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An investigation into the life history, methods of control, competition and dispersal of Cyperus esculentus L. (yellow nutgrass) with special reference to the highveld region of South Africa.

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Vigorous, sprouted tubers were planted in large clay pots (16" diameter x 12" height) at depths of 1", 3", 6", 9" and 11" below the soil surface. The tubers were covered with the required amount of screened soil during January, 1965. Single replicates of each treatment were placed in the open after planting. Water was applied at daily intervals. The number of emerged shoots recorded at regular intervals is given in Table 34 , together with respective aerial shoot and root weights. The number of tubers produced per pot are also given.

TABLE 34 : NUMBER OF EMERGED SHOOTS AND FINAL WEIGHT OF PLANT FRACTIONS.

Treatment	(Days after planting) 5	6	8	9	12	16	17	19	26	31	Weight Roots	Weight Stems	Tuber Wt.	Tuber Number
Pot 5) 1" below	6	8	8	9	13	15	15	15	15	15	6.9	6.8	4.9	35
Pot 4) 3" below	-	-	2	3	3	5	5	6	7	8	8.4	4.7	5.7	41
Pot 3) 6" below	-	-	-	-	-	-	1	1	2	4	6.7	2.1	4.0	29
Pot 2) 9" below	-	-	-	-	-	-	-	-	-	-	*	*		
Pot 1) 11" below	-	-	-	-	-	-	-	-	-	-	*	*		

* Heavily infested with Fimbristylus exilis.

Nutgrass tubers failed to emerge when planted 9" or more below the surface. The emergence of tubers was directly related to the depth of planting. Fimbristylus exilis invaded pots 1 and 2 where nutgrass failed to emerge. The seedlings of the latter resemble closely those of nutgrass.

From an agronomic point of view, nutgrass tubers located at depths below 6" in the soil do not appear to present a serious problem. Fertilizer placed below a 9" depth would therefore not be immediately utilized by the competing weed and may reduce nutrient competition under high fertility conditions.

4. Influence of Temperature on the Sprouting of Nutgrass Tubers.

Under field conditions the emergence of nutgrass is principally confined to the early summer months following the first summer rains, i.e. October and November. Emergence during the remainder of the summer is less pronounced. To establish whether sprouting was related to critical soil temperatures, freshly harvested tubers were exposed to various constant temperatures. The tubers were planted in and covered with sand in shallow plastic germinating trays. Rate of planting was 100 tubers per tray. To prevent excessive moisture losses, the trays were covered and placed in ovens and refrigerators maintained at constant temperatures as shown in Table 35 . Each treatment was replicated 3 times. Date of planting was mid-November.

Trays maintained at 40°C lost moisture very rapidly and required daily water replenishment. During the December vacations, this oven was shut down for a period of three days to prevent desiccation of the tubers.

Forty-two days after commencement of the trial, all the trays were transferred to an oven maintained at 30°C.

The number of sprouted tubers per treatment are recorded in Appendix Table 22 and the mean values in Table 35 . The angular transformation was applied to the sprouting percentages at 42 and 70 days. Results in Table 35 are thus tabulated as actual data and as transformed data for the two abovementioned dates.

TABLE 35 : INFLUENCE OF TEMPERATURE ON THE SPROUTING OF NUTGRASS TUBERS. MEAN NUMBER OF SPROUTED TUBERS.

DAYS AFTER PLANTING	TEMPERATURE						
	5°C	15°C	20°C	25°C	30°C	35°C	40°C
4	0	0	0	14.3	6.7	8.3	0.7
7	0	0	16.7	38.7	12.7	13.0	2.0
10	0	0	26.0	48.0	16.0	17.0	8.7
12	0	2	30.7	50.0	16.7	18.3	5.0
14	0	3.7	33.7	51.7	17.0	19.0	6.3
18	0	7.0	37.3	54.7	30.3	32.7	8.3
31	0	13.3	37.7	57.7	56.7	44.3	10.0
42	0	13.3	37.7	58.3	60.7	53.0	38.7
42 (Transformed) MEAN		21.3	37.8	49.8	51.2	52.5	38.4

L.S.D (p=0.05) 6.3

48	0	13.3	37.7	58.3	62.0	66.0	40.0
53	4.3	22.3	42.0	58.7	62.0	67.0	47.0
56	7.0	29.3	43.3	59.0	62.0	67.0	50.0
70	7.7	32.7	44.3	60.0	62.0	67.0	51.3
70 (Transformed) MEAN	15.8	34.8	41.7	50.8	51.9	54.9	45.7

L.S.D (p = 0.05) 6.4

RESULTS:

Two analyses were made, one of the percentage tubers sprouted up and until 42 days after planting from which the 5°C treatment was omitted and a second of the total percentage tubers sprouted up and until 70 days after planting. In both cases temperature exercised a significant effect on sprouting. The percentage of sprouted tubers increased up to 25°C, then remained fairly constant with further increases to 35°C and dropped sharply when the temperature was further increased to 40°C.

Also of interest is the behaviour of the tubers to extreme temperature exposures. Tubers kept at 5°C failed to sprout and when transferred to optimum temperature conditions, showed only a slight increase in sprouting percentage. High temperature exposure, however, appeared to inhibit sprouting initially, without causing permanent injury to the tuber.

A reduction in temperature from 40°C to room temperature over a 3-day period brought about an increase in the sprouting percentage of the tubers previously stored at 40°C.

Based on the foregoing results, the optimum temperature required for sprouting is not critical, but would appear to fall between 25°C. to 35°C.

From the soil temperature recorded at Frankenwald (See Table 3), it would appear that soil temperature cannot be regarded as a critical factor in explaining the specific sprouting periods of nutgrass. It would therefore appear that induced dormancy of the tubers - as reported by Tumbleson (1960), - may be a contributing factor.

Further investigations with regard to induced tuber dormancy were therefore initiated in which the influence of washing on tuber sprouting was examined. Two tests were carried out exposing tubers to increasing periods of washing under a strong jet of water.

5. Influence of Duration of Washing on the Sprouting of Nutgrass Tubers.

Test (a).

Freshly harvested, late seasonal nutgrass tubers, (25/2/64) were subjected to increasing periods of washing, namely, 0, 5 minutes, 10 minutes, 30 minutes, 60 minutes, 6 hours and 13 hours. Each treatment consisted of 250 tubers, subdivided into 5 replicates of 50 tubers per treatment. Tubers were placed in wire mesh screens under a stream of continuously flowing water. Tubers were planted in sterilized river sand in petri dishes and kept in an incubator at 30°C. The number of sprouted tubers were recorded daily over a weekly period. Sprouted tubers were not removed from the petri dishes. The total number of sprouted tubers for each date per washing treatment are given in Appendix Table 23 . Mean percentage germination (actual) and corresponding angular transformed data for the final count are given in Table 36 .

TABLE 36 : INFLUENCE OF DURATION OF WASHING ON THE SPROUTING OF NUTGRASS. ACTUAL AND ANGULAR TRANSFORMED PERCENTAGE SPROUTED TUBERS.

TREATMENT	NUMBER OF DAYS AFTER PLANTING						
	3	4	5	6	7	% Actual	% Trsf.
1. 5 minutes	9.6	17.6	18.0	20.4	22.8	24.8	29.7
2. 10 "	10.4	16.0	16.8	21.2	23.2	30.4	30.7
3. 30 "	10.8	23.2	26.4	31.2	37.2	39.2	38.6
4. 60 "	12.0	23.2	26.8	31.6	34.0	34.2	35.7
5. 6 hours	2.8	5.2	8.0	12.0	14.8	17.6	24.7
6. 13 "	3.2	6.4	7.2	8.4	13.2	16.0	23.1
7 Control	6.8	8.8	8.4	10.4	12.8	16.0	23.2
L.S.D ps 0.05							6.5

The percentage of sprouted tubers (transformed) was significantly affected by the duration of washing. An exposure of 5 and 10 minutes gave the same result and were just significantly higher than no washing. 30 and 60 minutes washing gave the highest sprouting percentage. Sprouting decreased significantly when washing time was extended to 6 and 13 hours, these two giving the same sprouting percentage as the unwashed control.

Test (b)

In a second trial, the periods of washing were reduced and the nutgrass samples harvested during mid-summer, i.e. after the first tubers had been produced. Tubers were subjected to washing periods of 0, 5, 30 and 60 minutes. Each treatment consisted of 420 nutgrass tubers, containing both mother and daughter tubers. The tubers were planted in germinating trays in washed river sand, covered and kept at room temperature. The number of sprouted tubers were recorded and removed almost daily over a period of 50 days. These results are graphically presented in Figure 37. The total number of sprouted nutgrass tubers for each washing period is given in Table 37.

FIGURE 37. INFLUENCE OF DURATION OF WASHING ON THE SPROUTING OF NUTGRASS TUBERS.

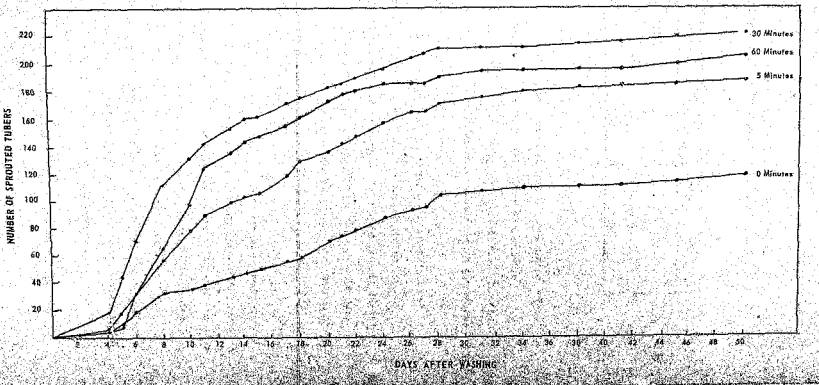


TABLE 37 : INFLUENCE OF DURATION OF WASHING ON THE SPROUTING OF NUTGRASS TUBERS.

DURATION OF WASHING	NUMBER OF SPROUTED TUBERS	PERCENTAGE SPROUTED
0 Minutes	119	28.3%
5 "	189	45.0%
30 "	222	52.9%
60 "	206	49.0%

RESULTS:

Washing of the nutgrass tubers exercised a pronounced effect on the sprouting of these organs. An exposure of 5 minutes produced a marked increase in percentage sprouted tubers. Increasing the washing period to 30 minutes increased the sprouting percentage still further.

Approximately 14 days after the commencement of this trial, a colour change in the outer layers of the daughter tubers was noticeable. A progressive discolouration from light grey or light brown to that of dark brown or light black was observed. The data obtained in both washing trials compared favourably with the results obtained by Tumbleson (1950).

5. Insolation of Tubers.

A number of tests were conducted in which freshly harvested tubers were exposed to the sun for increasing intervals. The purpose of these investigations was to determine the susceptibility of the tubers to insolation. After exposure, the treated tubers were inserted in an oven and kept at 28°C, comparing their viability with that of tubers stored in the laboratory for equivalent periods. With few minor exceptions, daily insolation was unaffected by cloud or rain on the days that the tests were conducted.

Test (a)

Tubers were placed on sand in metal trays and exposed in the open. Treatments were as follows:-

1. Tubers covered with a thick layer of thatch grass.

2. Tubers covered with a 1" layer of sand.

3. Tubers uncovered.

400 tubers were inserted in each tray, removing 100 tubers at periodic intervals after exposure. The exposed tubers were inserted under a polyethylene sheeting as a protection against rain. Exposures commenced on 18/1/61 and samples of tubers were withdrawn 2, 4 7 and 12 days after exposure. Results are given in Appendix Table 24 and Table 38.

TABLE 38 : PERCENTAGE SPROUTED TUBERS FOLLOWING INSOLATION OF TUBERS.

TREATMENT	Exposure Period			
	2 Days	4 Days	7 Days	12 Days
1. Grass cover	37	39	28	38
2. Sand cover	34	35	40	28
3. Uncovered	32	18	8	0
4. Laboratory	33	40	38	46

Uncovered tubers kept under a polyethylene sheeting showed reduced sprouting after an exposure period of 4 days. Samples of tubers withdrawn after a 2 day exposure showed no marked sprouting reduction compared with protected tubers. The sprouting percentage of tubers exposed to the sun for periods of 7 days decreased very rapidly. After an exposure of 12 days, exposed tubers failed to sprout.

Test (b)

Tubers were placed on sand in metal trays exposed in the glasshouse. Tubers were moistened twice per day. 500 tubers were inserted in each tray, removing 100 tubers at daily intervals on 5 successive days after exposure. Exposures commenced 20/4/64 and samples of tubers were withdrawn 1, 2, 3, 4 and 5 days after exposure. Percentage sprouted tubers are given in Appendix Table 25 and Table 39 .

TABLE 39 : PERCENTAGE SPROUTED TUBERS FOLLOWING INSOLATION OF TUBERS.

TREATMENT	Exposure Period				
	1 Day	2 Days	3 Days	4 Days	5 Days
1. Uncovered	60	67	70	66	46
2. Laboratory	80	62	50	27	28

The sprouting of exposed tubers was markedly better than that of tubers stored in the laboratory.

Test (a)

Tubers were placed on sand in germinating trays and exposed in the glasshouse, 20/1/65, the one series being completely covered with an opaque plastic sheet. 400 tubers were inserted in each tray, removing 100 tubers at periodic intervals after exposure. Results are given in Appendix Table 26 and Table 40.

TABLE40 : PERCENTAGE SPROUTED TUBERS FOLLOWING INSOLATION OF TUBERS.

TREATMENT	Period of Exposure			
	1 Day	2 Days	4 Days	5 Days
Glasshouse uncovered	29	17.5	25.5	23.0
Glasshouse covered	14	15.5	13.5	19.0
Laboratory	18	15.5	14.5	14.0

Uncovered tubers exposed in the glasshouse gave a higher sprouting percentage than covered tubers or tubers stored in the laboratory. The exposed tubers were highly susceptible to mould infections which did not appear to influence sprouting. Covered and laboratory stored tubers were not infected.

The results of the three exposure studies indicate that the tubers of C.esculentus are not susceptible to insolation. In two experiments the exposed uncovered tubers gave higher sprouting percentages than the tubers stored in the laboratory. This was particularly noticeable in the case of Test B where the tubers were harvested and exposed during late autumn.

Tubers exposed during mid-January showed reduced sprouting only after an insolation period of 4 days. These results are in agreement with the findings of Day and Russell (1955), who reported that the survival of yellow nutgrass, unlike that of C.rotundus, is not influenced by exposure to drying.

7. Water Absorption of Nutgrass Tubers.

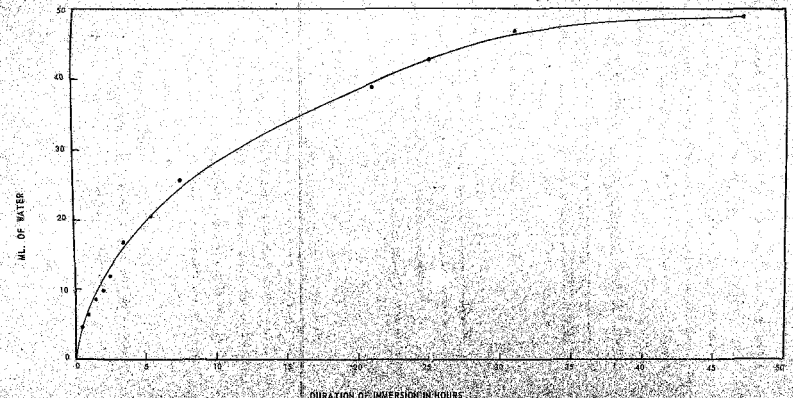
A few hours after a rain, shrivelled, dormant nutgrass tubers have been observed to swell and expand very rapidly. The water absorption of nutgrass tubers was therefore examined by means of volumetric and gravimetric methods. Gravimetric tests were conducted on two samples of nutgrass tubers, viz. desiccated and freshly harvested summer tubers. The volumetric test was also conducted on the desiccated nutgrass sample. In all the tests, 5 or 10 batches of nutgrass tubers were accurately weighed and permitted to soak in an excess volume of water. In the volumetric test, water absorption was determined by decanting and measuring the remaining water. In the gravimetric test, tubers were removed, permitted to drain and dry for a short period and weighed at certain intervals after immersion. The results are depicted in Figure 38 and have been converted to a standard basis, namely, the volume of water absorbed by 100 grams of tubers.

