilizer spreader is used in both crops, then the annual hours of use for bulk fertilizer spreading would be the number in the annual use column of Table 22 multiplied by 2, which is 32 hours per year. In short, the annual hours of use of implements are directly related to the acres of land allocated to the biomass crop production.

Table 22 Performance rate of implements and annual hours of use

Description	Annual Use		Performance Rate
	(A)	(B)	
	(hours)		(a/hr)
FERTILIZATION			
Bulk fertilizer, 25 ft		30	10.2
NH3 applicator, 15 ft		60	5.7
TILLAGE			
Chisel plow, 15 ft		80	7.4
Tandem disk, 17 ft		100	9.2
Disk with sprayer, 21 ft		100	7.8
Peg-tooth harrow, 7 section	9	40	18.0
Field cultivator, 21 ft		40	10.2
PLANTING			
Grain drill, 13 ft	28	40	5.7
Planter, 4 row NR		67	4.9
No-till planter, 6 row NR	24	60	6.7
Cultipacker, 15 ft	23	120	7.1
WEED CONTROL			
Sprayer, 40 ft		50	11.8
Cultivator, 4 row		80	7.4
HARVESTING			
Mower-conditioner, 12 ft	27	120	5.9
Flail chopper, 10 ft	35	80	4.6
Rake, 9 ft	34	100	4.7
Large round baler, 14 ft	21	120	7.5
Silage harvester, 3 row	100	200	1.6
Forage blower, 14 ft	27	50	6.0
Combine, corn head, 4 row NR		110	2.3
Combine, soybean platform, 13 ft		80	2.7
Haul hay, 15 ft trailer	40	80	4.0
Haul grain, 300 bu wagon		150	4.0
Haul silage, 7.17 ft	80	140	2.0
Haul stover, 7.17 ft	80	140	2.0

Source: ISU Cooperative Extension Service, "Estimating Field Capacity of Farm Machines," January 1986.

Note: (A) 160 acres biomass production is assumed.

(B) Estimated based on average Iowa equipment use.

The tillage systems used in estimation of the biomass crop production costs are ones typically practiced by Iowa farmers and not necessarily the ones used in the experimental trials. A list of equipment used in estimating production costs of biomass crops are shown in Tables 23 and 24. Implements used in the production of each biomass cropping system are listed in Tables 25 through 28 along with their field capacity and annual hours of use. For the systems involved with perennial grasses, implements used during the establishment year and implements used during the standing years are presented separately in Table 25 and 26, respectively. Annual hours of use of implements shown in Tables 25 through 28 are estimated by the same method used in Table 22.

Table 23 Implements used in production of perennial grasses and intercrop sorghum

Description	AL	RC	SWG	BB	ALI	RCI
FERTILIZATION						
Bulk fertilizer, 25 ft	x	*	*	*	x	*
TILLAGE						
Chisel plow, 15 ft	x	x	x	x	x	x
Tandem disk, 17 ft	x	x	x	x	x	x
Peg-tooth harrow, 7 section	x	x	x	x	x	x
PLANTING						
Grain drill, 13 ft	x	x	x	x	x	x
No-till planter, 6 row NR					#	#
Cultipacker, 15 ft	x	x	x	x	x	x
WEED CONTROL						
Sprayer, 40 ft	*	x	x	x	*	*
HARVESTING						
Mower-conditioner, 12 ft	*	*	*	*	*	*
Rake, 9 ft	+					
Large round baler, 14 ft	*	*	*	*	*	*
Haul hay, 15 ft	*	*	*	*	*	*

Note: AL=alfalfa; RC=reed canarygrass; SWG=switchgrass; BB=big bluestem; x = establishment year practices only; ALI=alfalfa/sorghum intercrop; RCI=reed canarygrass/sorghum intercrop.

* = activities used in both establishment year and maintenance year; + = maintenance year practice only; # = activities used in intercrop sorghum production only throughout the standing year except establishment year.

Table 24 Implements used in production of annual crops

Description	1	2	3	4	5	6
FERTILIZATION						
Bulk fertilizer, 25 ft	x	x	x	x	x	x
NH3 applicator, 15 ft	x	x	x	x	x	
TILLAGE						
Tandem disk, 17 ft		x		x		
Disk with sprayer, 21 ft	x		x		x	x
Peg-tooth harrow, 7 section	x	x	x	x	x	x
Field cultivator, 21 ft	x					
PLANTING						
Grain drill, 13 ft		x		x		
Planter, 4 row NR	x	x	x	x	x	x
WEED CONTROL						
Cultivator, 4 row	x				x	x
HARVESTING						
Mower-conditioner, 12 ft		x		x		
Flail chopper, 10 ft					x	
Rake, 9 ft					x	
Large round baler, 14 ft		x		x	x	
Silage harvester, 3 row	x	x	x	x		
Forage blower, 14 ft	x	x	x	x		
Combine, corn head, 4 row NR					x	
Combine, soybean platform, 13 ft						x
Haul hay, 15 ft		x		x		
Haul grain, 300 bu					x	
Haul silage, 7.17 ft	x	x	x	x		
Haul stover, 7.17 ft					x	

Note: 1 = monocrop sorghum; 2 = sorghum/rye double crop; 3 = sweet sorghum in rotation; 4 = sweet sorghum/rye in rotation; 5 = corn; 6 = soybeans.

Table 25 Field capacity and annual use of implements used in production of perennial including intercrop alfalfa and reed canarygrass during the establishment year

Description	Annual use		Field capacity	Crops			
	(A)	(B)		a	b	c	d
	(hours)			(a/hr)			
FERTILIZATION							
Bulk fertilizer, 25 ft		30	10.2	x	x	x	x
TILLAGE							
Chisel plow, 15 ft		80	7.4	x	x	x	x
Tandem disk, 17 ft		100	9.2	x	x	x	x
Peg-tooth harrow, 7 sect	9	40	18.0	x	x	x	x
PLANTING							
Grain drill, 13 ft	28	40	5.7	x	x	x	x
Cultipacker, 15 ft	23	120	7.1	x	x	x	x
WEED CONTROL							
Sprayer, 40 ft		50	11.8	x	x	x	x
HARVESTING							
Mower-conditioner, 12 ft	27	120	5.9	x	x	x	x
Large round baler, 14 ft	21	120	7.5	x	x	x	x
Haul hay, 15 ft	40	80	4.0	x	x	x	x

Note: a = alfalfa in both mono- and inter-crop; b = reed canarygrass in both mono- and inter-crop; c = switchgrass; d = big bluestem. (A) 160 acres biomass production is assumed. (B) Estimated based on average Iowa equipment use.

Table 26 Field capacity and annual use of implements used in production of perennial including sorghum intercropped into alfalfa and reed canarygrass for the standing years

Description	Annual use		Field capacity	Crops					
	(A)	(B)		a	b	c	d	e	f
	(hours)			(a/hr)					
FERTILIZATION									
Bulk fertilizer, 25 ft		30	10.2	0	3	0	3	2	2
PLANTING									
No-till planter, 6 row NR	24	60	6.7	0	0	1	1	0	0
WEED CONTROL									
Sprayer, 40 ft		50	11.8	2	0	1	1	0	0
HARVESTING									
Mower-conditioner, 12 ft	27	120	5.9	3	2	3	3	1	1
Rake, 9 ft	34	100	4.7	1	0	1	1	0	0
Large round baler, 14 ft	21	120	7.5	3	2	3	3	1	1
Haul hay, 15 ft	40	80	4.0	3	2	3	3	1	1

Note: a = alfalfa; b = reed canarygrass; c = intercrop alfalfa; d = intercrop reed canarygrass; e = switchgrass; f = big bluestem. (A) 160 acres biomass production is assumed. (B) Estimated based on average Iowa equipment use. The numbers appearing in the last six columns on the table indicate the number of times of the implement is used per year.

Table 27 Field capacity and annual use of implements used in production of monocrop sorghum and double sorghum/rye

Description	Annual use		Field capacity	Systems	
	(A)	(B)		a	b
	(hours)			(a/hr)	
FERTILIZATION					
Bulk fertilizer, 25 ft		30	10.2	x	x
NH3 applicator, 15 ft		60	5.7	x	x
TILLAGE					
Tandem disk, 17 ft		100	9.2		x
Disk with sprayer, 21 ft		100	7.8	x	
Peg-tooth harrow, 7 sect	9	40	18.0	x	x
Field cultivator, 21 ft		40	10.2	x	
PLANTING					
Grain drill, 13 ft	28	40	5.7		x
Planter, 4 row NR		67	4.6	x	x
WEED CONTROL					
Cultivator, 4 row		80	7.4	x	
HARVESTING					
Mower-conditioner, 12 ft	27	120	5.9		x
Large round baler, 14 ft	21	120	7.5		x
Silage harvester, 3 row	100	200	1.6	x	x
Forage blower, 14 ft	27	50	6.0	x	x
Haul hay, 15 ft	40	80	4.0		x
Haul silage, 7.17	80	140	2.0	x	x

Note: a = monocrop sorghum; b = sorghum/rye double crop

(A) 160 acres biomass production is assumed.

(B) Estimated based on average Iowa equipment use.

Table 28 Field capacity and annual use of implements used in production of corn, soybean and sweet sorghum or sorghum/rye in rotation

Description	Annual use		Field capacity	Crops			
	(A)	(B)		a	b	c	d
	(hours)			(a/hr)			
FERTILIZATION							
Bulk fertilizer, 25 ft		30	10.2	x	x	x	x
NH3 applicator, 15 ft		60	5.7	x		x	x
TILLAGE							
Tandem disk, 17 ft		100	9.2				x
Disk with sprayer, 21 ft		100	7.8	x	x	x	
Peg-tooth harrow, 7 sect	9	40	18.0	x	x	x	x
PLANTING							
Grain drill, 13 ft	28	40	5.7				x
Planter, 4 row NR		67	4.6	x	x	x	x
WEED CONTROL							
Cultivator, 4 row		80	7.4	x	x		
HARVESTING							
Mower-conditioner, 12 ft	27	120	5.9				x
Flail chopper, 10 ft	35	80	4.6	x			
Rake, 9 ft	34	100	4.7	x			
Large round baler, 14 ft	21	120	7.5	x			x
Combine, corn head, 4 row NR		110	2.3	x			
Combine, soybean platform		80	2.7		x		
Silage harvester, 3 row	100	200	1.6			x	x
Forage blower, 14 ft	27	50	6.0			x	x
Haul grain, 300 bu		150	4.0	x	x		
Haul stover, 7.17 ft	80	140	2.0	x			
Haul silage, 7.17 ft	80	140	2.0			x	x
Haul hay, 15 ft	40	80	4.0				x

Note: a = corn; b = soybean; c = sorghum; d = sorghum/rye.

(A) 160 acres biomass production is assumed.

(B) Estimated based on average Iowa equipment use.

Division of Costs

By the construction of the MSBG, the cash costs of variable factors of production such as operating inputs, labor, fuel, repairs and maintenance, and interest on operating capital are itemized under direct expenses. On the other hand, the non-cash costs of owning durable factors such as depreciation and interest on investment for machines are treated as fixed expenses. The land cost, which is not directly related to field operations, is itemized under the allocated cost heading. For the perennial grasses, the prorated establishment costs are treated as other durable inputs and categorized under establishment costs in estimating annual net production costs of the perennial.

Input prices used to estimate energy crop production costs are listed in Table 29. All prices in Table 29 are in nominal dollars for 1993. Price data are collected from many different sources. Price data for fertilizers, fungicides and herbicides are obtained from the local COOP in Nevada, Iowa. Corn and soybean seed prices are cited from Iowa State University publication, "Estimated Costs of Crop Production in Iowa, 1993," (Duffy and Judd, 1993). Other seed prices are collected from an extension agronomist, Dr. S. K. Barnhart, who is Extension Forage Specialist, in the College of Agriculture at Iowa State University.

Tables 3 through 14 in the previous section listed the amounts of fertilizer, herbicide, and seed applied to each cropping systems. The fertilizer rates are based on soil tests and discussions with project agronomists, Dr. D. R. Buxton and Dr. I. C. Anderson at Iowa State University.

Transportation costs to a conversion plant are assumed to be \$4.15 per ton of dry matter for all crops. This cost is estimated by using the biomass product transportation cost formula developed by Baht, et al (1992). The assumed distance is a 30 mile round trip. A semi-truck hauling 15.42 tons of hay is assumed to be used.

Currently there is no active market for biomass crops. Thus, we arbitrarily chose \$40/dry ton as a presumed selling price for all establishment year grown biomass crops for this research. This is necessary in order to allocate the returns for this year to the other production years. This is arbitrary, but not entirely fictional. This price is within the required selling price of biomass crops to break-even with corn, and to break-even with the production costs of biomass crops in the Midwest (Turhollow, 1994). The break-even prices for each biomass cropping systems in this research is presented later in Tables 41A and 41B. The assumed price, \$40 per dry ton is also much lower than the market price for hay, \$77/dry ton in Iowa and \$70.70/dry ton U.S. average in 1991 (USDA, 1992).

Table 29 List of input prices

Item	Unit	Price (dollars)
Fertilizers		
Phosphorus	lbs P ₂ O ₅	0.25
Potash	lbs K ₂ O	0.17
Nitrogen (bulk)	lbs	0.21
Anhydrous	lbs	0.12
Lime	ton	6.00
Fungicides		
Eptom	pt	2.81
Herbicides		
Atrazine	pt	1.58
Bladex	pt	3.07
Dual	pt	7.88
Lasso	pt	3.28
Lorsban 4E	pt	1.81
Paraquat	pt	4.46
2, 4D	pt	2.31
Seed		
Alfalfa	lbs	2.50
Reed canarygrass	lbs	4.50
Switchgrass	lbs	3.50
Big bluestem	lbs	9.00
Sweet sorghum	lbs	0.50
Sorghum x sudangrass	lbs	0.35
Rye	lbs	0.31
Corn	1000 kernels	0.90
Soybean	unit	14.00
Interest	%	10.00
Labor	hour	6.00
Diesel fuel	gal	0.83
Land	acre	115.00
		80.00

Nitrogen Levels and Management Systems

As mentioned before, four different levels of nitrogen were applied (0, 62.5, 125, 250 lbs/acre) while all other inputs were applied in the same amount to each biomass cropping system to see the yield response to nitrogen use. We treat each level of nitrogen application within the same cropping system as a different management system. This means that there are four different management systems for each biomass cropping system.

For the simplicity and convenience, just one management system from each biomass cropping systems was chosen to estimate the net production costs (budgets). Each cropping system has two estimated budgets: one is the table number affixed with letter A and the second is the table number affixed with letter

B. The difference between the two table is the assumption on the annual hours of use for implements, given years of ownership and performance rate. The tables with the letter A assume that the annual hours of use is based on 160 acres of biomass production (numbers in the use column below the letter A in Table 22) while the tables with the letter B assume that the average annual hours of use of implements is similar to the average of Iowa farmers (numbers in the use column below the letter B in Table 22).

As shown in Table 22, the annual hours of use of implements assumed by this study for farmers who grow biomass as a sideline is much lower than that of typical Iowa forage farmers due to the difference in assumption on acres of land for which implements are used. Consequently, the budgets estimated with the annual hours of use of implements in the use column below letter A of Table 22 (tables with letter A) are higher then the budgets estimated with the annual hours of use of implements in the use column below letter B of Table 22 (tables with letter B).

The amount of nitrogen used in estimation of the net production cost for each biomass cropping system is not the same as the nitrogen level actually applied during the experiment period. It is an "optimum" amount recommended by the two agronomists of this project, Dr. I. C. Anderson and Dr. D. Buxton. This nitrogen level is also consistent with the economically optimum level of nitrogen selection at the assumed dry matter price, \$40 per ton.

