FACTORS INFLUENCING THE CYANIDE CONTENT

OF

SORGHUM ALMUM PARODI

By

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HCN Levels in *Sorghum almum*

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ABSTRACT

An experiment was designed to study the seasonal variations and the effects of simulating grazing damage, on the HCN content of Sorghum almum under the dry land conditions of the Beqa'a plain, during 1963 and 1964. Artificial injury was inflicted to simulate grazing damage effects on the two stands of the crop seeded in 1961 and 1962.

Injured plants, where the growth was retarded, maintained higher levels of HCN for a longer period than did the plants which had normal and healthy growth.

New shoots of frosted second growth contained greater and dangerous amounts of HCN as compared with the unfrosted normal growth.

The HCN content in the green forage of S. almum showed a gradual decrease from the plant's beginning to its maturity being high in the earlier succulent stages of growth and low at more mature stages.

The 1961 stand of the crop gave a higher forage yield, and produced taller plants but with less dry matter and a lower protein content as compared with the 1962 stand.

TABLE OF CONTENTS

LIST OF FIGURE AND TABLES

INTRODUCTION

Sorghum (*Sorghum vulgare*, Pers.) has been cultivated in Afro-Asian countries since prehistoric periods but was introduced into the new world only in recent times.

Sorghums have a high potential use as a forage crop for silage, pasture and soiling purposes. The culture of forage sorghums can be of great value in areas of uncertain or scanty summer rainfall such as in Lebanon, because of its drought tolerance and versatile habit of growth.

Many cattle producers however, distrust sorghums as a pasture or soiling crop, because of the danger of cyanide poisoning from the relatively high levels of HCN produced under certain conditions.

The present investigations were carried out during the period from 16th June to 7th December, 1963 with subsequent observations made in the spring of 1964. The objectives of the experiment were to study the seasonal variations and also the effects of simulated grazing damage, on the HCN content of forage sorghums grown under non-irrigated conditions. This simulated grazing damage was inflicted on plants of sorghum (*S. almum*) at three different stages of growth on two different stands of the crop planted in the spring of the successive years 1961 and 1962.

REVIEW OF LITERATURE

Sorghum almum originated as a natural outcross between Johnson grass (*Sorghum halepense* (L.) Pers.) and an unknown *Sorghum* in Argentina and was first described by Parodi in 1943 (10).

According to Davies and Edye (10) *S. almum* has gained world-wide recognition in recent years as a highly productive perennial forage sorghum, because of its drought resistance and salt tolerance. *Sorghum almum* is considered primarily to be a pasture plant, suited to semi-arid areas with an average annual precipitation of 18-30". Both sheep and cattle can graze *Sorghum almum* readily if it is no more than 8 to 10 feet in height. In good seasons in Australia, this pasture has fattened two cattle per acre in the nine months from September to May inclusive.

Worzella (29) appraised sorghum varieties and hybrids for grain and forage production in Lebanon. It was reported that *S. almum* performed well under dry land conditions, depending primarily on soil moisture stored from rains during the winter season. With a winter rainfall total of 8-12", and none after April, *S. almum* produced considerable green pasture during September and October when most other vegetation was dry. It was further reported that about fifty percent winter injury resulted after the second season of growth following a temperature of 20°F during the winter.

Boyl and Imrie (8) obtained information on the stocking of *Sorghum almum* paddocks by sheep under Western Australia conditions where new land development was taking place. It was reported that sheep which were in very light condition when put into the paddocks, improved greatly. However, *S. almum* was prohibited in Queensland (Australia) because it was potentially toxic, difficult to eradicate, and its seed could not be readily distinguished from that of Johnson grass (10). In the United States of America also, S. almum is a controversial grass. Some states, for example Missouri, Kansas, and Arizona, have banned it; others are cautious (3, 4, 5).

Toxicity of S. almum

Davies and Edye (10) reviewed an anonymous report in the Queensland Agriculture Journal, where it was reported that S. almum in Queensland was considered potentially more toxic than improved varieties of forage sorghum and sudan grass (Sorghum vulgare var. sudanense).

On the basis of HCN content alone, Davies and Edye stated that only minor differences in the range of variation between individual plants of S. almum as well as in other varieties of sorghum were found.

According to Boyd et al. (7) grazing types of sorghums such as sudan grass, Johnson grass and S. almum contain relatively less toxic material than do the other forage and gfain sorghums. However, these crops can poison livestock when they are grazed at very early growth stages, because of their high HCN content at that period.

Scholl et al. (23) compared seven strains of sudan grass, two lots of S. almum, a sorghum x sudan grass hybrid and perennial sweet sorgrass, for HCN levels when the plants were 30-36" in height. It was found that S. almum contained potentially dangerous HCN levels with an average of 849 ppm. in one lot and 1032 ppm. in the other lot.

Henderson and Hinze (14) conducted a study in 1961 and 1962 under dry land conditions at Colorado to compare the HCN content of eight varieties of sorghum and sudan grass. It was concluded that S. almum and a variety of sorghum named Combine Kafir 60, were the highest in HCN content with an average of 433 and 474 ppm. respectively. These levels would be considered extremely dangerous for grazing.

Occurence and Formation of HCN in Plants.

Vinall (26) reported work by Dunstan and Henry in England in 1902, and by Peters, Slave and Avery in Nebraska in 1902 and 1903. These authors showed that there was little doubt that HCN was the direct cause of sorghum poisoning. Vinall also stated that it was not until 1902 that HCN was discovered in sorghum plants. According to the theory of Dunstan and Henry, sorghum poisoning was caused by the glucoside called "Dhurrin". This compound has the empirical formula $C_{14}H_{17}O_7N$, and "on hydrolysis by the enzyme emulsin in the plant, yielded one molecule each of prussic acid, parahydroxy-benzaldehyde and dextrose". Working independently of Dunstan and Henry, Slave and Avery arrived at practically the same conclusion.