Desiccated tubers absorbed more water and at a faster rate than freshly harvested smaller tubers. The speed at which water is absorbed by the nutgrass tuber in general could offer some explanation as to the reasons for the rapidity with which nutgrass emerges in the field following the first summer rains. Water was mainly absorbed during the first 24 hours.

8. Influence of Storage on the Viability of Tubers.

To test the longevity of tubers in the soil it would be necessary to bury tubers for given periods and establish viability and sprouting potential. Such tests were not undertaken. However, tuber samples which had been laboratory stored for varying periods were available. A sprouting test was thus conducted on these samples.

FIGURE 38. WATER ABSORPTION OF NUTGRASS TUBERS — AS ML. PER 100 GRAMS OF TUBERS



Nutgrass tubers which had been stored in closed paper bags in the laboratory for varying periods were examined for viability. 100 tubers of 4 nutgrass samples were permitted to soak in tap water for 48 hours and the swollen tubers transferred to petri dishes. The weight of 100 tubers and the viability of each group is given in Table 41 .

TABLE 41 : PERCENTAGE SPROUTED NUTGRASS TUBERS, AND AIR-DRY WEIGHT

ORIGIN AND AGE OF TUBERS	WEIGHT (GRAMS) PER 100 TUBERS	PERCENTAGE SPROUTED TUBERS
1. Freshly harvested-Frankenwald 1965	21.05	91
2. 1964 - Bapsfontein	6.6	35
3. 1963 - Bethal	8.5	32
4. 1961 - Frankenwald	8.95	44

Nutgrass tubers stored in the laboratory for periods of 4 years under air-dry conditions, showed no marked loss in viability. The results are not necessarily directly applicable to field conditions.

9. Miscellaneous Tuber Tests.

(a) Influence of smother crops on nutgrass.

Tubers planted simultaneously with teff and sunnhemp in large drums initially grew more rapidly than both smother crops. Both crops did eventually shade the nutgrass shoots but by this time the formation of daughter tubers had been completed. Smother crops are thus not effective in preventing the formation of daughter tubers.

(b) Composition of tubers.

Nutgrass tubers reaped at the end of the summer were analysed according to the methods prescribed in Chapter VI E1. The results are given on Page 98.

Protein	5.40%
Fat	11.13%
Fibre	11.47%
N-free extract	59.93%
Ash	6.07%
Moisture	6.00%
Carbohydrate	71.40%

From a nutritional point of view, nutgrass tubers are very rich in food reserves (carbohydrates) and this explains the reason for its widespread cultivation as a famine food.

(c) Influence of MCPA on the viability of tubers.

Where herbicides such as 2,4-D or MCPA are repeatedly applied to nutgrass in turf, there is evidence of a growth suppression. A turf site infested with nutgrass (8 leaf stage) received two MCPA sprays on 4/2/64 and 15/2/64 at the rate of 1.25 gallons per acre (5 lbs acid equivalent). Excellent top kill of the nutgrass was evident. The nutgrass was mown 1 week after the second spray. 3 weeks after the last spray, 240 tubers attached to the treated plants were removed at random, half of which were washed under a stream of running water. Unwashed and washed tubers were each subdivided in 3 lots of 40 tubers and placed in petri dishes in an incubator and kept at 28°C. The number of sprouted tubers was recorded. Results are given in Table 42.

TABLE 42 : INFLUENCE OF TWO APPLICATIONS OF MCPA ON THE VIABILITY OF NUTGRASS TUBERS.

TREATMENT	9/3/64	10/3/64	12/3/64	15/3/64	22/3/64
Washed	0	0.8%	1.7	2.5%	9.2%
Unwashed	0	0	3.3%	3.3%	5.8%

Nutgrass tubers attached to plants which had received two heavy applications of MCPA sprouted very poorly, suggesting some means of translocation within the treated plant.

B. PLANT - CLIPPING AND INSOLATION OF NUTGRASS.

Insolation and repeated clipping of the nutgrass plant have been suggested as possible methods of control. Experiments were conducted to investigate a) the period of insolation required to kill the nutgrass plant, and b), the influence of repeated clipping, when combined with a heavy fertilizer treatment, on the survival of the plant. It was postulated that this combination would expedite an exhaustion of the organic reserves in the tuber.

1. Influence of Clipping Frequency on the Growth of Nutgrass Plants.

The influence of repeated clipping on the growth of aerial and underground fractions of established nutgrass was investigated in an open-air experiment, during the period January to April. Actively growing plants in the pre-flowering stage and with roots intact, were harvested in the field and transplanted into deep asbestos trays. The plants were arranged in four rows in each tray, each row containing 25 plants. After transplanting, the stems were clipped back to a height of 1½ inches above soil level, excepting the plants in the control trays (2 clippings).

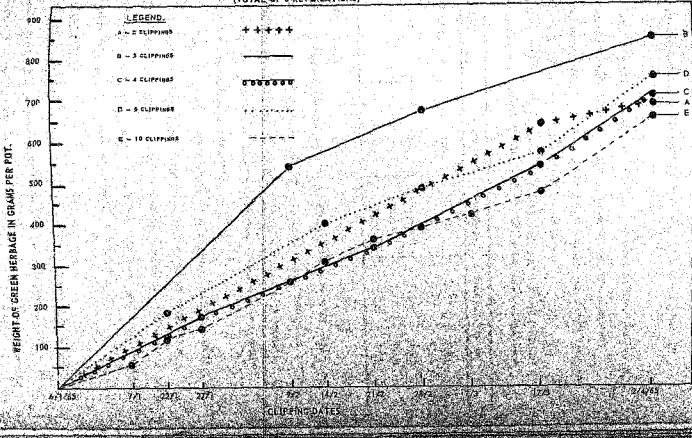
The first clipping treatments were applied 17/1/65. Clipping height was maintained at 1½ inches above soil level. All trays received fertilizer dressings, namely, 9 gms and 20 gms, Complesel per tray 8 days and 35 days after planting respectively. The trial ran for 3 months. Clipping dates for each frequency are shown in Figure 39 and in Appendix Table 27 . Treatments were replicated three times. Underground fractions were removed at the termination of the trial, washed and subdivided into roots and tubers.

The results of green aerial weights of nutgrass per clipping date are given in Appendix Table 27 . Accumulative aerial weights (based on the total of three replicates) for each clipping frequency is depicted in Figure 39 . The mean green aerial weight for each clipping frequency is given in Table 43 . The mean number and air-dry weight of tubers with their respective ~~ninety~~ root weights for each clipping frequency are presented in Appendix Table 28 and the means in Table 43.

TABLE 43 : INFLUENCE OF CLIPPING FREQUENCY ON THE TOTAL WEIGHT OF GREEN AERIAL AND AIR-DRY UNDERGROUND ROOT FRACTIONS OF NUTGRASS.

TREATMENT	WEIGHT (GRAMS) OF			NUMBER OF TUBERS
	GREEN HERBAGE	AIR-DRY ROOTS	AIR-DRY TUBERS	
10 Clippings	211.8	36.1	14.0	149
5 "	253.6	36.0	18.3	298
4 "	236.8	48.3	20.9	347
3 "	285.2	64.0	24.2	322
2 "	232.4	59.6	48.2	464
L.S.D (p=0.05)		14.5	20.7	N.S

FIGURE 38. INFLUENCE OF CLIPPING FREQUENCY ON THE HERBAGE YIELD OF HUTGRASS
ACCUMULATIVE YIELDS OF GREEN HERBAGE IN GRAMS PER POT.
(TOTAL OF 3 REPLICATIONS)



When the control trays (2 clipping) were first cut (17/3/65), a large aphid population was observed on these trays, which was absent on the remaining treatments.. Coccinellids, pentatomids, thrips and jassids were also found in large numbers on the control trays. The collection was submitted for identification. Details are given in Chapter XI 92.

At the conclusion of the trial, the air-dry herbage samples of the three replicates for each clipping date within each clipping frequency were bulked, thoroughly mixed and a composite sample withdrawn and analysed. The results are shown in Table 4 4 .

TABLE 44 : INFLUENCE OF CLIPPING FREQUENCY ON THE CHEMICAL COMPOSITION OF NUTGRASS HERBAGE

TREATMENT	% PROTEIN	% PHOSPHORUS	% CALCIUM	% ASH
10 Clippings	15.4	0.44	1.11	9.61
5 "	14.6	0.38	0.71	9.24
4 "	14.4	0.40	0.96	8.91
3 "	11.0	0.36	1.16	9.15
2 "	8.2	0.23	0.45	7.99

RESULTS:

Herbage: These clippings, applied at approximately monthly intervals, gave a significantly higher yield of nutgrass herbage than all the other treatments. Ten clippings at weekly intervals gave a significantly lower yield than 5 cuttings, two weeks apart. There was no regular linear effect of clipping frequency.

The most significant feature of the results depicted in Fig. 39 is the consistent production of nutgrass herbage, when applying a regular clipping frequency almost at weekly intervals. The yield curve for the latter clipping frequency does not appear to deviate markedly from those of the less frequently clipped treatments.

Roots and Tubers

Root weights increased with decreasing frequency of clipping up to 3 clippings, suggesting that frequency of clipping exercised a deleterious effect on the total air-dry weight. There is a suggestion of decreasing numbers of tubers with increased intensity of herbage removal, but the F-value was not found to be significant. Relationship between clipping and tuber weight, however, was significant at $p = 0.05$,

two clippings giving a higher weight than all the other treatments.

Chemical Composition.

The herbage protein content was of a particularly high order decreasing with reduced frequency of clipping. The percentages of phosphorus, calcium and ash, showed no linear relationship to treatment. The composition of the least frequently clipped herbage was clearly inferior in all respects. Generally, the phosphorus and calcium contents of the herbage were comparatively high, while that of ash, particularly low.

2. Clipping of Nutgrass Shoots in the Laboratory.

To test the regenerative properties of nutgrass tubers, 3 tests were conducted in the laboratory, using sprouted nutgrass tubers approximately 2 days old.

Test (a)

10 sprouted tubers were placed on filter paper on sand in 2 petri dishes, 2/1/62. The petri dishes were covered and incubated at 28°C. The vertical rhizomes were clipped back 4 times as close as possible to the tuber. The number of vertical rhizomes reappearing after each successive clipping per 5 tubers are given below:

Days after commencement of test.	Number of Shoots resprouted
0 =	-
5 =	5
13 =	3.5
23 =	1.5
40 =	1.5

Sprouted tubers were capable of reshooting when repeatedly clipped at the exit point of the vertical rhizome from the tuber. Resprouting after the 2nd, 3rd and 4th clipping decreased rapidly.

Test (b)

Ten sprouted tubers were planted in sterile sand in small PVC containers, ½" below the surface on 5/1/65. Five containers were planted and kept in the laboratory near the window. The shoots were clipped at the base of the stem, i.e. surface level. The clipping treatments, number of shoots and final length of shoots for each treat-

ment are given in Table 45.

TABLE 45 : NUMBER AND LENGTH OF NUTGRASS SHOOTS.

TREATMENT	NUMBER OF SHOOTS AFTER.			HEIGHT OF SHOOT IN CMS AFTER 56 DAYS
	26 DAYS	36 DAYS	56 DAYS	
UNCUT	10	10	10	40.1
1st Clip - 5/1/65	7	10	10	24.7
2nd " 5/1/65 and 20/1/65	3	7	10	19.0
3rd " 5/1/65 + 20/1/65 + 10/2/65	3	7	9	12.8
4th " 5/1/65 + 20/1/65 + 10/2/65 + 28/2/65	6	10	3	4.5

Frequent clipping of the nutgrass shoots at base level caused a marked reduction in resprouting only after the 4th clipping.

Test (c)

Sprouted nutgrass plants with incipient root growth, were subjected to 4 different methods of clipping. Tubers with vertical rhizomes were permitted to elongate until the first leaves had unfolded. Treatments were as follows:-

1. Uncut.
2. Cut at base of vertical rhizome - Exit position of vertical rhizome from the tuber.
3. Cut in the centre of the vertical rhizome.
4. Cut at junction of first two leaves.

The clipping treatments were applied once and 10 clipped plants of each treatment were planted in medium sized polethylene pots and transferred to the glasshouse. Treatments were applied 11/3/64 and the pots harvested 55 days later. The final weight and number of various fractions are given in Tables 46 and 47.

TABLE 46 : NUMBER OF SHOOTS, UMBELS AND TUBERS PER POT.

TREATMENT	SHOOTS AFTER 33 DAYS	UMBELS AFTER 41 DAYS	TUBERS AFTER 55 days
1. Uncut	10	5	20
2. Base of vertical rhizome	10	2	21
3. Centre of vertical "	22	5	33
4. Leaf junction"	10	5	27

TABLE 47 : WEIGHT OF SHOOTS, ROOTS AND TUBERS AFTER 55 DAYS IN GMS PER POT

TREATMENT	SHOOTS	ROOTS	TUBERS
1. Uncut	2.7	1.2	1.05
2 Base of vertical rhizome	2.2	2.3	1.1
3. Centre of " "	2.3	0.9	2.6
4. Leaf junction	2.7	1.2	1.75

The three methods of clipping did not influence the weight of stems produced. Clipping of the centre of the vertical rhizome resulted in the abnormal emergence of double shoots. The double shoots appeared to have developed as two separate plants since the final number and weight of tubers in these pots were almost double those produced on the remaining treatments. The results further illustrate that nutgrass growth was not adversely affected by a single clipping irrespective of how close the treatment was applied to the mother tuber.

Summary Growth of nutgrass plants and sprouted tubers are apparently unaffected by repeated clipping. In tht presence of adequate fertilizer repeated clipping of nutgrass as often as 10 times at weekly intervals, did not significantly reduce the total green herbage weight. There was some evidence to indicate that the underground fraction of nutgrass was reduced by frequent clipping treatment. The survival of large numbers of tubers on the frequently clipped pots, suggests that frequent clipping cannot be considered as a suitable control measure.

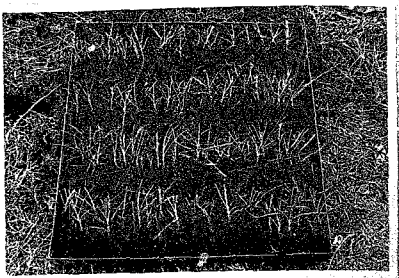
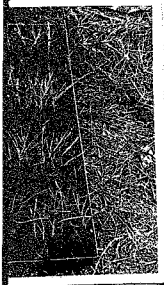


FIGURE 40: Insolation studies. Exposure of nutgrass plants



gaure of nutgrass plants.

Laboratory evidence on the influence of frequency and position of clipping of the vertical rhizome merely serve to confirm that nutgrass *is markedly resistant to frequent clipping*. The position of clipping of the vertical rhizome appears to bear some relationship to shoot emergence. Of considerable interest, however, is the chemical composition of the clipped herbage and the relationship between clipping frequency and herbage quality. From a pastoral point of view, herbage containing such a high percentage of protein, phosphorus and calcium, merits further examination.

Nutgrass plants exposed to the sun wilt after 1 - 2 hours of insolation. To establish whether such exposures produce a permanent desiccation of the plant, a pot experiment was carried out in which nutgrass plants were exposed directly to the sun for increasing periods and then planted in pots. The effect of this treatment was evaluated by examining the regrowth of the exposed nutgrass plants.

(3) Insolation of Plants.

Actively growing plants were removed from the field, cut back to approximately 3" from base level. The plants were placed on trays filled with sand and exposed to the sun for increasing periods during March (Fig. 40). Maximum day temperature for this date was 28.0°C and the hours of sunshine 9.1. The plants were exposed during the period 11.50 a.m to 5.40 p.m. The plants were rotated every ten minutes to ensure uniform insolation. 100 plants arranged in 4 rows of 25 plants, were transferred and planted in single replicated deep asbestos trays in the open air. The time and duration of exposure are given in Table 48 . Three weeks after treatment, the shoots were clipped at ground level, weighed and counted. The underground fraction was washed and screened. The air-dry weights of the latter and the number of nutgrass tubers per treatment are given in Table 48 .

