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FOLIAR APPLICATION OF NITROGEN SOLUTION FOR DESICCATION OF GRAIN SORGHUM, SORGHUM BICOLOR (L.) MOENCH

by

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INTRODUCTION

Grain sorghum (Sorghum bicolor (L.) Moench) production has become very important in the Great Plains in recent years. One of the most serious production problems encountered is delayed harvest due to adverse weather conditions in the fall, especially in the more humid regions. Severe economic losses have occurred in recent years because of unfavorable weather which slowed normal grain drying and delayed conventional harvest. An effective and economical practice to allow earlier harvest of grain sorghum would be a major breakthrough in grain sorghum production.

Two general approaches are possible. One is the harvest of high moisture grain, which has been investigated and shows much potential, however, it requires specialized storage and handling equipment or drying facilities. The other approach is to speed the drying rate of the grain in the field so harvest at a normal moisture content can be done earlier. This approach has been investigated some, however, no dependable, practical, and economical method has been found.

The grain sorghum plant is naturally a perennial, thus it does not die at maturity. Therefore, any attempt to accelerate drying of the grain necessarily involves killing all or part of the plant soon after all of the dry weight of the grain has been produced. Various studies have shown that killing the plant chemically or mechanically can effectively speed the drying rate of the grain in the field to permit earlier harvesting, however, an acceptable and dependable method of killing the plant has not been established for field use.

Chemical desiccants and defoliants have been used successfully for various aspects of production for numerous other crops for many years. For sorghum, the most reasonable method should be some type of chemical desiccant or mechanical treatment (such as flame) which will kill or partially kill the plant. Desiccation treatments applied to the plant after it has reached maximum dry weight (physiological maturity) should kill the leaves and possibly the stalks without affecting grain yield. The killing and dehydrating of other plant parts caused by the treatment should allow for more rapid drying of the grain. An additional advantage of desiccation should be reduced harvest losses because less green material would have to be handled by the combine which would allow better separation of grain from residue.

Various materials have been evaluated as desiccating materials for grain sorghum, however, some major problems have been encountered. The most effective chemicals for killing the plant and speeding the grain drying rate often leave residues which make the treated crop unfit for animal consumption. There is an economical limitation on desiccation practices, since the gain from earlier harvest should pay for the cost of desiccation. In spite of the problems, the magnitude of loss that can occur due to delayed harvest certainly warrants investigations in the area of pre-harvest drying of grain sorghum.

With this in mind, this study was designed to evaluate the use of 32% nitrogen solution as a desiccating material for grain sorghum. Nitrogen solution could have some major advantages over some of the other materials which have been used if it proves effective as a desiccant. It will not leave restrictive residues like many of the chemical desiccants which have been tried, and it should be economical. If nitrogen solution can be used to speed the drying rate of the grain, then part of the nitrogen applied should be recovered in the grain or forage, or be carried over and utilized by the succeeding crop. Thus the cost of desiccation would be only the cost of the nitrogen not recovered plus the cost of application.

REVIEW OF LITERATURE

Desiccation and Defoliation

A very limited number of studies have been conducted on pre-harvest desiccation of grain sorghum. Desiccation and defoliation have been practiced on a field scale for many years on various other crops (1,11). Studies have been performed to evaluate desiccants and defoliants for cotton (Gossypium herbaceum L.) (8,11), small seeded legumes harvested for seed (7,20,25), spring wheat (Triticum aestivum L.) (15), and other crops including rice (Oryza sativa L.), flax (Linum usitatissimum L.), potatoes (Solanum tuberosum L.), castorbeans (Ricinus communis L.), and grasses harvested for seed (1,11).

Hall (11) in 1956 described renewed interest in the use of pre-harvest chemicals because of the trends toward complete mechanization of crop production and harvesting, combined with improved varieties, effective use of plant pesticides, fertilizers, and irrigation, which have contributed to later maturation and delayed harvesting. The use of pre-harvest chemicals on cotton was already well established at that time, as approximately 18% of the total acres in production in 1955 were treated, primarily with defoliants, to improve harvest efficiency, stop active growth, cause more uniform opening of the bolls, and to control second growth.

Brown and Rhyne (8) showed that species and varieties of cotton differed in the amount of defoliation produced by treatment. Defoliation was also influenced by the stage of boll maturity at the time of treatment.

The use of chemical desiccants for seed production of small seeded legumes was also reviewed by Hall (11). Use of pre-harvest conditioners to kill succulant foliage and green weeds allowed direct combining of seed within 4 to 5 days. The most successful chemical seemed to be DNBP (dinitro-o-secondary-butylphenol) in diesel fuel.

Phillips (20) studied the desiccating properties of DNBP, PCP (pentachlorophenol), and Endothall (3,6-endoxohexahydrophthalic acid) on alfalfa (Medicago sativa L.) heavily infested with Kochia (Kochia scoparia (L.) Schrad.) and other weeds. DNBP in diesel fuel was the most effective treatment for reducing moisture content of both the alfalfa and weeds, but a second application was needed before the seed could be satisfactorily combined.

Shafer (25) found DNBP and PCP in diesel fuel to be the most effective chemicals for aiding seed harvest of Madrid sweetclover (Melilotus officinalis (L.) Lam.). Harvest 3 days after application resulted in about an 8% decrease in seed moisture with these treatments compared to direct combining without treatment.

At Nebraska, Bovey and Kehr (7) investigated diquat (6,7-dihydrodipyrido (1,2-a:2,1-c)pyrazidiinium salt) and paraquat (1,1'-dimethyl-4,4'-bipyridinium salt) for desiccation of alfalfa for seed production. These chemicals have much lower mammalian toxicity than DNBP and PCP which had already been proven to be most effective in drying legume crops and weeds in Nebraska. Paraquat in water was as effective as DNBP in diesel fuel for drying weeds and alfalfa foliage and seed pods three days after treatment. Diquat was effective on alfalfa, but not as effective as DNBP or paraquat on weeds.

McNeal et al. (15) concluded that chemical treatments on spring wheat were ineffective in reducing head moisture when sprayed at weekly intervals starting four weeks after heading. Only swathing was effective in speeding drying, but both swathing and chemical treatment caused yield reductions.

Desiccation of grain sorghum to speed the drying rate of the grain has been studied by several researchers since 1950, and many of the popular materials used on other crops have been evaluated. Research has primarily involved the evaluation of various chemicals and flame treatments as drying agents, and the effects of rate of application, timing of application, method of application, and variety and hybrid differences. In addition, the effects of desiccation on physiological processes within the plant have been studied by observing grain and forage yield, germination, residues, etc.

Hall (11) reviewed early work on grain sorghum desiccation in Texas in the 1950's. Endothall did not kill the leaves and stems completely, but reduced the moisture content of the grain to 10 to 11% within 10 days, while controls were still at 15 to 20%. In another test in 1956, magnesium chlorate, Endothall, and sodium chlorate-sodium borate solutions significantly reduced grain moisture within 10 days.

Applications of PCP or DNBP in diesel fuel or Endothall in water failed to reduce grain moisture when applied at an initial grain moisture of 18% in a study by Phillips (19). The DNBP and PCP formulations effectively dried the leaves, but did not seem to affect the peduncle or head, while Endothall was not visibly effective at the rates used. A warning was also issued concerning the possibility of chemical residues remaining on the grain after desiccation treatment.

Shafer (24) sprayed triplicate two acre plots of Martin milo with desiccants and harvested one week after treatment. Control plots showed 18.5% grain moisture, while PCP in diesel fuel reduced moisture to 11.5%. DNBP in diesel fuel and sodium mono-chloroacetate in water were less effective (14.9 and 13.6% respectively) and hydrin, a highly aromatic hydrocarbon, was not effective at any rate.

A similar study by Shafer (26) in 1954 included Endothall and magnesium chlorate. Moisture content at treatment was about 20%, and the untreated control area averaged 18.2% one week after treatment. All of the desiccants did affect grain moisture, with DNBP and PCP having the greatest effect and Endothall and sodium chloroacetate having the least effect.

Shafer (27) treated one acre blocks of male sterile Combine Kafir-60 when the moisture content of the grain was from 36 to 42%. PCP in diesel fuel gave the best drying results when moisture samples were taken at 8 and 30 days after treatment. DNBP, DEF (S,S,S-Tributylphosphorotrithioate), magnesium chlorate, and ammonium nitrate solution at various levels all gave similar drying results, reducing grain moisture to about 21 to 23% after 30 days as compared to 28% for the untreated control. Ammonium nitrate solution was used at a rate of 34 kg of nitrogen per hectare and produced the least response after 8 days of any of the treatments, and still had one of the higher moisture contents at 30 days, 23.6%.

In addition, Shafer (28) showed a significant variety x chemical interaction for the three varieties and ten hybrids used in this test, varying from great response to no response at all for different varieties. This differential response of varieties and hybrids to desiccation was very important for interpreting past results and designing future experiments.

Alvey and Pendleton (2) compared defoliation, severing the plant at the soil surface, and spraying with DNBP in diesel fuel or magnisium chlorate in water on DeKalb variety D-50 hybrid grain sorghum at three initial grain moistures. The chemicals and severing caused great reductions in moisture soon after treatment, but the loss was very slow after the treated plots had reached about 18% moisture. Grain yields were significantly reduced by all treatments at 48.2% initial moisture, but only by magnesium chlorate at 37.5% initial moisture, and were not reduced at all at 22.7% initial moisture. However, lesser drying effects were observed as initial moisture declined, and only severing the plant produced any significant drying effects at 22.7%. No difference in the drying effects of DNBP and magnesium chlorate was observed, and only on one occasion was severing more effective than the chemical desiccants. Defoliation was not effective in drying the grain, indicating that chemicals did more than just kill the leaves. Effect on the stalks was apparent when chemically treated stalks became brittle and lodged much worse than the control treatment.

A slightly different approach to grain sorghum desiccation is the use of heat and flame as a desiccant. Parks (17) reported significant increases in drying rates of grain sorghum using flame cultivators and field drying, which involved the use of heat under metal hoods. Applying the treatments at 25% initial grain moisture, drying rates to 14% moisture were 1.18% per day for field drying, 0.77% per day for flame desiccation, and 0.50% per day for the untreated control. Applications at lower initial moistures were successively less effective. Despite poor weather conditions and inconsistent results in his earlier studies, he concluded that field drying or flaming was still advantageous because of increased harvest efficiency. Increased grain yields of 300 to 500 kg/ha in 5650 kg/ha sorghum were attributed to reducting the grain normally carried out of the combine with the heavier, greener residue of the untreated plots. Residue handled by the combine was reduced from 7,722 kg/ha to 6350 kg/ha for flame desiccation and 5,618 kg/ha for field drying, making better separation and faster ground speed possible.

Reece et al. (21) concluded that desiccation of grain sorghum with flame, diquat, or paraquat significantly reduced grain moisture in a study at Manhattan, Kansas. Maximum effects occurred two weeks after application. Greater drying was observed in 1963 than in 1964 which was attributed to the initial grain moisture. Treatment at 35% grain moisture in 1963 was assumed to be closer to physiological maturity than treatment at 26% moisture in 1964. Nitrogen solution at 67 kg of N per ha was also used in this study, and was nearly as effective as paraquat or diquat as a desiccating material.

Bovey and McCarty (6) compared several desiccants with defoliation and severing the plant at the soil and below the head on two sorghum varieties, Martin and Combine Kafir-60. Magnesium chlorate and DNBP in diesel fuel at an initial grain moisture of approximately 50 or 40% gave grain drying results similar to leaf removal for Martin, indicating that the main effect was on the leaves, contrary to Alvey and Pendleton's (2) findings. A gain of about 10 days in harvest time was observed for the chemicals and leaf removal, while slightly greater gains were obtained by severing at the soil surface and even larger gains by severing below the head. Although producing the best drying results, seed weight and test weight were significantly reduced by treatment at 50% and 40% initial moisture. At 30% initial moisture, seed weight and test weight were not affected, but drying responses were not as great. In general, Combine Kafir-60 was more resistant to desiccation than Martin, confirming the variety x chemical interaction reported by Shafer (28). Results in 1962 differed only slightly from 1961 results.

In 1963, Bovey and McCarty (6) also found Diquat to be an effective chemical desiccant, comparing equally with cutting the plant at the soil. Its effectiveness at low concentration and its low toxicity to animals were reported as added advantages. Flaming the plant just below the panicle was effective at 50% initial grain moisture, but was not as effective at 33% initial moisture. Flaming near the base of the plant was ineffective, apparently because the leaf sheaths afforded protection for the stem.