Swanson (24) also found that HCN did not exist as such in the growing plant and liberation of HCN in sudan grass was intimately associated with enzyme activity. When this enzyme action was inhibited by the addition of hot water or acids, no HCN was liberated.

Akazawa et al. (2) designed an experiment to investigate the usefulness of Sorghum vulgare as an experimental material for biosynthesis studies of cyanogenic glycosides. Support was found for the theory of Dunstan and Henry which suggested that the cyanogenic glycoside occured in plants of the sorghum family. This glycoside was hydrolyzed enzymatically by an active enzyme glycosidase in sorghum forming equi-molar amounts of HCN and P-hydroxy benzaldehyde.

Factors Influencing the Cyanide Content of Sorghum

a. Mechanical Injury: Franzke and Hume (11) studied the effect of mechanical injury on the HCN content of sorghum strains. Injury was done with a two ounce ball hammer. The hammer was raised approximately nine inches above the point on the stem of the plant to be injured and allowed to fall by its own weight. Each plant subjected to injury was struck eight times on one side of the stem, then eight times on the opposite side. The content of HCN was greater in injured than in normal plants. The difference was almost negligible the first week after injury, but thereafter the HCN content of the injured plants grew steadily greater in comparison with that of the non injured plants. This difference became less as the plants approached maturity. Mechanical injury resulted in a slower rate of growth and development in injured plants. New growth which developed as side branches in the leaf axils of injured plants was found to contain more than twice as much HCN as compared to the original leaves of the injured plants.

b. Frost Injury: Swanson (25) reported that tests made on sudan grass immediately after a frost, showed very large amounts of HCN. However, as soon as the plants began to thaw and wilt, their HCN level dropped very rapidly. Vinall (26) also concluded that frost increased the HCN content of sorghums.

Boyd et al. (6) tested sudan grass, which was two feet tall, for cyanide content both before and after a killing frost. It was concluded that in contrast to Vinall's statement, freezing did not materially increase the cyanide content of sudan grass. It was further reported that when weather favorable for growth followed a killing frost, the sudan grass sent forth new shoots which were apt to be very high in HCN. If pastured, these plants would probably have caused cyanide poisoning. Franzke et al. (13) also conducted extensive experiments to obtain some information regarding changes in HCN content as related to freezing damage and found a reduction in the content of HCN in frozen sorghum. It was emphasized that freezing apparently resulted in a more rapid and complete liberation of HCN than was normally found in sorghum plants. This might explain some of the cases of sorghum poisoning where the animals had access to the sorghum immediately after freezing or when it was fed in a frozen condition. Franzke and Hume (12) later showed that two sorghum strains liberated no HCN during growth but did so during the process of thawing after being frozen. There was no further liberation of HCN from sorghum plants that had been frozen when the leaves on the plants were dead.

Boyd et al. (7) referring to the work of Erdman and Emmel (1952) revealed that it is dangerous to feed cyanogenic plants killed by frost. However frost had little effect on the HCN content of mature plants, since plants of sufficient maturity had outgrown the toxic state.

c. Drought Injury: Willaman and West (28) found that the HCN content of sorghum plants grown under inadequate moisture conditions was higher than that of plants grown under optimum conditions. Vinall (26) also concluded from a critical survey of the literature of several investigators, that the injury to growing sorghum plants by drought increased the HCN content but that stunted growth from lack of fertility in the soil diminished it. In general it was indicated that an injury of any kind which results in checking the growth of a sorghum plant results in an increase of HCN.

Boyd et al. (6) concluded that drought did not cause an increase in the amount of HCN present. It was suggested that drought does probably operate as a factor in HCN concentration in plants, but does so largely by keeping the plants small so that the amount of HCN per unit of dry plant material will be correspondingly higher.

Franzke et al. (13) presented data to show that sorghum plants grown on soil with a low moisture content contained more than twice as much HCN as plants grown at a high level of moisture. Hogg and Ahlgren (16) also found that the HCN content of sudan grass increased as the moisture content of soil decreased. Nelson (22) conducted an experiment to determine the hydrocyanic acid content of varieties of both grain and forage sorghums and common sudan grass under certain moisture conditions and fertility levels. It was shown from the results that injury to normally growing sorghum plants caused by drought and high nitrogen fertilization increased the HCN content of the plant material sampled before heading.

d. Stage of Maturity: Brunnich (9) concluded that the amount of HCN in sorghum gradually diminished as the crop matured and sorghum became absolutely safe for use when the seeds were well developed. Maxwell (20) in 1903 found HCN to be highest in sorghum in the early stages of growth and thereafter rapidly disappeared. In general, it was found that the sorghum plant, until it approached the flowering or seed production stage, is not safe for free feeding. Menaul and Dowell (21) observed that hydrocyanic acid levels decreased as sudan grass plants grew larger.