In principle, a farmer seeking a maximum net return, under the competitive market system, would choose the input level at where the contribution of each input used in production equals the cost of each input used, i.e., a profit maximizing farmer will determine the nitrogen input level where the marginal revenue product of nitrogen (MRPN) equals to the marginal factor cost of nitrogen (MFCN). Under the competitive market system, MRPN is defined as the market price of the output (dry matter) multiplied by the marginal product of nitrogen, and the MFCN is the market price of nitrogen itself. The MRPN is the benefit from an additional amount of nitrogen, and the MFCN is the cost of an additional amount of nitrogen. Therefore, a profit maximizing farmer will increase use of nitrogen if MRPN is greater than MFCN; otherwise, he will reduce nitrogen use. For example, as shown in Table 30, if we compare the marginal revenue product of nitrogen (MRPN) and the marginal factor cost of nitrogen (MFCN) in big bluestem production in Table 30, MRPN is greater than MCN at 62.5 pounds of nitrogen and MRPN is less than MNC at 125 pounds. This means that a profit maximizing farmer producing big bluestem should use nitrogen input more than 62.5 pounds but less than 125 pounds per acre. Thus, the recommended nitrogen level, 100 pounds per acre, used in the production cost estimation for big bluestem is in accordance with economic theory.

Table 30 shows the MRPN and the MFCN for each crop. As mentioned above, the MFCN is the market price of nitrogen, \$0.21 per pound of bulk nitrogen in 1993. To estimate the MRPN in Table 30, we made some assumptions. First, it is assumed that the production function is a piece-wise linear concave function in the output and nitrogen input space. It means that the production function is linear over the given range of inputs; for example, linear over 0 to 65 pounds per acre nitrogen level, and 65 to 125 pounds per acre, and so on. As a result, the total revenue function is also a piece-wise linear concave function in money and nitrogen space. This automatically leads to our second assumption that the MRPN is constant over the given range of nitrogen level. Thus, MRPN is estimated by dividing the change in total revenue by the change in the amount of nitrogen input. Third, as mentioned before, market price for the dry matter is assumed \$40 per dry matter ton. Thus, given output level, MRPN will change as the price of dry matter changes.

Table 30 indicates that the optimal nitrogen input level should be less than 250 pounds per acre for almost all of the biomass crop systems used in this research because MRPN is less than MFCN at the nitrogen level 250 pounds per acre, except the following crops: reed canarygrass at Ames, double crop sweet sorghum/rye at Chariton, and double crop sorghum x sudangrass hybrid/rye at both Ames and Chariton. For all cropping systems at both Ames and Chariton, the MRPN is much greater than the MFCN

at a nitrogen level of 62.5 pounds per acre. At the nitrogen level of 125 pounds per acre, the MRPN for some systems is less than the MFCN; for example, big bluestem at both Ames and Chariton, switchgrass at Ames, both monocrop sorghum at Chariton, sweet sorghum in rotation at Chariton, double crop sweet sorghum/rye in rotation at both Ames and Chariton, and the intercrop alfalfa/sweet sorghum at Ames.

Table 30 Marginal revenue product and marginal cost of nitrogen

Crop system and change in nitrogen use (lbs/acre)	Change in revenue (dollars)	MRPN	Change in revenue (dollars)	MRPN	MFCN
	<u>Ames</u>		<u>Chariton</u>		
Reed canarygrass					
62.5	32.80	0.52	46.94	0.75	0.21
62.5	34.40	0.55	30.76	0.49	0.21
125.0	50.12	0.40	12.95	0.10	0.21
Big bluestem					
62.5	17.73	0.28	43.84	0.70	0.21
62.5	3.87	0.06	10.25	0.16	0.21
125.0	13.20	0.11	7.55	0.06	0.21
Switchgrass					
62.5	81.60	1.31	24.82	0.40	0.21
62.5	0.00	0.00	37.23	0.60	0.21
125.0	9.20	0.07	9.17	0.07	0.21
Sweet sorghum					
62.5	65.60	1.05	46.30	0.74	0.21
62.5	16.00	0.26	8.74	0.14	0.21
125.0	-10.80	-0.09	-4.53	-0.04	0.21
Sorghum x sudangrass					
62.5	30.40	0.49	29.14	0.47	0.21
62.5	27.20	0.44	0.65	0.01	0.21
125.0	0.40	0.00	24.28	0.19	0.21
Sweet sorghum/rye ¹					
62.5	58.92	0.94	39.17	0.63	0.21
62.5	49.21	0.79	35.29	0.56	0.21
125.0	21.04	0.17	43.06	0.34	0.21
Sorghum x sudangrass/rye ¹					
62.5	70.25	1.12	50.83	0.81	0.21
62.5	39.50	0.63	35.94	0.57	0.21
125.0	56.33	0.45	38.20	0.31	0.21
Sweet sorghum ²					
62.5	20.23	0.32	6.80	0.11	0.21
Sweet sorghum/rye ²					
62.5	13.27	0.20	51.39	0.82	0.21

Table 30 continued

Crop system and change in nitrogen use (lbs/acre)	Change in revenue (dollars)	MRPN	Change in revenue (dollars)	MRPN	MFCN
	<u>Ames</u>		<u>Chariton</u>		
Corn					
62.5	54.71	0.88	8.42	0.13	0.21
62.5	40.79	0.65	23.31	0.37	0.21
125.0	20.72	0.17	7.12	0.06	0.21
Alfalfa/sweet sorghum					
62.5	3.20	0.05	17.00	0.27	0.21
Alfalfa/sorghum x sudangrass hybrid					
62.5	17.20	0.28	12.14	0.19	0.21
Reed canarygrass/sweet sorghum					
62.5	42.00	0.67			
Reed canarygrass/sorghum x sudangrass hybrid					
62.5	42.00	0.67			

Note: ¹ Double crop systems. ² Rotation.

- The numbers listed in the first column below the crop system indicates the changes in the amount of nitrogen use in the following manner: 0 to 62.5 lbs/acre; 62.5 to 125 lbs/acre; and 125 to 250 lbs/acre in turn.
- The second and fourth columns are the difference in total income at different levels of nitrogen use.
- The third and fifth columns are estimated by dividing the change in revenue by the change in nitrogen use.
- The changes in nitrogen level for the following systems are the changes from 62.5 to 125 lbs/acre: sweet sorghum and sweet sorghum/rye in rotation and in intercrop systems.

It should be noted that the MRPN listed in Table 30 for each biomass cropping system will change as either the price of dry matter changes or dry matter yields change. The purpose of this table is merely to show some economic selection criteria for the amount of nitrogen use in production.

Establishment Year and Annual Costs

For the perennial forages, the net production costs for both establishment year and annual production are developed. In the next section, the net production costs for the establishment of perennial grasses are first presented. This is followed by discussion of the annual net production costs for all cropping systems. The tables in the text contain summary information on costs of production. More complete tables giving quantities as well as prices are contained in Appendix A. These are only reported for average Iowa equipment use.

Establishment Costs for Perennial Forages

Once established, perennial grasses have a long lasting productive life so that the cost incurred at the establishment should be prorated over the useful life of perennial grasses. As shown in Table 1, the stand for perennial grasses is assumed to be 5 years for alfalfa, and 10 years for reed canarygrass, switchgrass, and big bluestem, respectively. With careful stand management, it is possible to have longer stand life.

In principle, when establishment costs are prorated, interest payments made on the establishment costs over the useful life of perennial grasses must be counted at the on going market interest rate. In other words, opportunity costs should be considered. However, for the simplicity, the net establishment year costs for each perennial grasses in this research was prorated evenly over the remaining years of the stand. For example, the net establishment year costs for switchgrass is prorated over the remaining 9 years of the stand. This understatement of cost, in some sense, compensates for the risk associated with establishment and given the other uncertainties in estimation introduces small error.

It is assumed that the perennial grasses will be harvested and sold in the establishment year. As a result, the net establishment year costs (total establishment year costs minus the income from sales) are prorated and these prorated net establishment costs are entered into the annual production cost estimation for the perennial grasses rather than the total establishment year production cost itself.

Perennial grasses are harvested as hay. This involves mowing-conditioning, raking, baling, hauling in the field, and transportation to the conversion plant. Switchgrass and big bluestem are assumed to be harvested once a year while alfalfa and reed canarygrass are harvested three times a year. The perennial grasses are assumed to field dry. Thus, no raking is assumed for the perennial grasses, except the first harvest of alfalfa and reed canarygrass. Raking is assumed to be applied to the first harvest of alfalfa and reed canarygrass because of typical rainy weather conditions in Iowa in the spring.

Despite transportation inefficiency inherent in the large round bales (Dobbins, et al., 1990), it is assumed that hay is baled into large round bales of 1200 pounds. The round bale system has relatively low capital investment and modest labor requirement. It can be a one-person operation. The bales can be stored in any open, well-drained area. This eliminates the need for a storage facilities (Dobbins, et al., 1990).

For switchgrass and reed canarygrass, machinery costs are the highest among the total specified establishment costs, which accounts for all costs, but land cost, involved in the production process (Tables 31 and 32). Machinery costs include fuel, repair and maintenance, and depreciation and interest on average investments in machines, tractors and implements. Fertilizer cost and seed cost are the second and the third largest costs of production, respectively.

For alfalfa, fertilizer cost is the largest because it is assumed that the total amount of fertilizer required for alfalfa production over the assumed standing life, 5 years, is applied at once during the establishment year. The second largest costs for alfalfa production are the machinery costs. Seed cost is the third largest establishment cost of alfalfa production.

Table 31A Estimated per acre cost of establishing alfalfa, reed canarygrass, switchgrass, and big bluestem in Ames (160 acres of biomass production is assumed).

Item	Alfalfa	Reed canary- grass	Switch- grass	Big- bluestem
	-dollars-			
Seed	30.00	40.50	28.00	108.00
Phosphorus	40.00	8.00	8.00	8.00
Potassium	106.25	15.98	15.98	15.98
Nitrogen		26.25		
Fungicide	8.43			
Herbicide	1.81	4.62	3.95	5.78
Machinery fuel	7.13	7.21	4.99	4.99
Repair and maintenance	29.80	29.80	18.01	18.01
Labor	13.73	13.87	9.38	9.38
Interest	18.31	7.15	4.76	8.27
Fixed expenses on machinery	<u>66.30</u>	<u>67.35</u>	<u>43.35</u>	<u>43.35</u>
Total Operating Cost	321.76	220.73	136.42	221.76
Transportation cost	10.42	9.59	13.78	10.58
<u>Total Specified Establishment Cost</u>	332.17	230.31	150.20	232.35
<u>Land</u>	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>
<u>Total Establishment Cost</u>	447.17	345.31	265.20	347.35
<u>Income from crop</u>	<u>100.40</u>	<u>92.40</u>	<u>132.80</u>	<u>102.00</u>
<u>Net Establishment Cost</u>	346.77	252.91	132.40	245.35
<u>Prorated Establishment Cost</u>	86.69	28.10	14.71	27.26

Note: Establishment cost of alfalfa is prorated over 4 years and establishment costs of the other perennial are prorated over 9 years.

Table 31B Estimated per acre cost of establishing alfalfa, reed canarygrass, switchgrass, and big bluestem in Ames (Estimated based on average Iowa equipment use).

Item	Alfalfa	Reed canary- grass	Switch- grass	Big- bluestem
-dollars-				
Seed	30.00	40.50	28.00	108.00
Phosphorus	40.00	8.00	8.00	8.00
Potassium	106.25	15.98	15.98	15.98
Nitrogen	.	26.25		
Fungicide	8.43			
Herbicide	1.81	4.62	3.95	5.78
Machinery fuel	7.13	7.21	4.99	5.37
Repair and maintenance	16.82	16.82	11.23	11.23
Labor	13.73	13.87	9.38	9.87
Interest	18.07	6.92	4.68	8.23
Fixed expenses on machinery	<u>32.60</u>	<u>33.64</u>	<u>23.58</u>	<u>23.58</u>
Total Operating Cost	274.84	173.81	109.79	196.04
Transportation cost	10.42	9.59	13.78	10.58
<u>Total Specified Establishment Cost</u>	285.26	183.40	123.57	206.62
Land	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>
<u>Total Establishment Cost</u>	400.26	298.40	238.57	321.62
Income from crop	<u>100.40</u>	<u>92.40</u>	<u>132.80</u>	<u>102.00</u>
<u>Net Establishment Cost</u>	299.85	206.00	109.77	219.62
<u>Prorated Establishment Cost</u>	74.96	22.89	11.75	24.40

Note: Establishment cost of alfalfa is prorated over 4 years and establishment costs of the other perennial are prorated over 9 years.

Table 32A Estimated per acre cost of establishing alfalfa, reed canarygrass, switchgrass, and big bluestem in Chariton (160 acres of biomass production is assumed).

Item	Alfalfa	Reed canary- grass	Switch- grass	Big- bluestem
-dollars-				
Seed	35.00	49.50	28.00	108.00
Phosphorus	40.00	8.00	8.00	8.00
Potassium	106.25	15.98	15.98	15.98
Lime	30.00			
Nitrogen		26.25		
Fungicide	8.43			
Herbicide	2.72	4.62	3.95	5.78
Machinery fuel	7.52	7.21	4.99	4.99
Repair and maintenance	30.60	29.80	18.01	18.01
Labor	14.42	13.87	9.38	9.38
Interest	21.76	7.61	4.78	8.24
Fixed expenses on machinery	<u>68.60</u>	<u>67.35</u>	<u>43.35</u>	<u>43.35</u>
<u>Total Operating Cost</u>	365.30	230.19	136.44	221.73
Transportation cost	8.55	10.25	13.03	7.06
<u>Total Specified Establishment Cost</u>	373.85	140.44	149.48	228.79
Land	<u>80.00</u>	<u>80.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Establishment Cost</u>	453.85	320.44	229.48	308.79
Income from crop	<u>82.40</u>	<u>98.80</u>	<u>125.60</u>	<u>68.00</u>
<u>Net Establishment Cost</u>	371.45	221.64	103.88	240.79
<u>Prorated Establishment Cost</u>	92.86	24.63	11.54	26.75

Note: Establishment cost of alfalfa is prorated over 4 years and establishment costs of the other perennial are prorated over 9 years.

Table 32B Estimated per acre cost of establishing alfalfa, reed canarygrass, switchgrass, and big bluestem in Chariton (Estimated based on average Iowa equipment use).

Item	Alfalfa	Reed canary- grass	Switch- grass	Big- bluestem
-dollars-				
Seed	35.00	49.50	28.00	108.00
Phosphorus	40.00	8.00	8.00	8.00
Potassium	106.25	15.98	15.98	15.98
Lime	30.00			
Nitrogen		26.25		
Fungicide	8.43			
Herbicide	2.72	4.62	3.95	5.78
Machinery fuel	7.52	7.21	4.99	5.37
Repair and maintenance	17.72	16.82	11.23	11.23
Labor	14.42	13.87	9.38	9.87
Interest	21.52	7.37	4.70	8.20
Fixed expenses on machinery	<u>34.89</u>	<u>33.64</u>	<u>23.58</u>	<u>23.58</u>
<u>Total Operating Cost</u>	318.47	183.26	109.81	196.01
Transportation cost	8.55	10.25	13.03	7.06
<u>Total Specified Establishment Cost</u>	327.02	193.51	122.84	203.07
Land	<u>80.00</u>	<u>80.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Establishment Cost</u>	407.02	273.51	202.84	283.07
Income from crop	<u>82.40</u>	<u>98.80</u>	<u>125.60</u>	<u>68.00</u>
<u>Net Establishment Cost</u>	324.62	174.71	77.24	215.07
<u>Prorated Establishment Cost</u>	81.16	19.41	8.58	23.90

Note: Establishment cost of alfalfa is prorated over 4 years and establishment costs of the other perennial are prorated over 9 years.