Anatomical studies by Bovey (4) indicated that rapid cellular changes occurred in leaf and stem tissue within a few hours after chemical desiccation. An altering of cellular function allows water and other contents to be lost from the cell which causes desiccation. In general, reduction of seed and test weights were observed for nearly all desiccation treatments at moisture levels above 40%. Germination of seed from desiccant treated plots was generally not affected for any treatment, and successful desiccation methods even gave some higher germinations.

A later study by Bovey and Miller (5) evaluated various herbicides, herbicide dosages, placement, and mixtures to increase desiccating and defoliating properties. Most desiccants produced maximum visible effects within one week. Diquat was found to be the most effective desiccant at low concentration for both field grown and greenhouse grown sorghum. At high concentrations, PCP and AP-20 (cis-2,3,5,5,5-pentachloro-4-ketopentenoic acid) produced more rapid desiccation within the first few hours, but were no more effective than diquat after 1 or 2 days. Cacodylic acid (dimethylarsinic acid) and a mixture of 2,4-D, 2,4,5-T, and picloram (4-amino-3,5,6-trichloropicolinic acid) caused desiccation at intermediate dosages. Various synergistic and antagonistic effects were observed using several mixtures on hibiscus (Hibiscus rosa sinensis L.), but no similar conclusions can be made for sorghum because of large differences in species response to chemicals.

Physiological Maturity

Based on results reported in the literature, it was apparent that best desiccation responses were obtained when treatment was made as soon as possible after physiological maturity to give maximum grain drying effects without reducing yield or quality. The relationship of grain drying patterns to physiological maturity is not clearly definable, however, and the determination of physiological maturity for desiccation in the field will be a problem.

Vanderlip and Reeves (31) described growth and dry matter accumulation of sorghum in detail and determined the relative proportion of each of the plant parts at each developmental stage. They defined physiological maturity as the point at which maximum dry weight of the plant has occurred. The time from flowering to physiological maturity and the grain moisture at physiological maturity vary with genetic material and environment.

Maximum dry weight of sorghum grain was observed by Clegg, Webster, and Grabouski (9) approximately 30 days after bloom at which time the grain contained 35 to 38% moisture.

Wikner and Atkins (33) found a range of 31 to 39% grain moisture at maximum dry weight for six varieties and hybrids evaluated in a grain drying study. Norghum and Midland ranged from 31 to 35% grain moisture at physiological maturity, while Martin, DeKalb variety C44a, RS610, and Double Dwarf Milo ranged from 34 to 39%, indicating significant variety differences. Forty to forty-six days elapsed between mid-bloom and physiological maturity in this study.

Kersting, Stickler, and Pauli (13) found that with Combine Kafir-60, maximum dry weight occurred 45 days after pollination at 23% grain moisture in 1958 and after 33 days at 30% moisture in 1959. This showed significant differences in both time between pollination and physiological maturity and grain moisture content at physiological maturity in successive years.

Pauli, Stickler, and Lawless (18) studied the effects of planting date, location, and variety on the developmental phases of grain sorghum, and found no differences in moisture content of the grain at physiological maturity due to date of planting, however, earlier planting dates tended to reduce the number of days from half-bloom to physiological maturity, which was attributed to higher temperatures. All varieties tended to be later and develop slower at Colby, Kansas than Manhattan, Kansas, which was attributed to the lower night temperatures at Colby. Moisture content of the grain was higher for the two hybrids (RS501 and KS701) than for the six open pollinated varieties, and differed significantly from Norghum and Combine Hegari. Varieties did not differ significantly in time from half-bloom to physiological maturity, however.

Nearly all of these studies indicated great variability in physiological maturity, whether based on per cent moisture at maximum dry weight or days from half-bloom to maximum dry weight, because of the several factors discussed. A more practical way of determining physiological maturity in the field has been proposed. Eastin, Hultquist, and Sullivan (10) showed that visual appearance of the dark closing layer near the placental area of the sorghum kernel coinsided closely with the end of translocation of radioactive ^{14}C labled assimilates to the kernel. They concluded that dark layer formation was an accurate method of determining physiological maturity in grain sorghum.

Grain Drying Patterns

Studies on the rate of water loss from the maturing sorghum caryopsis have been conducted by several researchers and should be considered when evaluating a desiccation study. A well defined pattern has not been established due to the magnitude of environmental influence on grain drying.

Wikner and Atkins (33) had exceptionally favorable temperature and moisture conditions for plant maturation and grain drying in 1958. Six entries varying in relative maturity and growth habits, particularly compactness of the head, showed comparatively uniform moisture loss from the grain for seven sampling dates and a linear regression was fitted to the data. Except for Double Dwarf Milo, no real differences in rate of water loss for the entries were observed. The drying rate averaged about 1.5% per day for the seven sampling dates, and then leveled off as the moisture content became low, as expected. Any major fluctuations were associated with light rainfall or frost before sampling. They found no consistent association between the rate of moisture loss from the grain and from other plant parts: pedicle, rachis, peduncle, leaves, or stalk. Moisture loss from stalks was very slow, and moisture remained at about 80% throughout the seven samplings, while other parts declined to about 15%, but not linearly like the grain. No relationship between moisture loss and head type was observed, although other genetic differences may have offset this effect.

Kersting, Stickler, and Pauli (13) showed that moisture content of the developing caryopsis decreased rather uniformly from 85% in the unfertilized ovary to about 40%. After the moisture reached 25%, it fluctuated greatly with changes in environmental conditions.

McBride, Singleton, and Zuber et al. (36) demonstrated that the influence of rainfall or humidity is reflected by an increase of moisture content in the entire plant, with the stems showing a larger increase than the heads.

In a study to evaluate maturity differences in grain sorghum hybrids, Warnes (32) found an overall average drying rate of about 1% per day. However, he found that hybrids differed significantly in the rates at which the grain fills and drys after blooming, and that this could account for differences in relative maturity classification of the hybrids. Climatic conditions had a major effect, as grain moisture loss was slowed and head-stem moisture content actually increased during periods of wet weather.

Nitrogen Accumulation Patterns

Since this study involves the use of nitrogen solution as a desiccant, patterns of nitrogen accumulation in sorghum should be understood to evaluate any residual nitrogen effect or uptake of nitrogen which may be possible, and to evaluate the effect of carryover of nitrogen to the succeeding crop.

Much natural variation is expected in total nitrogen content of sorghum grain. Miller et al. (16) showed significant differences in protein content of Kansas sorghum grain due to location and variety, ranging from 5.9 to 12.8%. Nitrogen fertilization increased both protein content and yield.

Worker and Ruckman (35) found variation of 8.54 to 21.53% crude protein depending on cultivar, year, and planting date.

Kersting, Pauli, and Stickler (12) found that percentage of nitrogen in the grain decreased steadily until about 18 to 24 days after pollination due to the dilution effect of carbohydrates, but then remained constant until maturity. Total nitrogen accumulation in the grain followed the same pattern as total dry matter accumulation in the developing grain. Nitrogen was apparently translocated into the developing grain as long as dry weight was increasing.

Vanderlip (30) reported that nutrient uptake preceded dry matter accumulation, and that the nutrients were required for further growth and dry matter accumulation throughout the plants' development.

Roy and Wright (22) found that the contribution of head weight to the total dry weight increased when nitrogen was applied. Nitrogen content of the grain was increased significantly by N fertilization.

Further studies by Roy and Wright (23) showed that nitrogen accumulated almost linearly until maturity, with higher rates corresponding to peak vegetative growth and grain-filling stages. They concluded that nitrogen translocation from the stem and leaves to the head started at initiation of heading, however, translocation was not sufficient to account for all of the nitrogen recovered in the heads for fertilized plants. Unfertilized plants, however, accumulated nitrogen primarily at the expense of translocation from the leaves and stem.

METHODS AND MATERIALS

Field Plots

Two grain sorghum hybrids, RS671 and DeKalb variety E57, were treated with three rates of foliar application of 32% nitrogen solution, 0, 67, and 134 kg N/ha, to evaluate desiccation effects.

The hybrids were similar in maturity, but differed in that RS671 was a compact head type while E57 was an open head type. The study was conducted in 1972 and repeated in 1973 at two locations: the Kansas State University, Ashland Research Farm at Manhattan and the East Central Kansas Experiment Field at Ottawa. Two dates of planting were used as main plots in each study to test desiccating effects under different drying conditions in the fall. Nitrogen solution was applied with a high clearance ground sprayer as soon as possible after physiological maturity, as determined by the grain black layer development (10).

Dates of planting and corresponding dates of foliar application for both years and both locations are summarized in Table 1.

Table 1. Dates of planting and corresponding dates of foliar N application at Manhattan and Ottawa in 1972 and 1973.

Year	Location	Date of Planting	Date of Treatment
1972	Manhattan	5-24 (Date 1)	9-4
		6-21 (Date 2)	10-6
1972	Ottawa	5-17 (Date 1)	9-15
		6-23 (Date 2)	10-5
1973	Manhattan	5-15 (Date 1)	8-20
		6-12 (Date 2)	9-5
1973	Ottawa	5-17 (Date 1)	8-22
		6-11 (Date 2)	not applied

The experimental design for each complete study was a split-plot with dates of planting as main plots and hybrids x N rates randomized as subplots, with three replications. In 1972, subplots were four 91.5-cm rows 22.9 m long. In 1973, four 76.2-cm rows 22.9 m long were used. All samplings for moisture and yield data were taken from the center two rows of each subplot. Border rows were planted between main plots, and 7.6 m alleys were maintained between replications to aid foliar N application.

Each of the four complete studies (location x year) were laid out on separate field sites. Soil types at Manhattan were a Muir silt loam in 1972 and a Reading silt loam in 1973. The Ottawa studies were both on a Woodson silty clay loam. Preplant applications of 84 kg N and 28 kg P_2O_5 per hectare as 30-10-0 were made across the entire plot area both years. Herban 21A herbicide was used and the plots were machine planted.

Nitrogen solution was applied with a high clearance ground sprayer with nozzles directed to provide uniform application over the entire 4-row width of the individual subplot area. The spray volume and ground speed were calibrated to deliver 67 kg N/ha and a double pass was made to apply 134 kg N/ha.

Grain samples were obtained for grain moisture determination from each subplot at the time of treatment and on a weekly basis until harvest. The sampling schedule was altered in several cases, however, due to unfavorable weather conditions which hindered the study both years, particularly at Ottawa. Ten head samples were obtained by taking every tenth head from the middle two rows from one end of the individual plots. Head samples were collected in closed plastic bags and were threshed with a single head thresher. A 200 g sample of grain was oven dried at 70-90° C for at least 48 hours to determine moisture content by loss of weight.

When the grain had reached a moisture level acceptable for harvest, 4.57 m sections of the center two rows of each plot were harvested, opposite from the end where moisture samples had been obtained. Heads were harvested by hand and then the forage was harvested with a one-row plot chopper, weighed, and a sample retained for moisture determination. The moisture content at harvest was above that suitable for safe storage (13%) but was at a moisture level (15-17%) at which harvest is started by many producers in this area because of the danger of further delays due to bad weather.

Yield data and nitrogen content were determined on an individual plot basis and then converted to a hectare basis for all studies. Harvesting and sampling was designed so yield data were partitioned into three parts: threshed heads, grain, and stover. Samples of each component were retained from the harvested material, ground, and stored in glass containers for nitrogen analysis. Total nitrogen was determined using the macro-Kjeldahl technique (3). Nitrate-nitrogen was not determined separately.

Statistical Procedures

Analysis of variance was performed on per cent grain moisture, rate of grain drying, and all yield and nitrogen data, including per cent nitrogen and total nitrogen content, according to Snedecor and Cochran (29).

Grain moisture and rate of drying data were anlyzed separately for each date of planting. Effects of hybrids, N rates, days after treatment, and all interactions were evaluated.

Yield and nitrogen data were analyzed and the error due to different dates of planting and application (replicate x date interaction) was partitioned out so effects of desiccation could be viewed independent of date. Hybrids, N rates, dates of planting, and all interactions were evaluated.

Nitrogen Carry-over

Data have been collected in 1973 to study carry-over of nitrogen applied as a desiccant in 1972. Carry-over data for 1973 will not be available until the end of the 1974 growing season.

Soil samples were taken on an individual plot basis on the 1972 plot sites before application and again in the spring of 1973 before planting and were analyzed for nitrogen content. Grain sorghum was then bulk planted over the entire plot area with no additional nitrogen fertilization. Plant tissue samples were taken in the summer of 1973 and were analyzed for total Kjeldahl nitrogen. Yield data and nitrogen data were collected and analyzed in the fall of 1973 in exactly the same way described for evaluating desiccation effects. A complete discussion of carry-over effects cannot be made until data from the 1973-1974 carry-over study are obtained.