Willaman and West (27) reported that HCN in sorghum plants was concentrated in the stalks during the first three or four weeks but then decreased and disappeared, persisting in the leaves in decreasing amounts until maturity. It was also suggested that the cyanogenic glucoside present was related to the vital processes of the plant, as it occured in the largest quantity in the leaves, during those stages when the plant was developing most rapidly. Vinall (26) concluded from a critical survey of the literature that the percentage of prussic acid in the sorghum plant decreased steadily from the time the plant began growth until it ripened its seed, provided the growth had been normal. In some cases where the growth had been interrupted by adverse climatic conditions, there might be noted an actual increase in the HCN content. Except for such abnormalities, sorghum or sudan grass, after it had headed out and set seed, was usually safe to feed to cattle. Swanson (24), Acharya (1), Boyd et al. (6), and Franzke et al. (13) are all agreed that young plants of vigorous growth contained more HCN than plants approacing maturity.

Martin and Stephens (19) emphasized in general that the HCN content of sorghum decreased as the plant approached maturity. Young branches and suckers were high in HCN content but mature plants with ripe seeds were seldom dangerous. If the growth had been normal and few young suckers or branches were present, most of the HCN was found in the leaves and particularly in the younger leaves. Hogg and Ahlgren (16) revealed that young actively growing parts of the plant contained a significantly higher HCN content than did the older parts of the plant. It was further observed that the HCN content of sudan grass decreased as the plant increased in height and age. Akazawa et al. (2) also reported that the glucoside was localized in the aerial shoots of plants and was abundant in young plants. The amount decreased as the plant increased in age and was absent in mature plants and in the seed.

e. Age of Stand: Maxwell (20) stated that the common belief among farmers, that sorghum ratoons are more liable to be poisonous than plant sorghum, is a mistake. The results of Maxwell's work showed that the young plant sorghum contained more HCN than did the ratoons when sampled at comparable growth stages.

Acharya (1) found that second growth or sorghum ratoons contained the highest content of HCN on a dry matter basis. Franzke et al. (13) on the other hand, found fifteen percent less HCN in the second growth of sorghum than in the first growth. His samples from the two cuttings were taken at comparative stages of development from the same sorghum plants, that is, at the shooting, heading and anthesis stages.

Hogg and Ahlgren (16) reported that second growth of sudan grass contained approximately twice as much HCN as did the first growth. Boyd et al. (7) also reported that new ratoon growth of cyanogenic plants, would be high in HCN content.

Relation of HCN Content of Sorghum Fodder to Toxicity for Grazing Animals

Brunnich (9) emphasized that all fodder plants related to sorghum must be used with discretion, in either the green or the dried state, and should not be given in large amounts to hungry animals.

Vinall (26) found that 0.5-0.6 grams of HCN would be fatal to a mature animal. The average amount of fresh material an animal would have to eat in order to ingest the 0.5 grams of HCN, is 18.9 pounds of sudan grass but only 7.6 pounds of sorghum. Boyd et al. (6) reported the following relation of HCN content of sudan grass fodder to toxicity in cattle:

Mgm. HCN per 100 grams dry plant tissue	Relative degree of toxicity
0-25	Very low (safe to pasture)
25-50	Low (safe to pasture)
50-75	Medium (doubtful)
75-100	High (dangerous to pasture)
> 100	Very high (very dangerous to pasture)

According to these observations, there was some variation between animals, concerning the amount of cyanide required to be fatal. If the animals were in a low state of vigor and very hungry, they were more apt to eat a fatal dose than when they were healthy and well fed. Boyd et al. further reported that several investigators had shown that a dose of about one gram of HCN would be required to kill a cow weighing 1000 pounds.

Martin and Stephens (19) observed that loss usually occured when hungry cattle strayed into a field of sorghum and offered the following suggestions:

"1. Pasturing of sorghum should not be attempted without first testing the field with an animal of little value.

2. The herd should not be turned into the field with empty stomachs. A light feed of grain given first should do much to prevent injury from HCN."

Davies and Edye (10) reviewing the findings of Coop (1951) reported that the glucoside content of the material ingested, the rate of the ingestion and the rate of the hydrolysis of the glucoside in the rumen, were important factors in toxicity. The greatest danger occured when hungry stock, exposed to an extremely palatable pasture, grazed greedily. It was generally agreed that S. almum could be safely grazed provided hungry stock did not gain access to material which had grown under conditions of drought, expecially if it were less than 14" in height.

MATERIALS AND METHODS

This study was carried out at the Agricultural Research and Education Center of the American University of Beirut, Lebanon. This area is characterized by rainfall of 375-400 mm. during winter and none during the summer months. The soil is well drained and of a calcareous nature with a pH of about 8.0.

Two stands of Sorghum almum, a perennial forage sorghum, planted in successive springs of the years 1961 and 1962, were subjected to injury treatments at three different periods of growth in order to compare the resulting HCN content.

The treatments were as follows:

A. Control - No injury.

B. Early season injury inflicted on June 16, 1963.

C. Mid-season injury inflicted on July 4, 1963.

D. Late season injury inflicted on July 25, 1963.

In addition plots from each of the two stands were evaluated for forage yield and quality.

A representative part of the field was selected as an experimental area, although the stand of the crop, especially that of the ratoon crop of the 1961 seeding, was not very uniform. The experiment was laid out in a split plot design with four replications. Years of planting were represented as main plots, and the treatments A to D described above, were randomized as sub-plots on each of the main plots. A plot unit consisted of four rows, each five meters in length, with a between row spacing of 75 cms.

Injury was inflicted by hand with a wooden stick measuring 69 x 4 x 1.5 cms. and weighing about one-half pound. Two strokes were given to either side of each plant receiving this treatment. The stick was raised to shoulder height, and the broad face was applied to the plants at each blow. Sufficient force was applied so that a uniform amount of leaf breakage and stem bending resulted from each blow. The first blow to a plant was applied at a point approximately one third of the distance from the base of the plant to the top of the plant. The second blow was applied at a point approximately one third of the distance from the top. Two blows were applied in the same way to the other side of the same plant.