TABLE 48 : INFLUENCE OF INCREASING PERIODS OF INSOLATION OF NUTGRASS PLANTS. NUMBER AND WEIGHT OF AERIAL AND UNDERGROUND FRACTIONS.

DURATION OF EXPOSURE	SHOOTS		AIR-DRY WEIGHT UNDERGROUND	TUBER NUMBER
	NUMBER	GREEN WEIGHT		
0 Minutes	88	27.5	47.9	236
15 "	61	25.3	51.9	252
30 "	71	22.8	21.9	229
60 "	67	24.3	22.7	122
2 Hours	64	18.6	27.4	115
3 "	66	21.1	26.4	124
4 "	58	14.4	20.1	62
5 "	59	11.4	18.8	83

RESULTS:

Aerial growth was adversely effected by the duration of exposure to the sun. The lack of replication, however diminishes the value of the results obtained in this test. An exposure period exceeding 2 hours, markedly influenced the final stem weight, while a 30 minute exposure or more, was sufficient to reduce the weight of the underground fraction. Tuber number was reduced by an exposure exceeding 60 minutes. It must be conceded that normal mid-summer temperatures are higher than those experienced during the above test. The results confirm that an exposure of 5 hours is inadequate to achieve a permanent desiccation of the plant. In this test, however, the plants were repeatedly rotated, thus ensuring complete exposure, a situation not usually encountered in the field. To attempt nutgrass control by means of insolation would therefore require exposure periods longer than 5 hours

CHAPTER X.

COMPETITION STUDIES

Interest centres on whether or not the marked growth suppression of the crop, competing with nutgrass under field conditions, is caused by a possible secretion, based on some antagonism of undefined origin from the underground system of nutgrass, or whether the symptomology of retarded growth and attendant visual foliar deficiencies are attributable to physiological disturbances produced by competition for environmental factors such as plant nutrients and water. In an effort to explain the manner of this competitive action, a number of studies were conducted in the laboratory, glasshouse and open air. The results have been grouped into two sections, namely, Direct and Indirect Competition.

A. DIRECT COMPETITION.

The investigations grouped under this section include the following:-

a) Response of maize when grown in the absence or presence of nutgrass under two levels of fertility.

b) Response of sorghum and cucumber when grown in the absence or presence of nutgrass under a high fertility level.

c) Response of sorghum to increasing plant populations of nutgrass.

d) Increasing nutgrass populations.

e) Water consumption of nutgrass and two common weed species.

1. Response of maize grown with or without nutgrass competition.

The purpose of this experiment was to study the influence of nutgrass on the growth of maize when grown in association with nutgrass or in the absence of competition. Two methods of planting were thus adopted, namely, an associate or competition method (alternate rows of maize and nutgrass - Figure (C1) 41 and separate method (maize and nutgrass separated from each other - Figure Co.Fig.41 & 42. The trial was conducted in deep fibre asbestos trays. For the separate planting method (Co), a PVC plastic sheeting ± 2 mm thick was inserted and sealed in the centre of each tray thus excluding horizontal soil moisture movement. Nutgrass plants approximately in the 5 - 6 leaf stage were removed intact from the field, clipped back to a height of 2" and planted at the rate of 4 rows (20 plants per row) per tray.

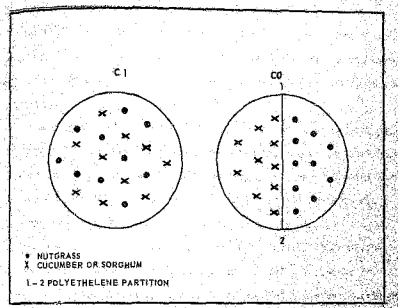


FIGURE: 44 DISTRIBUTION OF PLANTS IN POTS FOR COMPETITION EXPERIMENTS (GRUMMER & BEYER)

C1 – ROOT SYSTEMS OF THE SPECIES IN CONTACT
CO – ROOT SYSTEMS OF THE SPECIES SEPARATED

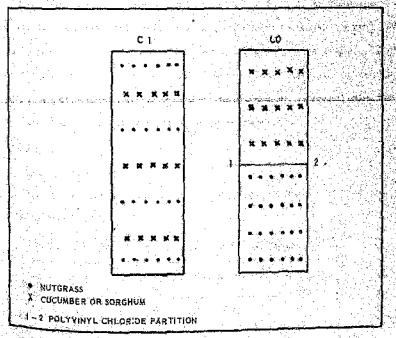


FIGURE: 41 DISTRIBUTION OF PLANTS IN TRAYS FOR COMPETITION EXPERIMENTS (GRUMMER & BEYER)

C1 – ROOT SYSTEMS OF THE SPECIES IN CONTACT.
CO – ROOT SYSTEMS OF THE SPECIES SEPARATED.

Maize seed was sown in 3 rows (10 seeds per row) per tray. Theoretically, the maize and nutgrass enjoyed the same volume of soil space per tray, irrespective of the method of planting. In the Associate method (C1) of planting, the maize was subject to direct bilateral nutgrass competition.

Two fertilizer treatments, viz. no fertilizer (Fo, and fertilizer (F1) (1500 lbs Compleseal/acre applied in two split applications) were superimposed over the two planting methods, giving the following treatments.

1. Associate planting (Competition present) - Fertilized - C1 F1.
2. Associate planting (Competition present) - Unfertilized - C1 Fo.
3. Separated planting (Competition absent) - Fertilized Co F1.
4. Separated planting (Competition absent) - Unfertilized Co Fo.

Each treatment was replicated 3 times. The trays were arranged at random in the open air. The maize was sown 7 days after the nutgrass plants had been planted. Fertilizer was applied at planting and 22 days later. Trays did not suffer water stress throughout the investigation. Maize germination counts were made 5, 6 and 9 days after planting. The trial was terminated 41 days after planting of the maize. Aerial maize and nutgrass stems were clipped at ground level and the respective green weights recorded. The heights of 10 maize plants selected at random from each tray were measured. Underground fractions were washed, divided into separate fractions and respective weights recorded.

Results.

1. Maize germination.

Mean maize populations per tray are given in Table 49 and in Appendix Table 29.

TABLE 49 : EMERGENCE OF MAIZE. MEAN NUMBER PER TRAY.

TREATMENTS	DAYS AFTER PLANTING		
	5	6	9
C1 - F	6	15	25
C1 - O	16	24	25
Co - F	10	18	27
Co - O	10	17	27



FIGURE 42: Growth of maize in competition experiments:
13 - Maize and nutgrass - Fo
3 - Maize only - Fo
- Maize and nutgrass - F1
23 - Maize only - F1



FIGURE 43: Growth of cucumbers in competition experiment:
A - Cucumber separated from nutgrass
B - Cucumber competing with nutgrass.

There was no evidence of a treatment effect on the rapidity and final emergence of maize.

2. Growth of maize and nutgrass.

Approximately 11 days after planting of the maize, there was strong evidence of a marked fertilizer response by both maize and nutgrass. Furthermore, maize grown according to the seperated planting method was taller and more vigorous than maize grown according to the associate method. In the absence of fertilizer this effect was accentuated. Approximately 3 weeks after planting, pronounced stunting, incipient foliar chlorosis, symptomatic of nitrogen deficiency, was observed on the maize growing in association with the nutgrass. The stunting effect on the maize plants was particularly evident in the absence of fertilizer. The above symptoms were not evident on the maize grown without nutgrass competition.

3. Aerial and underground plant fractions.

The green weights of nutgrass and maize stems together with respective maize heights are given in Appendix Table 29 . Fresh and air dry weights of maize and nutgrass roots, as well as number and air-dry weights of tubers are shown in Appendix Tables 30A & 30B. The means of all the results are summarized in Table 50 . Analyses of variance were not carried out on the number of maize and nutgrass stems. The data is included for comparative purposes.

TABLE 50 : WEIGHTS, HEIGHTS AND NUMBERS OF MAIZE AND NUTGRASS. WEIGHTS IN GMS PER TRAY.

Fraction Investigated	C1 (Associate Planting)		C2(Seperate Planting)	
	Fo	F1	Fo	F1
MAIZE				
1. Numbers	28	23	27	27
2. Weights (Inches)	12.0	20.5	13.0	23.2
3. Stem Weight (Green)	58.3	145.5	86.8	246.3
4. Root Weight (Fresh)	44.9	53.8	134.9	208.4
5. Root Weight (Airdry)	16.7	22.8	74.1	110.4
NUTGRASS				
6. Numbers	89	167	82	155
7. Stem Weight (Green)	140.4	266.3	133.2	186.9
8. Root Weight (Fresh)	544.7	677.7	445.9	500.3
9. Root Weight (Airdry)	291.8	428.5	249.0	289.0
10. Tuber Weight (Airdry)	67.2	69.3	50.6	44.1
11. Tuber number	296.3	315.7	236.0	337.0
MAIZE AND NUTGRASS				
12. Stems (Green Weight)	198.7	411.8	220.0	433.2
13. Roots (Fresh Weight)	589.6	731.5	580.8	708.7
14. Stems & Root (Fresh weight)	788.3	1143.3	800.8	1141.9

INTERACTIONS

1) Green Weight of Maize Stems

C - 166.5	vs	101.8
F - 72.5	vs	195.8
CxF - 86.8	vs	58.2
246.2	vs	145.4

2) Green Weight of Nutgrass Stems

C - 160.0	vs	203.3
F - 136.8	vs	220.6
CxF - 133.2	vs	140.4
186.9	vs	266.3

3) Green Stem Weights of Maize and Nutgrass combined.

C - 326.6	vs	305.2
F - 209.3	vs	422.5
CxF - 220.0	vs	198.7
433.2	vs	413.8

4) Fresh Weight of Maize Roots.

C - 171.6	vs	49.3
F - 89.9	vs	131.1
CxF - 134.8	vs	44.9
208.4	vs	53.7

5) Fresh Weight of Nutgrass Roots.

C - 473.1	vs	611.2
F - 495.3	vs	589.0
CxF - 445.9	vs	544.7
500.3	vs	677.6

6) Fresh Root Weight of Maize and Nutgrass combined.

C - 644.7	vs	660.5
F - 585.2	vs	720.1
CxF - 580.7	vs	589.7
708.7	vs	731.4

7) Air-dry Weight of Maize Roots

C - 269.0	vs	350.
F - 270.4	vs	358.7
CxF - 249.0	vs	291.7
289.0	vs	428.4

9) Air-dry Weight of Nutgrass Roots.

C - 92.25	vs	19.73
F - 45.40	vs	66.58
CxF 74.13	vs	16.66
110.36	vs	22.80

9) Air-dry Tuber Weights.

C - 47.35	vs	68.53
F - 58.88	vs	57.00
CxF - 50.60	vs	67.16
44.10	vs	69.90

10) Tuber Numbers

C - 231	vs	306
F - 266	vs	271
CxF - 236	vs	296
277	vs	316

11) Maize Heights

C - 18.1	vs	16.2
F - 12.5	vs	21.8
CxF - 13.0	vs	12.0
23.2	vs	20.5

The results were analysed as completely randomized 2 x 2 factorial with 3 replications.

1. Green weights of maize.

The effects of competition and fertilizer and the interaction were all highly significant. The competition effect was much more severe in the fertilized trays than in the unfertilized areas.

2. Green weights of nutgrass.

All the effects were significant. The competition effect was much more pronounced in the fertilizer trays than in the unfertilized ones.

3. Combined green weights of maize and nutgrass.

For each fertilizer treatment, the total weight of green material produced per tray remained almost constant, irrespective of whether the two species of plants were planted in alternate rows or separately. The interaction effect was completely removed by combining the weights. Fertilizer application increased the weights by 100%.

4. Fresh weight of maize roots.

All effects were highly significant. Fertilizer applications produced practically no effect when competition was present.

5. Air-dry weight of maize roots.

The competition, fertilizer and the interaction between the two were all highly significant. In the absence of competition from nutgrass, the fertilizer application increased the weight of maize roots by 36 gms per tray, in comparison with only 6 gms in the presence of competition.

6. Fresh weight of nutgrass roots.

The competition effect was significant.

7. Air-dry weight of nutgrass roots.

The competition effect just reached significance at $p = 0.05$. There are indications of a fertilizer and interaction effect, but there is insufficient replication to allow firm conclusions in this regard.

8. Combined fresh root weights of maize and nutgrass.

Competition had no effect and there was no sign of an interaction between competition and fertilization. The effect of fertilization was significant at $p = 0.05$.

9. Air-dry tuber weights.

The competition effect was significant at $p = 0.05$.

10. Tuber number

The competition effect was rather large but not significant.

11. Height of maize plants.

Only the fertilizer effect was significant.

It should be noted that the presence of competition, namely the associated planting method, instead of the separate planting, always favoured the growth of nutgrass and adversely affected the maize.

It seems that the nutgrass can better compete with maize then it can with its own species.

A salient feature of the above experiment was the fact that the competition effect, evaluated in terms of green maize weight, was much more severe in the fertilized trays than in the unfertilized trays. This suggests that when heavy fertilizer dressings are applied to a mixed population of nutgrass and maize, the nutgrass is able to utilize these nutrients more efficiently than the maize. Despite this efficient nutrient uptake by the nutgrass, it will be noted that in the presence or absence of nutgrass competition, the aerial growth of maize was increased approximately 3 times as a result of the application of fertilizer. In other words, the competitive effect of nutgrass is to a large extent offset by altering the nutrient status of the soil. The above results are applicable to conditions where maize is grown in competition with clipped, well developed nutgrass plants.

12. Competition and nutrient removal.

Composite air-dry herbage samples of maize and nutgrass were analysed. Results reflecting the composition of the herbage are given in Table 51 .

TABLE 51 : CHEMICAL COMPOSITION OF MAIZE AND NUTGRASS

PLANT FRACTION	PROTEIN %	PHOSPHORUS %	CALCIUM %	ASH %
MAIZE				
Associate - Fo	5.2	0.12	0.48	4.85
- F1	4.8	0.14	0.30	7.88
Separate - Fo	7.4	0.13	0.54	10.88
- F1	6.8	0.10	0.40	6.91
NUTGRASS				
Associate - Fo	3.6	0.09	0.48	11.03
- F1	5.8	0.12	0.40	10.38
Separate - Fo	4.2	0.09	0.52	8.89
- F1	7.0	0.14	0.46	9.18

Fertilizer applications increased the protein content of the nutgrass irrespective of the method of planting. Maize, on the other hand, showed no response to fertilizer dressings. In the case of the associate planting method, the reduction in protein content of the maize could be ascribed to active N uptake by the nutgrass. Phosphorus content of maize and nutgrass appeared to increase slightly, while calcium content appeared to decrease as a result of fertilizer treatment. The ash content showed no positive trend.

2) Competition between nutgrass and indicator crops.

The influence of nutgrass on the growth of two test crops, sorghum and cucumbers, was investigated. Nutrients were maintained at a high level to exclude any possible inter species competition. Large polythylene pots, divided by means of welded polysthylene central partitions, were used. Each pot was divided into two completely separated equal parts. The method of planting is similar to that described by Grümmer (1960) namely, associate planting, where nutgrass and indicator crop are planted within each side of the wall (figure 43b) so that root competition is possible and the identical nutgrass and indicator crops are planted separately on each side of the wall (Figure 43a) so that no root competition is possible. Each compartment was filled with the same weight of washed river sand and planted to indicator crop and sprouted nutgrass according to the pattern shown in figure 44, thus giving 4 treatments.

PLANTING METHOD	COMPARTMENT A	COMPARTMENT B
A. Separate planting - No competition.	10 Cucumbers	10 Nutgrass
B. Associate planting - competition.	5 Cucumbers + 5 Nutgrass	5 Cucumbers + 5 Nutgrass
C. Separate planting - No competition	10 Sorghum	10 Nutgrass
D. Associate planting - Competition.	5 Sorghum + nutgrass	5 Sorghum + 5 nutgrass
E. Separate planting - Dividing wall perforated	10 Cucumbers	15 nutgrass

In the case of Treatment E, the nutgrass and cucumbers were separated by means of a perforated dividing wall, thus excluding direct root competition but permitting exchange of nutrient soil solutions. In this treatment, the nutgrass population was increased to 15 plants per compartment. Treatments were replicated 5 times. The pots were kept in the glasshouse. Fertilizer (Compleseal Supra) was applied to all compartments at the rate of 0.2gms, 5 gms and 1 gm per compartment 4 days, 7 days and 14 days after planting, respectively. Tap water was applied daily at a constant rate.