RESULTS AND DISCUSSION

The main objective of this study was to evaluate the desiccating effects of 32% nitrogen solution applied to two grain sorghum hybrids to accelerate pre-harvest grain drying. In addition, the study was performed to determine the effects of timing of desiccation on grain drying and yield response. The potential advantages of using nitrogen solution as a desiccant, increasing the quality of the grain or forage by the added nitrogen and the carry-over of nitrogen to the succeeding crop, were also evaluated.

Important results are discussed with the aid of tables and figures within the text. All analyses of variance performed are summarized in tables in the Appendix, which identify significant (5% level) and highly significant (1% level) F values.

Grain Drying Effects

In general, the first visual effect of desiccation was apparent within two or three days. The leaves were burned severely where application was uniform, thus the upper leaves were the most noticeably effected. Burning of leaves was the first and primary result, however, treated plants generally began to show drying of the peduncles within two or three weeks, which was noted when moisture samples were collected.

Effects on the stalk tissue were more variable. At Ottawa in 1973, desiccation caused severe effects on the stalk tissue because treated plants completely died, became brittle, and lodged severely. At Manhattan, peduncles appeared dry, however, lodging was not noticeable and at harvest, considerable branching was noted on treated plants, indicating that the stalk tissue was still alive. Visual observations indicated that the Ottawa plots were desiccated more rapidly and completely than the Manhattan plots in 1973. Heavy rains in the period

2 to 5 weeks after treatment apparently helped to deteriorate the already dead plants at Ottawa, but stimulated branching on the plants that were not as severly effected at Manhattan. Most visual effects were slightly more severe with the 134 kg N rate than with the 67 kg rate, and no obvious difference between hybrids was noted.

Both per cent grain moisture at sampling dates and rate of moisture loss between successive sampling dates were analyzed to evaluate desiccation effects. A significant interaction between nitrogen rate and days after treatment (Appendix Tables 17 and 18) shows significant effects of desiccation on acceleration of grain drying. Differential hybrid response to desiccation shows in the interaction of hybrids x N rates x days after application.

Figure 1 represents highly significant differences in grain drying with N application at Manhattan for the first planting date in 1973. The greatest effect occurred the first 9 days after treatment, somewhat sooner than reported by Reece et al. (21) and others. Moisture content was reduced from 37.3% to 22% with nitrogen application within 9 days, while control plots were still at 28%.

A close examination of grain moisture values, however, shows that the effect of desiccation on speeding drying seems to level off after 9 days, when the treated plots were still at about 22%grain moisture, confirming the findings of Alvey and Pendleton (2). In addition, 1.56 cm of rainfall two days before the 16 day sampling may have influenced the results. After 16 days, the no treatment plots showed a greater drying rate than the treated plots, and by harvest, no difference in grain moisture was observed. The average moisture was still at 17%, too high for safe storage.

The influence of rainfall can probably account for much of this loss of response after 16 days. This is the time when numerous heavy rains started in the Manhattan area, which persisted for the remainder of the study. Daily precipitation (Figure 1) is shown directly below the grain moisture curves. No samplings are reported from 23 to 43 days, because noticeable gains in grain

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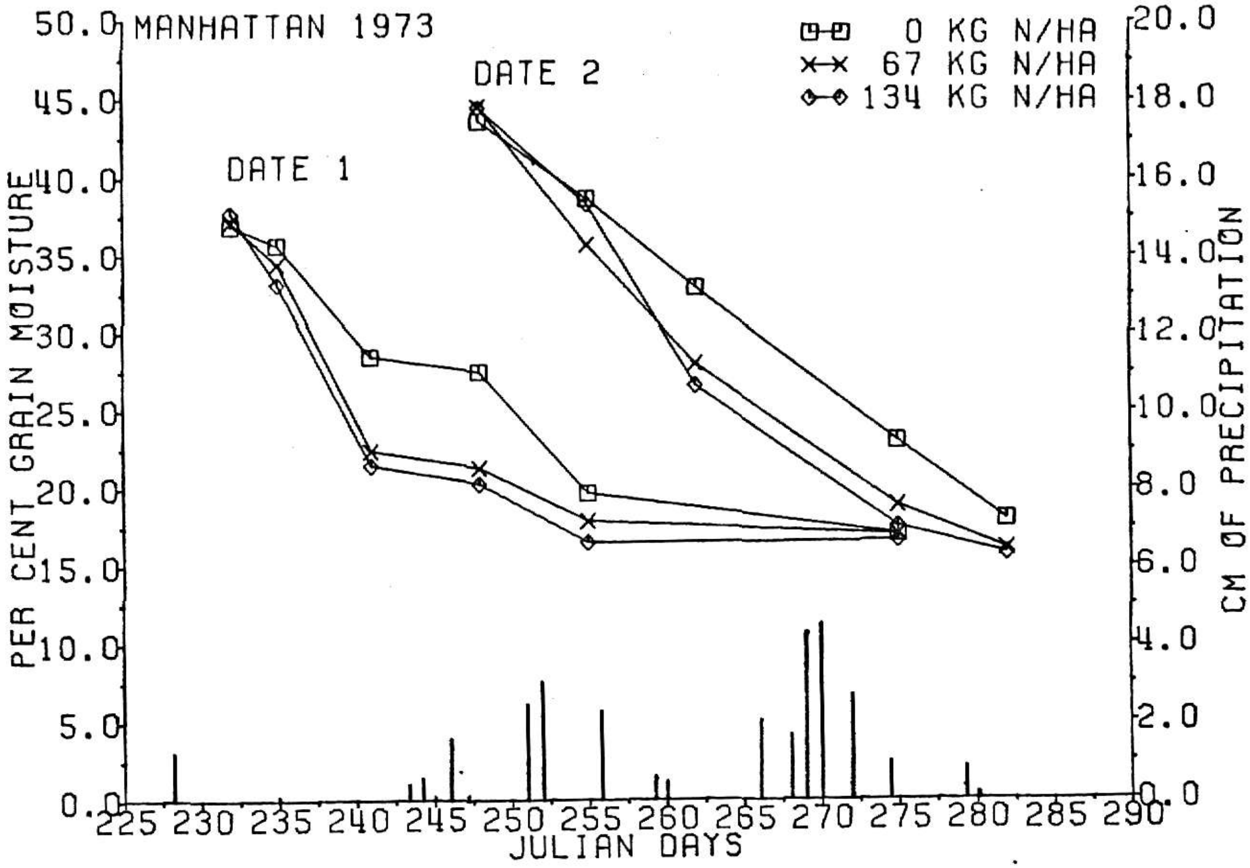

Figure 1. Effect of nitrogen rate on grain moisture after desiccation, Manhattan, 1973.

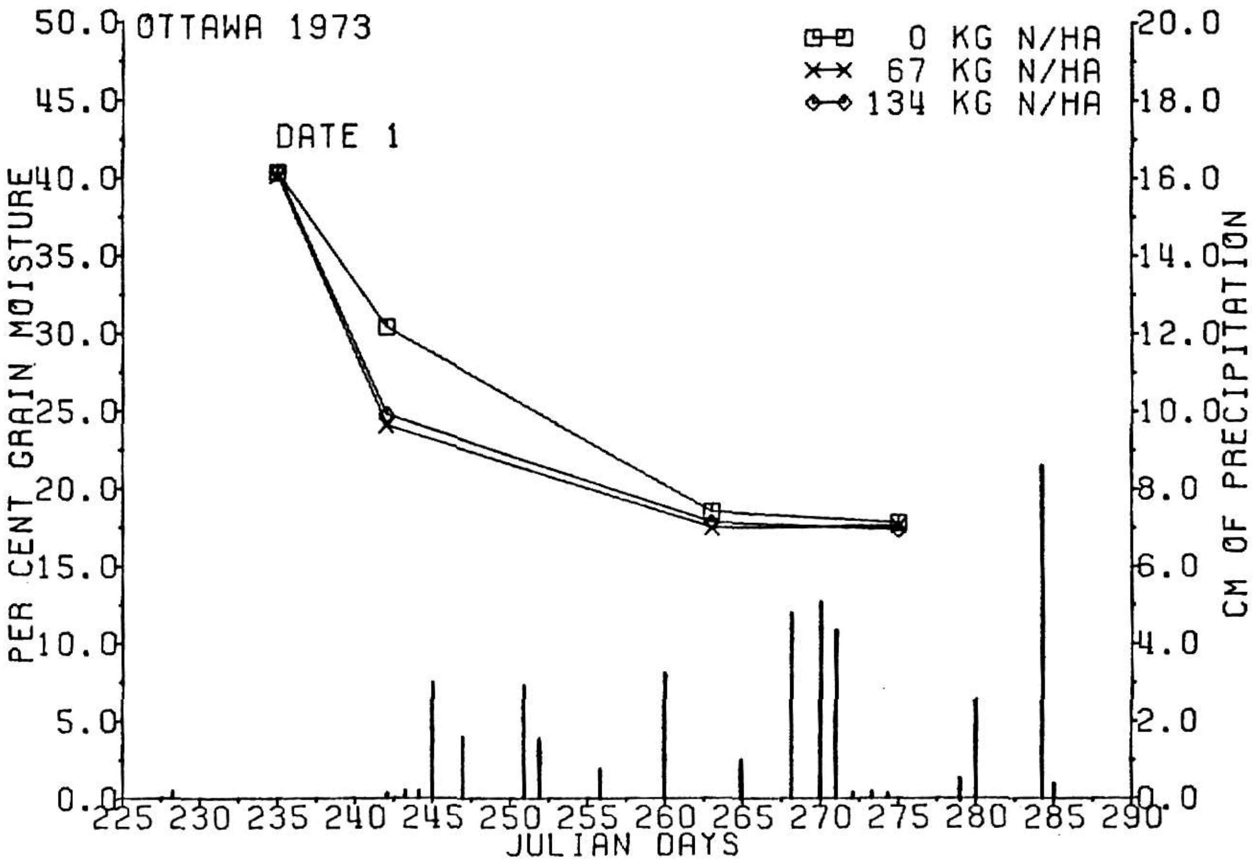

Figure 2. Effect of nitrogen rate on grain moisture after desiccation, Ottawa, 1973.

moisture from the level at 23 days were found, even when samplings were made 3 to 4 days after heavy rainfall. The effect of rainfall and high humidity on grain moisture content proved to be more important than the effect of desiccation after the initial desiccation response.

The rate of moisture loss between consecutive sampling dates also showed highly significant N rate x days after application interaction for Manhattan, date 1, 1973 (Appendix Table 18). Table 2 shows the average rate of moisture loss (% per day).

Table 2. Rate of moisture loss (% per day) between successive sampling dates as affected by days after treatment and N rate: Manhattan, date 1, 1973.

N Rate	Days After Treatment				
(kg/ha)	0-3	3-9	9-16	16-23	23-43
0	0.42	1.21	0.14	1.12	0.14
67	0.90	1.97	0.15	0.49	0.04
134	1.55	1.94	0.18	0.54	0.01

LSD(.05)=0.53

The first moisture sampling date was used as the initial moisture for each plot, and the rate of drying was calculated from the loss of moisture between any two consecutive sampling dates. The mean values show that treatment with nitrogen solution definitely increased the drying rate of the grain for the 134 kg rate the first 3 days and for both rates 3 to 9 days after treatment. However, between 16 and 23 days, the drying rate of the control exceeded the drying rate of the treated plots, which resulted in the absense of difference in grain moisture at harvest. The greatest positive effect of desiccation occurred in the period 3 to 9 days after treatment. Drying rates of 1.97 and 1.94% per day for treated plots were significantly greater than 1.21% per day for the control.

A good comparison of observed drying rates to normal drying rates cannot be made because of the great variability in grain drying rates between different periods for the control plots. These results are certainly not in agreement with the linear drying rates reported by Wikner and Atkins (33) under good drying conditions. This disagreement can be partially explained by the influence of climatic effects as shown by several researchers (13, 14, 32, 36).

The Manhattan study, first planting date, 1973, was the most promising for showing grain drying effects, but significant interaction of N rates x days after application (Appendix Tables 17 and 18) was also found for three other cases. Highly significant effects were found at Manhattan for the second planting date in 1973. Although the same general trend existed (Figure 1), it was not as consistent. The 67 kg rate caused its greatest effects on grain moisture the first seven days after treatment, while the 134 kg rate accelerated drying the second week (Table 3).

Table 3. Rate of moisture loss (% per day) between successive sampling dates as affected by days after treatment and N rate: Manhattan, date 2, 1973.