From treatments B and C duplicate random samples for chemical analyses were taken twice in succession at intervals of one week from the date of injury and a third was taken at maturity. In the case of treatment D samples were taken at two weeks after injury and at maturity which was four weeks after injury.

On December 7, 1963, samples for HCN determination were taken from second growth foliage which had been affected by freezing temperatures. The frosts occured the nights of November 28 and December 3, 1963. The minimum air temperatures were -0.2 and -0.5°C., respectively. At intervals of approximately one week, during the period June 16 to August 21 of 1963, uninjured plants of the two stands were sampled for HCN determination. This sampling was started again April 30, 1964 when new spring growth had started, and was continued until June 13, 1964.

The rapid method of HCN determination proposed by Hogg and Ahlgren (15) was used. The portion of the leaf sheath immediately below the uppermost leaf collar of actively growing young tillers, approximately 7-10 inches in length, was used as sampling material for HCN analyses. By using young tillers, it was possible to obtain comparable plant material from different treatments throughout most of the growing season.

In addition to HCN determinations, fresh samples for dry matter content were taken from the same plant and were oven-dried at 110°C for 48 hours. The results were expressed as milligrams of HCN per 100 grams of dry matter.

To obtain forage yields, the two center rows of each yield plot were harvested on August 8, 1963. One-half meter at the ends of the plots were left to protect against border effects. This left rows 4 meters long for yield determination. The plants harvested from each plot were air-dried for a period of six weeks. Duplicate representative samples were taken from this air dried material for the determination of protein content.

Plant height was determined by measuring two plants from each yield row just prior to harvest.

Protein content was determined by modified Kjeldahl method as outlined in the Official Methods of Analysis of the Association of Official Agricultural Chemists (17).

Statistical methods appropriate to the design were applied for the analysis of the data (18).

RESULTS AND DISCUSSION

The purpose of this investigation was to study factors influencing the cyanide content of two stands of S. almum planted in 1961 and 1962. In addition two stands of the crop were evaluated for forage yields, dry matter percentage, protein percentage and plant height.

The results pertaining to each factor studied, are given in Tables 1 to 4. Analysis of variance and observed "t" calculations are reported in the appendix in Tables 5 to 9.

HCN Content of S. almum as Influenced by Mechanical Injury.

The results concerning the effect of mechanical injury on the HCN content of two stands of S. almum are presented in Table 1 and in Figure 1.

Table 1 reveals that injury at early and mid stages of growth was followed by significant increases in the HCN content the second week after injury. The HCN content in plants injured at a late stage of growth, had decreased considerably four weeks after injury as compared to the high levels found the second week after injury. This decrease in HCN content following late stage injury can be explained by the fact that the plants at that period had reached the seed production stage. There is agreement among chemists as well as farmers that when sorghum has reached the stage of maturity in which seed is being formed, it contains much less HCN as compared with the early leaf growth stages.

The mean HCN content in plants of S. almum, injured at three different stages of growth, differed significantly being higher in plants injured at an early stage of growth. There was a highly significant interaction between stages of injury and weeks after injury (Appendix Tables 5

Table 1. HCN content of Sorghum almum, as affected by mechanical injury performed at three different stages of development, and on two stands grown under dryland conditions of the Beqa'a plain, Lebanon, in 1963.

Treatment	Weeks after injury	Mgms. of HCN per 100 gms. of dry plant material						
		Non injured plants			Injured plants			
		1961 stand	1962 stand	Average of two stands	1961 stand[a]	1962 stand[a]	Average of two stands[b]	Average for stage of injury of two stands[c]
Early season injury	1	26.0	26.3	26.2	33.8	30.0	31.9	
June 16, 1963	2	23.1	22.6	22.9	57.2	54.4	55.8	32.2
	9[d]	8.9	8.1	8.5	8.7	9.3	9.0	
Mid season injury	1	11.9	12.1	12.0	13.1	12.5	12.8	
July 4, 1963	2	10.6	9.8	10.2	28.0	27.8	27.9	16.6
	7[d]	8.9	8.1	8.5	9.3	9.1	9.2	
Late season injury	2	8.8	9.0	8.9	19.0	19.8	19.4	14.2
July 25, 1963	4[d]	8.9	8.1	8.5	9.1	9.1	9.1	

a. Stands of two different year's seeding do not differ significantly in HCN content.
b. Weeks after injury differ in HCN content significantly at the one percent level of probability.
c. Seasons of injury differ in HCN content significantly at the one percent level of probability.
d. Plants mature, date August 21, 1963.

and 6). This indicates that the differences in HCN content resulting from injury at the various seasons are not similar at equivalent periods of time after injury. For example there were 31.9 mgm. of HCN/100 gms. of dry matter found after a period of one week when damage was inflicted early in the season. This level increased to 55.8 mgm/100 gms. of dry matter the second week after injury. In contrast when damage was inflicted about mid season, these levels were 12.8 and 27.9 mgm/100 gms. of dry matter, after the one and two week intervals. These data are in accord with the findings of a number of investigators (6, 13, 16, 26). These workers have reported that production of HCN in plants of the Sorghum family was high in the early stages of growth and then rapidly decreased after the heading and seed setting stages were reached.

The HCN content in the ratoon of the 1961 seeding was, in most cases, slightly higher than in the ratoon of the 1962 seeding. These differences, however, were not statistically significant.