Aerial growth was clipped 27 days after planting and the underground fractions washed and separated and weighed 2 days later. The weights of aerial and underground fractions are given in Appendix Table 31 A,B,C. The mean green weights are shown in Table 52. The aerial weights of both compartments in respect of indicator crop as well as for nutgrass, were bulked together for purposes of statistical analysis. Underground fractions consisted of indicator crop + nutgrass for each treatment.

TABLE 52 : MEAN GREEN WEIGHTS OF INDICATOR CROP AND NUTGRASS IN GRAMS PER POT.

TREATMENT	AERIAL FRACTION			UNDERGROUND FRACTION
	CUCUMBERS	SORGHUM	NUTGRASS	INDICATOR CROP + NUTGRASS
A	42.86		14.06	18.56
B	48.74		16.18	20.78
E	41.06		-	-
C		28.5	14.68	12.02
D		25.3	12.26	10.68

Results

Because of the larger nutgrass population in Treatment E, strict comparisons between this treatment and the remaining treatments are not possible. The results are included for comparative purposes.

Weight of aerial fractions - Cucumbers and Sorghum.

There were no significant differences between the treatments, viz A and B and C and D.

Weight of aerial fractions - nutgrass.

Nutgrass growth was not significantly affected by the method of planting or the competing indicator crop.

Total underground fraction

Treatments A and B (cucumber and nutgrass) did not differ significantly from each other. Treatments C and D (sorghum and nutgrass) also showed no significant differences.

From the above results it would appear that, provided a high nutrient level is maintained, the competitive effects of nutgrass can be largely counteracted. Under the above circumstances, both cucumber and sorghum appeared to be unaffected by a high nutgrass population.

Aerial growth was clipped 27 days after planting and the underground fractions washed and separated and weighed 2 days later. The weights of aerial and underground fractions are given in Appendix Table 31 A,B,C. The mean green weights are shown in Table 52. The aerial weights of both compartments in respect of indicator crop as well as for nutgrass, were bulked together for purposes of statistical analysis. Underground fractions consisted of indicator crop + nutgrass for each treatment.

TABLE 52 : MEAN GREEN WEIGHTS OF INDICATOR CROP AND NUTGRASS IN GRAMS PER POT.

TREATMENT	AERIAL FRACTION			UNDERGROUND FRACTION INDICATOR CROP + NUTGRASS
	CUCUMBERS	SORGHUM	NUTGRASS	
A	42.86		14.06	18.66
B	48.74		16.18	20.78
C	41.06			
C		28.5	14.68	17.02
D		25.3	12.28	10.68

Results

Because of the larger nutgrass population in Treatment C, strict comparisons between this treatment and the remaining treatments are not possible. The results are included for comparative purposes.

Weight of aerial fractions - Cucumbers and Sorghum.

There were no significant differences between the treatments, viz A and B and C and D.

Weight of aerial fractions - nutgrass.

Nutgrass growth was not significantly affected by the method of planting or the competing indicator crop.

Total underground fraction

Treatments A and B (cucumber and nutgrass) did not differ significantly from each other. Treatments C and D (sorghum and nutgrass) also showed no significant differences.

From the above results it would appear that, provided a high nutrient level is maintained, the competitive effects of nutgrass can be largely counteracted. Under the above circumstances, both cucumber and sorghum appeared to be unaffected by a high nutgrass population.

3) Increasing nutgrass populations grown with Sorghum.

To establish the peak level of competition between nutgrass and a test crop grown under a moderate fertility level, increasing populations of nutgrass were planted, together with a constant sorghum population. Sorghum was sown in large polyethylene pots in the presence and absence of increasing nutgrass populations. The latter ranged from 3 - 20 tubers per half pot. The pots were sub-divided by means of polyethylene walls. 5 sorghum seedlings were retained in each sub-divided section. Increasing nutgrass populations were planted in only one half of each pot. Each pot therefore contained a control treatment for the sorghum. Each pot received 1 gm of compleesl per sub-section 4 days after planting. Each treatment was replicated 4 times. Pots were kept in the glasshouse and the herbage clipped 6 weeks after planting. The green weights of nutgrass and sorghum are given in Appendix Table 32 . The corresponding mean values are presented in Table 53 .

Results.

TABLE 53 . GREEN WEIGHT OF SORGHUM HERBAGE GROWN WITH AND WITHOUT NUTGRASS COMPETITION . GRAMS PER POT.

TREATMENT PER HALF POT	WEIGHT OF SORGHUM		WEIGHT OF NUTGRASS
	WITH NUTGRASS	NO NUTGRASS	
1. 3 Tubers	5.62	21.8	17.07
2. 6 "	3.02	24.0	21.35
3. 12 "	1.80	23.0	22.17
4. 15 "	1.75	23.4	29.00
5. 20 "	1.20	23.9	28.10
L.S.D	1.56	-	6.06

Weights of sorghum grown in the absence of nutgrass competition (No nutgrobe), were excluded from the analysis.

The green aerial weight of nutgrass increased significantly with increased rates of planting up to 15 tubers per pot. A further increase to 20 tubers per pot did not influence the aerial growth of nutgrass.

The green weight of sorghum stems were significantly decreased with an increased nutgrass planting density. Increasing the nutgrass tuber population from 3 to 12 decreased the weight of sorghum from 5.62 to 1.80 per pot. A further increase in the number of tubers to 20 per pot, decreased the weight of sorghum by 0.55, which was not significant.

Under moderate fertility levels, nutgrass was able to tolerate severe intra species competition. The growth of sorghum however was markedly reduced by increased competition from nutgrass. The important role of nutrient supply under these highly competitive conditions is borne out by the results obtained in the experiment.

4) Increasing nutgrass populations.

Increasing populations of sprouted nutgrass tubers were planted in clay pots (15 cms in diameter) filled with a soil mixture (equal parts of washed river sand and Bethal sand loam). Nutgrass populations ranged from 1 to 24 plants per pot, and each treatment was replicated three times. Pots were kept in the glasshouse. Aerial and underground fractions were harvested and separated 6 weeks after planting. Air-dry weights (grams per pot) for each fraction are given in Appendix Table 33 and the mean values presented in Table 54 .

TABLE 54 : INFLUENCE OF POPULATION DENSITY ON THE GROWTH OF NUTGRASS.(GRAMS PER POT)

TUBERS PER POT	AIR-DRY WEIGHT OF		NUMBER OF TUBERS
	AERIAL	UNDERGROUND*	
1	0.31	0.02	10.6
2	0.70	0.70	19.6
4	0.97	2.45	33.0
8	0.99	2.05	37.6
16	1.84	5.25	70.6
24	1.32	4.30	77.0
L.S.D	0.84	2.02	13.13

*Tubers and roots.

Increased density of planting up to 16 plants per pot, significantly increased the total number of tubers produced per pot, after which the rate of increase appeared to fall. The number of tubers produced per plant was 10.6, 9.8, 8.2, 4.7, 4.4, and 3.2 per pot containing 1, 2, 4, 8, 16 and 24 plants respectively.

The underground weights increased up to 16 plants per pot, at which stage the maximum weight had apparently been realised. The air-dry weights of nutgrass revealed a very similar type of response to that of the underground weights.

The results confirm the ability of nutgrass to tolerate severe intra species competition. While the tuber population per plant decreased, the total tuber population per pot increased with increased populations of nutgrass plants. Where 24 tubers were planted in a pot (15 cm diameter), a total of 77 tubers were removed after a growing period of 6 weeks during March to April. Despite shorter day lengths and reduced temperatures, the production of tubers during the autumn period is therefore possible. These results confirm the findings of Rahn et al. (1962).

5) Water Consumption.

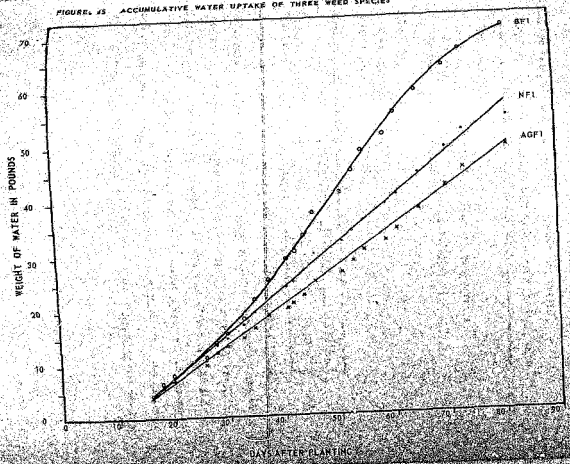
Water and nutrient uptake are two factors which influence plant competition. Two trials were conducted in which the nutrient and water uptake of nutgrass and two common annual weeds were compared. In the first trial, the weeds were grown under two levels of fertility and in the second trial the three weeds were grown in competition with maize.

(a) Water consumption of three weed species grown under two levels of fertility.

The water consumption of three weed species, namely, nutgrass, Eleusine indica and Tagetes minuta was investigated in a pot experiment. The weeds were grown under two levels of fertility, viz. no fertilizer and 900 lbs. of Compossal per acre applied at planting (Fo and F1).

Large polyethylene buckets, 24 cms in diameter x 28 cms high were filled with soil removed from a Trachypogon - Other Species grassland at Frankenwald. The soil was brought to field capacity. Young weed seedlings obtained in the field and sprouted nutgrass tubers were planted at the rate of 12 per bucket on 29/12/16. Each treatment (3 weed species x 2 levels of fertility) was replicated 4 times and arranged at random in the open air. An unplanted control was included in each replicate. The weight of each bucket was recorded on a spring balance and raised daily to a constant level. A calculated volume of water based on the recorded rainfall, following each precipitation, was included in the total water consumption for each bucket. Rainfall was recorded on a rain gauge situated next to the experiment. Daily and accumulative water consumption for each weed species and the evaporational losses from the control treatments are given in Appendix Table 34. The mean seasonal water consumption is given in Table 55, and graphically presented in Figure 45.

FIGURE 15 ACCUMULATIVE WATER UPTAKE OF THREE WEED SPECIES



A. G. - Eleusine indica
N - Nutgrass
B - Tagetes minuta
F. - 900 lbs Compound per acre

The trial was terminated 12 weeks after planting. Weed stems were clipped at ground level and the roots removed and washed. The air dry weights of stems and roots are given in Appendix Table 35 and the means in Table 56 . The data have been analysed according to a factorial design from which the unplanted controls have been excluded.

During the initial experimental stages, the growth of Eleusine was poor, especially on the unfertilized buckets. The same symptoms, but to a less marked degree, were revealed by the nutgrass. Growth of Tagetes however was vigorous and unaffected throughout the trial.

TABLE 55 L MEAN SEASONAL WATER CONSUMPTION OF THREE WEED SPECIES IN LBS PER BUCKET.

Weed Species

1. Nutgrass	-	44.83	L.S.D for Weed Species
2. Eleusine	-	40.27	
3. Tagetes	-	58.13	p =(0.05)- 3.56

Fertilizer

1. No fertilizer	37.77
2. Fertilizer	57.71

Fertilizer x Weed Species.

	NUTGRASS	ELEUSINE	TAGETES
No fertilizer	35.59	32.65	45.08
Fertilizer	54.07	47.88	71.19

The total water consumed by the three weed species differed significantly from one another. Fertilizer application increased the water consumption by 20 lbs per bucket on the average. The effect of fertilizer was not the same with all weed species, the greatest effect viz. 26 lbs per bucket being shown by Tagetes, and the smallest effect viz 15 lbs per bucket by the annual grass. The interaction was significant. The pattern of water consumption for Tagetes differed from that of Eleusine and nutgrass (figure 45).

TABLE 56 :A.MEAN AIR-DRY WEIGHT OF WEED STEMS IN GRAMS PER BUCKET.

Weed Species

1. Nutgrass	-	71.3
2. Eleusine	-	64.2
3. Tagetes	-	69.0

Fertilizer

1. No fertilizer	51.4
2. Fertilizer	84.9

Fertilizer x Weed Species.

	NUTGRASS	ELEUSINE	TAGETES
No fertilizer	53.2	53.6	47.4
Fertilizer	89.3	74.8	90.5

TABLE 56 :B.MEAN AIR-DRY WEIGHT OF ROOTS IN GMS PER BUCKET.

Weed Species. L.S.D for Weed Species p =(0.05)= 9.55

1. Nutgrass	-	53.0
2. Eleusine	-	30.5
3. Tagetes	-	10.2

Fertilizer.

1. No fertilizer	23.2
2. Fertilizer	39.3

Fertilizer x Weed Species.

	NUTGRASS	ELEUSINE	TAGETES
No fertilizer	37.2	26.6	5.9
Fertilizer	68.9	34.4	14.5

Fertilizer was the only factor which significantly influenced the air-dry weight of the weed stems. All the weed species differed significantly from one another in respect of air dry weights of root material, nutgrass producing the highest and Tagetes the lowest. The response to fertilizer treatment was much larger in the case of nutgrass (31 grams per bucket) than in the case of Eleusine and Tagetes. The total air-dry plant weight (stems and roots) of nutgrass was higher than that of Eleusine and Tagetes.

(b) Water consumption of three weed species grown with maize.

The comparative water uptake of three principal weed species, grown in conjunction with maize, was investigated in a glasshouse experiment. Liberal water and nutrient levels in the buckets were maintained throughout the duration of the trial.

White polythene buckets, 24 cms diameter and 28 cms high, were filled with a uniform volume of Frankenwald soil. The soil was brought to field capacity.

Young seedlings of Tagetes minuta, or Eleusine indica or sprouted nutgrass tubers were planted in each bucket, together with maize (SA4) thinning out to six weed plants and six maize plants per bucket. All buckets received the equivalent of 1000 lbs per acre of Complesal Supra prior to planting, 14/1/65. A second fertilizer treatment equivalent to 3000 lbs per acre Complesal was made 38 days later when the maize plants revealed incipient deficiency symptoms. Treatments were replicated 5 times. The 15 buckets were placed at random in the glasshouse. The weight of each bucket was recorded daily on a spring balance and raised to a constant level. Daily water consumption was calculated and the results based on the totals of the 5 replications are shown in Appendix Table 36 and Fig.46. The mean water consumption for the three treatments is given in Table 57. The trial was terminated 9 weeks after planting when the maize and weeds were clipped at ground level. Green and air-dry weights for the various plant fractions are given in Appendix Table 37 and the means in Table 57 . As separation of the maize and weed roots was not possible, fresh and air-dry root weights refer to the combined weights of the weed and maize. These results are included in Appendix Table 37 .

Results.

Using the maize as an indicator of competition, the effect of the weed species was Eleusine >= Nutgrass >= Tagetes. Aerial growth of Tagetes was poor. Eleusine grew very vigorously, forming a dense canopy over the soil surface. Nutgrass tended to produce long leaves in contrast to the shorter upright forms normally produced under field conditions. (See Figure 47).

FIGURE 46 - ACCUMULATIVE WATER CONSUMPTION OF 60 NUTGRASS AND 30 MAIZE PLANTS. (TOTAL OF 5 REPLICATIONS).





FIGURE 47: Moisture studies. Growth of maize and 3 weed species.

The emergence of the inflorescence of the three weed species was as follows:-

Nutgrass 26 days after planting

Eleusine 33 " " "

Tagetes 36 " " "

TABLE 57 : MEAN WATER CONSUMPTION AND WEIGHTS OF 3 WEED SPECIES GROWN IN COMPETITION WITH MAIZE.

PLANT FRACTION	WEED SPECIES			L.S.D p=0.05
	NUTGRASS	TAGETES	ELEUSINE	
1. Water consumption in lbs per bucket	71.3	71.92	72.84	N.S
2. Maize - green weight of stems, ozs per bucket.	14.58	16.75	8.65	5.07
3. Maize - air-dry weight of stems, gms per bucket.	45.00	42.88	28.06	11.5
4. Weeds - green weight of stems, ozs per bucket.	4.69	2.09	8.46	2.3
5. Weeds - air-dry weight of stems, gms per bucket.	23.98	13.18	59.82	10.9
6. Maize + weed roots air-dry weight, gms per bucket.	64.72	36.22	37.86	15.9
7. Maize + weed stems -air dry weight, gms per bucket.	69.0	56.1	87.9	
8. Maize + weed combined stems + roots. Air-dry weight, gms per bucket.	133.72	92.32	125.76	

Composite air-dry herbage samples of maize and weeds as well as the total roots were analysed. Those results, together with the respective weights of nutrient are shown in Table 58 . Weights of material are expressed as grams per bucket x 100.