The rankings of production costs for big bluestem are as follows: seed cost is the highest followed by the machinery costs and fertilizer cost in turn. For big bluestem, seed cost is exceptionally high because, as shown in Table 29, big bluestem seed price is much higher, \$9 per pound, than the other perennial seeds - \$2.50 for alfalfa, \$4.50 for reed canarygrass, and \$3.50 for switchgrass per pound. This high input price for seed is the sole reason for high seed cost for big bluestem. (Note that although the market price of big bluestem seed had decreased to \$8 per pound in 1994 (Barnhart, personal communication), in estimation of the establishment costs, the market price of big bluestem seed in 1993 (\$9 per pound) is used to be consistent with other input data.)

The lowest cost for all perennial grasses is the cost of controlling weeds.

Switchgrass has both the lowest establishment cost and the lowest net establishment cost per acre while alfalfa has both the highest establishment cost and net establishment cost per acre among the perennial grasses at both Ames and Chariton. With higher land allocation to biomass crop production, total establishment cost and net establishment cost for reed canarygrass are unambiguously lower than for big bluestem at both locations (Tables 31B and 32B); however, the cost comparison between reed canarygrass and big bluestem is somewhat complex with lower land allocation (Tables 31A and 32A). The lower operating costs and higher dry matter yields are the key factors contributing to the lowest establishment cost and net establishment cost for switchgrass.

As expected, when we compare the establishment year production costs of perennial grasses, switchgrass has the least prorated establishment cost while alfalfa has the largest. Between reed canarygrass and big bluestem, there is almost no difference on the prorated establishment cost (Tables 31A/B and 32A/B).

From this establishment cost analysis, we make the following observations. Machinery costs could be reduced by relying on custom hiring or by renting of equipment. These would reduce the need for large capital outlays. A no-till system could be employed to reduce machinery costs and soil erosion. Soil testing before establishment might enable the producer to fine tune application of fertilizer.

Annual Production Costs for Perennial Grasses

As explained in the description of the tillage systems, maintenance and harvesting costs are the only ones involved in production of the monocrop perennial biomass crops following the establishment year. Tables 33A (33B) and 34A (34B) show the annual production costs of monocrop perennial grasses at Ames and Chariton, respectively.

Once a good stand has been established for perennial grasses, maintaining a healthy, vigorous and productive stand of these perennial grasses is very important for continued production and long lasting stand life. Thus, good production management practices, which include monitoring soil nutrients and controlling weeds and insects, are important for the production of perennial grasses. Good management practices will result in continued high annual yields and longer stand life. Continued high annual yields will reduce the net production cost per ton given per acre production costs. Longer stand life is crucial in reducing the prorated establishment cost. For example, the prorated establishment cost of alfalfa in Ames could be reduced to \$59.97 from \$74.96 (Table 31B) (or to \$69.35 from \$89.21 (Table 31A)) if stand life was 6 years instead of 5 years.

Applying proper amounts of fertilizer, especially nitrogen, phosphorus, and potassium, each year is an important management practice for continued high yields. The amount of each necessary fertilizer application will vary slightly from year to year. It will also differ in different regions due to differences in soil conditions. Soil testing will help to determine proper amounts needed each year in different regions. Annual use of fertilizers for all perennial grasses, except alfalfa, over the standing years is assumed to be 32 pounds per acre for phosphorus and 94 pounds per acre for potash, respectively, at both Ames and Chariton. These are the amounts determined by the soil test performed during the experiment period. For alfalfa, there

is no annual fertilizer cost because both phosphorus and potash are assumed to be applied once in the establishment year.

Weed control is also an important factor for high yields. The decision to use herbicides for weed control in established perennial grasses should be based on the degree of the weed infestation, the type of weeds present and most importantly the density of the existing stand (Undersander, et al. 1991). However, to keep treatment economical, annual weed control measures after establishment were kept at minimum for the following reasons: first, because of the ability of these species to out compete weeds in general; second, the density of existing stand for all perennials in this research was reasonably good; and third, nutrition quality was not an important concern for the purpose of this research, use of biomass crops for energy use.

Switchgrass has both the lowest annual production costs and the lowest net annual production costs among perennial grasses at both Ames and Chariton (Tables 33A/33B and 34A/34B). Big bluestem has the second lowest annual production costs and net annual production costs at both locations. Alfalfa has the highest annual production costs and its annual production costs are higher than that of reed canarygrass at both locations. However, when we compare the net production costs between alfalfa and reed canarygrass, the results are not consistent with that of production costs. The annual net production costs for alfalfa at Ames are lower than those of reed canarygrass while reed canarygrass has much lower net production costs at Chariton than alfalfa, because the dry matter yields of reed canarygrass at Chariton are much higher than those of alfalfa (Tables 33A/33B and 34A/34B).

Productivity, machinery costs and establishment costs are the primary factors contributing to differences in production costs and net production costs among the perennial grasses. Although switchgrass and big bluestem have the same crop management practices, the costs of production are different due to the difference in the prorated establishment cost. Big bluestem has higher prorated establishment cost (almost twice as much) than switchgrass. In addition to lower production costs, higher productivity of switchgrass also contributes to lower net production costs for switchgrass. For alfalfa and reed canarygrass, the differences in the production costs comes largely from differences in prorated establishment costs and machinery costs. The prorated establishment cost of alfalfa is about three times larger than that of reed canarygrass. Alfalfa and reed canarygrass have higher machinery costs because of the differences in the number of harvests: three times for alfalfa, two times for reed canarygrass, and one for both switchgrass and big bluestem.

Table 33A Estimated per acre annual production cost of alfalfa, reed canarygrass, switchgrass, and big bluestem in Ames (160 acres of biomass production is assumed).

Item	Alfalfa	Reed canary- grass	Switch- grass	Big- bluestem
-dollars-				
Phosphorus		8.00	8.00	8.00
Potassium		15.98	15.98	15.98
Nitrogen		42.00	21.00	21.00
Herbicide	3.62			
Machinery fuel	6.69	4.82	2.60	2.60
Repair and maintenance	36.53	24.47	12.68	12.68
Labor	13.94	9.66	5.18	5.18
Interest	2.06	6.25	3.85	3.82
Fixed expenses on machinery	<u>70.88</u>	<u>50.29</u>	<u>26.29</u>	<u>26.29</u>
<u>Total Operating Cost</u>	133.72	161.47	95.58	95.55
Transportation cost	18.26	13.82	18.68	15.89
Establishment cost	<u>86.69</u>	<u>28.10</u>	<u>14.71</u>	<u>27.26</u>
<u>Total Specified Cost</u>	238.67	203.39	128.97	138.70
Land	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>
<u>Total Cost</u>	353.67	318.39	243.97	253.70
Income from crop ¹	<u>176.00</u>	<u>133.20</u>	<u>182.00</u>	<u>153.20</u>
<u>Net Return</u>	-177.67	-185.19	-61.97	-100.51
Cost per ton ²	80.38	95.61	54.22	66.07

Note: ¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 4.40 ton for alfalfa, 3.33 ton for reed canarygrass, 4.50 ton for switchgrass, 3.84 ton for big bluestem (Table 15). Negative net return means loss and positive means profit.

Table 33B Estimated per acre annual production cost of alfalfa, reed canarygrass, switchgrass, and big bluestem in Ames (Estimated based on average Iowa equipment use).

Item	Alfalfa	Reed canary- grass	Switch- grass	Big- bluestem
-dollars-				
Phosphorus		8.00	8.00	8.00
Potassium		15.98	15.98	15.98
Nitrogen		42.00	21.00	21.00
Herbicide	3.62			
Machinery fuel	6.69	4.82	2.60	2.60
Repair and maintenance	17.37	12.08	6.49	6.49
Labor	13.94	9.66	5.18	5.18
Interest	1.52	4.78	3.80	3.77
Fixed expenses on machinery	<u>27.86</u>	<u>22.43</u>	<u>12.36</u>	<u>12.36</u>
<u>Total Operating Cost</u>	<u>71.00</u>	<u>119.75</u>	<u>75.41</u>	<u>75.38</u>
Transportation cost	18.26	13.82	18.68	15.89
Establishment cost	<u>75.96</u>	<u>22.89</u>	<u>11.75</u>	<u>24.40</u>
<u>Total Specified Cost</u>	<u>164.22</u>	<u>156.46</u>	<u>105.84</u>	<u>115.67</u>
Land	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>
<u>Total Cost</u>	<u>279.22</u>	<u>271.46</u>	<u>220.84</u>	<u>230.67</u>
Income from crop ¹	<u>176.00</u>	<u>133.20</u>	<u>182.00</u>	<u>153.20</u>
<u>Net Return</u>	<u>-103.22</u>	<u>-138.26</u>	<u>-38.84</u>	<u>-77.47</u>
Cost per ton ²	63.46	81.52	49.08	60.07

Note: ¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 4.40 ton for alfalfa, 3.33 ton for reed canarygrass, 4.50 ton for switchgrass, 3.84 ton for big bluestem (Table 15). Negative net return means loss and positive means profit.

Table 34A Estimated per acre annual production cost of alfalfa, reed canarygrass, switchgrass, and big bluestem in Chariton (160 acres of biomass production is assumed).

Item	Alfalfa	Reed canary- grass	Switch- grass	Big- bluestem
-dollars-				
Phosphorus		8.00	8.00	8.00
Potassium		15.98	15.98	15.98
Nitrogen		42.00	21.00	21.00
Herbicide	3.62			
Machinery fuel	6.69	4.82	2.60	2.60
Repair and maintenance	36.53	24.47	12.78	12.78
Labor	13.94	9.66	5.18	5.18
Interest	2.00	5.03	3.85	3.81
Fixed expenses on machinery	<u>70.88</u>	<u>50.29</u>	<u>26.29</u>	<u>26.29</u>
<u>Total Operating Cost</u>	133.66	160.25	95.68	95.64
Transportation cost	14.40	19.63	19.46	14.73
Establishment cost	<u>92.86</u>	<u>24.63</u>	<u>11.54</u>	<u>26.75</u>
<u>Total Specified Cost</u>	240.92	204.51	126.68	137.12
Land	<u>80.00</u>	<u>80.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	320.92	284.51	206.68	217.12
Income from crop ¹	<u>138.80</u>	<u>189.20</u>	<u>187.60</u>	<u>142.00</u>
<u>Net Return</u>	-182.12	-95.31	-19.08	-75.12
Cost per ton ²	92.48	60.15	44.07	61.16

Note: ¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 3.47 ton for alfalfa, 4.73 ton for reed canarygrass, 4.69 ton for switchgrass, 3.55 ton for big bluestem (Table 15). Negative net return means loss and positive means profit.

Table 34B Estimated per acre annual production cost of alfalfa, reed canarygrass, switchgrass, and big bluestem in Chariton (Estimated based on average Iowa equipment use).

Item	Alfalfa	Reed canary- grass	Switch- grass	Big- bluestem
-dollars-				
Phosphorus		8.00	8.00	8.00
Potash		15.98	15.98	15.98
Nitrogen		42.00	21.00	21.00
Herbicide	3.62			
Machinery fuel	6.69	4.82	2.60	2.60
Repair and maintenance	17.37	12.08	6.49	6.49
Labor	13.94	9.66	5.18	5.18
Interest	1.46	4.83	3.80	3.76
Fixed expenses on machinery	<u>27.85</u>	<u>22.43</u>	<u>12.36</u>	<u>12.36</u>
<u>Total Operating Cost</u>	70.93	119.80	75.41	75.37
Transportation cost	14.40	19.63	19.46	14.73
Establishment cost	<u>81.16</u>	<u>19.41</u>	<u>8.58</u>	<u>23.90</u>
<u>Total Specified Cost</u>	166.49	158.84	103.45	114.00
Land	<u>80.00</u>	<u>80.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	246.49	238.84	183.45	194.00
Income from crop ¹	<u>138.80</u>	<u>176.40</u>	<u>187.60</u>	<u>142.00</u>
<u>Net Return</u>	-107.69	-62.44	4.15	-52.00
Cost per ton ²	71.03	50.49	39.12	54.65

Note: ¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 3.47 ton for alfalfa, 4.73 ton for reed canarygrass, 4.69 ton for switchgrass, 3.55 ton for big bluestem (Table 15). Negative net return means loss and positive means profit.

Annual Costs for Intercrop Systems

Tables 35A/35B and 36A/36B show annual production costs for the intercrop systems at Ames and Chariton, respectively. Since sorghum is an annual crop, sorghum is interplanted every year into the established alfalfa and reed canarygrass for the intercrop systems. Thus, the annual production costs of intercrop systems - sorghum/alfalfa and sorghum/reed canarygrass - are higher than monocrop alfalfa and reed canarygrass production cost by the seed and planting cost of sorghum.

Table 35A Estimated per acre annual production cost of intercrop sorghum/alfalfa and sorghum/reed canarygrass, in Ames (160 acres of biomass production is assumed).

Item	A	B	C	D
			-dollars-	
Seed	3.50	2.45	3.50	2.45
Phosphorus			8.00	8.00
Potassium			15.98	15.98
Nitrogen			42.00	42.00
Herbicide	1.78	1.78	1.78	1.78
Machinery fuel	6.91	6.91	8.06	8.06
Repair and maintenance	38.51	38.51	41.21	41.21
Labor	14.42	14.42	16.49	16.49
Interest	2.10	2.05	6.79	6.75
Fixed expenses on machinery	<u>77.82</u>	<u>77.82</u>	<u>84.71</u>	<u>84.71</u>
<u>Total Operating Cost</u>	145.04	143.94	228.52	227.43
Transportation cost	25.73	25.32	18.05	18.30
Establishment cost	<u>86.69</u>	<u>86.69</u>	<u>28.10</u>	<u>28.10</u>
<u>Total Specified Cost</u>	257.46	255.95	274.67	273.83
Land	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>
<u>Total Cost</u>	372.46	370.95	389.67	388.83
Income from crop ¹	<u>248.00</u>	<u>244.00</u>	<u>174.00</u>	<u>176.40</u>
<u>Net Return</u>	-124.46	-126.95	-215.67	-212.43
Cost per ton ²	60.07	60.81	89.58	88.17

Note: A = Sweet sorghum/alfalfa; B = Sorghum x sudangrass/ alfalfa; C = Sweet sorghum/reed canarygrass; D = Sorghum x sudangrass/reed canarygrass.

¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 6.2 ton for A, 6.1 ton for B, 4.35 ton for C, 4.41 ton for D.

Table 35B Estimated per acre annual production cost of intercrop sorghum/alfalfa and sorghum/reed canarygrass, in Ames (Estimated based on average Iowa equipment use).