Figure 1 shows a comparison of the differences in HCN content of normal, healthy plants of S. almum and those affected by mechanical injury. Mechanically injured plants of S. almum did not show an increase in HCN content during the first week after injury as compared to the uninjured plants. This difference became more than twice as great the second week after injury. At the late stage of injury, however, little difference in HCN content was found between uninjured and mechanically injured plants, when sampled four weeks after injury. This absence of high levels of HCN in plants injured at a late stage of growth can be attributed to the maturity of the plants, when production of HCN is usually much lower than at younger growth stages.

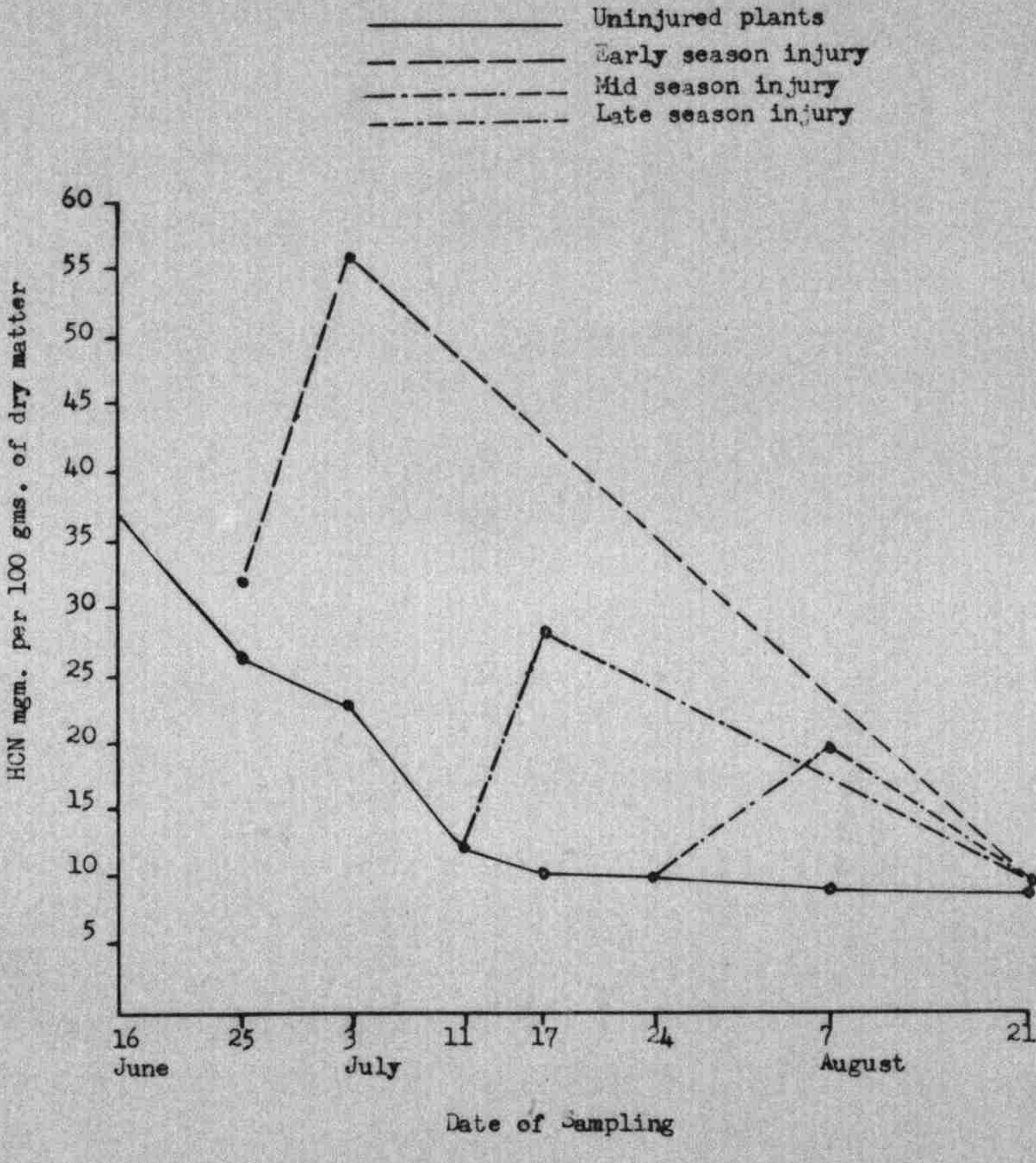

Figure 1. Comparison of the HCN content of plants of _Sorghum almum_ as influenced by injury.