TABLE 58 : CHEMICAL COMPOSITION AND WEIGHT OF NUTRIENT REMOVED BY 3 WEED SPECIES. (GRAMS x 100)

PLANT FRACTION	PROTEIN		PHOSPHORUS	
	%	WEIGHT	%	WEIGHT
Nutgrass + Maize				
1. Maize stems	10.8	486.000	0.19	8.55
2. Nutgrass stems	12.4	297.352	0.25	5.995
3. Roots	5.2	336.544	0.10	6.472
Total		1119.896		21.017
Elausine + Maize				
1. Maize stems	9.8	274.988	0.28	7.857
2. Elausine stems	11.2	669.994	0.27	16.151
3. Roots	3.4	129.724	0.10	3.786
Total		1073.696		27.794
Tagetes + Maize				
1. Maize stems	14.0	600.32	0.29	12.435
2. Tagetes stems	6.8	696.24	0.13	1.713
3. Roots	18.6	673.292	0.07	2.535
Total		1363.636		16.683

The percentage protein of the maize grown in competition with Tagetes showed a strong inverse relationship to the composition of its partner weed. Whereas Tagetes contained the lowest percent of protein of the three weed species, the maize in these pots contained the highest percent of protein. This applied to both stems and roots. The highest weight of protein was found in both the stems and roots of maize growing in competition with Tagetes, the lowest weight of protein in maize growing in competition with Elausine, with nutgrass being intermediary.

Phosphorus uptake by the maize stems growing in competition with Tagetes was greater than that absorbed by the weed stems. Total weight of phosphorus in the maize stems, however, was highest with maize growing in competition with Tagetes.

The results of the trial may be summarized as follows:-

1. Total water consumption.

There were no significant differences among the three treatments. In general, the total water lost from each bucket remained a constant, irrespective of the weed which was competing with the maize.

2. Green and air-dry weights of maize stems.

Maize competing with Eleusine indica produced a significantly lower weight of maize stems than maize growing with nutgrass or Tagetes minuta.

3. Green and air-dry weights of weed stems.

All weeds differed significantly from one another. Eleusine produced the largest and Tagetes the smallest.

4. Air-dry weight of roots (maize + weeds).

The combined root weights of maize + nutgrass was significantly higher than the weights of maize plus each of the corresponding weed species.

5. Combined air-dry stems or stems + roots of maize + weeds.

There was evidence of a constant factor per bucket.

6. Comparative competition of the weed species.

Eleusine was responsible for the lowest maize yield, but produced the highest aerial stem weight. Since the total water consumption remained a constant, the evidence would strongly indicate that Eleusine can, under optimum nutrient conditions, utilize, withdraw or prohibit the uptake of these nutrients by the maize which, in turn, might influence directly or indirectly the uptake of moisture by this crop. At a similar population level, namely, 6 plants per bucket, nutgrass did not compete as actively with the maize as did Eleusine.

Summary of Direct Competition Studies.

A series of experiments were conducted to establish the influence of nutgrass on the growth and development of a number of test crops.

Various techniques were employed to investigate the nature of the competition. The results revealed that nutrient competition was of primary importance. Where liberal applications of nutrients (presumably nitrogen) were made, ~~the influence of~~ nutgrass did not exert a suppressive influence on crop growth.

The effects of competition could thus be explained in terms of nutrient competition (Welbank 1960).

Total water uptake by the nutgrass in both moisture studies was not significantly higher than that of the other two weed species. In both moisture studies, however, it was evident that the underground weights of nutgrass were comparatively heavier than those of the two weed species.

8. INDIRECT COMPETITION.

The experimental data presented in this section refer to investigations of the possible role of toxic substances produced by nutgrass, which could be responsible for reduction of crop growth. The competitive behaviour of nutgrass in the field suggests that if toxic plant excretion was to be of any biological significance in determining this inter-relationship, the substance or substances should be present in readily detectable concentrations of reasonable stability and freely available in the soil solution.

The results of a number of laboratory and glasshouse tests have been evaluated from the standpoint of growth response of selected indicator crops in terms of germination, root and stem elongation and seedling weight. The object of these studies was not to identify, but to establish a qualitive effect which, if responsible for the competition, should be present and detectable in macroquantities.

1. Growth regulators in the tubers.

Field observations have revealed that seedling emergence of most crops, especially maize and sorghum, when sown in nutgrass infested sites, are severely effected after emergence. Delayed or poor germination coupled with a retarded initial growth and incipient nutrient deficiency symptoms are normally evident. To clarify this problem, the seeds of three crops were sown in the presence (+ T) and absence (-T) of nutgrass tubers, and at increasing intervals after the nutgrass tubers had been planted.

Galvanised trays, approximately 1½ inches deep, were filled with washed river sand and planted to unsprouted nutgrass tubers.

The latter were planted at density rates which ensured thorough blanket covering of the sand surface. Tubers were covered with a ½" layer of sand after planting. The seed was sown on this sand layer and covered. For each treatment, unplanted nutgrass trays served as control. The number of tubers per tray varied in each test. Four dates of seeding were used in each test, namely, simultaneous (crop + nutgrass) and three staggered planting times. After sowing, the trays were kept in the laboratory on benches and covered with transparent polethylene sheeting until emergence.

Emergence rate, length and weight of seedling were recorded. Seedlings were considered as having germinated after breaking through the sand surface. Seedling stem lengths were measured after clipping, with the exception of Test (b) where lengths were recorded during growth. Seedling length refers to the distance between the apex of the coleoptile or hypocotyl and the respective base. Weights refer to green weights. Three experiments were carried out.

The t-test for unequal samples (+T vs -T) (Patterson 1939) has been applied in respect of seedling stem lengths only. Significance is indicated by an asterisk*. N.S indicates not significant. The voluminous Appendix Tables reflecting original data have been omitted for all three tests.

Test 1.

Weight of tubers per tray was not constant. The trays were uniformly covered with nutgrass. Two rows of sorghum (12 seeds per row) and 2 rows of sunflower (12 seeds per row) were sown in each tray, with and without nutgrass tubers as follows:-

I - 0 days after planting of nutgrass tubers.

II - 1 " " " " " "

III - 4 " " " " " "

IV - 6 " " " " " "

Mean rates of emergence, seedling stem length and weights are given in Table 59 .

TABLE 59 : MEAN LENGTHS AND WEIGHTS OF SORGHUM AND SUNFLOWER STEMS.

DAYS AFTER TUBERS PLANTED	DAYS AFTER SOWING CROP	LENGTHS (CMS)		NUMBER GERMINATED/ROW		WEIGHT PER STEM (GMS)	
		+T	-T	+T	-T	+T	-T
SORGHUM							
I 0	7	4.96	2.75*	8	4.5	0.078	0.047
II 1	6	4.25	2.77*	12	8.5	0.074	0.053
III 4	11	9.16	7.62NS	7	4.5	0.059	0.054
IV 6	9	6.37	5.35NS	9	4.0	0.040	0.009
SUNFLOWER							
I 0	7	8.94	5.85*	10	6.5	0.875	0.703
II 1	6	9.27	7.06*	11.5	9.0	0.838	0.684
III 4	11	15.87	17.51NS	9.0	4.0	0.822	0.643
IV 6	9	14.33	9.25*	9.5	5.5	0.624	0.465

Test 2.

400 grams of tubers were planted per tray. 5 rows of sorghum (22 seed per row) and 5 rows of sunflower (12 seeds per row) were sown in each tray with and without nutgrass tubers as follows:

I - 0 days after planting of nutgrass tubers

II - 1 day " " " "

III - 2 days " " " "

IV - 4 " " " " "

Mean rates of emergence, seedling stem length and weight are given in Table 60 and Table 61. Stem lengths of the growing seedlings were recorded in this test. 4 rows of each indicator crop were harvested.

TABLE 66 : RATE OF GERMINATION FOR SORGHUM AND SUNFLOWER(NUMBER PER ROW)

TREATMENT SEEDING IN DAYS	GROWN WITH	SORGHUM DAYS AFTER FIRST SOWING									
		4	4	5	6	7	8	9	10	11	13
I 0	+T +										
	Nutgrass	8.6		15.8	18.6	18.8					
	-T -										
	Nutgrass	3.4		18.2	20.8	21.0					
II 1	+T +										
	Nutgrass	0.2		8.4	15.7	19.4	-	-	20		
	-T -										
	Nutgrass	0.0		0.0	11.0	19.0	-	-	21		
III 2	+T +										
	Nutgrass				0.4	0.8	1.4	-	-	16.6	
	-T -										
	Nutgrass				1.2	13.8	20.2	-	-	20.8	
IV 4	+T +										
	Nutgrass							0.4	8.8	-	19.6
	-T -										
	Nutgrass							18.2	20.6	-	20.8

		SUNFLOWER									
I 0	+T +										
	Nutgrass	8.8	11.4	11.8	12.0	12.0					
	-T -										
	Nutgrass	1.6	7.4	10.8	11.8	12.0					
II 1	+T +										
	Nutgrass		3.6	11.4	11.8	11.8	-	-	11.8		
	-T -										
	Nutgrass		0	0	8.0	9.4	-	-	11.4		
III 2	+T +										
	Nutgrass				5.8	6.4	7.0	-	-	7.6	
IV 4	+T +				4.2	11.8	12.0	-	-		
	Nutgrass							2.2	5.4	12.0	9.6
	-T -										
	Nutgrass							11.6	11.6		11.6

TABLE 61 : MEAN LENGTHS AND WEIGHTS OF SORGHUM AND SUNFLOWER STEMS

SORGHUM

TREATMENTS SEEDING IN DAYS.	STEM LENGTH IN CMS						NUMBER GERMINATED						WEIGHT IN GMS	
	1ST x		2ND x		3RD x		1ST		2ND		3RD			
	+T	-T	+T	-T	+T	-T	+T	-T	+T	-T	+T	-T	+T	-T
I 0	2.62	1.49*	4.72	2.60*	11.76	5.87*	18.6	20.6	18.0	21.0	19.6	20.6	0.084	0.060
II 1	2.93	1.96*	11.54	10.91*	-	-	19.2	19.0	21.0	21.0			0.079	0.054
III 2	3.17	3.60NS	8.31	10.36*	-	-	1.4	20.0	16.6	20.8			0.442	0 073
IV 4	1.32	3.26*	4.78	8.58*	-	-	8.8	20.6	19.6	20.6			0.049	0.073

SUNFLOWER

I 0	11.21	9.10*	13.82	12.16*	-	-	12.0	12.0	12.0	11.6			0.729	0.621
II 1	8.11	4.76*	14.73	11.29*	-	-	11.8	9.4	12.0	11.4			0.736	0.580
III 2	10.29	9.75NS	14.53	14.83NS	-	-	7.0	12.0	7.6	12.0			0.821	0.779
IV 4	3.68	8.41*	9.44	15.63*	-	-	5.4	11.6	9.6	11.6			0.559	0.871

x NUMBER OF DAYS AFTER GERMINATION FOR RECORDING STEM LENGTH AND GERMINATION

	SORGHUM			SUNFLOWER	
	1	2	3	1	2
I 0	6	7	9	7	9
II 1	6	12		6	12
III 2	6	12		6	9
IV 4	6	9		6	9

Test 3.

175 grams of tubers were planted per tray. 5 rows of sorghum (18 seeds per row) and 5 rows of maize (10 seeds per row) were sown in each tray with an without nutgrass tubers, as follows.

I - 0 days after planting of nutgrass tubers

II -1 " " " " " "

III -2 " " " " " "

IV -3 " " " " " "

Means seedling stem lengths are given in Table .

TABLE 62 : MEAN LENGTHS AND WEIGHTS OF SORGHUM AND MAIZE STEMS

SORGHUM

DAYS AFTER PLANTING	LENGTH (CMS)		NUMBER GERMINATED 1 ROW		WEIGHT PER STEM (GMS)	
	+T	-T	+T	-T	+T	-T
0	8.36	8.85 N.S	15.3	16.5	0.058	0.061
1	7.04	6.81 N.S	15.3	16.8	0.057	0.054
2	6.10	7.05*	15.8	10.3	0.066	0.086
3	6.35	7.97*	16.5	16.3	0.037	0.054

MAIZE

0	13.14	12.95 N.S	9.8	9.3	0.559	0.569
1	11.05	10.65 N.S	9.8	10.5	0.529	0.474
2	11.45	11.19 N.S	9.8	9.8	0.507	0.447
3	12.39	12.91 N.S	9.8	10.0	0.506	0.526

The results obtained on the three tests, reveal a certain trend which may be summarised as follows:-

1) Date of emergence.

Planting of sorghum and sunflower together with nutgrass tubers (0 and 1 days) appeared to stimulate the emergence rate of both sorghum and sunflower. When sowing was delayed, 3 - 4 days after the nutgrass tubers had been planted, a *reverse* behaviour pattern was evident, namely a retardation of sunflower and sorghum germination. The final number of seedlings to emerge in a particular test was not apparently affected by the nutgrass.

2) Length of seedling.

Seedling length of sorghum and sunflower recorded, either during the growing period or after clipping, was closely related to the method and time of seeding. The final length of sorghum and sunflower seedlings

sown with nutgrass (0 and 1 days) were longer than seedlings grown in the absence of nutgrass. Delayed seeding with nutgrass caused a growth suppression of sorghum and sunflower, particularly in Test 2.

The degree of stimulation or inhibition appears to be related to the nutgrass tuber planting density. The most pronounced inhibition was found in Test 2 where 400 grams of tubers were planted, followed by Test 1. Response in Test 3 was not very pronounced. [illegible] appeared to be insensitive to the population density of nutgrass in Test 3.

3) Weight of seedlings.

The weight of seedling showed a similar trend to that of seedling length and appears to be a more sensitive means of measuring treatment responses.

2. Aqueous extracts and homogenates of plant material.

In the early experiments, the extracts were prepared by cutting the plant material into ½" - ¼" segments, adding tap water and blending known concentrations of the segmented material by means of a low frequency mixer for a period of 10 minutes. The supernatant slurries or extracts so produced, were applied without filtering directly to the indicator crops which had been seeded in germinating trays, pots or petri dishes filled with sand. This experimental series is referred to as "Aqueous extracts".

The second series of tests were conducted with aqueous homogenates prepared in a Janke and Kunkel Turax homogeniser. The homogenates were blended for approximately 3 - 4 minutes with distilled water, filtered through cheese cloth and screened for inhibitory properties. The homogenates were applied to several indicator crops grown in petri dishes incubated at 28°C. Seedling lengths are given in cms. This experimental series is referred to as "Aqueous homogenates". In all the extract tests, tap water was applied as a control while for the homogenate tests distilled water was used. To avoid degradation by microbial decomposition, extracts and homogenates were stored at 0°C. - 3°C.

With the exception of "Aqueous Extract Test 2" the experimental data of the remaining series of experiments appearing in this chapter, have not been included in the Appendix. Statistical analysis of the data has not been undertaken. Mean values have been presented throughout

2.(a) Aqueous extracts.

The series consisted of 6 tests which were designed to establish the degree of growth inhibition exercised by extracts of nutgrass on certain indicator crops. It was necessary to screen various concentrations of nutgrass extracts and compare the influence of such extracts with those of other weed species, i.e. C.rotundus, Eleusine indica, etc., using both aerial and underground fractions. In an effort to obtain a sensitive response to the extracts, a large number of test crops were examined. Extracts prepared from both washed and unwashed plant material were also compared.

Test 1.

A 50% slurry was prepared from dry dormant nutgrass tubers and roots. The latter was applied at a constant volume to the seeds of several test crops placed on filter paper in petri dishes and incubated at 28°C. Sorghum seedlings showed the most marked sensitivity to the aqueous nutgrass extracts resulting in a growth inhibition of coleoptile and roots.

Test 2.