Item	A	B	C	D
	-dollars-			
Seed	3.50	2.45	3.50	2.45
Phosphorus			8.00	8.00
Potassium			15.98	15.98
Nitrogen			42.00	42.00
Herbicide	1.78	1.78	1.78	1.78
Machinery fuel	6.91	6.91	8.06	8.06
Repair and maintenance	18.06	18.06	20.77	20.77
Labor	14.42	14.42	16.49	16.49
Interest	1.56	1.51	6.30	6.26
Fixed expenses on machinery	<u>30.54</u>	<u>30.54</u>	<u>37.42</u>	<u>37.42</u>
<u>Total Operating Cost</u>	<u>76.77</u>	<u>75.67</u>	<u>160.30</u>	<u>159.21</u>
Transportation cost	25.73	25.32	18.05	18.30
Establishment cost	<u>74.96</u>	<u>74.96</u>	<u>22.88</u>	<u>22.88</u>
<u>Total Specified Cost</u>	<u>177.46</u>	<u>175.95</u>	<u>201.23</u>	<u>200.39</u>
Land	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>	<u>115.00</u>
<u>Total Cost</u>	<u>292.46</u>	<u>290.95</u>	<u>316.23</u>	<u>315.39</u>
Income from crop ¹	<u>248.00</u>	<u>244.00</u>	<u>174.00</u>	<u>176.40</u>
<u>Net Return</u>	<u>-44.46</u>	<u>-46.95</u>	<u>-142.23</u>	<u>-138.99</u>
Cost per ton ²	47.17	47.70	72.70	71.52

Note: A = Sweet sorghum/alfalfa; B = Sorghum x sudangrass/ alfalfa; C = Sweet sorghum/reed canarygrass; D = Sorghum x sudangrass/reed canarygrass.

¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 6.2 ton for A, 6.1 ton for B, 4.35 ton for C, 4.41 ton for D.

Table 36A Estimated per acre annual production cost of intercrop sweet sorghum/alfalfa and sorghum x sudangrass/alfalfa in Chariton (160 acres of biomass production is assumed)

Item	A	B
	-dollars-	
Seed	3.50	2.45
Herbicide	1.78	1.78
Machinery fuel	6.91	6.91
Repair and maintenance	38.51	38.51
Labor	14.42	14.42
Interest	2.04	2.02
Fixed expenses on machinery	<u>77.82</u>	<u>77.82</u>
<u>Total Operating Cost</u>	144.98	143.91
Transportation cost	17.80	21.41
Establishment cost	<u>92.86</u>	<u>92.86</u>
<u>Total Specified Cost</u>	255.64	258.18
Land	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	335.64	338.18
Income from crop ¹	<u>171.60</u>	<u>206.40</u>
<u>Net Return</u>	-164.04	-131.79
Cost per ton ²	78.23	65.54

Note: A = Sweet sorghum/alfalfa; B = Sorghum x sudangrass/ alfalfa.

¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 4.29 ton for sweet sorghum/alfalfa, 5.16 ton for sorghum x sudangrass hybrid/alfalfa.

Table 36B Estimated per acre annual production cost of intercrop sweet sorghum/alfalfa and sorghum x sudangrass/alfalfa in Chariton (Estimated based on average Iowa equipment use).

Item	A	B
	-dollars-	
Seed	3.50	2.45
Herbicide	1.78	1.78
Machinery fuel	6.91	6.91
Repair and maintenance	18.06	18.06
Labor	14.42	14.42
Interest	1.49	1.48
Fixed expenses on machinery	<u>30.54</u>	<u>30.54</u>
<u>Total Operating Cost</u>	76.70	75.64
Transportation cost	17.80	21.41
Establishment cost	<u>81.15</u>	<u>81.15</u>
<u>Total Specified Cost</u>	175.65	178.20
Land	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	255.65	258.82
Income from crop ¹	<u>171.60</u>	<u>206.40</u>
<u>Net Return</u>	-84.05	-51.80
Cost per ton ²	59.59	50.16

Note: A = Sweet sorghum/alfalfa; B = Sorghum x sudangrass/ alfalfa.

¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 4.29 ton for sweet sorghum/alfalfa, 5.16 ton for sorghum x sudangrass hybrid/alfalfa.

For these cropping systems, fertilizer costs, especially nitrogen, and productivity are the factors making differences in production costs and net production costs between systems. Annual production costs of the intercrop sorghum/alfalfa systems are lower than those of the sorghum/reed canarygrass systems. The primary cost difference between these systems is the use of nitrogen. Since alfalfa is a nitrogen fixer, nitrogen is not applied to alfalfa production while reed canarygrass requires nitrogen application for high yield. Higher dry matter yields of the sorghum/alfalfa systems at Ames along with the lower production costs contributes to the lower net production costs. At Chariton, sorghum/reed canarygrass systems were not established due to weather conditions. Thus, we are not able to compare the production costs.

Within the sorghum/alfalfa systems, there are almost no differences in net production costs at Ames; however, sorghum x sudangrass/alfalfa system at Chariton has almost 50% lower net annual production

costs than the sweet sorghum/alfalfa system. This was due to the differences in dry matter yield. Sorghum x sudangrass/alfalfa had higher yield than sweet sorghum/alfalfa at Chariton.

Annual Production Costs of Annual Biomass Crops

Annual biomass crops include sweet sorghum, sorghum x sudangrass, and rye. Rye was used as a winter crop in both the doublecrop sorghum system and the doublecrop sorghum in rotation. Corn and soybean were produced primarily to compare yield response and production costs of monocrop sorghum and doublecrop sorghum/rye systems with monocrop and doublecrop sweet sorghum systems in rotation with corn and soybean. Tables 37A/37B through 40A/40B show annual production costs of the different annual biomass crop systems.

For all annual crops, machinery costs are the highest as shown in Tables 37A/37B through 39A/39B. These costs include repair and maintenance of tractors and implements used in seed bed preparation, planting, fertilization, herbiciding and harvesting activities. They also include fuel costs. In addition to these direct operating costs of machinery, they include fixed expenses of owning machinery, such as depreciation and interest on investment.

Fertilization costs are the second largest production cost for all annual crops. Interest payments are the smallest cost in production of annual biomass crops.

By comparing the annual production costs in Tables 37A/37B through 39A/39B, we observe that both monocrop sweet sorghum systems - the pure monocrop systems and the monocrop system in rotation with corn and soybean- have the least net production costs among the different sorghum production systems. At Chariton, monocrop sorghum x sudangrass has lower net production costs than sweet sorghum at Ames.

The monocrop sweet sorghum system at Chariton has a positive net return at the assumed market price of dry matter, \$40.00 per ton (Tables 37A/37B). Both sweet sorghum and sweet sorghum/rye systems in rotation at Chariton also show positive net returns (Table 39B).

Although the sorghum production management systems at both Ames and Chariton are the same, there is a significant difference in net production costs. The differences in yields and land costs are the primary reasons for this difference in net production costs between two sites.

Monocrop sweet sorghum systems in rotation require less nitrogen input use. (Compare nitrogen costs in Tables 37 through 39.) If we adopt doublecrop sorghum/rye systems solely based on economic profitability without considering soil conservation, these systems are the worst among the different sorghum production systems. These systems have the largest net production costs because of the high seed costs and nitrogen costs.

Table 37A Estimated per acre annual production cost of monocrop sorghum (160 acres of biomass production is assumed).

Item	A	B	A	B
	-dollars-			
	<u>Ames</u>		<u>Chariton</u>	
Seed	3.50	2.45	3.50	2.45
Phosphorus	14.50	14.50	14.50	14.50
Potassium	7.99	7.99	7.99	7.99
Nitrogen	12.00	12.00	12.00	12.00
Herbicide	15.76	15.76	15.76	15.76
Machinery fuel	9.44	9.44	9.44	9.44
Repair and maintenance	24.61	24.61	24.61	24.61
Labor	15.39	15.39	15.39	15.39
Interest	6.70	6.39	9.04	8.62
Fixed expenses on machinery	<u>46.23</u>	<u>46.23</u>	<u>46.23</u>	<u>46.23</u>
<u>Total Operating Cost</u>	156.12	154.76	158.46	156.99
Transportation cost	<u>29.38</u>	<u>26.81</u>	<u>30.21</u>	<u>26.39</u>
<u>Total Specified Cost</u>	185.50	181.57	188.67	183.38
Land	<u>115.00</u>	<u>115.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	300.50	296.57	268.67	263.38
Income from crop ¹	<u>283.20</u>	<u>258.40</u>	<u>291.20</u>	<u>254.40</u>
<u>Net Return</u>	-17.30	-38.17	22.53	-8.98
Cost per ton ²	42.44	45.91	36.91	41.41

Note: A = Sweet sorghum; B = Sorghum x sudangrass hybrid.

¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 7.08 and 7.28 ton for sweet sorghum, 6.46 and 6.36 ton for sorghum x sudangrass hybrid, at Ames and Chariton, respectively.

Table 37B Estimated per acre annual production cost of monocrop sorghum (Estimated based on average Iowa equipment use)

Item	A	B	A	B
			-dollars-	
		<u>Ames</u>		<u>Chariton</u>
Seed	3.50	2.45	3.50	2.45
Phosphorus	14.50	14.50	14.50	14.50
Potassium	7.99	7.99	7.99	7.99
Nitrogen	12.00	12.00	12.00	12.00
Herbicide	15.76	15.76	15.76	15.76
Machinery	9.44	9.44	9.44	9.44
Repair and maintenance	22.08	22.08	22.08	22.08
Labor	15.39	15.39	15.39	15.39
Interest	6.67	6.37	8.79	8.38
Fixed expenses on machinery	<u>40.57</u>	<u>40.57</u>	<u>40.57</u>	<u>40.57</u>
<u>Total Operating Cost</u>	147.90	146.55	150.02	148.56
Transportation cost	<u>29.38</u>	<u>26.81</u>	<u>30.21</u>	<u>26.39</u>
<u>Total Specified Cost</u>	177.28	173.36	180.23	174.95
Land	<u>115.00</u>	<u>115.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	292.28	288.36	260.23	254.95
Income from crop ¹	<u>283.20</u>	<u>258.40</u>	<u>291.20</u>	<u>254.40</u>
<u>Net Return</u>	-9.32	-30.20	30.97	-0.55
Cost per ton ²	41.28	44.63	35.75	40.09

Note: A = Sweet sorghum; B = Sorghum x sudangrass hybrid.

¹ Estimated at \$40/dry ton.² Estimated by dividing total cost by average annual yields per acre: 7.08 and 7.28 ton for sweet sorghum, 6.46 and 6.36 ton for sorghum x sudangrass hybrid, at Ames and Chariton, respectively.

Table 38A Estimated per acre annual production cost of doublecrop sorghum/rye (160 acres of biomass production is assumed).

Item	A	B	A	B
	-dollars-			
	<u>Ames</u>		<u>Chariton</u>	
Seed	34.50	33.45	40.70	39.65
Phosphorus	14.50	14.50	14.50	14.50
Potassium	7.99	7.99	7.99	7.99
Nitrogen	34.02	34.02	34.02	34.02
Machinery fuel	10.74	10.74	10.74	10.74
Repair and maintenance	35.01	35.01	35.01	35.01
Labor	18.77	18.77	18.77	18.77
Interest	8.94	8.86	9.76	9.43
Fixed expenses on machinery	<u>69.28</u>	<u>69.28</u>	<u>69.28</u>	<u>69.28</u>
<u>Total Operating Cost</u>	233.75	232.62	240.77	239.39
Transportation cost	<u>29.13</u>	<u>26.89</u>	<u>25.73</u>	<u>25.69</u>
<u>Total Specified Cost</u>	262.88	259.51	266.50	265.08
Land	<u>115.00</u>	<u>115.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	377.88	374.51	346.50	345.08
Income from crop ¹	<u>280.80</u>	<u>259.20</u>	<u>248.00</u>	<u>247.60</u>
<u>Net Return</u>	-97.08	-115.31	-98.50	-97.48
Cost per ton ²	53.83	57.80	55.84	55.75

Note: A = Sweet sorghum/rye; B = Sorghum x sudangrass hybrid/rye.

¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 7.02 and 6.20 ton for sweet sorghum/rye, 6.48 and 6.19 ton for sorghum x sudangrass hybrid, at Ames and Chariton, respectively.

Table 38B Estimated per acre annual production cost of doublecrop sorghum/rye (Estimated based on average Iowa equipment use).

Item	A	B	A	B
	-dollars-			
		<u>Ames</u>		<u>Chariton</u>
Seed	34.50	33.45	40.70	39.65
Phosphorus	14.50	14.50	14.50	14.50
Potassium	7.99	7.99	7.99	7.99
Nitrogen	34.02	34.02	34.02	34.02
Machinery fuel	10.74	10.74	10.74	10.74
Repair and maintenance	26.12	26.12	26.12	26.12
Labor	18.77	18.77	18.77	18.77
Interest	8.68	8.60	9.49	9.17
Fixed expenses on machinery	<u>48.60</u>	<u>48.60</u>	<u>48.60</u>	<u>48.60</u>
<u>Total Operating Cost</u>	203.92	202.79	210.93	209.56
Transportation cost	<u>29.13</u>	<u>26.89</u>	<u>25.73</u>	<u>25.69</u>
<u>Total Specified Cost</u>	233.05	229.68	236.66	235.25
Land	<u>115.00</u>	<u>115.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	348.05	344.68	316.66	315.25
Income from crop ¹	<u>280.80</u>	<u>259.20</u>	<u>248.00</u>	<u>247.60</u>
<u>Net Return</u>	-67.25	-85.48	-68.66	-67.65
Cost per ton ²	49.58	53.19	51.07	50.93

Note: A = Sweet sorghum/rye; B = Sorghum x sudangrass hybrid/rye.

¹ Estimated at \$40/dry ton. ² Estimated by dividing total cost by average annual yields per acre: 7.02 and 6.20 ton for sweet sorghum/rye, 6.48 and 6.19 ton for sorghum x sudangrass hybrid, at Ames and Chariton, respectively.

Table 39A Estimated per acre annual production cost of sweet sorghum and sweet sorghum/rye in corn-soybean rotation (160 acres of biomass production is assumed).

Item	A	B	A	B
	-dollars-			
		<u>Ames</u>		<u>Chariton</u>
Seed	3.50	34.50	3.50	40.70
Phosphorus	14.50	14.50	14.50	14.50
Potassium	7.99	7.99	7.99	7.99
Nitrogen	6.00	21.00	6.00	21.00
Herbicide	15.76		15.76	
Machinery fuel	8.60	10.35	8.60	10.35
Repair and maintenance	23.94	34.11	23.94	34.11
Labor	13.73	18.08	13.73	18.08
Interest	6.26	8.57	8.80	9.17
Fixed expenses on machinery	<u>42.06</u>	<u>66.99</u>	<u>42.06</u>	<u>66.99</u>
<u>Total Operating Cost</u>	142.34	216.09	144.88	222.89
Transportation cost	<u>27.72</u>	<u>33.74</u>	<u>29.67</u>	<u>36.44</u>
<u>Total Specified Cost</u>	170.06	249.83	174.55	259.33
Land	<u>115.00</u>	<u>115.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	285.06	364.83	254.55	339.33
Income from crop ¹	<u>267.20</u>	<u>325.20</u>	<u>286.00</u>	<u>351.20</u>
<u>Net Return</u>	-16.86	-39.63	32.55	11.87
Cost per ton ²	42.67	44.87	35.60	38.65

Note: A = Sweet sorghum; B = Sweet sorghum/rye.

¹ Estimated at \$40/dry ton.² Estimated by dividing total cost by average annual yields per acre: 6.68 and 7.15 ton for sweet sorghum, 8.13 and 8.78 ton for sweet sorghum/rye, at Ames and Chariton, respectively.

Table 39B Estimated per acre annual production cost of sweet sorghum and sweet sorghum/rye in corn-soybean rotation (Estimated based on average Iowa equipment use).