N Rate	Days After Treatment			
(kg/ha)	0-7	7-14	14-27	27-34
0	0.71	0.83	0.75	0.73
67	1.26	1.10	0.70	0.40
134	0.89	1.68	0.69	0.25

LSD(.05)=0.36

Although both rates do accelerate grain drying, a good reason for this pattern is not clear and must be due to sampling error. As with date 1, the 0 kg rate showed significantly greater drying rate than the 134 kg rate for the last sampling interval, resulting in no real difference in actual moisture at harvest (15-17%). Initial moisture in this study was 44.2%. Drying rates for the control were nearly linear in this study.

Although no interaction was found for per cent grain moisture due to the large error mean square (Appendix Table 17), highly significant response of grain drying rate to nitrogen application was found at Ottawa in 1973 (Appendix Table 18). The effect was only for the first eight days after treatment, but was quite large for both N rates (Table 4).

Table 4. Rate of moisture loss (% per day) between successive sampling dates as affected by days after treatment and N rate: Ottawa, date 1, 1973.

N Rate	Days After Treatment		
(kg/ha)	0-8	8-29	29-41
0	1.43	0.57	0.06
67	2.30	0.31	-0.01
134	2.24	0.33	0.04

LSD(.05)=0.31

Moisture content dropped 2.30 and 2.24% per day with 67 and 134 kg N/ha, compared to 1.43% per day for the control. Heavy and numerous rains (Figure 2) essentially destroyed the remainder of this study, however, as no grain moisture loss was found between 29 and 41 days after, while moisture content remained at about 17.5% (Figure 2). One set of samples taken in this interval the day after a rain averaged 25% moisture, and were discarded.

At Ottawa in 1972, date 2, greatest drying acceleration is shown for the treated plots between 8 and 15 days after treatment (Figure 4). The rate of moisture loss is shown in Table 5.

Table 5. Rate of moisture loss (% per day) between successive sampling dates as affected by days after treatment and N rate: Ottawa, date 2, 1972.

N Rate	Days After Treatment		
(kg/ha)	0-8	8-15	15-22
0	1.05	0.36	1.17
67	1.22	0.73	0.96
134	1.17	0.57	0.93

LSD(.05)=0.22

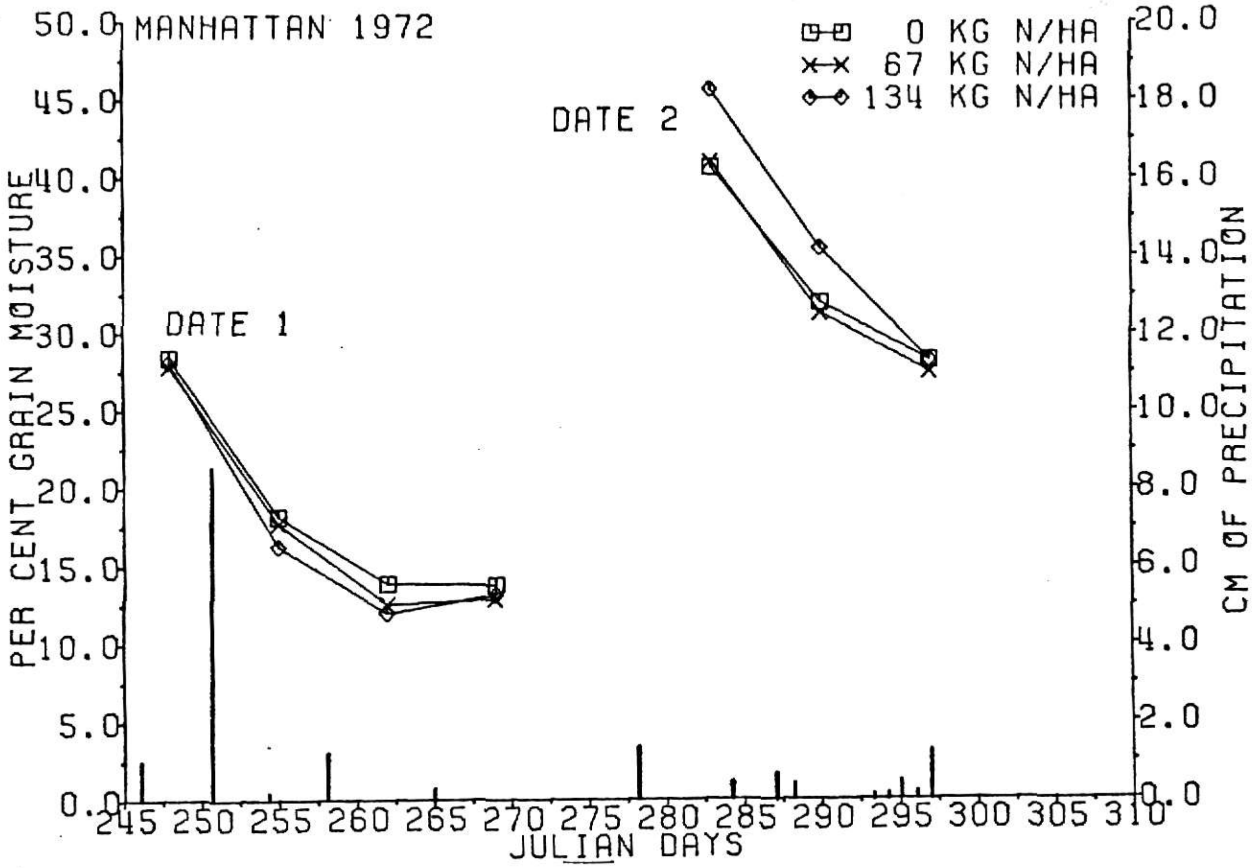

Figure 3. Effect of nitrogen rate on grain moisture after desiccation, Manhattan, 1972.

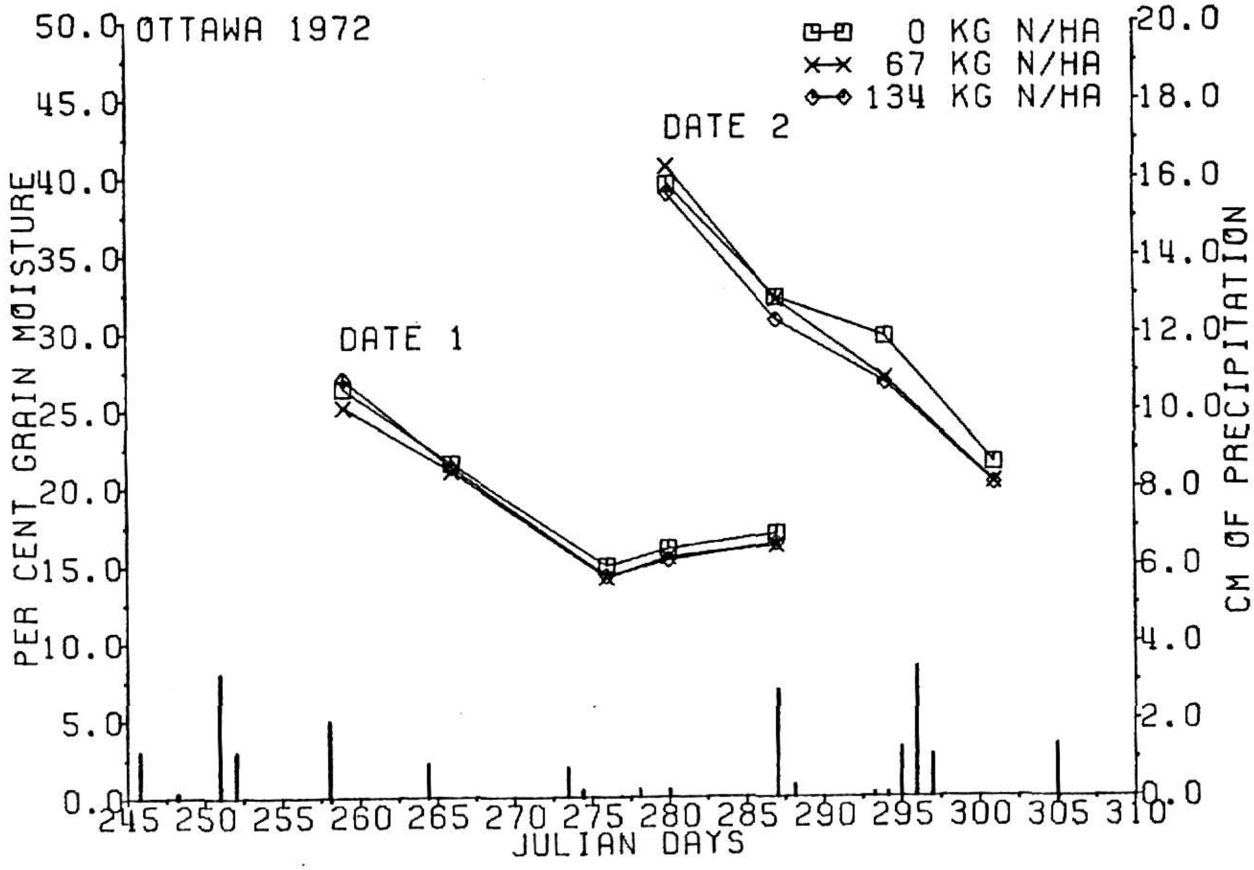

Figure 4. Effect of nitrogen rate on grain moisture after desiccation, Ottawa, 1972.

Actually, only the 67 kg N rate produced any significant increase in drying rate. Some of the N rate x days after interaction was accounted for by the significantly greater drying rate of the control plots between 15 and 22 days. Again, all desiccation effects on grain moisture after treatment at 39.7% initial moisture had completely disappeared by the time the grain was harvested at 18-22% moisture. Poor drying conditions due to rainfall and cool temperatures prevailed, and frost occurred two weeks after application.

In summarizing grain drying response to desiccation, it appears that desiccation actually just causes the normal grain drying pattern to be pushed ahead one or two weeks. In no case was there an extended grain moisture response to desiccation averaged over all days after application (N rate factor alone). Usually the control plots showed a period of rapid drying later, even under poor drying conditions, which allowed them to catch up to the treated plots. A similar rapid drying period occurred immediately after desiccation of the treated plots, however, the effect occurred only if treatment was made near physiological maturity. Any response to desiccation would naturally be expected to level off after a period of time. As the grain moisture content gets lower, there is actually less moisture available in the grain thus the rate of water loss should and does slow down normally. With desiccation, the period of rapid water loss occurred sooner, thus the point of slower water loss was reached sooner. This point appears to be at about 20-25%. After this point, the effect of rainfall and humidity became more important than the effect of desiccation on grain moisture, confirming the findings of Kersting, Stickler, and Pauli (13).

From these results, the potential for using nitrogen solution to speed harvest in a conventional harvest system is not good, particularly under poor grain drying conditions, which is the exact problem that must be overcome if desiccation is to be helpful. However, in combination with a high moisture harvest system, the initial, positive effect of desiccation on grain drying could be utilized to speed harvest. Results from Manhattan in 1973, date 1, showed that the time required to reach 20-22% grain moisture when nitrogen application was made near physiological maturity was reduced from about 21 days for the control to 9 days for treatment (Figure 1). Similar trends were obtained in the other studies which had significant grain drying effects. With a high moisture harvest system, considerable gains in harvest time may be possible with desiccation. In addition, staggered applications could be used to spread harvest time so the entire crop would not be ready at one time.

Four of the seven studies showed significant N rate x days after application interactions for grain moisture and/or rate of drying (Appendix Tables 17 and 18). Lack of response in the other cases can perhaps be explained. Table 6 shows the grain moisture at treatment averaged over all individual plots for each study and identifies those that resulted in significant acceleration of grain drying.

Table 6. Relationship between grain moisture at treatment and acceleration of grain drying.

Study	Average initial grain moisture	Significant Acceleration of Grain Drying
1972 Manhattan Date 1	28.0	
1972 Manhattan Date 2	42.4	
1972 Ottawa Date 1	26.2	
1972 Ottawa Date 2	39.7	x
1973 Manhattan Date 1	37.3	x
1973 Manhattan Date 2	44.2	x
1973 Ottawa Date 1	40.3	x

All studies that showed significant acceleration of grain drying were made at or above those moistures generally reported for physiological maturity (9, 13, 33). Treatment at 28.0% and 26.2% initial grain moisture at Manhattan and Ottawa for the first planting date in 1972 clearly was delayed too long. The plots showed physiological maturity by the black closing layer of the grain, but rain and mechanical problems with the sprayer delayed treatment too far beyond physiological maturity and no grain drying response to desiccation was observed. An 8.7 cm rain 3 days after treatment at Manhattan could also have reduced any desiccation effects which would be most likely to occur in the first sampling interval (Figure 3).