Concentrated water extracts (50%) of freshly harvested nutgrass tubers, roots and stem were applied to the seeds of 4 test crops placed on filter paper in germinating trays. The pH of the extracts were as follows:-

Roots - 6.38
Stems - 5.35
Tubers - 4.30

The extracts were stored in dark bottles at 5°C and applied to the 3 test crop seeds 4 days after preparation. 50 seeds of maize and sunflower and 100 seeds of sorghum were planted in each germinating tray. The filter paper was saturated with each respective slurry and the treatments were replicated 4 times. The treated seed was covered with filter paper and placed in a dark germinating chamber maintained at 20°C (16 hours) and 30°C (8 hours).

Tap water was applied to the controls and to the treated trays. An assessment of seedling growth was made 6 days after planting. The mean ratings of 4 replications are given in Table 63 . 8 days after planting, the seedlings were clipped at the stem base. 25 seedlings selected at random from each tray were measured. The results are given in Appendix Table 38 and the means in Table 64 .

Results:

TABLE 63 : INFLUENCE OF NUTGRASS EXTRACTS ON THE GROWTH OF 3 TEST CROPS. RATING OF SEEDLINGS - MEANS OF 4 REPLICATIONS.

TREATMENT	MAIZE	SORGHUM	SUNFLOWER
Tuber Extract	5	3	1
Stem Extract	3	4	1
Root Extract	6	6	3
Control	10	10	10

0 = No growth
10 = Growth of controls

Extracts of all three plant fractions inhibited stem growth of the three species, with sunflower showing particular sensitivity. The degree of inhibition was more pronounced with the tuber and stem extracts. Root growth of sorghum was severely retarded by the tuber and stem extracts.

TABLE 64 : INFLUENCE OF NUTGRASS EXTRACTS ON THE GERMINATION AND STEM LENGTHS OF 3 TEST CROPS (LENGTH IN CMS).

Means per Replication

	MAIZE			SORGHUM			SUNFLOWER		
	% Germination Tran.	Act.	Length	% Germination Tran.	Act.	Length	% Germination Tran.	Act.	Length
Tuber extract	77.99	95.5	1.82	71.61	89.8	2.30	60.52	75.5	1.36
Stem "	71.28	89.5	1.71	75.27	93.5	2.45	61.42	77.0	0.91
Root "	70.33	88	2.78	70.36	88.5	3.38	53.02	63.5	2.77
Control	76.92	94.5	4.75	70.93	89.3	4.00	67.59	86	5.88
L.S.D p = 0.05 N.S			0.65	N.S		N.S	7.77		1.41

Seedling stem lengths

a) Length of Sunflower.

All extracts produced significantly shorter stems than the control. Nutgrass tuber and stem extracts gave significantly shorter sunflower stems than the root extract.

b) Length of maize

All nutgrass extracts significantly affected growth, tuber and stem extracts being more drastic than root extract.

c) Length of sorghum
effect
Treatment/was not significant. The variation was very high.

Percent germination of seeds (Angular Transformation)
effect
1) Maize and sorghum The treatment/was not significant.

2) Sunflower The root extract significantly decreased germination.

Test 3.

Extracts containing 15% plant material were prepared from the stems and roots of three freshly harvested weed species, namely, C.esculentus (pre-flowering stage), C.rotundus (flowering stage) and Eleusine indica (flowering stage). Sorghum, radish and hairy vetch were seeded in moist sand in small polyethylene pots. Extracts were applied twice (50 mls after seeding followed by 50 mls 4 days later). Treatments were replicated twice. Pots were kept in the glasshouse. The pH of each extract was as follows:-

Eleusine indica stems	4.8
Eleusine indica roots	6.8
Cyperus esculentus stems	7.1
Cyperus esculentus runts	6.3
Cyperus rotundus stems	6.7
Cyperus rotundus roots	6.7

Stem lengths refer to the means of the two replications per treatment. The response of the three indicator crops to the six aqueous extracts are given in Table 65 .

TABLE 65 : INFLUENCE OF PLANT EXTRACTS ON THE LENGTH (INCHES) OF 3 TEST CROPS.MEANS PER 2 REPLICATIONS.

TEST CROPS	C.esculentus		C.rotundus		Eleusine		Control
	Stems	Roots	Stems	Roots	Stems	Roots	
Sorghum No.Germ.	22.5	22.5	22.5	22.5	23.0	21.0	22.5
Stem length	6.12	5.88	6.03	5.49	5.74	6.07	6.22
Radish No.Germ.	24.5	22.5	22.0	23.0	19.5	21.5	21.5
Stem length	3.[illegible]	3.98	4.32	3.82	2.30	4.0	3.89
Hairy Vetch No.	22.[illegible]	22.0	22.0	23.0	22.0	22.0	21.5
Germ.							
Stem length	5.[illegible]	9.08	9.41	9.46	7.81	9.64	9.74

No. = Number

With the exception of Eleusine stem extracts, there was no marked difference among the various extracts with regard to the emergence or growth of the 3 indicator crops. The inhibitory effect attributable to Eleusine stems appeared to be linked with the pH of this particular extract.

Test 4.

Sorghum, cucumber, radish and peas were sown in germination trays filled with sterilised river sand, at the rate of 4 rows x 8 seeds per tray. Aqueous extracts of roots and stems of grass (5 - 8 leaf stage) and nutgrass (5 - 8 leaf stage)were prepared. Rate of extract application was 250 mls immediately after planting followed by a further 250 mls one day later. The radish seedlings were cut 7 days, the cucumbers and peas on 9 days and the sorghum, 10 days after sowing, respectively. Length and weights of stems are shown in Table 66.

Emergence of seedlings was not markedly influenced by the various extracts. All the test crops showed distinct increases in stem length as a result of the addition of aqueous extracts, with root extracts of both nutgrass and grass consistently producing favourable stimulation.

TABLE 66 : INFLUENCE OF PLANT EXTRACTS ON THE LENGTH (CMS) OF 3 TEST CROPS MEANS PER 2 REPLICATIONS.

TREATMENT	SORGHUM			CUCUMBER			RADISH			PEAS		
	NUM.	STEM		NUM.	STEM		NUM.	STEM		NUM.	STEM	
	GERM.	LENGTH	WEIGHT	GERM.	LENGTH	WEIGHT	GERM.	LENGTH	WEIGHT	GERM	LENGTH	WEIGHT
Nutgrass roots (31.5%)	7.2	5.73	0.06	7.5	7.53	0.23	7.5	9.11	0.19	7.8	14.85	0.44
Nutgrass stems (16.8%)	7.2	5.63	0.06	7.2	7.64	0.24	7.8	8.16	0.19	7.5	15.52	0.43
Grass roots (25%)	8.0	5.19	0.05	8.5	7.48	0.23	7.3	9.41	0.22	6,5	13,98	0.36
Grass stems (15.3%)	6.8	5.06	0.05	7.5	7.10	0.20	7.6	7.78	0.17	7.8	14.11	0.43
Control	7.2	4.52	0.05	7.8	5.74	0.18	6.3	6.54	0.15	8.0	12.73	0.35

* NUM. = NUMBER.

Test 5.

Various aqueous stem and root extracts of nutgrass and Eleusine indica (see Table 67) were prepared from freshly harvested plant material. Root material was divided into washed and non-washed fractions. Washed roots were immersed in tap water for a period of 15 minutes, changing the water once every three minutes. The extracts were applied to beans, seeded at the rate of 15 seeds in small polyethylene pots. The treatments were replicated three times and the buckets placed in the glasshouse. Extracts were applied at planting (150 ml: per pot)and on three consecutive days (25 ml par pot per day). The mean number of germinated beans per pot and the respective stem lengths and weights per seedling are given in Table 67 .

TABLE 67 : INFLUENCE OF PLANT EXTRACTS ON STEM LENGTHS (CMS) AND WEIGHTS (GRAMS) OF BEANS. MEANS FOR 3 REPLICATIONS.

TREATMENT	NUMBER GERMINATED	STEM LENGTH	STEM WEIGHT
1.Nutgrass stems -Unwashed 15.0%	14.0	20.00	3.08
2.Nutgrass roots -Unwashed 15.0%	10.7	16.88	3.20
3.Nutgrass roots -Washed 15.0%	12.3	28.00	3.40
4.Eleusine stems-Unwashed 15.0%	11.3	27.27	3.64
5.Eleusine roots-Unwashed 11.3%	12.7	20.78	2.93
6.Eleusine roots - Washed 11.3%	11.0	27.27	2.91
7 Control	9.3	21.82	2.61

No marked differences in the emergence of beans were evident. There were indications of a growth stimulation with washed roots of nutgrass and grass, as well as with unwashed grass stems in respect of stem length. A slight inhibition of bean stem length was evident with unwashed nutgrass root extracts. Weights per bean stem showed no marked treatment variance, but were all higher than the controls. The latter emerged more slowly and were consistently smaller than the beans receiving extracts.

Test 6.

Stem and root extracts containing 4.8% of freshly harvested nutgrass and teff (Eragrostis tef') were prepared and applied to beans, sorghum and lucerne sown in rows in sterilised river sand in galvanised metal trays. 200 mls of extract were applied daily for four days. Each tray contained 4 rows of each test crop. 10 beans, 10 sorghum and 15 lucerne seeds were sown per row. Lucerne, beans and sorghum were clipped and measured 7, 8 and 9 days after sowing respectively. Trays were kept in the laboratory. The pH of each extract was as follows:-

Nutgrass stems	5.5
Nutgrass roots	5.4
Teff stems	4.4
Teff roots	5.9
Water	7.5

Response of the three indicator crops to the 4 aqueous extracts is shown in Table 68 . Stem weights and lengths are based on the means of the 4 rows for each test crop.

TABLE 68 : INFLUENCE OF PLANT EXTRACTS ON THE STEM LENGTH (INCHES) OF 3 TEST CROPS. MEANS OF 4 ROWS PER SINGLE REPLICATE.

TEST CROP	Extract				CONTROL
	NUTGRASS		TEFF		
	Stems	Roots	Stems	Roots	
Sorghum - No. germinated	8.0	9.3	8.8	9.3	9.3
Stem length*	3.35	3.35	3.86	3.65	3.70
Beans - No. germinated	9.8	10	10	10	9.8
Stem length*	8.41	10.30	8.28	8.21	10.31
Lucerne - No.germinated	14.0	13.0	12.5	13.8	13.4
Stem length*	0.93	1.07	1.01	1.06	1.08

The results in Table 68 show that emergence of the three indicator crops was not arrested by the application of the 4 aqueous extracts.

Nutgrass stem and root extracts appear to have slightly reduced sorghum coleoptile length. A similar response is revealed by the bean hypocotyle. Lucerne showed no response to treatment.

Summary.

The results obtained in this series confirmed that whereas highly concentrated aqueous extracts of nutgrass stems, roots and tubers caused marked growth inhibition of a number of crop seedlings, this effect was less pronounced when the concentration of plant material was reduced. In several cases, there was evidence of a growth stimulation when aqueous extracts, especially underground material, were applied.

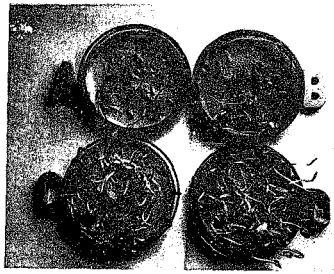


FIGURE 48: Influence of aqueous homogenates on the germination and growth of cucumber. A - Root, B - Tubers, C - Control, D - Rhizome.

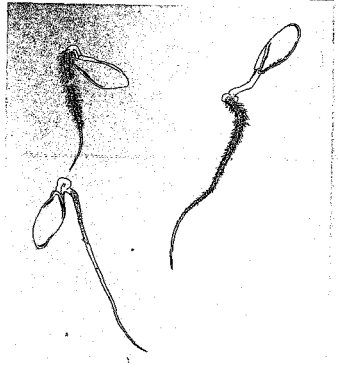


FIGURE 49: Influence of aqueous homogenates of nutgrass roots on the growth of cucumbers. Note absence of root hairs, bottom left.



omogenates on the
of cucumber.
C - Control



homogenates of
growth of cucumbers.
heirs, bottom left.

2(b) Aqueous homogenates.

In this particular series, the influence of C.esculentus homogenates on the germination and growth of a number of selected test crops was investigated. The homogenates were filtered and in certain cases centrifuged prior to the treatment of the test crops.

Test 1.

Nutgrass in the 6 - 8 leaf stage was permitted to dry for 4 hours. 10% homogenates of the roots, rhizomes and tubers were prepared. The homogenates were filtered and centrifuged in a Gallenkamp centrifuge at 2,500 r.p.m for 20 minutes. Supernatant liquid was decanted. The pH of each homogenate was as follows:

Roots	5.7
Tubers	5.7
Rhizomes	5.7

The homogenates were stored overnight and applied to test seeds. The latter were placed on filter paper in standard 10 cm diameter petri dishes. 2.5 mls of homogenate were applied to the filter paper and 2.5/subsequently over the seed in each petri dish. A further 10 mls of homogenate were applied to the seeds 4 days later. Rate of planting per petri dish was 40 seeds for sorghum and cucumber and 25 seeds for maize. Centrifuging removed the discolouration from the extracts to yield essentially clear solutions.

Cucumber seedlings which had been treated with root homogenates were stunted and failed to develop root hairs (Figures 48 & 49). The growth of sorghum seedlings receiving the rhizome homogenate was severely retarded. One week after application of the homogenates the seedlings were cut and the lengths of stem and root measured. Results are given in Tables 69 .

TABLE69: INFLUENCE OF NUTGRASS HOMOGENATES ON THE GERMINATION AND LENGTH (CMS) OF TEST CROPS.

RECORD OF	TUBER	RHIZOME	ROOT	CONTROL
Sorghum				
Number germinated	39	34	35	40
Number retarded	1	1	-	-
Stem length	6.12	3.00	7.28	8.45
Root length	9.12	4.56	8.50	8.65
Cucumber				
Number germinated	23	36	30	34
Number retarded	4	2	1	3
Stem length	7.28	8.19	1.80	6.09
Root length	9.08	9.68	4.16	7.97
Maize				
Number germinated	23	25	25	25
Number retarded	1	-	-	-
Stem length	10.13	12.66	11.84	5.92
Root length	4.75	5.10	4.84	4.15

Root homogenates arrested cucumber growth and ~~dwarf~~ rhizome extracts retarded the growth of sorghum. The remaining homogenates tended to stimulate seedling growth, especially in the case of maize.

Test 2

In an attempt to confirm the growth inhibition obtained in the preceding test (Test 1), nutgrass plants representing two growth stages i.e. advanced flowering and the late vegetative (pre-flowering) were harvested and permitted to air dry for 22 hours. 10% homogenates of the roots, rhizomes, tubers and stems were prepared. The blended material was filtered but not centrifuged. Homogenates were stored overnight and applied at the rate of 5 mls homogenate per dish to 30 cucumber seeds per petri dish. Each homogenate treatment was replicated three times. The mean length of 20 seedlings, selected at random from each replicate i.e 60 per treatment were recorded 1 week after application of the homogenate. Results are given in Table 70 .

TABLE 70 : INFLUENCE OF NUTGRASS HOMOGENATES ON THE LENGTH (CMS) OF CUCUMBER SEEDLINGS. MEANS OF 3 REPLICATIONS X 20 SEEDLINGS.

HOMOGENATE	STEM LENGTH	ROOT LENGTH
Young Plants		
Tuber	3.65	5.68
Rhizome	3.46	5.61
Root	6.92	5.71
Old Plants		
Tuber	4.89	5.62
Rhizome	3.85	6.49
Root	4.66	6.41
Stems	2.50	4.56
Control	3.16	6.14

Where stem homogenates were applied, there was evidence of a great inhibition of cucumber seedlings. Root homogenates however, did not produce the same level of inhibition as was obtained in Test 1. The maturity of the nutgrass did not appear to influence the growth of the cucumber seedling. A growth stimulation was observed where root homogenates were applied. Centrifuging or drying (4 hours vs 22 hours) are two factors which could possibly account for the difference between the results obtained in Test 1 and Test 2.

Test 3.

The influence of centrifuging and the period of post-harvest drying were compared in this experiment.