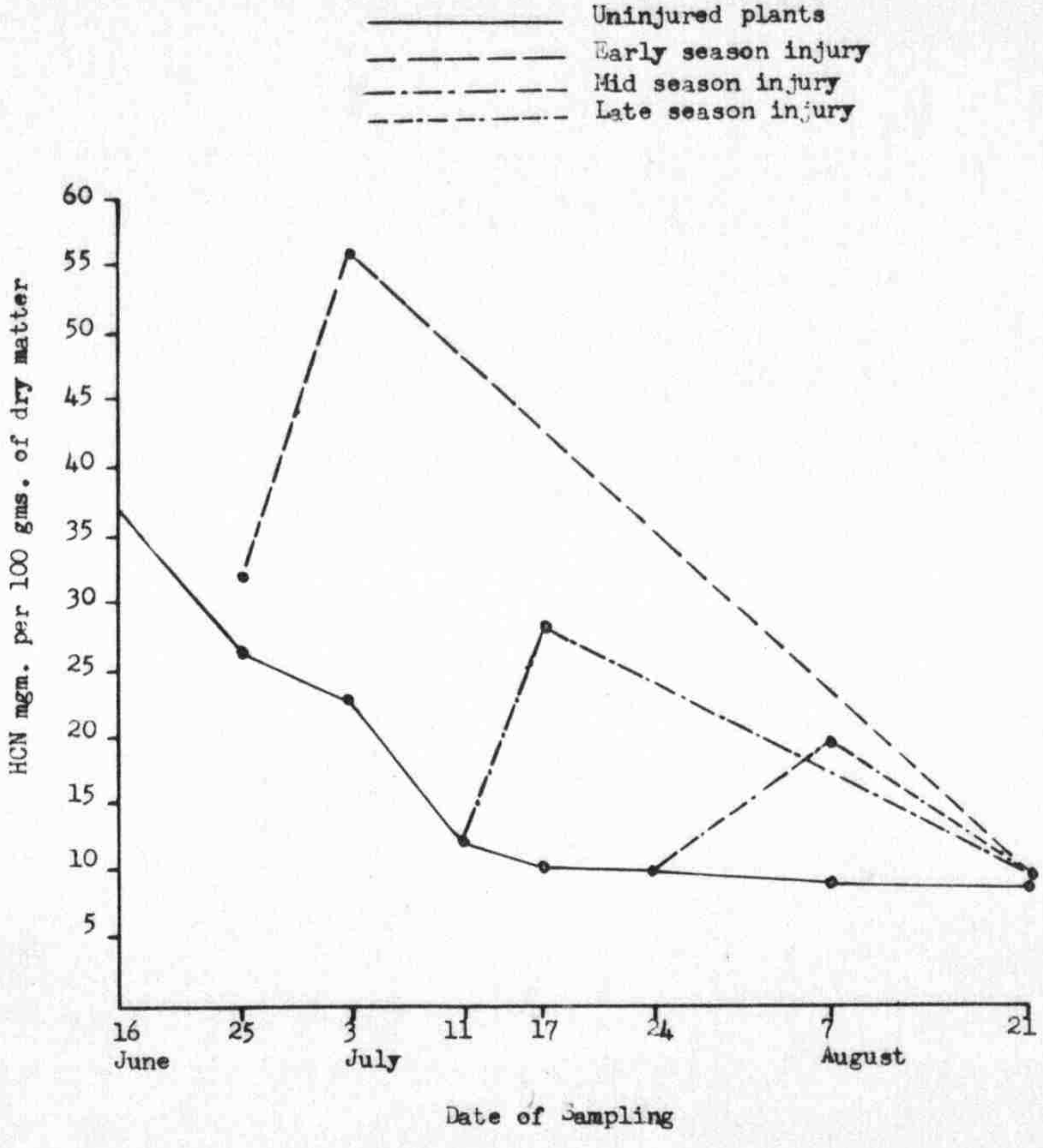

Figure 1. Comparison of the HCN content of plants of Sorghum almum as influenced by injury.

The injury inflicted on the plants caused a slower rate of growth and development. This was accompanied by an increase in HCN content in the injured plants for a longer period than was found in the plants where the growth was normal. These results are in agreement with those reported by Franzke and Hume (11) who found a greater HCN content in mechanically injured plants than in normal plants.

Effect of Frost on the HCN Content of Second Growth of S. almum

A common belief among stockmen is that sorghum or sudan grass affected by frost or other adverse climatic conditions contains a larger quantity of HCN than where the crop has made normal growth. Table 2 reports the data pertaining to the effect of frost on the HCN content of second growth of S. almum.

HCN levels found in the new growth following a frost were so high as to be considered dangerous for grazing cattle (6). It is interesting to note that the ratoon of the 1962 seeding contained a significantly higher amount of HCN than did the ratoon of the 1961 seeding. This may be due to there being younger smaller growth in the stand of the 1962 seeding, which was liable to be more susceptible to frost injury as compared with the older stand of the 1962 seeding.

The new shoots of second growth of frosted S. almum plants tested on December 7, 1963, had three times as much HCN as was found in the first growth sampled on June 16, 1963. Plants sampled at each date were at approximately equivalent stages of growth. An increase in HCN content of new young shoots following a killing frost was to be expected, but such a three fold increase in HCN content was beyond expectation. These findings are supported by Swanson (25), Vinall (26), and Boyd et al. (7). These

Table 2. Effect of frost on the HCN content of second growth of S. almum. Determinations made on normal plants June 16, 1963, and on new shoots of second growth December 7, 1963 following a killing frost which occurred the nights of November 28 and December 3, 1963.

Year of Seeding	Level of HCN in mgm/100 gms. of dry matter	
	June 16, 1963	December 7, 1963
1961	37.5	104.9⁺⁺
1962	36.9	114.2⁺⁺

++ These values are significantly different from each other at the one percent level.

authors concluded that frost increased the HCN content of Sorghum. These results do not agree with Boyd et al. (6) and Franzke et al. (13) because these workers studied the HCN content the next day following the heavy frost when the plants and leaves had thawed out and become wilted. Furthermore, the plants had reached the heading stage at the time of frost occurence. Consequently, frost had little effect on the HCN content of mature plants, because at that period plants had outgrown their toxic state.

Effect of Stage of Growth on the HCN Content of *S. almum*.

Analyses of HCN content of the two stands of *S. almum*, made at different periods of growth are summarized in Table 3.