The second application at Manhattan in 1972 was made at 42.4%, which should have been before physiological maturity. Application was hurried, because it was getting late in the growing season and temperatures were low. Frost occurred within two weeks after treatment, which would have made further study of desiccation effects invalid, so the plots were harvested to complete the study before severe weather set in. No grain drying effects were observed after treatment, perhaps because of the several light rains and low temperatures which prevailed during the period from treatment to frost. There was also great variability in initial plot moisture, ranging about 10%, which made results difficult to interpret.

In general, per cent moisture of individual plots was less variable in 1973 than in 1972 which allowed more meaningful interpretation of results. Analyses performed were based on the individual plot initial moisture as the starting point. An alternative approach would be to use the overall average grain moisture content at application. The great variability which was found in individual plot initial moistures, even within hybrids and within replicates, especially in 1972, seemed to justify the individual plot approach.

No significant difference in hybrid response to nitrogen application was found for grain moisture content at different sampling dates (hybrids x N rates x days after application) in any study (Appendix Table 17). Although significant hybrid differences in grain drying rate in response to N rates and days after treatment were found in two cases (Appendix Table 18), they were not consistent and reliable.

At Ottawa, date 2, 1972, different hybrid drying rates were found in the control (Table 7). DeKalb variety E57 showed faster drying rate the first 8 days and RS671 was faster 15-22 days after. The 67 kg N rate showed the same pattern of differences. Drying rates the first 8 days were not different between hybrids at the 134 kg N rate, however, and RS671 dryed faster during the 8-15 day interval. These results indicate that the 134 kg rate caused RS671 to dry as fast as E57 after treatment.

Table 7. Rate of moisture loss (% per day) between successive sampling dates as affected by days after treatment, hybrid, and N rate: Ottawa, date 2, 1972.

N Rate (kg/ha)	Hybrid	Days After Treatment 0-8	8-15	15-22
0	RS671	0.77	0.41	1.33
	E57	1.32	0.32	1.01
67	RS671	1.06	0.67	1.18
	E57	1.40	0.79	0.74
134	RS671	1.05	0.74	0.81
	E57	1.30	0.41	1.05

LSD(.05)=0.31

The only other study which showed significant hybrid x N rate x days after treatment interaction on drying rate was at Manhattan, date 1, 1973, but the interaction must be attributed to sampling error. All of the difference was at the 67 kg N rate. E57 had a much greater drying rate the first 3 days and then a much slower drying rate the next 6 days compared to RS671, while no hybrid differences were found in these same intervals for the 0 and 134 kg rates. These results are not explainable.

In general, no differential grain drying response to desiccation between the compact (RS671) and open (E57) head type hybrids was established. Significant differences in overall grain drying patterns were observed between hybrids, however (hybrids x days after application) (Appendix Tables 17 and 18). Although not directly related to the objectives of this study, they are worth noting.

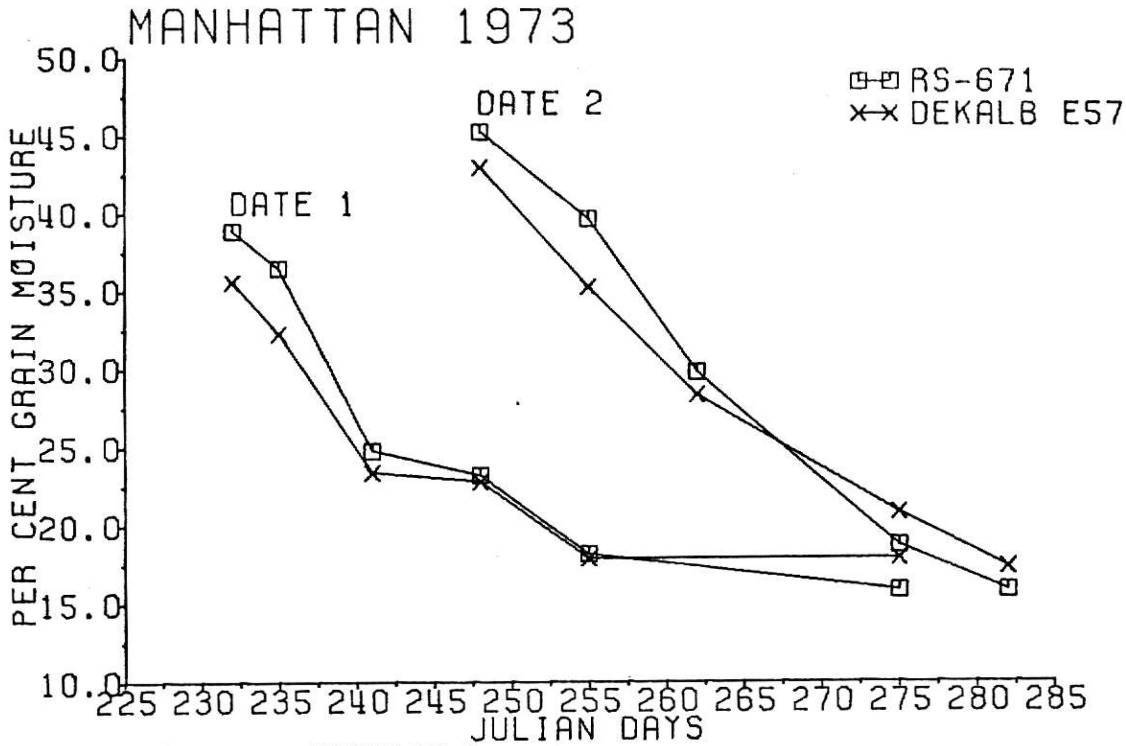

Figure 5. Effect of hybrid on grain moisture, Manhattan, 1973.

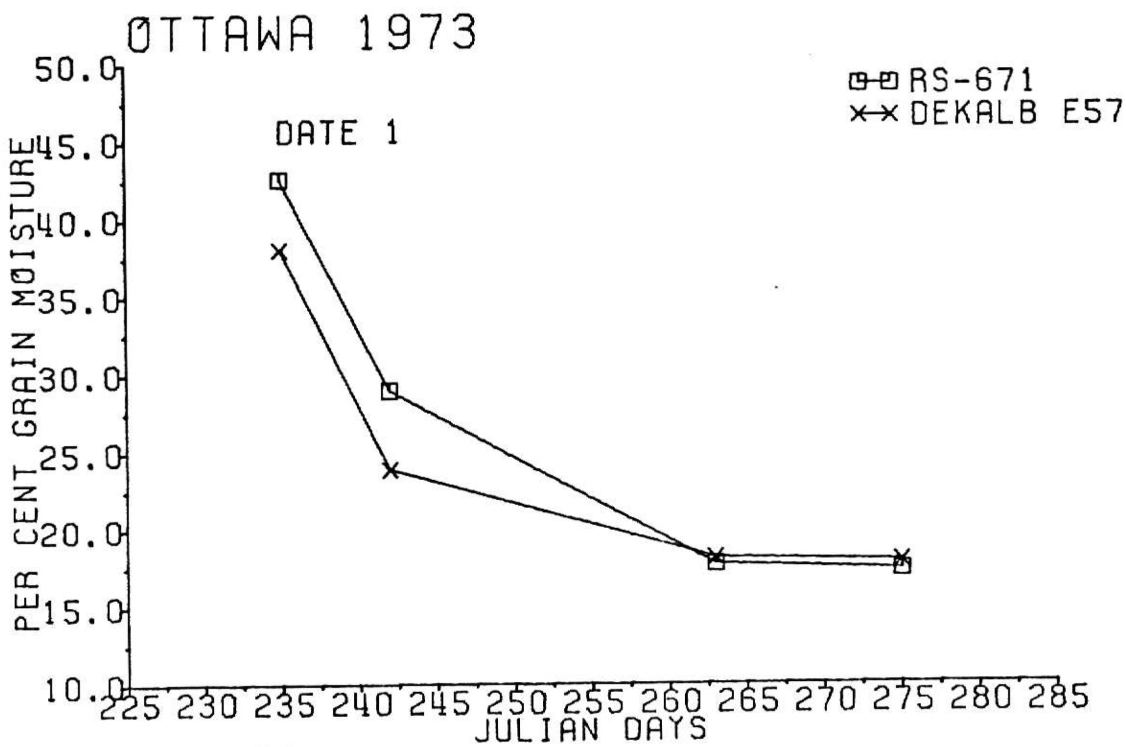

Figure 6. Effect of hybrid on grain moisture, Ottawa, 1973.

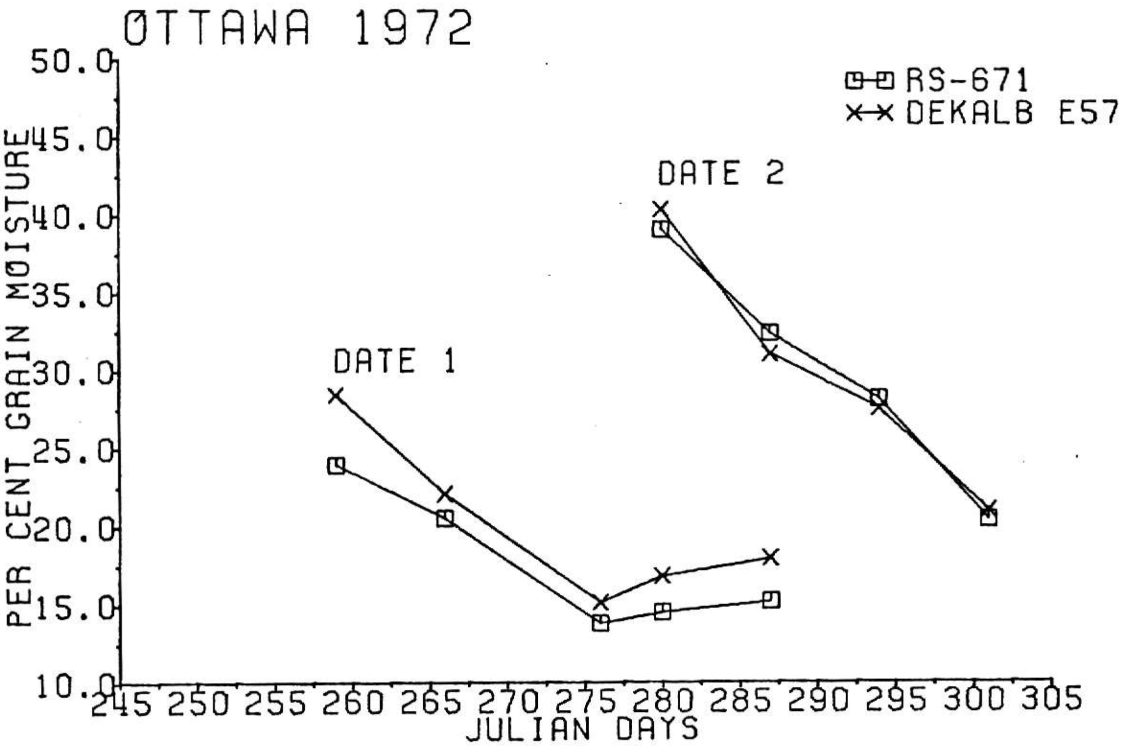

Figure 7. Effect of hybrid on grain moisture, Ottawa, 1972.

RS671 had significantly higher initial grain moisture than E57 in all three studies in 1973 (Figures 5 and 6). However, the overall drying rate of RS671 was greater than that of E57, which allowed it to reach the same or even significantly lower grain moisture at harvest. The consistency of the 1973 results showed that RS671 and E57 did show different grain drying patterns, as indicated by Warnes (32).

In 1972, hybrid differences occurred only at Ottawa, but were different than in 1973. E57 had higher initial moisture than RS671 for both dates, followed by a greater drying rate the first week (Figure 7). Year and location effects may explain part of the opposite patterns obtained, however, the 1972 results are not as conclusive. For date 1, initial grain moistures were at 24 and 28%, while initial moistures in the 1973 studies were all near 40%. This really represents two different portions of the overall drying curve, thus valid comparisons cannot be made at initial moisture sampling.

Differences in hybrid drying patterns were certainly not as well established in 1972 as in 1973, and probably should be assumed non-existent. Year effects apparently can determine whether hybrids differ in grain drying patterns. Although not related directly to desiccation since no hybrid x N rate x days after treatment interaction was established for grain moisture, differential hybrid drying patterns may be important for speeding grain drying by genetic incorporation. A better understanding of the physiology of grain drying could result in a different approach to accelerating drying rate.