10% homogenates of roots, rhizomes, tubers and stems were prepared from nutgrass air dried for 24 hours and from freshly harvested plant material. The nutgrass was in the pre-flowering stage. Filtrates were centrifuged for 10 minutes at 15,000 r.p.m in a Servall Superspeed Rutomatic Centrifuge. The supernatant liquid was decanted. Part of the homogenates prepared from freshly harvested material was not centrifuged. Homogenates prepared from the air-dried material were centrifuged. Homogenates were stored overnight and applied at the rate of 5 mls per 30 cucumbers per petri dish. Seedlings were measured 6 days after application of homogenates. Results are given in Table 71.

TABLE 71 : INFLUENCE OF NUTGRASS HOMOGENATES ON THE GERMINATION AND GROWTH OF CUCUMBERS. MEANS OF TOTAL GERMINATED SEEDLINGS

HOMOGENATE		NUMBER		SHOOT LENGTH	ROOT LENGTH	pH OF HOMOGENATE
		Normal germ.	Retarded			
Air-dried Centrifuged	Tuber	20	4	3.79	7.30	6.9
	Rhizome	27	2	7.77	8.57	6.2
	Root	-	26	-	-	6.3
	Stems	28	2	4.45	8.19	7.5
Fresh Centrifuged	Tuber	25	1	6.98	8.18	6.2
	Rhizome	26	3	7.22	9.17	7.4
	Root	29	-	6.84	8.26	6.7
	Stems	-	26	-	-	6.8
Fresh. Not Centrif'ed						
	Tuber	23	2	7.24	8.53	6.8
	Rhizome	27	1	8.54	9.36	7.1
	Root	23	4	7.20	9.05	7.0
	Stems	27	1	6.26	10.42	7.1
Water 1		28	1	6.98	7.86	7.8
Water 2		28	2	7.27	7.72	

Centrifuged extracts prepared from air dried roots and freshly harvested stems caused a marked suppression in the germination of cucumbers. The corresponding treatments, namely freshly harvested roots and air-dried herbage failed to influence germination or growth. In the absence of centrifuging, all the homogenates of freshly harvested nutgrass failed to inhibit germination or retard growth. There is again evidence of increased cucumber root length with the non-centrifuged homogenates of fresh nutgrass material. In this test it was observed that tuber homogenate retarded the development of root hairs and reduced the stem length.

Test 4

In this test the experimental procedure was changed. The homogenates were not applied to the ungerminated seeds as in the previous cases but the seeds were germinated and stem lengths measured prior to application of homogenates (A) and on three subsequent dates (B, C and D). Homogenates were prepared from freshly harvested air-dried (24 hours) and oven dried (60°C - 1 hour) nutgrass in the flowering stage. The homogenates were centrifuged and applied (26/1/65) to cucumber seeds, 3 replicates of 10 seeds per petri dish. Results reflecting stem elongation and respective root lengths are given in Table 72 .

TABLE 72 : INFLUENCE OF NUTGRASS HOMOGENATES ON THE ELONGATION OF CUCUMBER STEMS AND ROOT LENGTHS (CMS). MEANS OF 3 REPLICATIONS.

TREATMENTS	Stem Lengths				Elongation		Root Length
	A	B	C	D	B - A	D-C	
Air-dry roots 7%	0.39	1.5	2.6	8.94	1.11	6.34	9.83
3.5%	0.33	1.4	2.9	8.87	1.07	5.97	10.24
Oven-dry roots 5%	0.36	1.5	2.9	7.96	1.14	5.06	10.14
Fresh roots 20%	0.37	1.3	2.5	9.16	0.93	6.66	8.71
Fresh rhizomes 10%	0.4	1.3	2.5	8.01	0.90	5.51	11.15
Fresh tubers 20%	0.37	1.3	2.5	7.86	0.93	5.36	10.46
10%	0.36	1.5	2.7	8.47	1.14	5.71	9.61
Control	0.41	1.6	3.7	10.45	1.19	6.75	8.96

Nutgrass homogenates appeared to retard the elongation of cucumber stems from 24 till 48 hours after application. This effect was of a transitory nature. There were no marked treatment differences at the termination of the test. Root lengths were not apparently influenced by the homogenate treatments.

Results.

The influence of nutgrass homogenates on the growth of a number of test crops, particularly cucumbers, was investigated in 4 independent tests. The results indicated that root homogenates inhibited germination, provided the homogenate was centrifuged prior to application. The same reaction was observed with homogenates prepared from freshly harvested nutgrass stems. Where homogenates were applied to germinated cucumbers, no growth inhibition was evident.

3. Root Leachates.

In this series of tests, a third method of determining the influence of nutgrass on the growth of certain test crops was investigated. The root systems of nutgrass plants, of varying maturity, were placed in tap water in polythene buckets. The leachates from the root systems were applied to the test crops grown in sterile sand in germinating trays. Each tray consisted of 4 rows containing 8 seeds per row. 100 mls of tap water was applied to each tray, followed by 250 mls of leachate. Trays were kept in the laboratory. Stem and root lengths are expressed in cms. Where leachates of washed root systems were applied, the entire root system was first placed under a strong water stream for two minutes.

Test 1.

Nutgrass plants (10 leaf stage), washed and unwashed, were placed in water for 10 hours at the rate of 150 plants per 2000 mls of water. Leachates were applied to radish, sorghum, cucumber and pea seeds, followed by a further application of 150 mls of extract per tray, 2 days later. Radish, sorghum, cucumber and pea stems were cut and weighed 7, 8 9 and 10 days after planting respectively. Results are given in Table 73.

TABLE 73 : INFLUENCE OF NUTGRASS ROOT LEACHATES ON THE GROWTH OF TEST CROPS. MEANS OF 4 ROWS PER SINGLE REPLICATE.

TREATMENT	SORGHUM		CUCUMBER		RADISH		PEA	
	STEM		STEM		STEM		STEM	
	Length	Wt	Length	Wt	Length	Wt	Length	Wt
1. Nutgrass washed	3.77	0.03	8.13	0.18	8.13	0.17	13.61	0.38
2. Nutgrass unwashed	3.09	0.03	4.47	0.08	7.72	0.19	10.07	0.20
3. Control	4.41	0.05	8.85	0.23	10.0	0.22	13.51	0.44

Wt* - Weight

Leachates of unwashed nutgrass root systems reduced the stem length and weight of the 4 indicator crops included in this test. Inhibition was very marked in the case of cucumbers. The degree of inhibition with washed nutgrass was less pronounced and only detectable with sorghum and radish .

Test 2.

This test was a repetition of Test 1, using older nutgrass plants (pre-flowering stage). Leachates were applied after the root system had been soaked for 24 hours.

Stems were cut, measured and weighed 10 days after planting. Results are shown in Table 74 .

TABLE 74 : INFLUENCE OF NUTGRASS ROOT LEACHATES ON THE GROWTH OF TEST CROPS. MEANS OF 4 ROWS PER SINGLE REPLICATE.

TREATMENT	SORGHUM		CUCUMBER		RADISH		PEA	
	STEM		STEM		STEM		STEM	
	Length	Wt	Length	Wt	Length	Wt	Length	Wt
1. Nutgrass washed	4.82	0.01	5.78	0.09	8.49	0.12	18.88	0.41
2. Nutgrass unwashed	3.74	0.01	3.31	0.03	7.85	0.09	16.70	0.31
3. Control	2.79	0.01	5.24	0.11	9.52	0.09	12.19	0.20

Leachates of unwashed nutgrass reduced the length and weight of cucumber and the length of radish stems. The growth of the remaining crops was apparently not restricted with washed or unwashed leachates. The growth of sorghum and pea seedlings was apparently stimulated by both leachates.

Test 3.

Unwashed and washed nutgrass plants 150/2000 mls water (late vegetative) were soaked for 21 hours. Leachates were applied to 80 cucumber seeds in petri dishes. The shoot and root lengths were determined after 6 days. Results are given in Table 75 .

TABLE 75 : INFLUENCE OF NUTGRASS ROOT LEACHATES ON THE GROWTH OF CUCUMBER SEEDLINGS. MEANS OF 50 PLANTS.

TREATMENT	LENGTH OF	
	SHOOT	ROOT
1. Nutgrass washed	8.4	7.8
2. Nutgrass unwashed	7.8	7.01
3. Control	5.18	5.1

There was no evidence of growth inhibition. The results suggest a stimulating effect with both washed and unwashed leachates on the growth of cucumber roots and stems.

Test 4.

Leachates prepared from washed and unwashed nutgrass and unwashed Bidens pilosa (125 plants per 3000 mls of tap water) were compared with leachates prepared from nutgrass. 20 cucumber seeds were sown per polythene pot filled with sterilised river sand. Leachates were applied immediately after sowing (EA - early) or 3 days after sowing (LA-late). The pH of the leachates was measured after 48 hours and again after 96 hours. Results are given in Table 76 .

TABLE 76 : pH OF LEACHATES.

TREATMENT	pH OF LEACHATE AFTER IMMERSION PERIOD OF	
	48 hours	96 hours
Nutgrass - Unwashed	6.4	6.8
Nutgrass - Washed	6.4	6.5
Bidens pilosa	6.1	6.3
Tapwater	7.8	7.8

Lengths and weights of cucumber stems for each series (EA and LA) were recorded 7 days after planting. Results are given in Table 77.

TABLE 77 : INFLUENCE OF NUTGRASS ROOT LEACHATES ON THE GROWTH OF CUCUMBER SEEDLINGS. MEANS OF 3 REPLICATIONS.

TREATMENT	STEM LENGTH	STEM WEIGHT
Nutgrass washed .EA	10.39	0.26
Nutgrass washed .LA	10.19	0.23
Nutgrass un-washed .EA	11.32	0.30
Nutgrass unwashed .LA	11.50	0.29
Bidens unwashed .EA	12.95	0.34
Bidens unwashed .La	14.70	0.40
Control - EA	12.09	0.33
Control - .LA	12.56	0.33

The pH of the leachate did not change very markedly with storage. The nutgrass leachates caused a reduction in cucumber stem length and weight. There were no differences between early or late treatments. The Bidens pilosa leachates [illegible] did not reduce stem length of cucumbers.

4. Root Percolates.

These tests were introduced to examine the possible production and liberation of toxins by undisturbed plants grown in a modified apparatus which permitted an exchange of soil solutions. Several techniques were employed attempting to relate the method to conditions which might prevail in the field. The population of selected plants per unit area, within the apparatus, was always considerably higher than that encountered under field conditions.

a) Funnel studies.

In this series, plants with attached roots were removed from the field and placed in tin plated metal funnels fitted with mesh screens at the outlets. The funnels were placed in a wooden housing and connected by means of rubber hosing to collection beakers. The plants were placed in a layer of sterile river sand and closely packed. Sand was inserted in the interspaces (See Figure 50). All tests were conducted in the glasshouse.

i) Flushing of percolates.

The treatments in this experiment consisted of living Eragrostis curvula and Trachypogon spicatus tussocks and nutgrass in the pre-flowering stage. The aerial parts were clipped to a height of 5" and inserted in the funnels. Washed (30 minutes) and unwashed nutgrass tubers were planted at the rate of 320 grams per funnel, i.e. very dense population.

The funnels were flushed with 400 mls of tap water twice per day. The percolates were collected in the receiving beakers and immediately applied, at the rate of 100 mls, to each of 4 replicates consisting of polythene pots, each sown to 35 sorghum seeds. Sorghum was sown 3 days after the treatments had been set up in the funnels. Sorghum weights were determined 11 days after sowing. Results are shown in Table 78 .



TABLE 50: Drip percolate apparatus. Application of nutrient solution.



TABLE 51: Drip percolate apparatus. Indicator crops used for evaluating percolates.



tus. Application of



tus. Indicator
ring percolates.

TABLE 78 : INFLUENCE OF ROOT PERCOLATES ON THE GROWTH OF SORGHUM. MEANS OF 4 REPLICATES.

TREATMENT	NUMBER GERMINATED	SHOOT LENGTH IN CMS	WEIGHT (GMS)		
			STEM	ROOT	TOTAL
1. Nutgrass plants established.	32	11.15	0.16	0.22	0.38
2. Nutgrass tubers washed	32	10.01	0.13	0.25	0.38
3. Nutgrass tubers unwashed	31	9.85	0.13	0.27	0.40
4. Eragrostis	31	9.19	0.12	0.24	0.36
5. Trachypogon	31	8.87	0.13	0.25	0.39
6. Control	31	9.86	0.13	0.26	0.39

There was no evidence to indicate that the growth of sorghum seedlings, when receiving bi-daily applications of the abovementioned percolates, were adversely affected.

ii) Drip percolates.

This experiment differed from the previous one in that the method of planting and percolation was modified. The plants were removed from the field and planted in their respective soil in the funnels, the lower 3" layer within the funnel consisting of sand. The nutgrass roots (Treatment 2) were washed for 10 minutes under a strong stream of water. All the nutgrass treatments were planted on a Bapefontein loam as was the bare soil treatment (Treatment 6). The grasses and nutgrass were clipped.

To exclude the effects of a nutrient imbalance, the plants in the funnels received a continuous slow drip solution of nutrients which was fed for 2 x 1½ hourly periods/daily from an elevated Winchester. This nutrient solution was made up by dissolving 15 gms of Complesal in 9000 mls H_2O, permitting the residue to precipitate and using the decanted supernatant solution.

Percolates were collected and applied to each of 3 replicates consisting of divided buckets each planted to 15 seeds of cowpeas and 15 seeds of sorghum. Percolates were applied at the rate of 50 mls per test crop bi-daily. (Figure 51).

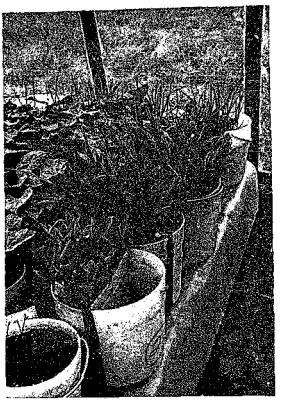


FIGURE 52: Exchange percolates.

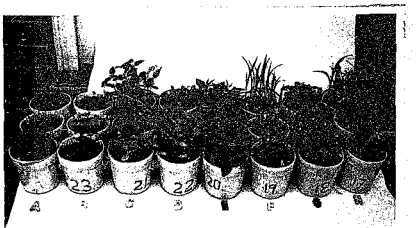


FIGURE 53: Crops sown in soil sampled in infested and non-infested nutgrass sites.

The test crops ~~experiment was~~ cut, measured and weighed 27 days later. Results are shown in Table 79 .

TABLE 79 : INFLUENCE OF PLANT ROOT PERCOLATES ON THE GROWTH OF SORGHUM AND COWPEAS. MEANS OF 3 REPLICATES.

TREATMENT	Number germinated		Shoot length		Stem weight	
	Sorghum	Cowpeas	Sorghum	Cowpeas	Sorghum	Cowpeas
1.Nutgrass established	12	13	20.09	17.49	0.30	1.43
2.Nutgrass established (roots washed)	14	14	19.40	16.23	0.28	1.39
3.Nutgrass tubers	13	14	18.07	16.17	0.27	1.35
4 Eragrostis	14	15	19.77	16.51	0.31	1.39
5.Trachypogon	13	14	18.45	17.95	0.28	1.44
6. Soil	14	14	16.99	15.11	0.27	1.34

A nutrient drip solution passed through various growing plants and then applied to two test crops did not influence the growth of the latter. Nutgrass percolates under these conditions did not exercise an inhibiting effect on the emergence or growth of both test crops.

b) Exchange percolates.

Polythene pots containing perforated dividing walls and filled with sand were planted to nutgrass and maize. The one series contained nutgrass on the one side of the wall and maize on the other side, while the second series contained maize only. The pots were kept in the glasshouse. Tap water was added daily to the nutgrass and the unseeded section until the opposite half of the pots was thoroughly saturated. Treatments caused no noticeable delay in germination or final emergence of maize. (Figure 52).

c) Lysimeter study.

Nutgrass plants were placed in blackened 4-gallon galvanised metal containers. The drums were fitted with outlet tubes at the bases. The nutgrass planted in these funnels were treated as follows:-



sampled in infested and
es sites.

1. Root system washed for 1 hour - Stems not cut.
2. Root system " " " " - Stems cut to a height of 2".
3. Root system not washed - Stems cut to a height of 2"
4. Root system not washed - Stems not cut.
5. Bidens pilosa root system washed for 1 hour - Stems cut to a height of 4".
6. Soil only.