Item	A	B	A	B
	-dollars-			
		<u>Ames</u>		<u>Chariton</u>
Seed	3.50	34.50	3.50	40.70
Phosphorus	14.50	14.50	14.50	14.50
Potassium	7.99	7.99	7.99	7.99
Nitrogen	6.00	21.00	6.00	21.00
Herbicide	15.76		15.76	
Machinery fuel	8.60	10.35	8.60	10.35
Repair and maintenance	20.40	25.22	20.40	25.22
Labor	13.73	18.08	13.73	18.08
Interest	6.23	8.31	8.56	8.91
Fixed expenses on machinery	<u>36.41</u>	<u>46.31</u>	<u>36.41</u>	<u>46.31</u>
<u>Total Operating Cost</u>	133.12	186.26	135.45	193.06
Transportation cost	<u>27.72</u>	<u>33.74</u>	<u>29.67</u>	<u>36.44</u>
<u>Total Specified Cost</u>	160.84	220.00	165.12	229.50
Land	<u>115.00</u>	<u>115.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	275.84	334.75	245.12	309.50
Income from crop ¹	<u>267.20</u>	<u>325.20</u>	<u>286.00</u>	<u>351.20</u>
<u>Net Return</u>	-8.64	-9.80	40.88	41.70
Cost per ton ²	41.29	41.21	34.28	35.25

Note: A = Sweet sorghum; B = Sweet sorghum/rye.

¹ Estimated at \$40/dry ton.² Estimated by dividing total cost by average annual yields per acre: 6.68 and 7.15 ton for sweet sorghum, 8.13 and 8.78 ton for sweet sorghum/rye, at Ames and Chariton, respectively.

Table 40A Estimated per acre annual production cost of corn and soybean (160 acres of biomass production is assumed)

Item	A	B	A	B
	-dollars-			
		<u>Ames</u>		<u>Chariton</u>
Seed	27.00	14.00	27.00	14.00
Phosphorus	14.50	10.00	14.50	10.00
Potassium	7.99	12.75	7.99	12.75
Nitrogen	15.00		15.00	
Herbicide	31.75	19.68	31.75	19.68
Machinery fuel	10.04	5.28	10.04	5.28
Repair and maintenance	27.85	12.97	27.98	13.11
Labor	17.73	8.83	18.29	9.38
Interest	7.89	3.80	6.68	3.96
Fixed expenses on machinery	<u>54.77</u>	<u>28.85</u>	<u>54.88</u>	<u>28.96</u>
<u>Total Operating Cost</u>	214.52	116.16	214.11	117.12
Transportation cost	<u>13.11</u>		<u>11.08</u>	
<u>Total Specified Cost</u>	227.63	116.16	225.19	117.12
Land	<u>115.00</u>	<u>115.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	342.63	231.16	305.19	197.12
Income from crop ¹	<u>403.94</u>	<u>152.16</u>	<u>313.11</u>	<u>220.29</u>
<u>Net Return</u>	61.31	-79.00	7.92	23.17

Note: A = Corn; B = Soybean

¹ Estimated at \$2.35 bu. for corn grain, \$5.45 bu. for soybean grain, and \$40/dry ton for corn stover. Yields for corn grain were 118.10 bu per acre and 87.79 bu per acre at Ames and Chariton, respectively. For corn stover, 3.16 ton and 2.67 ton per acre at Ames and Chariton, respectively. For soybean, 27.92 bu and 40.42 bu per acre.

Table 40B Estimated per acre annual production cost of corn and soybean (Estimated based on average Iowa equipment use).

Item	A	B	A	B
	-dollars-			
	<u>Ames</u>		<u>Chariton</u>	
Seed	27.00	14.00	27.00	14.00
Phosphorus	14.50	10.00	14.50	10.00
Potassium	7.99	12.75	7.99	12.75
Nitrogen	15.00		15.00	
Herbicide	31.75	19.68	31.75	19.68
Machinery fuel	10.04	5.28	10.04	5.28
Repair and maintenance	23.36	12.77	23.40	12.91
Labor	17.73	8.83	18.29	9.38
Interest	7.84	3.79	6.63	3.95
Fixed expenses on machinery	<u>42.77</u>	<u>26.74</u>	<u>42.88</u>	<u>26.84</u>
<u>Total Operating Cost</u>	197.98	113.84	197.57	114.79
Transportation cost	<u>13.11</u>		<u>11.08</u>	
<u>Total Specified Cost</u>	211.09	113.84	208.65	114.79
Land	<u>115.00</u>	<u>115.00</u>	<u>80.00</u>	<u>80.00</u>
<u>Total Cost</u>	326.09	228.84	288.65	194.79
Income from crop ¹	<u>403.94</u>	<u>152.16</u>	<u>313.11</u>	<u>220.29</u>
<u>Net Return</u>	77.85	-76.68	24.46	25.50

Note: A = Corn; B = Soybean.

¹ Estimated at \$2.35 bu. for corn grain, \$5.45 bu. for soybean grain, and \$40/dry ton for corn stover. Yields for corn grain were 118.10 bu per acre and 87.79 bu per acre at Ames and Chariton, respectively. For corn stover, 3.16 ton and 2.67 ton per acre at Ames and Chariton, respectively. For soybean, 27.92 bu and 40.42 bu per acre.

Break-even Price and Gross Margin Analysis

A break-even price and gross margin analysis is the easiest way of testing the economic viability of biomass production. Break-even prices for the each cropping systems in this research are listed in Tables 41A and 41B.

In the previous section, production costs for each of the thirteen biomass cropping systems were presented. Since they are the costs of producing the biomass dry matter, the production costs are divided by the given average dry matter yields of the each cropping systems to estimate the break-even prices shown in Tables 41A/41B. These are the prices that make $[(\text{yield} \times \text{price}) - \text{cost}]$ even, where yield is assumed to be given in these tables. Thus, if market price for biomass is greater than the break-even price, then there is a profit; otherwise, a loss.

The break-even price estimated in this study is the price derived from the specific production management systems described in the previous sections and biomass yield associated with that management systems. Thus, the break-even price can be changed as yield changes or as production cost changes by employing different crop management systems. Since break-even price estimates are based on the current state of technology, it can also be changed with better biomass production technology; for example, the development of weather and disease resistance hybrid seeds or cost saving and resource conserving technology.

The break-even prices listed in Tables 41A and 41B are different because, as explained previously, of the differences in annual hours of use of implements, which are directly related to acres of land allocated to the biomass energy crop production. The assumed annual hours of use are smaller for Table 41A than that of 41B. As a result, the break-even prices in Table 41A are greater than those of Table 41B.

Total cost(TC) is defined as total specified costs(TSC) plus land cost. TSC includes all costs except for land. TSC also includes the prorated establishment costs. Average cost(AC) is TC divided by the total biomass yield. Thus, AC represents the break-even price of producing biomass crops. Notice that the biomass yields for perennial forages in Tables 41A/41B do not include the yields in the establishment year. These are the average yields of the standing years. For the annuals, the yields are the average of the experimental period, 1988-1992.

Even though AC represents the break-even price, biomass producers may produce biomass crops in the short run, if the gross margin - the difference between total income and total variable costs - is positive. Any positive gross margin represents a contribution of the biomass crops to fixed costs, which is just the land cost in this study. Thus, we estimated average specified cost(ASC), TSC divided by yield, to look at whether biomass production makes any contribution to fixed costs in the short run at the assumed dry matter price. If ASC is greater than or equal to the market price for dry matter, then biomass crop producers may engage in biomass production in the short run; otherwise, they will stop biomass production. Notice that ASC in this report is different from the widely used concept of average variable cost(AVC) frequently used in economic profession in the following sense. While AVC excludes any fixed costs involved in capital investment, ASC excludes only land costs. Thus, ASC includes fixed expenses, such as interest payment on and depreciation of machinery, and on capital investments.

At present, the production of biomass crops as an energy substitute for fossil fuels is not economically feasible in most cases. However, biomass energy crops may have long run economic feasibility due to the environmental concerns related to fossil fuels and exhaustability of fossil fuels. For this reason, comparing average specified costs to the market price of dry matter is especially important in biomass production decision making process.

As shown in Table 41B, the break-even price of biomass crops range from \$34.28 per dry matter ton to \$81.52 per dry matter ton. Sweet sorghum and sweet sorghum/rye in rotation have the least break-even price at both Ames and Chariton, \$41.29/dry ton for sweet sorghum and \$41.21/dry ton for sweet

sorghum/rye, respectively, at Ames, and \$34.28/dry ton for sweet sorghum and \$35.25/dry ton for sweet sorghum/rye, respectively, at Chariton. On the other hand, with Table 41A, the break-even prices ranges from \$35.60 for sweet sorghum in rotation at Chariton to \$95.51 for reed canarygrass at Ames.

Among the perennial grasses, monocrop reed canarygrass at Ames has the highest AC per dry matter ton, \$95.61 (\$81.52)¹. At Chariton, alfalfa has the highest AC per dry matter ton, \$92.48 (\$71.03). Higher AC means a higher market price for biomass dry matter to break-even. Switchgrass has the lowest break-even price, \$54.22 (\$49.08) per ton at Ames and \$44.07 (\$39.12) per ton at Chariton. See Table 41A/41B.

Compared to AC, ASC is much lower because land cost is excluded. ASC ranges from \$22.06 per dry ton for switchgrass at Chariton to \$47.98 per dry ton for alfalfa also at Chariton. Switchgrass has the lowest ASC among all the cropping systems used in this research at both sites. Sweet sorghum in rotation has the second largest ASC (Table 41B). The results are different in Table 41A. The ASC ranges from \$24.41 per dry ton for sweet sorghum in rotation at Chariton to \$69.43 per dry ton for alfalfa at Chariton. Switchgrass at Chariton is the next least ASC, \$27.01 per dry ton.

In the short run, biomass energy crop producers will participate in biomass production as long as the market price for biomass dry matter equals to ASC. At this price, all the costs occurred, except land cost, from biomass crop production will be recovered.

By comparing Tables 41A and 41B, the existence of economies of scale can be clearly observed. As annual hours of use of implements increase, the production costs decrease and so does the break-even prices. Thus there is greater incentive for current forage producers to engage in biomass production.

¹First price is assuming use on only 160 acres and price in parenthesis is assuming average Iowa equipment use.

Table 41A Costs and break-even prices of the crop production systems (160 acres of biomass production is assumed).

Crop systems	Yield (ton)	TSC	TC (dollar/ton)	ASC/ton	AC/ton
<u>Ames</u>					
Alfalfa	4.40	238.67	353.67	54.24	80.38
Reed canarygrass	3.33	203.39	318.39	61.08	95.61
Switchgrass	4.50	128.97	243.97	28.66	54.22
Big bluestem	3.84	138.70	253.70	36.11	66.07
Sweet sorghum	7.08	185.50	300.50	26.20	42.44
Sorghum x sudangrass	6.46	181.57	296.57	28.11	45.91
Sweet sorghum/Rye	7.02	262.88	377.88	37.45	53.83
SS/Rye	6.48	259.51	374.51	40.05	57.80
Sweet sorghum ¹	6.68	170.06	285.06	25.46	42.67
Sweet sorghum/Rye ¹	8.13	249.83	364.83	30.73	44.87
Sweet sorghum/Alfalfa	6.20	257.46	372.46	41.53	60.07
SS/Alfalfa	6.10	255.95	370.95	41.96	60.81
Sweet sorghum/RC	4.35	274.67	389.67	63.14	89.58
SS/Reed canarygrass	4.41	273.83	388.83	62.09	88.17
<u>Chariton</u>					
Alfalfa	3.47	240.92	320.92	69.43	92.48
Reed canarygrass	4.73	204.51	284.51	43.24	60.15
Switchgrass	4.69	126.68	206.68	27.01	44.07
Big bluestem	3.55	137.12	217.12	38.63	61.16
Sweet sorghum	7.28	188.67	268.67	25.92	36.91
Sorghum x sudangrass	6.36	183.38	263.38	28.83	41.41
Sweet sorghum/Rye	6.20	266.50	346.50	42.98	55.89
SS/Rye	6.19	265.08	345.08	42.82	55.75
Sweet sorghum ¹	7.15	174.55	254.55	24.41	35.60
Sweet sorghum/Rye ¹	8.78	259.33	339.33	29.54	38.65
Sweet sorghum/Alfalfa	4.29	255.64	335.64	59.59	78.23
SS/Alfalfa	5.16	258.18	338.18	50.03	65.54

Note: ¹ Sweet sorghum and sweet sorghum/rye in rotation with corn and soybean. SS = sorghum x sudangrass. RC = reed canarygrass

Table 41B Costs and break-even prices of the crop production systems (Estimated based on average Iowa equipment use).

Crop systems	Yield (ton)	TSC	TC (dollar/ton)	ASC/ton	AC/ton
<u>Ames</u>					
Alfalfa	4.40	164.22	279.22	37.32	63.46
Reed canarygrass	3.33	156.46	271.46	46.98	81.52
Switchgrass	4.50	105.84	220.84	23.52	49.08
Big bluestem	3.84	115.67	230.67	30.12	60.07
Sweet sorghum	7.08	177.28	292.28	25.03	41.28
Sorghum x sudangrass	6.46	173.36	288.36	26.83	44.63
Sweet sorghum/Rye	7.02	233.05	348.05	33.20	49.58
SS/Rye	6.48	229.68	344.68	35.44	53.19
Sweet sorghum ¹	6.68	160.84	275.84	24.07	41.29
Sweet sorghum/Rye ¹	8.13	220.00	335.00	27.06	41.21
Sweet sorghum/Alfalfa	6.20	177.46	292.46	28.62	47.17
SS/Alfalfa	6.10	175.95	290.95	28.84	47.70
Sweet sorghum/RC	4.35	201.23	316.23	46.26	72.70
SS/Reed canarygrass	4.41	200.39	315.39	45.44	71.52
<u>Chariton</u>					
Alfalfa	3.47	166.49	246.49	47.98	71.03
Reed canarygrass	4.73	158.84	238.84	33.58	50.49
Switchgrass	4.69	103.45	183.45	22.06	39.12
Big bluestem	3.55	114.00	194.00	32.12	54.65
Sweet sorghum	7.28	180.23	260.23	24.76	35.75
Sorghum x sudangrass	6.36	174.95	254.95	27.51	40.09
Sweet sorghum/Rye	6.20	236.66	316.66	38.17	51.07
SS/Rye	6.19	235.25	315.25	38.00	50.93
Sweet sorghum ¹	7.15	165.12	245.12	23.09	34.28
Sweet sorghum/Rye ¹	8.78	229.50	309.50	26.14	35.25
Sweet sorghum/Alfalfa	4.29	175.65	255.65	40.94	59.59
SS/Alfalfa	5.16	178.20	258.82	34.53	50.16

Note: ¹ Sweet sorghum and sweet sorghum/rye in rotation with corn and soybean. SS = sorghum x sudangrass. RC = reed canarygrass

Conclusions. As expected, systems involving sorghum have the highest dry matter yields. Sweet sorghum/rye in rotation produced the largest dry matter at all levels of nitrogen use. Among the perennial grasses, switchgrass produced the largest dry matter for all levels of nitrogen even on the marginal land at Chariton. Generally, annual energy crops produced more dry matter than perennial grasses.

In Iowa, biomass energy crops can be produced at \$35.60 (\$34.28) to \$95.61 (\$81.52) per ton of dry matter depending on species, production system, the acres of land allocated to biomass crop production, and location. These estimates of unit production cost change as yield, management systems, and input costs change.

Switchgrass has the lowest cost per ton among the perennial crops while sweet sorghum and sweet sorghum/rye in rotation have the lowest cost among all systems.

Since we are also interested in the environmental impact, primarily soil erosion, of the species and of different cropping systems, both switchgrass and sweet sorghum and sweet sorghum/rye in rotation serve as good choices as biomass energy crops.