Yield Effects

A major problem of successful desiccation methods reported by Bovey (4) and others has been the reduction of yield and quality when desiccation was performed early enough to provide good grain drying effects. Analyses of variance on yield data for both years and locations in this study are presented in Appendix Tables 19, 21, 23, and 25.

The relationship between positive acceleration of grain drying and initial moisture content at treatment has already been discussed (Table 6). In general, these two factors also correlated with the effect of desiccation on yield. Acceleration of grain drying was observed only when nitrogen solution was applied at an initial grain moisture above about 37%. However, if this was before physiological maturity, killing the plant probably stopped the accumulation of assimilates in the head, which was the portion of the plant that was still increasing in dry weight at this time (31). Thus, desiccation too early could be expected to reduce grain yields.

A relationship between initial grain moisture, significant acceleration of grain drying, and yield reduction due to nitrogen rates was observed (Table 8).

Table 8. Relationship between initial grain moisture, significant acceleration of grain drying, and grain yield reduction.

Year	Location	Significant Grain Yield Reduction	Initial Moisture		Acceleration of Grain Drying	
			Date 1	Date 2	Date 1	Date 2
1972	Manhattan		28.0	42.4		
1972	Ottawa		26.2	39.7		x
1973	Manhattan	x	37.3	44.2	x	x
1973	Ottawa	x	40.2	----	x	-

In 1973 at Manhattan, significant grain drying effects due to nitrogen application were observed for both dates when initial moisture was at 37.3 and 44.2%. However, grain yields were significantly reduced by application of nitrogen at both rates (Table 9).

Yields were reduced by 409 and 610 kg/ha from 5132 kg/ha for the 67 and 134 kg N rates. No significant difference was observed in yield response to N rates between dates (dates x N rates) or hybrids (hybrids x N rates). For both dates, application was apparently made before physiological maturity and resulted in yield reduction. Since no serious lodging was observed, physical loss of grain did not contribute to the reduced yields.

Table 9. Grain yield (kg/ha) as affected by nitrogen rate at Manhattan and Ottawa in 1972 and 1973.

N Rate	Manhattan		Ottawa	
(kg/ha)	1972	1973	1972	1973
0	5237	5132	5585	3422
67	5067	4721	5340	2663
134	4515	4522	5284	1983
LSD(.05)	NS	410	NS	630

Stover yields were also reduced by nitrogen application in 1973 at Manhattan (Table 10).

Table 10. Stover yield (kg/ha) as affected by nitrogen rate at Manhattan and Ottawa in 1972 and 1973.

N Rate	Manhattan		Ottawa	
(kg/ha)	1972	1973	1972	1973
0	3150	4349	2901	2925
67	2828	3653	2783	2251
134	2539	3473	2682	2110
LSD(.05)	408	464	NS	524

This can probably be attributed to physical loss of dead leaves before harvest from the desiccated plants. When the plots were harvested, visual observations indicated considerable defoliation of leaves from the treated plants. The combined reduction of grain and stover yields explains the significant reduction of total dry matter due to nitrogen application (Appendix Table 25). No differences between the two rates of application were found for any harvested portion.

At Ottawa in 1973 (one date only), initial grain moisture averaged 40.3%. Again, desiccation increased drying rate, and significant reduction in grain yield with nitrogen rates was found (Table 9). Part of this effect must be attributed to physical loss of grain due to lodging, however. Visually, the plots treated with the 134 kg rate appeared to be lodged worse, which may explain the difference between the two rates (Table 9). The large reduction in stover yield (674 and 815 kg/ha) was quite obviously due to leaf loss in this study, as many of the treated plants were almost completely defoliated. The effect of the wet weather must not be overlooked as a contributor to this serious deterioration of leaf tissue and grain, thus we cannot attribute the entire difference directly to nitrogen application.

In 1972, no significant effect of N rate on grain yield was observed at either location (Appendix Tables 19 and 21). However, in only one case (Ottawa, date 2) was any effect on grain drying observed. As indicated before, date 1 treatments at both locations were probably made after physiological maturity (28.0 and 26.2%), which explains the lack of drying response and explains the absense of grain yield reduction for date 1. Stover yields were reduced at Manhattan by the 134 kg N rate, which can be explained by physical loss of desiccated leaf tissue.

Since no date x N rate interaction was observed for grain yield at either location, yields were not reduced for date 2 treatments either, in spite of higher initial moistures. Although 39.7 and 42.4% initial moistures at Ottawa and Manhattan were higher than some initial moisture contents which resulted in yield reductions in 1973, Kersting, Stickler, and Pauli (13) have indicated that grain moisture at physiological maturity may vary considerably from year to year. At Manhattan, low temperatures and rainfall prevented both visual and grain drying responses to desiccation, thus grain yields should not have been effected either since the plants were not effectively killed. Even though the N rate factor was not significant for either location in 1972, the trend in grain yields

(Table 9) indicated possible effects at Manhattan, which could have been due primarily to date 2.

Certainly this experiment has proven the necessity of correct timing of desiccation practices to achieve the greatest drying effects without yield reduction. Application must be made as near physiological maturity as possible as shown by Reece et al. (21), Bovey and McCarty (6), and others. However, this experiment has shown that this standard is rather difficult to measure. The lack of reliable and practical method of determining physiological maturity in grain sorghum may limit the effectiveness of desiccation practices.

Some differences among hybrids and/or among dates of planting were found for harvested portions particularly in 1972 (Appendix Tables 19 and 21). However, they are not really important to this study, since no differences in yield response due to desiccation was found between hybrids or dates (hybrids x N rates) (dates x N rates).

Nitrogen Effects

Analyses of variance for per cent nitrogen in the threshed heads, grain, and stover, as well as the total kg of nitrogen removed per hectare with each portion are presented in Appendix Tables 20, 22, 24, and 26. One of the advantages of using nitrogen solution as a desiccant is the possibility of increasing the quality of the grain or forage by increasing the nitrogen content following application.

Significant increases in grain per cent nitrogen were found with nitrogen application at Ottawa both years, but not at Manhattan (Table 11). It cannot be determined whether nitrogen may have been on the grain itself or taken up by the plant and translocated to the grain. The heavy rains which occurred after application should have removed any nitrogen on the plant tissue, however, so it was probably accounted for within the grain. Lack of nitrogen content increases at Manhattan, however, make definite conclusions on the effect of application on grain nitrogen content questionable, since there is no apparent reason for the location differences.

Table 11. Grain per cent nitrogen as affected by nitrogen rate at Manhattan and Ottawa in 1972 and 1973.

N Rate (kg/ha)	Manhattan 1972	Manhattan 1973	Ottawa 1972	Ottawa 1973
0	1.95	1.76	1.79	1.71
67	1.99	1.85	1.92	1.93
134	1.99	1.85	1.93	1.98
LSD(.05)	NS	NS	0.10	0.22

The increase in per cent nitrogen of the grain at Ottawa with N rate was not great enough to cause a significant increase in the total amount of nitrogen removed in the grain in 1972. In 1973, total removal of N was actually significantly reduced with N rate, because of the large decrease in dry weight of the grain caused by physical loss from lodged plants (Table 12).

Table 12. Grain total nitrogen content (kg N/ha) as affected by nitrogen rate at Manhattan and Ottawa in 1972 and 1973.

N Rate (kg/ha)	Manhattan 1972	Manhattan 1973	Ottawa 1972	Ottawa 1973
0	101.1	90.4	100.0	58.2
67	99.9	86.9	102.5	51.1
134	89.2	83.1	100.6	38.8
LSD(.05)	NS	NS	NS	12.2

In 1973, significant reductions in stover nitrogen content were found at both locations (Table 13).

Table 13. Stover per cent nitrogen as affected by nitrogen rate at Manhattan and Ottawa in 1972 and 1973.

N Rate (kg/ha)	Manhattan 1972	Manhattan 1973	Ottawa 1972	Ottawa 1973
0	1.36	1.43	1.21	0.79
67	1.39	1.26	1.34	0.67
134	1.34	1.13	1.34	0.69
LSD(.05)	NS	0.09	NS	0.07

At Manhattan, E57 showed greater reduction than RS671 (hybrids x N rates). These results can probably be explained by the difference in the ratio of leaf to stalk tissue in the treated versus the untreated plants. Plants which had lost numerous leaves would be expected to show a lower nitrogen content in the forage than plants with all the leaves attached, since leaf tissue is naturally higher in nitrogen content than stalk tissue. This was found with the treated versus the untreated plots in 1973, resulting in a lower leaf to stalk ratio and correspondingly lower nitrogen content in the harvested stover from treated plots. In addition, when the plant is killed, translocation of nitrogen from the leaves to the upper portions of the plant may stop, thus loss of leaves from treated plants may result in relatively more nitrogen loss than natural loss of leaves from untreated plants.

Highly significant reductions in kg of nitrogen removed with the stover due to N rates were observed in 1973 (Table 14). Reductions are obviously a result of the lower nitrogen contents and lower stover yields, which have both been attributed to physical loss of leaves because of desiccation. Clearly, harvestable forage quality and quantity were both reduced by desiccation.

Date 2 showed significantly greater nitrogen content in the threshed heads in all three studies where two dates were used (dates factor) (Appendix Tables 20, 22, and 26). Date 2 also gave higher nitrogen in the grain and stover at

Manhattan in 1972. These were the only differences which may have been attributed to residual nitrogen. Nitrogen probably remained on the treated plants until harvest because of the late application and short interval until harvest at Manhattan in 1972.

Table 14. Stover total nitrogen content (kg N/ha) as affected by nitrogen rate at Manhattan and Ottawa in 1972 and 1973.

N Rate	Manhattan		Ottawa	
(kg/ha)	1972	1973	1972	1973
0	43.3	61.9	36.0	23.6
67	39.8	46.7	37.9	15.0
134	35.0	39.5	36.4	14.3
LSD(.05)	NS	6.4	NS	4.9

Nitrogen may have remained on the threshed head tissue longer than on other parts because it was not completely exposed to rainfall which washed most of the residual nitrogen from the leaves and grain. Effects showed only for date 2, indicating that any residual nitrogen decreased with time after application.

Significant differences in nitrogen content of plant parts were found between hybrids (Appendix Tables 20, 22, 24, and 26). In every study, RS671 was higher in per cent nitrogen in the grain than E57. At Manhattan in 1973, the effect was only for date 2. These results confirm the findings of Miller et al. (16) and Worker and Ruckman (35) on the variation of grain sorghum nitrogen content. RS671 also showed higher nitrogen content in the threshed heads where significant differences were observed (hybrids) (dates x hybrids), however, significance was not found in every study. No consistent differences in nitrogen content of the stover were found between hybrids. Significant differences in total kg of nitrogen in plant parts between hybrids or dates correspond to differences in per cent nitrogen or total yield of the respective plant parts which determine total nitrogen.

Carry-over Effects

The carry-over data for the 1972 desiccation study have been analyzed and are presented in Appendix Tables 27, 28, 29, and 30. Grain yield and total dry matter production of bulk planted grain sorghum in 1973 were increased significantly at Ottawa on the plot areas desiccated with nitrogen solution in 1972 (Table 15).

Table 15. Grain yield (kg/ha) and total dry matter (kg/ha) of grain sorghum in 1973 as affected by nitrogen carry-over from desiccation in 1972.

N Rate	Manhattan		Ottawa	
(kg/ha)	Grain Yield	Total Dry Matter	Grain Yield	Total Dry Matter
0	3576	9903	3669	8990
67	3709	10191	4078	9703
134	3809	10262	4527	10463
LSD(.05)	NS	NS	381	784

Grain yield increased from 3669 kg/ha to 4078 kg/ha and 4527 kg/ha with 67 and 134 kg N/ha. Total dry matter increased only with the 134 kg N rate, but the LSD was larger, thus the overall difference in means was greater than for the grain yield alone. This indicates that stover and threshed heads also contributed to the increase in total dry matter due to nitrogen application.

No difference in per cent nitrogen was found due to carry-over of nitrogen at Ottawa (Appendix Table 30) in any of the harvested portions or in the plant tissue samples taken in July. However, nitrogen uptake was significantly greater (Table 16) because of the increased yields of these portions.

Nitrogen recovery in the grain increased 7.4 kg/ha for the 67 kg N rate and 13.0 kg/ha for the 134 kg N rate. Total nitrogen uptake increased 13.2 and 18.7 kg/ha, again indicating the contribution of the stover and threshed heads, which was verified by examination of the means. Since no significant amount of nitrogen was accounted for in the fall of 1972, these values represent the total recovery of nitrogen applied as a desiccant. The increased yields can also be attributed to desiccant nitrogen for an economic analysis.