It is clear from these data that the amount of HCN in the two stands of *S. almum* decreased progressively as the plants advanced in maturity. Maximum HCN content occurred at the early growth stages diminishing slowly until the plants reached the flowering stage on July 3, 1963. After the flowering stage HCN content diminished rapidly, reaching a minimum at complete maturity on August 21, 1963. During 1964, a decreasing trend in the production of HCN was also found as the plants advanced in age and growth. Similar results have been obtained by several investigators (6, 13, 16, 26) regarding the influence of stage of growth on the HCN content of sorghums and sudan grass.

In the series of HCN analyses performed, no significant differences were found between the HCN content of the two stands of *S. almum* planted in 1961 and 1962. Maxwell (20) and Franzke et al. (13) found that the ratoons or second growth contained less HCN than did the plant sorghum or first growth. Acharya (1), Hogg and Ahlgren (16), and Boyd et al. (7)

Table 3. Effect of stage of growth on the HCN content of two stands of *S. almum* during 1963 and 1964.

Sampling date	Mgm. of HCN/100 gms. of dry matter 1961 stand	1962 stand	Average of two stands
1. June 16, 1963	37.5	36.9	37.2
2. June 25, 1963	26.0	26.3	26.2
3. July 3, 1963	23.1	22.6	22.9
4. July 11, 1963	11.9	12.1	12.0
5. July 17, 1963	10.6	9.8	10.2
6. July 24, 1963	10.0	9.8	9.9
7. August 7, 1963	8.8	9.0	8.9
8. August 21, 1963	8.9	8.1	8.5
9. April 30, 1964	328.9	327.4	328.2
10. May 5, 1964	192.1	191.5	191.8
11. May 17, 1964	136.9	136.7	136.8
12. June 3, 1964	101.9	100.6	101.2
13. June 13, 1964	81.3	80.8	81.0

reported that the second or new ratoon growth would be high in HCN content. In the present investigation the two stands of S. almum, compared for HCN content, were both ratoon, the 1961 seeding being two years old and the 1962 seeding, one year old. Both the ratoons headed at the same time and were affected by similar conditions of drought, hence significant differences in HCN content between the two were not observed.

All HCN levels found in the two stands of S. almum during 1963, were below the critical levels of animal toxicity as reported by Boyd et al. (6). However, samples taken during 1964 were found to contain highly toxic levels of HCN at the very early growth stages. Perhaps this was caused by the poor condition of the stands, which were very weedy. The two stands of the crop were to be discontinued during the summer of 1964, therefore, no proper management of the crop as regards cultivation and weed control was followed during the period the tests were performed (April 30 to June 13, 1964).

Forage Yield, Dry Matter Percentage, Protein Percentage and Plant Height for Two Stands of S. almum

Table 4 shows a summary of the data collected, concerning the two stands of S. almum.

a. Forage Yield: Green and air dried forage yield data did not show significant differences between the two stands of S. almum. The average green and air dried forage yields for the 1961 stand of S. almum were higher as compared with the 1962 stand. This appeared to be because of taller plants and more tillers per plant produced by the 1961 stand. Worzella (29) reported that S. almum can produce a considerable amount of green pasture during the summer months under the dry land conditions in the Beqa'a plain, Lebanon.

Table 4. Green and air dried weights, dry matter percentage, protein percentage and plant height for two stands of S. almum planted in 1961 and 1962.

Observation	Average of stand of	
	1961	1962
Green weight in kgs. per dunum	816.29	696.97
Air dried weight in kgs. per dunum	359.85	325.75
Dry matter percentage	40.79	43.60++
Protein percentage	7.77	8.33++
Height in cms.	136.38	126.72+

+ 1962 stand significantly different from the 1961 stand at the five percent level.

++ 1962 stand significantly different from the 1961 stand at the one percent level.

b. Dry Matter Percentage: The average percentage of dry matter for the 1962 stand of S. almum as found in Table 4 was significantly higher than in the 1961 stand. This is probably a result of smaller green forage yield obtained from the 1962 stand.

c. Protein Percentage: Forage yields alone are not an adequate measure of the feeding value of a crop. Protein content is a useful meansof determining whether a crop is likely to be palatable and nutritious.

The two stands of S. almum varied significantly in protein content, the 1962 stand being richer than the 1961 stand. It is suggested that the higher crude protein of the 1962 stand can be accounted for by the greater green leaf area of the plants at harvest time. In addition, it is known that there is an inverse relationship between protein percentage and forage yield, and the yield of forage in the 1962 stand was lower. The 1961 stand of S. almum produced a higher forage yield, but a lower protein percentage.

d. Plant Height: The 1961 stand of S. almum produced significantly taller plants than did those of the 1962 stand. This was perhaps due to better establishment of plants in the 1961 stand, which might have been more efficient in uptake of water and nutrients from the soil.

Plant height has a direct correlation with the yield of forage crops, and in this case, the taller plants of the 1961 stand of S. almum did give a higher forage yield.

SUMMARY AND CONCLUSIONS

The present study was undertaken under dry land conditions of the Beqa'a Plain, Lebanon during 1963 with subsequent observations made in the spring of 1964. The purpose of the investigation was to determine the seasonal variations and the effects of simulated grazing damage on the HCN content of S. almum, a perennial forage sorghum. Artificial injury was inflicted to simulate the effects of grazing damage, at three different periods of growth, on plants of two different stands planted in 1961 and 1962. The two stands were also evaluated for yield and quality of forage and plant height.

Mechanical injury caused a slower rate of growth and development, in the injured plants, which was followed by an increase in the HCN content as compared with the uninjured plants. The content of HCN did not show a significant increase in the injured plants the first week after injury. The level was more than twice as great in the injured plants as compared to those not injured, the second week after injury. Thereafter, and until the plants reached maturity, the difference between HCN content in the injured and uninjured plants was negligible.