Summary and Conclusions

By combining experimental and typical management practice data, this report has considered the costs of producing herbaceous biomass crops in Iowa. Representative sites in central (Ames) and southern (Chariton) Iowa were considered. Costs of production were based on a careful delineation of appropriate practices for biomass production by typical producers. The practices are carefully specified so that changes in practice can be easily analyzed. Cost estimates are presented based on average Iowa usage of machinery and equipment and on lower annual usage for producers who grow biomass as a sideline enterprise. The lower cost estimates should not be routinely used as typical since many current proposed systems for producing biomass involve use of CRP acres, stream banks, waterways, or other less than full scale sites. All estimates given in this summary refer to costs based on 160 acres of biomass per producer with the lower full-scale costs given in parentheses.

Costs of production were generally lower in southern Iowa, primarily because of lower land costs. The sorghum species grown singly or in rotation were the least expensive way to produce biomass. Costs of production in southern Iowa for sweet sorghum as a monocrop are \$36.91 (35.75) per ton. Costs in central Iowa for monocrop sweet sorghum are \$42.44 (41.28) per ton. The costs of sweet sorghum in rotation with corn and soybean are marginally lower in southern Iowa and marginally higher in central Iowa. Given some of the problems of monocrop sorghum, production in rotation seems preferred. Costs for forage sorghum (sorghum x sudangrass) are 3-5 dollars higher in both locations. In central Iowa the sweet sorghum/rye double crop in rotation has similar costs with the monocrop of \$44.87 (41.21) per ton. Thus the costs of adding the soil conservation benefits of winter rye are small or non-existent using central Iowa data. Winter rye, however, adds significantly to the costs in southern Iowa. Yields of this double crop in the experiments were lower, probably based on reduced soil moisture following the winter rye. More research on this issue seems in order. Intercropped sweet sorghum in alfalfa cost \$60.07 (47.17) per ton as opposed to the monocrop cost of \$42.44 (41.28) in the central Iowa location. The costs of intercropped sorghum in alfalfa are higher in southern Iowa. Per ton cost was \$78.23 (59.59). Again this may be due to dry conditions during the study period. Costs for intercropped sorghum x sudangrass are similar in central Iowa and slightly lower in southern Iowa as compared to intercropped sweet sorghum. Costs for sorghum intercropped into reed canarygrass as compared to alfalfa are much higher at the central Iowa site and were not computed for the southern Iowa site due to failure of stand establishment. With respect to the use of sorghums for biomass production, double cropped sweet sorghum with rye in rotation with corn and soybean seems the logical choice in areas where spring moisture is adequate. Where moisture is a concern, the soil conservation benefits of the rye must be balanced against the potential of lower sorghum yields. The intercropped sorghums were higher in cost than single or double crops (\$6-\$14) but would have significant soil conservation effects.

Among the perennial grasses, switchgrass has the lowest costs at both sites. Big bluestem is less expensive to produce than reed canarygrass in central Iowa but more expensive in southern Iowa. Alfalfa is the most expensive crop in southern Iowa, while reed canarygrass is the most expensive in central Iowa. Thus the ranking from least to most expensive is switchgrass, reed canarygrass, big bluestem and alfalfa in southern Iowa and switchgrass, big bluestem, alfalfa and reed canarygrass in central Iowa. Costs of switchgrass in southern Iowa are \$44.07 (39.12) while with higher land costs they are \$54.22 (49.08) in central Iowa. Thus the costs of the cheapest perennial grasses are 7-10 dollars a ton more than the costs of the annual sorghums. The costs of switchgrass are higher than intercropped or double cropped sorghum in central Iowa, but lower than intercropped sorghum in southern Iowa. The sweet sorghum/rye rotation is cheaper than switchgrass in southern Iowa. The costs of big bluestem are around \$10-15 more per ton than switchgrass, primarily due to higher establishment costs. Reed canarygrass is about \$15 per ton higher than switchgrass in southern Iowa and much higher still in central Iowa. Alfalfa is not competitive with switchgrass at either location. Of the perennial crops, switchgrass is clearly the lowest in cost.

In determining optimal cropping patterns for biomass use, many factors must be considered. Based on costs alone, the annual sorghums dominate the perennial grasses in all locations. The use of rye as a winter crop with sorghum is also less expensive than the grasses. The results for the intercropped sorghums are mixed. If the producer has sufficient acres to fully use forage and grain equipment, then the intercropped sorghums are cheaper than switchgrass at the central Iowa location. With lower equipment use, switchgrass is cheaper than the intercropped sorghum in central Iowa. In southern Iowa, switchgrass dominates the intercropped sorghum. Thus the use of intercrops depends critically on location, equipment usage, and climate conditions. Soil conservation considerations clearly favor the perennial grasses or the intercrops. Thus decisions must be made on a case by case basis using the information presented here as a benchmark.

Appendix

Budgets for Each Biomass Cropping Systems and Species Based on Average Iowa Hours of Equipment Use

Table A1. Estimated Establishment Year Budget for Alfalfa, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Alfalfa	ton	40.00	2.51	<u>100.40</u>
TOTAL INCOME				100.40
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	160.00	40.00
Potassium	lbs	0.17	625.00	106.25
FUNGICIDES				
Eptom	pt	2.81	3.00	8.43
HERBICIDES				
Lorsban 4E	pt	1.81	1.00	1.81
SEED				
Alfalfa seed	lbs	2.50	12.00	30.00
TRANSPORTATION				
Haul to plant	ton	4.15	2.51	10.42
OPERATOR LABOR				
Tractors	hour	6.00	2.29	13.73
DIESEL FUEL				
Tractors	gal	0.83	8.60	7.13
REPAIR and MAINTENANCE				
Implements	acre	5.47	1.00	5.47
Tractors	acre	11.35	1.00	11.35
INTEREST ON OP. CAP.	acre	18.07	1.00	<u>18.07</u>
TOTAL DIRECT EXPENSES				252.66
RETURN ABOVE DIRECT EXPENSES				-152.26
FIXED EXPENSES				
Implements	acre	16.88	1.00	16.88
Tractors	acre	15.72	1.00	<u>15.72</u>
TOTAL FIXED EXPENSES				<u>32.60</u>
TOTAL SPECIFIED EXPENSES				285.25
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-184.85
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-299.85

Table A2. Estimated Annual Budget for Alfalfa, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Alfalfa	ton	40.00	4.40	<u>176.00</u>
TOTAL INCOME				176.00
DIRECT EXPENSES				
HERBICIDES				
Lorsban 4E	pt	1.81	2.00	3.62
TRANSPORTATION				
Haul to plant	ton	4.15	4.40	18.26
OPERATOR LABOR				
Tractors	hour	6.00	2.32	13.94
DIESEL FUEL				
Tractors	gal	0.83	8.07	6.69
REPAIR and MAINTENANCE				
Implements	acre	5.88	1.00	5.88
Tractors	acre	11.49	1.00	11.49
INTEREST ON OP. CAP.	acre	1.52	1.00	<u>1.52</u>
TOTAL DIRECT EXPENSES				61.40
RETURN ABOVE DIRECT EXPENSES				114.60
FIXED EXPENSES				
Implements	acre	12.57	1.00	12.57
Tractors	acre	15.28	1.00	<u>15.28</u>
TOTAL FIXED EXPENSES				<u>27.86</u>
ESTABLISHMENT COST	acre	74.96	1.00	74.96
TOTAL SPECIFIED EXPENSES				164.22
RETURN ABOVE TOTAL SPECIFIED EXPENSES				11.78
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-103.22

Table A3. Estimated Annual Budget for Intercrop Alfalfa/Sweet Sorghum, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Alfalfa/Sweet sorghum	ton	40.00	6.20	<u>248.00</u>
TOTAL INCOME				248.00
DIRECT EXPENSES				
HERBICIDES				
Paraquat	pt	4.46	0.40	1.78
SEED				
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	6.20	25.73
OPERATOR LABOR				
Tractors	hour	6.00	2.40	14.42
DIESEL FUEL				
Tractors	gal	0.83	8.32	6.91
REPAIR and MAINTENANCE				
Implements	acre	6.28	1.00	6.28
Tractors	acre	11.78	1.00	11.78
INTEREST ON OP. CAP.	acre	1.56	1.00	<u>1.56</u>
TOTAL DIRECT EXPENSES				<u>71.96</u>
RETURN ABOVE DIRECT EXPENSES				176.04
FIXED EXPENSES				
Implements	acre	14.83	1.00	14.83
Tractors	acre	15.71	1.00	<u>15.71</u>
TOTAL FIXED EXPENSES				<u>30.54</u>
ESTABLISHMENT COST	acre	74.96	1.00	74.96
TOTAL SPECIFIED EXPENSES				177.46
RETURN ABOVE TOTAL SPECIFIED EXPENSES				70.54
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-44.46

Table A4. Estimated Annual Budget for Intercrop Alfalfa/Sorghum x sudangrass hybrid, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Alfalfa/Sorghum x sudan	ton	40.00	6.10	<u>244.00</u>
TOTAL INCOME				244.00
DIRECT EXPENSES				
HERBICIDES				
Paraquat	pt	4.46	0.40	1.78
SEED				
Sorghum x sudan seed	lbs	0.35	7.00	2.45
TRANSPORTATION				
Haul to plant	ton	4.15	6.10	25.32
OPERATOR LABOR				
Tractors	hour	6.00	2.40	14.42
DIESEL FUEL				
Tractors	gal	0.83	8.32	6.91
REPAIR and MAINTENANCE				
Implements	acre	6.28	1.00	6.28
Tractors	acre	11.78	1.00	11.78
INTEREST ON OP. CAP.	acre	1.51	1.00	<u>1.51</u>
TOTAL DIRECT EXPENSES				70.45
RETURN ABOVE DIRECT EXPENSES				173.55
FIXED EXPENSES				
Implements	acre	14.83	1.00	14.83
Tractors	acre	15.71	1.00	<u>15.71</u>
TOTAL FIXED EXPENSES				<u>30.54</u>
ESTABLISHMENT COST	acre	74.96	1.00	74.96
TOTAL SPECIFIED EXPENSES				175.95
RETURN ABOVE TOTAL SPECIFIED EXPENSES				68.05
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-46.95

Table A5. Estimated Establishment Year Budget for Reed Canarygrass, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Reed canarygrass	ton	40.00	2.31	<u>92.40</u>
TOTAL INCOME				92.40
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	125.00	26.25
HERBICIDES				
2,4-D	pt	2.31	2.00	4.62
SEED				
Reed canarygrass seed	lbs	4.50	9.00	40.50
TRANSPORTATION				
Haul to plant	ton	4.15	2.31	9.59
OPERATOR LABOR				
Tractors	hour	6.00	2.31	13.87
DIESEL FUEL				
Tractors	gal	0.83	8.69	7.21
REPAIR and MAINTENANCE				
Implements	acre	5.36	1.00	5.36
Tractors	acre	11.46	1.00	11.46
INTEREST ON OP. CAP.	acre	6.92	1.00	<u>6.92</u>
TOTAL DIRECT EXPENSES				149.75
RETURN ABOVE DIRECT EXPENSES				-57.35
FIXED EXPENSES				
Implements	acre	17.76	1.00	17.76
Tractors	acre	15.89	1.00	<u>15.89</u>
TOTAL FIXED EXPENSES				<u>33.64</u>
TOTAL SPECIFIED EXPENSES				183.40
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-91.00
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-206.00

Table A6. Estimated Annual Budget for Reed canarygrass, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Reed canarygrass	ton	40.00	3.33	<u>133.20</u>
TOTAL INCOME				133.20
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	200.00	42.00
TRANSPORTATION				
Haul to plant	ton	4.15	3.33	13.82
OPERATOR LABOR				
Tractors	hour	6.00	1.61	9.66
DIESEL FUEL				
Tractors	gal	0.83	5.81	4.82
REPAIR and MAINTENANCE				
Implements	acre	4.14	1.00	4.14
Tractors	acre	7.94	1.00	7.94
INTEREST ON OP. CAP.	acre	4.78	1.00	<u>4.78</u>
TOTAL DIRECT EXPENSES				111.14
RETURN ABOVE DIRECT EXPENSES				22.06
FIXED EXPENSES				
Implements	acre	11.56	1.00	11.56
Tractors	acre	10.87	1.00	<u>10.87</u>
TOTAL FIXED EXPENSES				<u>22.43</u>
ESTABLISHMENT COST	acre	22.89	1.00	22.89
TOTAL SPECIFIED EXPENSES				156.46
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-23.26
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-138.26

Table A7. Estimated Annual Budget for Intercrop Reed Canarygrass/Sweet Sorghum, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Reed canarygrass/ Sweet sorghum	ton	40.00	4.35	<u>174.00</u>
TOTAL INCOME				174.00
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	200.00	42.00
HERBICIDES				
Paraquat	pt	4.46	0.40	1.78
SEED				
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	4.35	18.05
OPERATOR LABOR				
Tractors	hour	6.00	2.75	16.49
DIESEL FUEL				
Tractors	gal	0.83	9.71	8.06
REPAIR and MAINTENANCE				
Implements	acre	7.30	1.00	7.30
Tractors	acre	13.47	1.00	13.47
INTEREST ON OP. CAP.	acre	6.30	1.00	<u>6.30</u>
TOTAL DIRECT EXPENSES				140.93
RETURN ABOVE DIRECT EXPENSES				33.07
FIXED EXPENSES				
Implements	acre	19.21	1.00	19.21
Tractors	acre	18.21	1.00	<u>18.21</u>
TOTAL FIXED EXPENSES				<u>37.42</u>
ESTABLISHMENT COST	acre	22.89	1.00	22.89
TOTAL SPECIFIED EXPENSES				201.24
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-27.24
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-144.24

Table A8. Estimated Annual Budget for Intercrop Reed Canarygrass/Sorghum x Sudangrass Hybrid, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Reed canarygrass/ Sorghum x sudangrass	ton	40.00	4.41	<u>176.40</u>
TOTAL INCOME				176.40
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	200.00	42.00
HERBICIDES				
Paraquat	pt	4.46	0.40	1.78
SEED				
Sorghum x sudan seed	lbs	0.35	7.00	2.45
TRANSPORTATION				
Haul to plant	ton	4.15	4.41	18.30
OPERATOR LABOR				
Tractors	hour	6.00	2.75	16.49
DIESEL FUEL				
Tractors	gal	0.83	9.71	8.06
REPAIR and MAINTENANCE				
Implements	acre	7.30	1.00	7.30
Tractors	acre	13.47	1.00	13.47
INTEREST ON OP. CAP.	acre	6.26	1.00	<u>6.26</u>
TOTAL DIRECT EXPENSES				140.09
RETURN ABOVE DIRECT EXPENSES				36.31
FIXED EXPENSES				
Implements	acre	19.21	1.00	19.21
Tractors	acre	18.21	1.00	<u>18.21</u>
TOTAL FIXED EXPENSES				<u>37.42</u>
ESTABLISHMENT COST	acre	22.89	1.00	22.89
TOTAL SPECIFIED EXPENSES				200.40
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-24.00
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-139.00

Table A9. Estimated Establishment Year Budget for Switchgrass, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Switchgrass	ton	40.00	3.32	<u>132.80</u>
TOTAL INCOME				132.80
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
HERBICIDES				
Atrazine 4L	pt	1.58	2.50	3.95
SEED				
Switchgrass seed	lbs	3.50	8.00	28.00
TRANSPORTATION				
Haul to plant	ton	4.15	3.32	13.78
OPERATOR LABOR				
Tractors	hour	6.00	1.56	9.38
DIESEL FUEL				
Tractors	gal	0.83	6.01	4.99
REPAIR and MAINTENANCE				
Implements	acre	3.46	1.00	3.46
Tractors	acre	7.77	1.00	7.77
INTEREST ON OP. CAP.	acre	4.68	1.00	<u>4.68</u>
TOTAL DIRECT EXPENSES				99.99
RETURN ABOVE DIRECT EXPENSES				32.81
FIXED EXPENSES				
Implements	acre	12.71	1.00	12.71
Tractors	acre	10.87	1.00	<u>10.87</u>
TOTAL FIXED EXPENSES				<u>23.58</u>
TOTAL SPECIFIED EXPENSES				123.57
RETURN ABOVE TOTAL SPECIFIED EXPENSES				9.23
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-105.77