Table 16. Grain nitrogen recovery (kg N/ha) and total nitrogen recovery (kg N/ha) by grain sorghum in 1973 as affected by nitrogen carry-over from desiccation in 1972.

N Rate (kg/ha)	Manhattan		Ottawa	
	Grain	Total	Grain	Total
0	41.0	91.8	39.6	72.0
67	45.4	99.5	47.0	85.2
134	47.6	103.8	52.6	91.3
LSD(.05)	NS	NS	6.6	12.5

At Manhattan, however, results were even less promising. No differences in yield were found due to carry-over of nitrogen (Appendix Table 27). The increase in per cent nitrogen in the threshed heads with nitrogen rate is not explainable (Appendix Table 28). Differences in per cent nitrogen in the tissue samples due to 1972 hybrids could have been attributed to removal of more nitrogen in the grain in 1972 with RS671, since it did have a higher grain nitrogen content, and all grain was harvested from the plot areas in the fall of 1972. However, no difference in total grain nitrogen removal in 1972 was observed, and since differences were gone by harvest, they are probably not important. Differences in nitrogen removal in the grain or threshed heads found in the previous year for any factor must be subtracted off when analyzing carry-over data. The harvested stover was returned to the plot area, thus differences in N content of the stover should have no effects.

Lack of consistency in carry-over effects between locations gives questionable conclusions about any advantage of nitrogen solution as a desiccant because of carry-over of nitrogen. Recovery was not nearly as great as expected, although the very wet fall of 1972 and spring of 1973 certainly may have reduced nitrogen carry-over. A very large portion of the nitrogen solution originally applied as a desiccant may have been lost by volatilization after treatment, since there was not any way to measure this loss. If carry-over effects are not highly significant, then perhaps lower N rates should be tried for desiccation to avoid any possible waste of costly nitrogen. Completion of the 1974 studies should lead to more definite conclusions.

SUMMARY AND CONCLUSIONS

Although nitrogen solution did show some potential as a desiccant for grain sorghum, several significant problems were revealed. In general, differences in response could be best explained by the timing of application and the subsequent weather conditions. Correct timing of application seemed to be a very critical factor affecting the results. Significant acceleration of grain drying was observed only when application was made at or before physiological maturity, when grain moisture content was above 37%. However, application before physiological maturity using the grain black layer development was difficult.

The effect of rain and high humidity which produced poor drying conditions proved to be greater than the effect of desiccation on grain moisture after an initial, rapid increase in drying rate which usually occurred the first few days to two weeks after treatment. In no case where significant acceleration of grain drying was observed after treatment, were differences in grain moisture still observed by the time the treated plots had reached a moisture level acceptable for harvest. The slowing of drying was attributed to poor drying conditions, since increases in grain moisture of treated plots were often recorded in response to rainfall. Good drying conditions would probably have resulted in more positive results, however, if good drying conditions were guaranteed, there would be no need for desiccation. Since desiccation with nitrogen solution did not overcome the effects of poor drying conditions to reduce moisture to an acceptable harvest level, its potential for field use would appear to be limited, since this is the very problem which desiccation must eliminate to be practical.

Lodging of killed plants also proved to be a problem in one study, which resulted in negative effects on both grain and stover yield. The economics and availability of nitrogen solution and application methods may also limit its practical use.

No consistent differences in the effect of nitrogen solution on grain drying were found between dates of application or between the open head and closed head type hybrids, even though the hybrids differed in overall grain drying pattern themselves. Yields differed between dates and between hybrids, but this was not important to the objectives of the study, since no interaction between hybrids and N rates was found for any harvested portion. Grain yields were reduced by N rates when application was made before physiological maturity.

Increased quality of the grain or forage by nitrogen application was not as promising as expected. Increased nitrogen content of the grain was found in two studies, and some indication of residual nitrogen, particularly on the threshed heads, was found when time between application and harvest was short (date 2). Combination of desiccation with a high moisture harvest system would reduce this time interval, and could make this factor more important. Nitrogen content and total yield of the stover were decreased because of loss of leaf tissue from the treated plants, thus both quality and quantity of harvestable forage were reduced by desiccation.

The use of nitrogen solution as a desiccant in combination with a high moisture harvest system appears to be the only way harvest could be successfully speeded under poor drying conditions. This system would take advantage of the initial effects of desiccation, and could speed harvest one week or more if timed correctly. Restrictive residues from herbicides would be more likely with this system, which would give nitrogen solution an advantage. The added advantage of improving combine harvest efficiency by reducing green residue as reported by Parks (17) should be even more important, since greater threshing losses are possible at higher grain moisture (34).

Recovery of nitrogen by the succeeding grain sorghum crop was significant at Ottawa, but actual recovery was only about 15 to 20%. Yield increases were also recorded, which could be attributed to carry-over nitrogen. However, no N recovery or yield increases were found at Manhattan. The 1974 studies will permit more definite conclusions on carry-over effects.

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APPENDIX

Table 17. Analysis of variance for per cent grain moisture at sampling dates in 1972 and 1973 at Manhattan and Ottawa for two planting dates.

Source	d.f.	Mean Squares						
		1972				1973		
		Manhattan		Ottawa		Manhattan		Ottawa
		Date 1 5-24	Date 2 6-21	Date 1 5-17	Date 2 6-23	Date 1 5-15	Date 2 6-12	Date 1 5-17
Replicates	2	44.50	36.10	32.47	1.46	77.89	5.69	126.50
Hybrids	1	41.44**	19.07	141.37**	0.01	38.89**	18.39*	84.61*
N Rates	2	10.72	55.21**	4.05	15.15**	92.88**	70.97**	26.19
Days After	(n-1)[1]	1339.95**	971.50**	423.81**	1136.80**	79.11**	2431.38**	2050.17**
Hybrids x N Rates	2	4.46	88.64**	9.00*	1.50	4.01	5.16	14.46
Hybrids x Days After	(n-1)	8.35	6.20	7.22*	6.37*	21.28**	33.50**	41.88*
N Rates x Days After	2(n-1)	1.26	11.52	1.04	4.36*	17.88**	17.66**	15.91
Hybrids x N Rates x Days After	2(n-1)	2.13	5.19	1.22	2.02	3.11	3.06	3.31
Error	(12n-2)	3.45	8.99	2.64	1.74	3.54	2.95	12.80
[1]n= number of moisture sampling dates		5	3	5	4	6	5	4

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 18. Analysis of variance for rate of moisture loss (per cent per day) from grain between sampling dates in 1972 and 1973 at Manhattan and Ottawa for two planting dates.

Source	d.f.	Mean Squares						
		1972				1973		
		Manhattan		Ottawa		Manhattan		Ottawa
		Date 1 5-24	Date 2 6-21	Date 1 5-17	Date 2 6-23	Date 1 5-15	Date 2 6-12	Date 1 5-17
Replicates	2	0.050	0.009	0.087	0.001	0.107	0.017	0.220
Hybrids	1	0.226	0.235	0.022	0.016	0.146	0.113	0.054
N Rates	2	0.021	0.423	0.028	0.062	0.378	0.113	0.201
Days After	(n-2)[1]	7.176**	3.927**	4.988**	1.754**	7.499**	1.813**	19.538**
Hybrids x N Rates	2	0.012	0.142	0.014	0.002	0.093	0.028	0.043
Hybrids x Days After	(n-2)	0.030	0.054	0.351**	0.403**	0.301	0.492**	0.133
N Rates x Days After	2(n-2)	0.089	0.145	0.021	0.149**	0.768**	0.617**	0.679**
Hybrids x N Rates x Days After	2(n-2)	0.060	0.211	0.053	0.150**	0.508*	0.076	0.105
Error	(12n-14)	0.120	0.304	0.060	0.036	0.186	0.096	0.071
[1]n= number of moisture sampling dates		5	4	5	4	6	5	4

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 19. Analysis of variance for yield data from nitrogen solution desiccation study at Manhattan in 1972.

Source	d.f.	Mean Squares				
		Heads/Plot	Threshed Heads (kg/ha)	Grain (kg/ha)	Stover (kg/ha)	Total Dry Matter (kg/ha)
Replicates	2	74.72	327951	836845	978022	5203965
Dates	1	0.15	29648537**	3970377	1382854	21422001
Error (a)	2	541.67	300116	2461846	103018	5938757
Hybrids	1	1131.62	69026	221324	1796775**	367818
N Rates	2	307.07	125563	1618088	1052650*	6855884
Dates x Hybrids	1	51.63	67592	258844	27883	875517
Dates x N Rates	2	89.42	163571	207946	497498	2404931
Hybrids x N Rates	2	10.51	50702	32060	175831	473996
Dates x Hybrids x N Rates	2	90.74	192118	613193	35247	1082422
Error (b)	20	424.05	354689	666835	214568	2431539
Grand Mean		106.77	2119.15	4939.80	2838.98	9898.06

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 20. Analysis of variance for per cent N and total N content from nitrogen solution desiccation study at Manhattan in 1972.

Source	d.f.	Mean Squares						
		Threshed Heads % N	Grain % N	Stover % N	Threshed Heads kg N/ha	Grain kg N/ha	Stover kg N/ha	Total kg N/ha
Replicates	2	0.0078	0.0073	0.1118	34.73	168.63	502.80	1596.04
Dates	1	0.8424**	0.2610*	1.1026**	4865.86**	183.05	2078.72**	10369.36
Error (a)	2	0.0022	0.0027	0.0020	14.09	799.65	13.33	1117.71
Hybrids	1	0.0026	0.1466**	0.0004	1.62	97.91	338.70*	726.52
N Rates	2	0.0004	0.0074	0.0078	1.58	492.84	196.78	1347.13
Dates x Hybrids	1	0.0261*	0.0001	0.0067	0.30	192.70	7.30	113.99
Dates x N Rates	2	0.0133	0.0319	0.0019	31.84	61.06	34.03	308.59
Hybrids x N Rates	2	0.0091	0.0027	0.0002	16.55	25.06	35.94	192.15
Dates x Hybrids x N Rates	2	0.0014	0.0025	0.0036	26.59	241.12	0.61	234.40
Error (b)	20	0.0048	0.0166	0.0126	34.88	200.20	73.75	553.74
Grand Mean		0.94	1.98	1.36	21.24	96.73	39.36	157.32

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 21. Analysis of variance for yield data from nitrogen solution desiccation study at Ottawa in 1972.

Source	d.f.	Mean Squares				
		Heads/Plot	Threshed Heads (kg/ha)	Grain (kg/ha)	Stover (Kg/ha)	Total Dry Matter (kg/ha)
Replicates	2	88.79	85717	149119	299636	358210
Dates	1	869.85	478568*	38599215**	8360580*	70742005**
Error (a)	2	129.76	22346	51790	92028	150626
Hybrids	1	5.02	32785	352583	2194506**	3588347*
N Rates	2	156.41	73890	307046	143449	1303516
Dates x Hybrids	1	80.28	334423	275723	17565	1528883
Dates x N Rates	2	96.83	135863	36809	131528	326024
Hybrids x N Rates	2	46.10	148023	334241	45157	244129
Dates x Hybrids x N Rates	2	98.16	37183	130414	62104	409125
Error (b)	20	87.11	121469	208318	165997	780664
Grand Mean		80.61	1817.69	5403.60	2788.92	10010.12

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 22. Analysis of variance for per cent N and total N content from nitrogen solution desiccation study at Ottawa in 1972.

Source	d.f.	Mean Squares Threshed Heads % N	Grain % N	Stover % N	Threshed Heads kg N/ha	Grain kg N/ha	Stover kg N/ha	Total kg N/ha
Replicates	2	0.0154	0.0003	0.0115	4.43	42.20	74.98	93.75
Dates	1	0.6241**	0.0676	0.3080	436.31**	10532.78**	2920.32*	18441.64**
Error (a)	2	0.0076	0.0432	0.0444	3.95	44.26	88.39	84.77
Hybrids	1	0.0001	0.3173**	0.0148	5.62	1625.70**	221.34	2796.57*
N Rates	2	0.0049	0.0649*	0.0734	2.40	20.66	11.92	69.08
Dates x Hybrids	1	0.0215	0.0001	0.0191	8.59	216.36	23.73	502.60
Dates x N Rates	2	0.0036	0.0188	0.0047	17.39	120.22	32.79	239.04
Hybrids x N Rates	2	0.0020	0.0063	0.0428	8.39	189.18	111.43	214.28
Dates x Hybrids x N Rates	2	0.0037	0.0127	0.0254	4.30	168.49	61.43	319.63
Error (b)	20	0.0060	0.0127	0.0317	12.98	105.18	97.77	348.84
Grand Mean		0.92	1.88	1.30	16.81	101.01	36.78	154.62

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 23. Analysis of variance for yield data from nitrogen solution desiccation study at Manhattan in 1973.