The mean HCN content in the plants injured at the early stage of growth was significantly higher than that in the plants injured at the mid and late stages of growth. No significant differences in the HCN content of two stands of S. almum were found to exist.

New shoots, from the second growth of frosted plants, when tested for HCN content, contained three times more HCN as compared with the early season, normal growth. Such potential HCN levels in frost damaged sorghum are considered dangerous to grazing cattle.

The results regarding the effect of stage of maturity on the HCN content showed that maximum HCN occured at the early leaf stages with a gradual reduction towards the later stages of maturity. The HCN content, however, diminished more rapidly after the heading stage and reached a minimum at complete maturity.

Plant height appeared to have a relationship with forage yield. The 1961 stand of S. almum produced taller plants with high forage yields, while the short plants of the 1962 stand gave a lower forage yield. However plants of the 1962 stand had a higher percentage of dry matter and protein as compared with the 1961 stand.

In view of the results obtained from this experiment, the following suggestions can be made for the grazing of S. almum pastures by cattle under Beqa'a conditions:

1. S. almum pastures would be safe for cattle provided that growth had been normal. On the contrary if growth had been stunted at the early stages of plant development, then the plants might be dangerous for grazing cattle.
2. New growth following a heavy killing frost is likely to have very high levels of HCN and thus should be considered extremely likely to cause cyanide poisoning among grazing cattle.
3. Plants should not be pastured in the very early growth stages both from the stand-point of danger from poisoning and from that of proper pasture mangement. However, it would be safe to pasture S. almum after it had reached the heading and seed setting stage because of the low levels of HCN found at that period.
4. Higher yields of good quality forage can be expected if normal and uniform stands of S. almum are maintained and there is enough winter

rain under the dry conditions of the Beqa'a plain. Furthermore, pastures planted to this crop should be able to maintain cattle and sheep in good condition throughout the summer months with proper management practices and care. However, a feeding trial should be conducted to evaluate the nutritive value of this crop for cattle and sheep.

5. If the pastures of S. almum are to be continued more than one year, it would be advisable to practice fall or early spring cultivation so as to conserve moisture and prevent weed growth.

6. This experiment should be continued in the future to varify above results and to study the effects of the fluctuating environment of the Beqa'a.

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APPENDIX

Table 5. Analysis of variance for comparing the influence of injury on the HCN content in the green forage of the ratoon from two different stands of S. almum at two different stages of plant growth.

Source	D.F.	M.S.
Replications	3	11.43
Ratoons	1	8.58
Error "a"	2+	7.07
Injury treatments	1	2921.88++
Ratoons x Injury treatments	1	15.76
Error "b"	6	6.72
Weeks after injury	2	4348.89++
Weeks x Ratoons	2	5.21
Weeks x Injury treatments	2	827.06++
Weeks x Ratoons x Injury treatments	2	18.98
Error "c"	24	11.10

\+ D.F. reduced by one due to confounding.

++ Significant at the one percent level.

Table 6. Analysis of variance for comparing the influence of injury on the HCN content in the green forage of the ratoon from two different stands of S. almum at three different stages of plant growth.

Source	D.F.	M.S.
Replications	3	11.49
Ratoons	1	2.34
Error "a"	2+	9.90
Injury treatments	2	1441.66++
Ratoons x Injury treatments	2	1.56
Error "b"	12	3.49
Weeks after injury	1	7665.91++
Weeks x Ratoons	1	6.45
Weeks x Injury treatments	2	1464.16++
Weeks x Ratoons x Injury treatments	2	7.81
Error "c"	18	12.51

\+ D.F. reduced by one due to confounding.

++ Significant at the one percent level.

Table 7. Observed "t" for the comparison of effect of frost on the HCN content of two stands of second growth of <u>S. almum.</u>

Sampling date	Observed "t"	D.F.	P value
June 16, 1963	0.706	2	.5 - .6
December 7, 1963	15.413	6	$\angle$ .001++

++ Significant at the one percent level.

Table 8. Observed "t" for the comparison of effect of stage of growth on the HCN content of two stands of <u>S. almum</u> during 1963 and 1964.

Sampling date	Observed "t"	D.F.	P value
June 16, 1963	0.706	2	.5 - .6
June 25, 1963	0.351	2	.7 - .8
July 3, 1963	0.714	2	.5 - .6
July 11, 1963	0.563	2	.6 - .7
July 17, 1963	0.166	2	.8 - .9
July 24, 1963	0.555	2	.6 - .7
August 7, 1963	2.210	2	.1 - .2
August 21, 1963	2.199	2	.1 - .2
April 30, 1964	0.0484	10	$>$ .9
May 5, 1964	0.0441	10	$>$ .9
May 17, 1964	0.0217	10	$>$ .9
June 3, 1964	0.2332	10	.8 - .9
June 13, 1964	0.0783	10	$>$ .9

Table 9. Observed "t" for the comparison of green and dried weights, dry matter percentages, protein percentage, and plant height for two stands of S. almum planted in 1961 and 1962.

Observation	Observed "t"	D.F.	P value
Green weight in kgs. per dunum	2.001	6	.05 - .1
Air dried weight in kgs. per dunum	1.205	6	.2 - .3
Dry matter percentage	4.861	6	.005 - .001[++]
Pfotein percentage	8.895	6	$<$ .001[++]
Height in cms.	3.232		.01 - .02[+]

\+ Significant at the five percent level.

++ Significant at the one percent level.