Table A10. Estimated Annual Budget for Switchgrass, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Switchgrass	ton	40.00	4.50	<u>182.00</u>
TOTAL INCOME				182.00
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	100.00	21.00
TRANSPORTATION				
Haul to plant	ton	4.15	4.50	18.68
OPERATOR LABOR				
Tractors	hour	6.00	0.86	5.18
DIESEL FUEL				
Tractors	gal	0.83	3.14	2.60
REPAIR and MAINTENANCE				
Implements	acre	2.24	1.00	2.24
Tractors	acre	4.25	1.00	4.25
INTEREST ON OP. CAP.	acre	3.80	1.00	<u>3.80</u>
TOTAL DIRECT EXPENSES				81.72
RETURN ABOVE DIRECT EXPENSES				100.28
FIXED EXPENSES				
Implements	acre	6.51	1.00	6.51
Tractors	acre	5.85	1.00	<u>5.85</u>
TOTAL FIXED EXPENSES				<u>12.36</u>
ESTABLISHMENT COST	acre	11.75	1.00	11.75
TOTAL SPECIFIED EXPENSES				105.83
RETURN ABOVE TOTAL SPECIFIED EXPENSES				76.17
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-38.83

Table A11. Estimated Establishment Year Budget for Big Bluestem, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Big bluestem	ton	40.00	2.55	<u>102.00</u>
TOTAL INCOME				102.00
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
HERBICIDES				
2,4-D	pt	2.31	2.50	5.78
SEED				
Switchgrass seed	lbs	9.00	12.00	108.00
TRANSPORTATION				
Haul to plant	ton	4.15	2.55	10.58
OPERATOR LABOR				
Tractors	hour	6.00	1.64	9.87
DIESEL FUEL				
Tractors	gal	0.83	6.47	5.37
REPAIR and MAINTENANCE				
Implements	acre	3.38	1.00	3.38
Tractors	acre	7.96	1.00	7.96
INTEREST ON OP. CAP.	acre	8.23	1.00	<u>8.23</u>
TOTAL DIRECT EXPENSES				183.13
RETURN ABOVE DIRECT EXPENSES				-81.13
FIXED EXPENSES				
Implements	acre	12.10	1.00	12.10
Tractors	acre	11.48	1.00	<u>11.48</u>
TOTAL FIXED EXPENSES				<u>23.58</u>
TOTAL SPECIFIED EXPENSES				206.72
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-104.72
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-219.72

Table A12. Estimated Annual Budget for Big Bluestem, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Big bluestem	ton	40.00	3.83	<u>153.20</u>
TOTAL INCOME				153.20
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	100.00	21.00
TRANSPORTATION				
Haul to plant	ton	4.15	3.83	15.89
OPERATOR LABOR				
Tractors	hour	6.00	0.86	5.18
DIESEL FUEL				
Tractors	gal	0.83	3.14	2.60
REPAIR and MAINTENANCE				
Implements	acre	2.24	1.00	2.24
Tractors	acre	4.25	1.00	4.25
INTEREST ON OP. CAP.	acre	3.77	1.00	<u>3.77</u>
TOTAL DIRECT EXPENSES				78.91
RETURN ABOVE DIRECT EXPENSES				74.29
FIXED EXPENSES				
Implements	acre	6.51	1.00	6.51
Tractors	acre	5.85	1.00	<u>5.85</u>
TOTAL FIXED EXPENSES				<u>12.36</u>
ESTABLISHMENT COST	acre	24.40	1.00	24.40
TOTAL SPECIFIED EXPENSES				115.67
RETURN ABOVE TOTAL SPECIFIED EXPENSES				37.53
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				<u>-77.47</u>

Table A13. Estimated Establishment Year Budget for Alfalfa, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Alfalfa	ton	40.00	2.06	<u>82.40</u>
TOTAL INCOME				82.40
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	160.00	40.00
Potassium	lbs	0.17	625.00	106.25
Lime	ton	6.00	5.00	30.00
FUNGICIDES				
Eptom	pt	2.81	3.00	8.43
HERBICIDES				
Lorsban 4E	pt	1.81	1.50	2.71
SEED				
Alfalfa seed	lbs	2.50	14.00	35.00
TRANSPORTATION				
Haul to plant	ton	4.15	2.06	8.55
OPERATOR LABOR				
Tractors	hour	6.00	2.40	14.42
DIESEL FUEL				
Tractors	gal	0.83	9.06	7.52
REPAIR and MAINTENANCE				
Implements	acre	5.81	1.00	5.81
Tractors	acre	11.91	1.00	11.91
INTEREST ON OP. CAP.	acre	21.52	1.00	<u>21.52</u>
TOTAL DIRECT EXPENSES				292.12
RETURN ABOVE DIRECT EXPENSES				-209.72
FIXED EXPENSES				
Implements	acre	18.34	1.00	18.34
Tractors	acre	16.56	1.00	<u>16.56</u>
TOTAL FIXED EXPENSES				<u>34.89</u>
TOTAL SPECIFIED EXPENSES				327.01
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-244.61
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-324.61

Table A14. Estimated Annual Budget for Alfalfa, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Alfalfa	ton	40.00	3.47	<u>138.80</u>
TOTAL INCOME				138.80
DIRECT EXPENSES				
HERBICIDES				
Lorsban 4E	pt	1.81	2.00	3.62
TRANSPORTATION				
Haul to plant	ton	4.15	3.47	14.40
OPERATOR LABOR				
Tractors	hour	6.00	2.32	13.94
DIESEL FUEL				
Tractors	gal	0.83	8.07	6.69
REPAIR and MAINTENANCE				
Implements	acre	5.88	1.00	5.88
Tractors	acre	11.49	1.00	11.49
INTEREST ON OP. CAP.	acre	1.46	1.00	<u>1.46</u>
TOTAL DIRECT EXPENSES				57.48
RETURN ABOVE DIRECT EXPENSES				81.32
FIXED EXPENSES				
Implements	acre	12.57	1.00	12.57
Tractors	acre	15.28	1.00	<u>15.28</u>
TOTAL FIXED EXPENSES				<u>27.86</u>
ESTABLISHMENT COST	acre	81.16	1.00	81.16
TOTAL SPECIFIED EXPENSES				166.49
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-27.69
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-107.69

Table A15. Estimated Annual Budget for Intercrop Alfalfa/Sweet Sorghum, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Alfalfa/Sweet sorghum	ton	40.00	4.29	<u>171.60</u>
TOTAL INCOME				171.60
DIRECT EXPENSES				
HERBICIDES				
Paraquat	pt	4.46	0.40	1.78
SEED				
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	4.29	17.80
OPERATOR LABOR				
Tractors	hour	6.00	2.40	14.42
DIESEL FUEL				
Tractors	gal	0.83	8.32	6.91
REPAIR and MAINTENANCE				
Implements	acre	6.28	1.00	6.28
Tractors	acre	11.78	1.00	11.78
INTEREST ON OP. CAP.	acre	1.49	1.00	<u>1.49</u>
TOTAL DIRECT EXPENSES				63.97
RETURN ABOVE DIRECT EXPENSES				107.63
FIXED EXPENSES				
Implements	acre	14.83	1.00	14.83
Tractors	acre	15.71	1.00	<u>15.71</u>
TOTAL FIXED EXPENSES				<u>30.54</u>
ESTABLISHMENT COST	acre	81.16	1.00	81.16
TOTAL SPECIFIED EXPENSES				175.67
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-4.07
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-84.07

Table A16. Estimated Annual Budget for Intercrop Alfalfa/Sorghum x sudangrass hybrid, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Alfalfa/Sorghum x sudan	ton	40.00	5.16	<u>206.40</u>
TOTAL INCOME				206.40
DIRECT EXPENSES				
HERBICIDES				
Paraquat	pt	4.46	0.40	1.78
SEED				
Sorghum x sudan seed	lbs	0.35	7.00	2.45
TRANSPORTATION				
Haul to plant	ton	4.15	5.16	21.41
OPERATOR LABOR				
Tractors	hour	6.00	2.40	14.42
DIESEL FUEL				
Tractors	gal	0.83	8.32	6.91
REPAIR and MAINTENANCE				
Implements	acre	6.28	1.00	6.28
Tractors	acre	11.78	1.00	11.78
INTEREST ON OP. CAP.	acre	1.48	1.00	<u>1.48</u>
TOTAL DIRECT EXPENSES				66.52
RETURN ABOVE DIRECT EXPENSES				139.88
FIXED EXPENSES				
Implements	acre	14.83	1.00	14.83
Tractors	acre	15.71	1.00	<u>15.71</u>
TOTAL FIXED EXPENSES				<u>30.54</u>
ESTABLISHMENT COST	acre	81.16	1.00	81.16
TOTAL SPECIFIED EXPENSES				178.21
RETURN ABOVE TOTAL SPECIFIED EXPENSES				28.19
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-51.81

Table A17. Estimated Establishment Year Budget for Reed Canarygrass, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Reed canarygrass	ton	40.00	2.47	<u>98.80</u>
TOTAL INCOME				98.80
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	125.00	26.25
HERBICIDES				
2,4-D	pt	2.31	2.00	4.62
SEED				
Reed canarygrass seed	lbs	4.50	11.00	49.50
TRANSPORTATION				
Haul to plant	ton	4.15	2.47	10.25
OPERATOR LABOR				
Tractors	hour	6.00	2.31	13.87
DIESEL FUEL				
Tractors	gal	0.83	8.69	7.21
REPAIR and MAINTENANCE				
Implements	acre	5.36	1.00	5.36
Tractors	acre	11.46	1.00	11.46
INTEREST ON OP. CAP.	acre	7.37	1.00	<u>7.37</u>
TOTAL DIRECT EXPENSES				159.87
RETURN ABOVE DIRECT EXPENSES				-61.07
FIXED EXPENSES				
Implements	acre	17.76	1.00	17.76
Tractors	acre	15.89	1.00	<u>15.89</u>
TOTAL FIXED EXPENSES				<u>33.64</u>
TOTAL SPECIFIED EXPENSES				193.52
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-94.72
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-174.72

Table A18. Estimated Annual Budget for Reed canarygrass, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Reed canarygrass	ton	40.00	4.73	<u>189.20</u>
TOTAL INCOME				189.20
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	200.00	42.00
TRANSPORTATION				
Haul to plant	ton	4.15	4.73	19.63
OPERATOR LABOR				
Tractors	hour	6.00	1.61	9.66
DIESEL FUEL				
Tractors	gal	0.83	5.81	4.82
REPAIR and MAINTENANCE				
Implements	acre	4.14	1.00	4.14
Tractors	acre	7.94	1.00	7.94
INTEREST ON OP. CAP.	acre	4.83	1.00	<u>4.83</u>
TOTAL DIRECT EXPENSES				117.00
RETURN ABOVE DIRECT EXPENSES				72.20
FIXED EXPENSES				
Implements	acre	11.56	1.00	11.56
Tractors	acre	10.87	1.00	<u>10.87</u>
TOTAL FIXED EXPENSES				<u>22.43</u>
ESTABLISHMENT COST	acre	19.41	1.00	19.41
TOTAL SPECIFIED EXPENSES				158.84
RETURN ABOVE TOTAL SPECIFIED EXPENSES				30.36
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-49.64

Table A19. Estimated Establishment Year Budget for Switchgrass, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Switchgrass	ton	40.00	3.14	<u>125.60</u>
TOTAL INCOME				125.60
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
HERBICIDES				
Atrazine 4L	pt	1.58	2.50	3.95
SEED				
Switchgrass seed	lbs	3.50	8.00	28.00
TRANSPORTATION				
Haul to plant	ton	4.15	3.14	13.03
OPERATOR LABOR				
Tractors	hour	6.00	1.56	9.38
DIESEL FUEL				
Tractors	gal	0.83	6.01	4.99
REPAIR and MAINTENANCE				
Implements	acre	3.46	1.00	3.46
Tractors	acre	7.77	1.00	7.77
INTEREST ON OP. CAP.	acre	4.70	1.00	<u>4.70</u>
TOTAL DIRECT EXPENSES				99.27
RETURN ABOVE DIRECT EXPENSES				26.33
FIXED EXPENSES				
Implements	acre	12.71	1.00	12.71
Tractors	acre	10.87	1.00	<u>10.87</u>
TOTAL FIXED EXPENSES				<u>23.58</u>
TOTAL SPECIFIED EXPENSES				122.85
RETURN ABOVE TOTAL SPECIFIED EXPENSES				2.75
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-77.25

Table A20. Estimated Annual Budget for Switchgrass, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Switchgrass	ton	40.00	4.69	<u>187.60</u>
TOTAL INCOME				187.60
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	100.00	21.00
TRANSPORTATION				
Haul to plant	ton	4.15	4.69	19.46
OPERATOR LABOR				
Tractors	hour	6.00	0.86	5.18
DIESEL FUEL				
Tractors	gal	0.83	3.14	2.60
REPAIR and MAINTENANCE				
Implements	acre	2.24	1.00	2.24
Tractors	acre	4.25	1.00	4.25
INTEREST ON OP. CAP.	acre	3.80	1.00	<u>3.80</u>
TOTAL DIRECT EXPENSES				82.51
RETURN ABOVE DIRECT EXPENSES				105.09
FIXED EXPENSES				
Implements	acre	6.51	1.00	6.51
Tractors	acre	5.85	1.00	<u>5.85</u>
TOTAL FIXED EXPENSES				<u>12.36</u>
ESTABLISHMENT COST	acre	8.58	1.00	8.58
TOTAL SPECIFIED EXPENSES				103.45
RETURN ABOVE TOTAL SPECIFIED EXPENSES				84.15
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				4.15

Table A21. Estimated Establishment Year Budget for Big Bluestem, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Big bluestem	ton	40.00	1.77	<u>68.00</u>
TOTAL INCOME				68.00
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
HERBICIDES				
2,4-D	pt	2.31	2.50	5.78
SEED				
Switchgrass seed	lbs	9.00	12.00	108.00
TRANSPORTATION				
Haul to plant	ton	4.15	1.70	7.06
OPERATOR LABOR				
Tractors	hour	6.00	1.64	9.87
DIESEL FUEL				
Tractors	gal	0.83	6.47	5.37
REPAIR and MAINTENANCE				
Implements	acre	3.38	1.00	3.38
Tractors	acre	7.96	1.00	7.96
INTEREST ON OP. CAP.	acre	8.20	1.00	<u>8.20</u>
TOTAL DIRECT EXPENSES				179.58
RETURN ABOVE DIRECT EXPENSES				-111.58
FIXED EXPENSES				
Implements	acre	12.10	1.00	12.10
Tractors	acre	11.48	1.00	<u>11.48</u>
TOTAL FIXED EXPENSES				<u>23.58</u>
TOTAL SPECIFIED EXPENSES				203.16
RETURN ABOVE TOTAL SPECIFIED EXPENSES				-135.16
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-215.16