		Mean Squares				
Source	d.f.	Heads/Plot	Threshed Heads (kg/ha)	Grain (kg/ha)	Stover (kg/ha)	Total Dry Matter (kg/ha)
Replicates	2	58.93	11819	203564	132270	350728
Dates	1	145.65	141590	1166818	26026	294370
Error (a)	2	55.49	43245	368271	139404	1267000
Hybrids	1	1258.60**	328550	7148	233049	28
N Rates	2	113.50	9305	1090868*	2423170**	7228267*
Dates x Hybrids	1	92.04	66126	132169	169419	268423
Dates x N Rates	2	199.96	123259	75330	767683	2161033
Hybrids x N Rates	2	44.58	14651	700123	557675	1994714
Dates x Hybrids x N Rates	2	91.52	37988	585358	543876	2879903
Error (b)	20	111.76	101557	217000	277498	1310554
Grand Mean		66.83	2497.80	4792.19	3825.81	11116.04

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 24. Analysis of variance for per cent N and total N content from nitrogen solution desiccation study at Manhattan in 1973.

Source	d.f.	Mean Squares						
		Threshed Heads % N	Grain % N	Stover % N	Threshed Heads kg N/ha	Grain kg N/ha	Stover kg N/ha	Total kg N/ha
Replicates	2	0.0050	0.0025	0.0291	2.92	40.62	107.54	134.08
Dates	1	0.3637**	0.0011	0.1237	334.97**	426.37	245.84*	174.44
Error (a)	2	0.0026	0.0226	0.0120	0.45	110.91	5.42	164.70
Hybrids	1	0.0620*	0.1294**	0.0412	0.93	291.18*	6.96	236.17
N Rates	2	0.0117	0.0281	0.2449**	4.18	152.40	1478.75**	2443.63**
Dates x Hybrids	1	0.0014	0.0551*	0.0452*	9.52	284.97*	195.37	772.58*
Dates x N Rates	2	0.0148	0.0180	0.0133	19.27	74.67	137.44	499.60
Hybrids x N Rates	2	0.0079	0.0314	0.0537*	1.67	226.60*	245.48*	647.51*
Dates x Hybrids x N Rates	2	0.0059	0.0116	0.0049	0.08	97.83	123.07	450.09
Error (b)	20	0.0107	0.0098	0.0104	5.87	52.30	51.97	177.67
Grand Mean		0.78	1.82	1.28	19.39	86.79	49.36	155.53

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 25. Analysis of variance for yield data from nitrogen solution desiccation study at Ottawa in 1973 (one date of planting only).

Source	d.f.	Mean Squares				
		Heads/Plot	Threshed Heads (kg/ha)	Grain (kg/ha)	Stover (kg/ha)	Total Dry Matter (kg/ha)
Replicates	2	45.39	443373	68791	888123	2136624
Hybrids	1	460.06	6653	370580	14300	324839
N Rates	2	151.06	285312	3101993**	1139127*	10107225**
Hybrids x N Rates	2	44.06	210035	55533	82192	939460
Error	10	142.12	82309	240688	165713	730400
Grand Mean		50.61	862.71	2689.61	2428.97	5981.48

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 26. Analysis of variance for per cent N and total N content from nitrogen solution desiccation study at Ottawa in 1973 (one date of planting only).

Source	d.f.	Mean Squares						
		Threshed Heads % N	Grain % N	Stover % N	Threshed Heads kg N/ha	Grain kg N/ha	Stover kg N/ha	Total kg N/ha
Replicates	2	0.0098	0.0197	0.0680	57.53	45.82	115.24	229.76
Hybrids	1	0.1267*	0.1901*	0.1405**	9.53	7.98	73.61*	6.97
N Rates	2	0.0172	0.1238*	0.0253**	21.51	575.04*	161.69**	1321.36**
Hybrids x N Rates	2	0.0058	0.0468	0.0014	26.52	14.04	12.73	44.74
Error	10	0.0164	0.0303	0.0026	15.84	89.68	14.86	152.30
Grain Mean		0.84	1.88	0.72	7.37	49.37	17.65	74.39

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 27. Analysis of variance for yield data collected in 1973 from 1972 nitrogen solution desiccation carry-over N study at Manhattan.

Source	d.f.	Mean Squares: Heads/Plot	Threshed Heads (kg/ha)	Grain (kg/ha)	Stover (kg/ha)	Total Dry Matter (kg/ha)
Replicates	2	813.51	566865	1762757	2336861	10816930
Dates	1	333.04	518688	477850	19630	1617836
Error (a)	2	303.44	169407	912641	653961	4149513
Hybrids	1	1258.60	681	248938	386006	1196608
N Rates	2	54.93	34493	155374	6902	410162
Dates x Hybrids	1	318.28	4068	2297	430875	409067
Dates x N Rates	2	107.57	41581	189900	212223	1198444
Hybrids x N Rates	2	88.56	33326	180637	53095	352909
Dates x Hybrids x N Rates	2	132.15	1746	305852	12011	196788
Error (b)	20	366.79	77161	286565	283373	1309800
Grand Mean		96.88	1833.92	3701.50	4583.85	10119.25

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 28. Analysis of variance for per cent N and total N content data collected in 1973 from 1972 nitrogen solution carry-over N study at Manhattan.

Source	d.f.	Mean Squares							
		Tissue % N	Threshed Heads % N	Grain % N	Stover % N	Threshed Heads kg N/ha	Grain kg N/ha	Stover kg N/ha	Total kg N/ha
Replicates	2	0.1008	0.0045	0.0144	0.0415	27.41	401.41	401.93	1896.43
Dates	1	0.3766	0.0226	0.0790	0.0921**	1.09	11.64	254.37	332.45
Error (a)	2	0.0442	0.0041	0.0175	0.0006	1.71	247.79	66.95	604.47
Hybrids	1	0.0978*	0.0043	0.0016	0.0162	1.35	28.81	0.05	44.87
N Rates	2	0.0253	0.0105*	0.0286	0.0163	8.72	126.49	39.48	415.01
Dates x Hybrids	1	0.0026	0.0003	0.0115	0.0027	0.04	14.68	9.41	49.90
Dates x N Rates	2	0.0360	0.0017	0.0155	0.0082	0.24	91.38	44.86	213.10
Hybrids x N Rates	2	0.0251	0.0007	0.0145	0.0043	0.54	2.47	13.75	31.56
Dates x Hybrids x N Rates	2	0.0713*	0.0001	0.0322	0.0221	0.10	170.80	40.10	369.24
Error (b)	20	0.0160	0.0023	0.0094	0.0108	2.65	66.95	48.19	202.28
Grand Mean			0.55	1.20	0.95	10.03	44.65	43.74	98.42

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 29. Analysis of variance for yield data collected in 1973 from 1972 nitrogen solution desiccation carry-over N study at Ottawa.

Source	d.f.	Mean Squares				
		Heads/Plot	Threshed Heads (kg/ha)	Grain (kg/ha)	Stover (kg/ha)	Total Dry Matter (kg/ha)
Replicates	2	10.78	167371	362592	932850	3706476
Dates	1	93.44	324141	459647	231939	2958893
Error (a)	2	171.44	116472	947831	562820	4184572
Hybrids	1	16.00	4616	87206	2465	77255
N Rates	2	17.03	130147	2219193**	489881	6503107**
Dates x Hybrids	1	0.11	4719	223	6993	881
Dates x N Rates	2	0.69	30014	80816	135128	656341
Hybrids x N Rates	2	51.58	80127	28096	230147	819225
Dates x Hybrids x N Rates	2	15.36	63921	198686	70943	873730
Error (b)	20	62.48	58666	200281	152142	848455
Grand Mean		66.56	1339.08	4090.80	4288.79	9718.59

**Statistically significant at 1% level
*Statistically significant at 5% level

Table 30. Analysis of variance for per cent N and total N content data collected in 1973 from 1972 nitrogen solution desiccation carry-over N study at Ottawa.

Source	d.f.	Mean Squares							
		Tissue % N	Threshed Heads % N	Grain % N	Stover % N	Threshed Heads kg N/ha	Grain kg N/ha	Stover kg N/ha	Total kg N/ha
Replicates	2	0.3105	0.0166	0.0741	0.0513	16.17	276.98	242.31	1283.24
Dates	1	0.0160	0.0196	0.0400	0.0140	28.90	257.70	76.32	912.20
Error (a)	2	0.2192	0.0050	0.0508	0.0088	11.75	421.79	91.06	1109.76
Hybrids	1	0.2467	0.0001	0.0160	0.0090	0.24	69.93	20.75	154.55
N Rates	2	0.3171	0.0061	0.0283	0.0242	8.67	504.34**	92.41	1153.01**
Dates x Hybrids	1	0.1764	0.0054	0.0036	0.0272	2.82	11.04	59.72	161.12
Dates x N Rates	2	0.0538	0.0037	0.0211	0.0274	3.64	69.58	95.37	399.83
Hybrids x N Rates	2	0.0278	0.0004	0.0049	0.0025	5.23	20.99	33.51	122.33
Dates x Hybrids x N Rates	2	0.0308	0.0007	0.0083	0.0036	4.18	53.55	0.79	88.59
Error (b)	20	0.1663	0.0027	0.0109	0.0130	4.39	60.74	42.02	215.57
Grand Mean			0.58	1.12	0.66	7.91	46.45	28.48	82.84

**Statistically significant at 1% level
*Statistically significant at 5% level

FOLIAR APPLICATION OF NITROGEN SOLUTION FOR DESICCATION OF GRAIN SORGHUM, SORGHUM BICOLOR (L.) MOENCH

by

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B. S., Kansas State University, 1972

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Delayed harvest due to adverse weather conditions in the fall is one of the major problems facing producers of grain sorghum, Sorghum bicolor (L.) Moench. One possible solution is to speed the drying rate of the grain in the field by application of chemical or mechanical desiccants which kill or partially kill the plant.

This study evaluated the effects of foliar application of 32% nitrogen solution as a desiccant for grain sorghum. In addition, the possibility of increasing the quality of grain or forage by added nitrogen and the carry-over of nitrogen to the succeeding crop were evaluated.

Nitrogen solution was applied at 67 and 134 kg N/ha to two grain sorghum hybrids, RS671 and DeKalb variety E57, planted at two different dates, at Manhattan and Ottawa in 1972 and 1973. Treatment was made when the grain was near physiological maturity. Grain moisture samples were taken at weekly intervals until harvest. Yield and nitrogen content were determined at harvest. Grain sorghum was bulk planted on the plot areas the following spring to evaluate carry-over effects.

Nitrogen solution effectively killed leaf tissue within two or three days, and peduncles and stalks were usually affected within one or two weeks.

Significant acceleration of grain drying was usually found within a few days to two weeks when application was made at or before physiological maturity. Heavy precipitation immediately after treatment or treatment delayed too long after physiological maturity prevented grain drying effects. In no case were the effects of desiccation on grain moisture still apparent by the time the grain had reached a moisture level safe for conventional harvest and storage, however. After the initial, significant effects which reduced grain moisture to about 20-25%, the effects of precipitation and high humidity became more important than the effects of desiccation on determining grain moisture. Poor drying conditions hindered the study both years, however, this is the very problem which must be overcome if a desiccation method is to be useful.

No differences in desiccation effects were found between the closed head (RS671) and open head (E57) type hybrids, although differences in the overall grain drying patterns between hybrids were noted. No consistent difference between the two planting dates and corresponding application dates was observed for response to desiccation.

Grain yields were significantly reduced when application was made before physiological maturity. Accurate timing of application to achieve maximum drying effects without yield reduction was difficult. Harvestable stover yields were also reduced, which was attributed to physical loss of leaves in response to desiccation. Severe lodging was attributed to desiccation followed by heavy rains at Ottawa in 1973.

Grain nitrogen content was significantly increased by nitrogen application in some cases, but increases were small. Stover nitrogen content was decreased by nitrogen application. Loss of leaves from treated plants decreased the leaf to stalk ratio of the harvested stover, which caused lower nitrogen contents. Results indicated little potential for increasing grain or forage quality with pre-harvest nitrogen application.

Carry-over nitrogen caused significant grain yield increases at Ottawa in 1973, but not at Manhattan. No difference in per cent nitrogen in the plants was observed, however, and the total kg of nitrogen recovered was only about 10% of that initially applied as a desiccant.

Nitrogen solution may have some potential use as a desiccant for grain sorghum in combination with a high moisture harvest system, however, its use with conventional harvest systems appears to be limited because of its inability to overcome the effects of poor environmental drying conditions.