Table A22. Estimated Annual Budget for Big Bluestem, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Big bluestem	ton	40.00	3.55	<u>142.00</u>
TOTAL INCOME				142.00
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potassium	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.21	100.00	21.00
TRANSPORTATION				
Haul to plant	ton	4.15	3.55	14.73
OPERATOR LABOR				
Tractors	hour	6.00	0.86	5.18
DIESEL FUEL				
Tractors	gal	0.83	3.14	2.60
REPAIR and MAINTENANCE				
Implements	acre	2.24	1.00	2.24
Tractors	acre	4.25	1.00	4.25
INTEREST ON OP. CAP.	acre	3.76	1.00	<u>3.76</u>
TOTAL DIRECT EXPENSES				77.74
RETURN ABOVE DIRECT EXPENSES				64.26
FIXED EXPENSES				
Implements	acre	6.51	1.00	6.51
Tractors	acre	5.85	1.00	<u>5.85</u>
TOTAL FIXED EXPENSES				<u>12.36</u>
ESTABLISHMENT COST	acre	23.91	1.00	23.91
TOTAL SPECIFIED EXPENSES				114.01
RETURN ABOVE TOTAL SPECIFIED EXPENSES				27.99
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-52.01

Table A23. Estimated Annual Budget for Sweet Sorghum, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Sweet sorghum	ton	40.00	7.08	<u>283.20</u>
TOTAL INCOME				283.20
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	100.00	12.00
HERBICIDES				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	7.08	29.38
OPERATOR LABOR				
Tractors	hour	6.00	2.56	15.39
DIESEL FUEL				
Tractors	gal	0.83	11.37	9.44
REPAIR and MAINTENANCE				
Implements	acre	5.24	1.00	5.24
Tractors	acre	16.84	1.00	16.84
INTEREST ON OP. CAP.	acre	6.67	1.00	<u>6.67</u>
TOTAL DIRECT EXPENSES				136.70
RETURN ABOVE DIRECT EXPENSES				146.50
FIXED EXPENSES				
Implements	acre	13.75	1.00	13.75
Tractors	acre	26.83	1.00	<u>26.83</u>
TOTAL FIXED EXPENSES				<u>40.57</u>
TOTAL SPECIFIED EXPENSES				177.27
RETURN ABOVE TOTAL SPECIFIED EXPENSES				105.93
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-9.07

Table A24. Estimated Annual Budget for Sorghum x Sudangrass Hybrid, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Sorghum x sudangrass	ton	40.00	6.46	<u>258.40</u>
TOTAL INCOME				258.40
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	100.00	12.00
HERBICIDES				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum seed	lbs	0.35	7.00	2.45
TRANSPORTATION				
Haul to plant	ton	4.15	6.46	26.81
OPERATOR LABOR				
Tractors	hour	6.00	2.56	15.39
DIESEL FUEL				
Tractors	gal	0.83	11.37	9.44
REPAIR and MAINTENANCE				
Implements	acre	5.24	1.00	5.24
Tractors	acre	16.84	1.00	16.84
INTEREST ON OP. CAP.	acre	6.37	1.00	<u>6.37</u>
TOTAL DIRECT EXPENSES				132.78
RETURN ABOVE DIRECT EXPENSES				125.62
FIXED EXPENSES				
Implements	acre	13.75	1.00	13.75
Tractors	acre	26.83	1.00	<u>26.83</u>
TOTAL FIXED EXPENSES				<u>40.57</u>
TOTAL SPECIFIED EXPENSES				173.35
RETURN ABOVE TOTAL SPECIFIED EXPENSES				85.05
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-29.95

Table A25. Estimated Annual Budget for Doublecrop Rye/Sweet Sorghum, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Winter rye	ton	40.00	1.80	72.00
Sweet sorghum	ton	40.00	5.22	<u>208.80</u>
TOTAL INCOME				280.80
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.21	162.00	34.02
SEED				
Rye seed	lbs	0.31	100.00	31.00
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	7.02	29.13
OPERATOR LABOR				
Tractors	hour	6.00	3.13	18.77
DIESEL FUEL				
Tractors	gal	0.83	12.93	10.74
REPAIR and MAINTENANCE				
Implements	acre	6.55	1.00	6.55
Tractors	acre	19.57	1.00	19.57
INTEREST ON OP. CAP.	acre	8.68	1.00	<u>8.68</u>
TOTAL DIRECT EXPENSES				184.44
RETURN ABOVE DIRECT EXPENSES				96.36
FIXED EXPENSES				
Implements	acre	18.39	1.00	18.39
Tractors	acre	30.21	1.00	<u>30.21</u>
TOTAL FIXED EXPENSES				<u>48.60</u>
TOTAL SPECIFIED EXPENSES				233.05
RETURN ABOVE TOTAL SPECIFIED EXPENSES				47.75
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				<u>-67.25</u>

Table A26. Estimated Annual Budget for Doublecrop Rye/Sorghum x Sudangrass Hybrid,
Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Winter rye	ton	40.00	1.59	63.60
Sweet sorghum	ton	40.00	4.89	<u>195.60</u>
TOTAL INCOME				259.20
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.21	162.00	34.02
SEED				
Rye seed	lbs	0.31	100.00	31.00
Sweet sorghum seed	lbs	0.35	7.00	2.45
TRANSPORTATION				
Haul to plant	ton	4.15	6.48	26.89
OPERATOR LABOR				
Tractors	hour	6.00	3.13	18.77
DIESEL FUEL				
Tractors	gal	0.83	12.93	10.74
REPAIR and MAINTENANCE				
Implements	acre	6.55	1.00	6.55
Tractors	acre	19.57	1.00	19.57
INTEREST ON OP. CAP.	acre	8.60	1.00	<u>8.60</u>
TOTAL DIRECT EXPENSES				181.08
RETURN ABOVE DIRECT EXPENSES				78.12
FIXED EXPENSES				
Implements	acre	18.39	1.00	18.39
Tractors	acre	30.21	1.00	<u>30.21</u>
TOTAL FIXED EXPENSES				<u>48.60</u>
TOTAL SPECIFIED EXPENSES				229.68
RETURN ABOVE TOTAL SPECIFIED EXPENSES				29.52
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-85.48

Table A27. Estimated Annual Budget for Sweet Sorghum in Rotation, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Sweet sorghum	ton	40.00	6.68	<u>267.20</u>
TOTAL INCOME				267.20
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	50.00	6.00
HERBICIDES				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	6.68	27.72
OPERATOR LABOR				
Tractors	hour	6.00	2.29	13.73
DIESEL FUEL				
Tractors	gal	0.83	10.36	8.60
REPAIR and MAINTENANCE				
Implements	acre	4.94	1.00	4.94
Tractors	acre	15.46	1.00	15.46
INTEREST ON OP. CAP.	acre	6.23	1.00	<u>6.23</u>
TOTAL DIRECT EXPENSES				124.43
RETURN ABOVE DIRECT EXPENSES				142.77
FIXED EXPENSES				
Implements	acre	11.41	1.00	11.41
Tractors	acre	25.00	1.00	<u>25.00</u>
TOTAL FIXED EXPENSES				<u>36.41</u>
TOTAL SPECIFIED EXPENSES				160.85
RETURN ABOVE TOTAL SPECIFIED EXPENSES				106.35
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-8.65

Table A28. Estimated Annual Budget for Rye/Sweet Sorghum in Rotation, Ames, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Winter rye	ton	40.00	2.35	94.00
Sweet sorghum	ton	40.00	5.78	<u>231.20</u>
TOTAL INCOME				325.20
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.21	100.00	21.00
SEED				
Rye seed	lbs	0.31	100.00	31.00
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	8.13	33.74
OPERATOR LABOR				
Tractors	hour	6.00	3.01	18.08
DIESEL FUEL				
Tractors	gal	0.83	12.47	10.35
REPAIR and MAINTENANCE				
Implements	acre	6.21	1.00	6.21
Tractors	acre	19.01	1.00	19.01
INTEREST ON OP. CAP.	acre	8.31	1.00	<u>8.31</u>
TOTAL DIRECT EXPENSES				173.69
RETURN ABOVE DIRECT EXPENSES				151.51
FIXED EXPENSES				
Implements	acre	16.93	1.00	16.93
Tractors	acre	29.37	1.00	<u>29.37</u>
TOTAL FIXED EXPENSES				<u>46.31</u>
TOTAL SPECIFIED EXPENSES				219.99
RETURN ABOVE TOTAL SPECIFIED EXPENSES				105.21
ALLOCATED COST ITEMS				
LAND	acre	115.00	1.00	115.00
RESIDUAL RETURNS				-9.79

Table A29. Estimated Annual Budget for Sweet Sorghum, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Sweet sorghum	ton	40.00	7.28	<u>291.20</u>
TOTAL INCOME				291.20
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	100.00	12.00
HERBICIDES				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	7.28	30.31
OPERATOR LABOR				
Tractors	hour	6.00	2.56	15.39
DIESEL FUEL				
Tractors	gal	0.83	11.37	9.44
REPAIR and MAINTENANCE				
Implements	acre	5.24	1.00	5.24
Tractors	acre	16.84	1.00	16.84
INTEREST ON OP. CAP.	acre	8.79	1.00	<u>8.79</u>
TOTAL DIRECT EXPENSES				139.66
RETURN ABOVE DIRECT EXPENSES				151.54
FIXED EXPENSES				
Implements	acre	13.75	1.00	13.75
Tractors	acre	26.83	1.00	<u>26.83</u>
TOTAL FIXED EXPENSES				<u>40.57</u>
TOTAL SPECIFIED EXPENSES				180.23
RETURN ABOVE TOTAL SPECIFIED EXPENSES				110.97
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				30.97

Table A30. Estimated Annual Budget for Sorghum x Sudangrass Hybrid, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Sorghum x sudangrass	ton	40.00	6.36	<u>254.40</u>
TOTAL INCOME				254.40
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	100.00	12.00
HERBICIDES				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum seed	lbs	0.35	7.00	2.45
TRANSPORTATION				
Haul to plant	ton	4.15	6.36	26.39
OPERATOR LABOR				
Tractors	hour	6.00	2.56	15.39
DIESEL FUEL				
Tractors	gal	0.83	11.37	9.44
REPAIR and MAINTENANCE				
Implements	acre	5.24	1.00	5.24
Tractors	acre	16.84	1.00	16.84
INTEREST ON OP. CAP.	acre	8.38	1.00	<u>8.38</u>
TOTAL DIRECT EXPENSES				134.37
RETURN ABOVE DIRECT EXPENSES				120.03
FIXED EXPENSES				
Implements	acre	13.75	1.00	13.75
Tractors	acre	26.83	1.00	<u>26.83</u>
TOTAL FIXED EXPENSES				<u>40.57</u>
TOTAL SPECIFIED EXPENSES				174.95
RETURN ABOVE TOTAL SPECIFIED EXPENSES				79.45
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-0.55

Table A31. Estimated Annual Budget for Doublecrop Rye/Sweet Sorghum, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Winter rye	ton	40.00	1.72	68.80
Sweet sorghum	ton	40.00	5.22	<u>179.20</u>
TOTAL INCOME				248.00
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.21	162.00	34.02
SEED				
Rye seed	lbs	0.31	120.00	37.20
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	6.20	25.73
OPERATOR LABOR				
Tractors	hour	6.00	3.13	18.77
DIESEL FUEL				
Tractors	gal	0.83	12.93	10.74
REPAIR and MAINTENANCE				
Implements	acre	6.55	1.00	6.55
Tractors	acre	19.57	1.00	19.57
INTEREST ON OP. CAP.	acre	9.49	1.00	<u>9.49</u>
TOTAL DIRECT EXPENSES				188.05
RETURN ABOVE DIRECT EXPENSES				59.95
FIXED EXPENSES				
Implements	acre	18.39	1.00	18.39
Tractors	acre	30.21	1.00	<u>30.21</u>
TOTAL FIXED EXPENSES				<u>48.60</u>
TOTAL SPECIFIED EXPENSES				236.65
RETURN ABOVE TOTAL SPECIFIED EXPENSES				11.35
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-68.65

Table A32. Estimated Annual Budget for Doublecrop Rye/Sorghum x Sudangrass Hybrid, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Winter rye	ton	40.00	1.72	68.80
Sweet sorghum	ton	40.00	4.47	<u>178.80</u>
TOTAL INCOME				247.60
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.21	162.00	34.02
SEED				
Rye seed	lbs	0.31	120.00	37.20
Sweet sorghum seed	lbs	0.35	7.00	2.45
TRANSPORTATION				
Haul to plant	ton	4.15	6.19	25.69
OPERATOR LABOR				
Tractors	hour	6.00	3.13	18.77
DIESEL FUEL				
Tractors	gal	0.83	12.93	10.74
REPAIR and MAINTENANCE				
Implements	acre	6.55	1.00	6.55
Tractors	acre	19.57	1.00	19.57
INTEREST ON OP. CAP.	acre	9.17	1.00	<u>9.17</u>
TOTAL DIRECT EXPENSES				186.65
RETURN ABOVE DIRECT EXPENSES				60.95
FIXED EXPENSES				
Implements	acre	18.39	1.00	18.39
Tractors	acre	30.21	1.00	<u>30.21</u>
TOTAL FIXED EXPENSES				<u>48.60</u>
TOTAL SPECIFIED EXPENSES				235.25
RETURN ABOVE TOTAL SPECIFIED EXPENSES				12.35
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				-67.65

Table A33. Estimated Annual Budget for Sweet Sorghum in Rotation, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Sweet sorghum	ton	40.00	7.15	<u>286.00</u>
TOTAL INCOME				286.00
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	50.00	6.00
HERBICIDES				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	7.15	29.67
OPERATOR LABOR				
Tractors	hour	6.00	2.29	13.73
DIESEL FUEL				
Tractors	gal	0.83	10.36	8.60
REPAIR and MAINTENANCE				
Implements	acre	4.94	1.00	4.94
Tractors	acre	15.46	1.00	15.46
INTEREST ON OP. CAP.	acre	8.56	1.00	<u>8.56</u>
TOTAL DIRECT EXPENSES				128.71
RETURN ABOVE DIRECT EXPENSES				157.29
FIXED EXPENSES				
Implements	acre	11.41	1.00	11.41
Tractors	acre	25.00	1.00	<u>25.00</u>
TOTAL FIXED EXPENSES				<u>36.41</u>
TOTAL SPECIFIED EXPENSES				165.12
RETURN ABOVE TOTAL SPECIFIED EXPENSES				120.88
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				40.88

Table A34. Estimated Annual Budget for Rye/Sweet Sorghum in Rotation, Chariton, Iowa, 1993.

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
INCOME				
Winter rye	ton	40.00	1.93	77.20
Sweet sorghum	ton	40.00	5.78	<u>274.00</u>
TOTAL INCOME				351.20
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potassium	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.21	100.00	21.00
SEED				
Rye seed	lbs	0.31	120.00	37.20
Sweet sorghum seed	lbs	0.50	7.00	3.50
TRANSPORTATION				
Haul to plant	ton	4.15	8.78	36.44
OPERATOR LABOR				
Tractors	hour	6.00	3.01	18.08
DIESEL FUEL				
Tractors	gal	0.83	12.47	10.35
REPAIR and MAINTENANCE				
Implements	acre	6.21	1.00	6.21
Tractors	acre	19.01	1.00	19.01
INTEREST ON OP. CAP.	acre	8.91	1.00	<u>8.91</u>
TOTAL DIRECT EXPENSES				183.18
RETURN ABOVE DIRECT EXPENSES				168.02
FIXED EXPENSES				
Implements	acre	16.93	1.00	16.93
Tractors	acre	29.37	1.00	<u>29.37</u>
TOTAL FIXED EXPENSES				<u>46.31</u>
TOTAL SPECIFIED EXPENSES				229.49
RETURN ABOVE TOTAL SPECIFIED EXPENSES				121.71
ALLOCATED COST ITEMS				
LAND	acre	80.00	1.00	80.00
RESIDUAL RETURNS				41.71

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