The lower half of the metal containers contained washed river sand. The nutgrass and Bidens were planted in disturbed Frankenwald soil. The containers were kept in the open air and received water daily in accordance with growth requirements. Percolates through the soil cores were collected and applied to cucumber seeds planted in sterilised river sand. The volume of water per lysimeter was adjusted to ensure a percolate of 300 mls per collection. The quantity of water added per day thus varied from 1000 - 2500 mls per lysimeter depending on the water consumption of the plants.

100 mls of percolate was added daily to each of three pots containing the indicator cucumber seedlings. Cucumber seeds were sown 7 days after nutgrass. Percolates applied 2 days later.

Treatments caused no noticeable delay in germination, in the final emergence or visual growth of cucumber seedlings.

5. Plant Residues in the Soil.

Experiments were conducted to test toxin production from decaying plant residues. Freshly harvested plant material was cut up into 1" sections, thoroughly mixed with sterilised river sand and potted. Tap water was added at a uniform rate, sufficient to saturate the pot contents. Test crops were sown immediately after incorporating the plant residues. The pots were kept in the glasshouse.

Test 1

Aerial and underground plant residues were potted in small polythene pots at the rate of ± 300 grams fresh material per pot. 35 sorghum and 35 radish seeds were planted in the pots. The seedlings were clipped 10 days after planting. Results of stem length, stem weight and root weight are given in Table 80 .

TABLE 80 : INFLUENCE OF PLANT RESIDUES ON THE GROWTH OF SORGHUM AND RADISH. MEANS OF GERMINATED SEEDLINGS.

TREATMENT	RADISH			SORGHUM		
	STEM LENGTH	STEM WEIGHT	ROOT WEIGHT	STEM LENGTH	STEM WEIGHT	ROOT WEIGHT
C.esculentus stems	3.31	0.10	0.01	3.91	0.06	0.08
C.esculentus roots	4.63	0.19	0.10	4.66	0.08	0.21
C.rotundus stems	3.83	0.16	0.07	5.47	0.11	0.11
C.rotundus roots.	3.66	0.13	0.02	4.54	0.08	0.10
Eleusine stems	3.48	0.13	0.04	5.57	0.12	0.06
Eleusine roots	3.97	0.17	0.07	5.34	0.10	0.06
Control (Sand)	3.63	0.15	0.13	5.84	0.12	0.07

The results in Table 80 indicate that, apart from the incorporation of nutgrass stems, ch produced slightly shorter radish and sorghum stems, seedling growth was not influenced by the incorporated plant residues.

Test 2.

In this test only the underground residues of nutgrass were examined for inhibition. Nutgrass in the early and late vegetative stages were compared. The nutgrass samples were further divided into two sections, namely with tubers (+C) and without (-C). 10 maize seeds were sown in each of 4 replicated pots. The maize seedlings were cut 13 days after sowing. Stem lengths and weights of stems and roots are given in Table 81 .

TABLE 81:INFLUENCE OF NUTGRASS RESIDUES ON THE GROWTH OF MAIZE. MEANS PER 4 REPLICATIONS.

TREATMENT	LENGTH OF SHOOTS IN CMS	WEIGHT OF SHOOTS IN GMS	WEIGHT OF ROOTS IN GMS
1.Roots early (-C) vegetative	13.53	0.69	1.53
2. Roots late vegetative -C	14.41	0.70	1.69
3. Roots +C into vegetative	14.06	0.70	1.44
4. Control	13.03	0.68	1.15

There was no evidence of growth inhibition due to the incorporation of nutgrass residues.

6. Inhibitory Soil Residues.

Investigations were carried out to establish whether the distinctive aromatic character of nutgrass infested soils was related to a residue therein. Within the same field, representative soil samples were removed from nutgrass infested and a non-infested sites. The top 6" layer was sampled and the random samples bulked and screened. An adjoining field continuously cultivated for 7 years was employed as control. An analysis of the soil samples revealed no marked differences between the three sites. The soils were placed in pots and sown to a number of test crops. The latter consisted of maize, peas, beet, cowpeas, sorghum, radish, teff, lucerne, cucumbers and sunflower. The growth of crops sown on the continuously cultivated soil was not better than that of crops sown on the infested and non-infested nutgrass soil sites.

There was no evidence in these tests to indicate that living nutgrass produced a toxin in the soil which, after the weed had been removed, could influence the germination or growth of a number of crops.

Summary of Indirect Competition Studies.

In this experimental series no evidence was obtained which indicated that living nutgrass liberates a physiologically active toxin capable of inhibiting the germination or growth of a number of test crops. These results apply to cases where leachates and percolates from the living plant were applied to the indicator crops, or where the latter were seeded in a medium containing the nutgrass plant residues.

Where highly concentrated aqueous extracts of nutgrass plant material were applied to the seeds of certain test crops, germination and growth inhibition was demonstrated, the level of inhibition being related to the concentration of plant material. Similarly, aqueous homogenates exercised a marked inhibitory influence, but the degree of inhibition was largely dependent on the method of preparation.

The growth stimulation observed when seeding certain test crops with nutgrass tubers was of a transitory nature. It is therefore unlikely that this effect could be associated with the suppressive action exercised by nutgrass in the field.

The results therefore suggest that growth inhibitors are not produced by the living plant. The inhibition produced by the extracts or homogenates of dead plant material should not be regarded as a conclusive case of allelopathy.

CHAPTER XI

CONTROL

A. TILLAGE

Du Preez (1944) and Sellschop and Hettingh (1956) have outlined the advantages of summer discing. The available literature on this subject, however, reveals a lack of experimental evidence, particularly with regard to local conditions. Rheinhold (1942a) established the influence of winter discing on the survival of nutgrass. Present recommendations regarding summer cultivation appear to be mainly speculative and primarily aimed at destroying the newly produced daughter tubers. To determine the influence of summer discing, as well as the effect of frequency of discing on the survival of nutgrass, three discing experiments were conducted over a number of seasons. Each trial was located at a different site. The effect of hand hoeing on nutgrass survival was examined in a separate trial.

1. Summer Tillage - Bapsfontein.

This trial was conducted to investigate the residual effect of mechanical cultivation, applied during the preceding summer, on the emergence of nutgrass in the season following treatment. A severely infested nutgrass site at Bapsfontein was divided into two blocks (A and B). The following treatments were applied during the summer of 1959/60.

TREATMENT	SITE A	SITE B
Disc-ploughed -	winter	winter
" " in summer	13/11/59	13/11/59
Tandem disced 1	16/11/59	16/11/59
2	19/11/59	
3	9/12/59	
4	29/12/59	
Spike tooth harrowed	16/11/59	16/11/59

Site A thus received 4 discings during the summer and Site B only one. Both sites were ploughed during the 1960 winter and planted to maize on 4/11/60. No cultivation of the seeded fields was carried out during the 1960/61 season.

Assessment of results.

Nutgrass counts. On the 30/11/60 (26 days after seeding) the nutgrass population in each of 20 frames (20" x 20") placed at regular intervals across the block diagonals of each site was recorded. The means are given in Table 82.

TABLE 82 : NUMBER OF NUTGRASS SHOOTS PER 20" x 20" QUADRAT IN THE SEASON FOLLOWING MECHANICAL CULTIVATION.

	SITE	NUMBER OF NUTGRASS SHOOTS
A	4 Discings	15.7
B	1 Discing	77.65

Results.

Four summer discings applied during a 6 week period, reduced the number of nutgrass shoots in the season subsequent to cultivation. The results indicate that a population of nutgrass nevertheless survived the discing treatments which, if left undisturbed, was capable of reinfesting the site. Where complete eradication of the species is sought, it would therefore be essential to exercise tillage operations over a number of seasons.

2. Summer Tillage - Bethel.

Seven discing treatments were applied to a poorly drained, heavily infested nutgrass site at Bethel. The site was ploughed and disced following the first summer rains. The discing treatments were as follows:

A. 1 Discing 11/11/63
B. 2 Discings 11/11/63 and 3/12/63
C. 3 Discings 11/11/63, 3/12/63 and 26/12/63
D. 4 Discings 11/11/63, 3/12/63, 26/12/63 and 4/1/64
E. 5 Discings 11/11/63, 3/12/63, 26/12/63, 4/1/64 and 14/1/64
F. Non-cultivated control (Summer fallow)
G. 1 late summer discing - 17/2/64

The treatments were not replicated and were arranged systematically as indicated above. Plot size was 4 yds x 96 yds. At the commencement of the trial, 11/11/63, the nutgrass had already reached the 11 - 12 leaf stage. The first evidence of mature seeds was observed on 23/12/63. On each date of treatment the tandem discing was repeated twice to ensure thorough disturbance of the plot.

Selection of discing times was, to a large extent, influenced by the soil moisture conditions . After a heavy rainfall, the site often became waterlogged which, in turn restricted mechanical cultivation. After completion of the 5 summer discings, (Treatments A to E) a weed infestation survey of each plot was made on 24/1/64. The number of nutgrass shoots and annual grass seedlings in 12, 1' x 1' square quadrats was recorded. The means of these results are presented in Tables 83 and 84 .

TABLE 83: MEAN NUMBER OF NUTGRASS SHOOTS AND ANNUAL GRASSES PER DISCING SEEDLINGS PER 1' x 1' QUADRAT. 24/1/64.

TREATMENT	NUMBER OF	
	NUTGRASS SHOOTS	ANNUAL GRASSES
1 Discing	119	55
2 Discings	36	282
3 Discings	19	344
4 Discings	14	70
5 Discings	0	0
Control	216	19

TABLE 84: GROWTH STAGE OF NUTGRASS SHOOTS AND ANNUAL GRASSES ON 24/1/64 IN EACH DISCING TREATMENT

TREATMENT	NUTGRASS	ANNUAL GRASSES
1 Discing	Mature Seed	Flowering
2 Discing	Flowers emerging (11 - 12 leaf stage)	5 - 6 leaf stage
3 Discings	8 - 9 Leaf stage	7 - 8 leaf stage
4 Discings	6 - 8 Leaf stage	5 leaf stage
5 Discings	4 - 5 Leaf stage	Grasses absent
Control	Mature seed	Full flower.

A number of observations were made during the course of this experiment with regard to weed population changes which, together with the results obtained in Table 83 permit certain conclusions.

After completion of the summer discings it was evident that the nutgrass population had been greatly reduced on all the plots which had received 2 or more discings. Furthermore the latter plots had been invaded by annual grasses. There also appeared to be a relationship between the number of discings and the specific annual grass invader.

plots receiving 2 and 3 discings were dominated by stands of Eleusine indica, whereas the grass population on the plots which had received 4 discings consisted mainly of Eleusine indica, with sporadic pockets of Digitaria sanguinalis. The latter however was the dominant on the plot receiving 5 discings.

A single discing treatment reduced the nutgrass population but the ratio of nutgrass to annual grasses was still very high, the population density of annual grasses on the plot increasing as the season progressed. The control plots were heavily invaded by Cosmos spp. and to a lesser degree by Digitaria sanguinalis and Setaria spp.

Late summer discing.

Since initiation and differentiation of daughter tubers takes place mainly after flowering and according to Rahn et al.(1962) is influenced by photoperiodism, mechanical cultivation during the late summer could possibly prevent tuber formation. On the Highveld, this would co-incide with the period mid-January to mid-March.

A late summer discing treatment was therefore applied to a section of the control plot on 17/2/64. Approximately 1 month later, this plot (G) became severely infested with newly emerged nutgrass shoots.

Under Highveld conditions, emergence of nutgrass during March is uncommon, the weed seldom making an appearance after the end of November. The emergence of nutgrass on the plot during the late summer suggests that low autumn soil temperature is not a factor limiting the sprouting of the nutgrass tubers. The question is posed as to why nutgrass normally fails to sprout during mid-summer in the field. It is suggested that the sprouting inhibition could possibly be ascribed to a self inhibiting mechanism present in the tuber, as described by Tumblesom (1960). A plausible extension of this theory is that with the advent of the first rains, the concentration of this inhibiting toxin in the quiescent tubers is reduced, permitting general sprouting of the tubers. Toxin level in the soil solution probably increases during periods of active growth which, in turn, leads to induced inhibition of dormant or newly formed tubers. Under laboratory conditions it has been observed that dormant tubers which swell and fail to sprout, develop dormancy tendencies (Mes 1961). On undisturbed nutgrass sites, a late summer



FIGURE 54: Discing experiments at Frankenwald

mechanical disturbance produces a disruption of the daughter-mother tuber relationship, releasing free, unattached daughter tubers. It would appear that these liberated newly formed daughter tubers represent the basis of this late summer nutgrass infestation.

Examination of the plots during the following summer 1964/65, confirmed that increased frequency of discing reduced the nutgrass population. Nutgrass emergence on the undisturbed control plots was less pronounced than on the plots which had received 1 or 2 discings during the previous summer. The heaviest infestations were present on the late summer disced plots followed by 1, 2 and 3 discings respectively.

3. Nutgrass Infestation in Winter Fodder Crops.

A site at Bapsfontein seeded to winter fodder crops during March 1964, was severely infested with nutgrass. The site had been summer fallowed and disced during late summer prior to sowing of the winter crops. Nutgrass invasions on the above site at the termination of summer confirm the results of the previous tillage experiment at Bethel

4. Summer Tillage - Frankenwald. (Figure 54).

Three discing frequencies were applied to an arable field infested with nutgrass. The site had previously been employed as an Eragrostis nursery at Frankenwald and was ploughed over during the winter of 1964. After a spring discing, Babala (Pennisetum typhoides) was sown. Nutgrass infested areas were selected within the field. Discing was by means of a tractor-mounted 7' offset disc. To ensure thorough disturbance of the plot, the operation was repeated 4 times on each discing date. Depth of disturbance ranged between 6 to 8 inches. Disced strips were alternated with undisturbed control. The discing treatments were as follows:-

A. 1 Discing	6/1/65 (8 - 10 leaf Stage)
B. 2 Discings	6/1/65 and 14/1/65
C. 3 Discings	6/1/65, 14/1/65 and 26/1/65
D. No Discing.	

Treatments were replicated three times and arranged in randomised blocks. To assess the effect of the treatments on the survival of nutgrass, the underground fractions from 4, 20" x 20" quadrats were excavated within each disced strip on 29/4/65.

Quadrats were sampled at 8 yard intervals and excavated to a depth of 1 foot. The total soil volume was sieved through a 2 mm mesh sieve. Nutgrass roots and tubers were separated, air-dried and weighed. Tubers from each quadrat were counted. Results are given in Appendix . Actual and the square root transformed means are given in Table 85 . Weights are expressed in grams per quadrat.

TABLE 85: MEAN WEIGHT OF NUTGRASS ROOTS, TUBERS AND TUBER NUMBERS PER ¼ SQ.METRE QUADRAT. PER DISCING TREATMENT

TREATMENT	NUMBER OF TUBERS		WEIGHT OF TUBERS		ROOT WTS
	ACTUAL	S.R.TRANSF	ACTUAL	S.R TRANSF	ACTUAL
1 Discing	27.6	10.35	1.8	2.63	2.5
2 Discings	11.8	6.73	0.6	1.53	2.7
3 Discings	11.2	6.67	0.7	1.56	4.
Control	47.5	13.34	4.6	4.12	28.8

The square root transformation was applied to both numbers and weights of tubers because of the large differences in actual yields. In both cases the *differences between* the discing treatments were not significant. The number of tubers in the one plot receiving one discing treatment did not differ significantly from the control, but *two and three discings* decreased the number of tubers significantly. The control plots gave a significantly higher weight of tubers than all discing treatments.

Differences between the control and disced plots in regard to weight of roots is obvious. Discing frequency had no apparent effect on the weight of roots. Root weights were not statistically analysed.

During the 1965/66 summer season, the experimental site was re-ploughed, disced and planted to maize, the direction of tillage being at right angles to the former plot orientation. Despite this criss-cross disturbance, former treatment delineation was very striking during the early summer of 1965/66, indicating a persistent *residual* effect, even with one discing operation.

5. Hand-forking and Hand-hoeing.

A trial was conducted at Bethel to investigate the effect of hand hoeing and hand forking on the persistence of nutgrass under field conditions. Hand forking entailed the removal of the entire aerial and underground fractions. Hand hoeing merely involved a severing of the aerial growth. Each treatment was replicated 4 times and the treatments fully randomised. Treatments were applied to a very dense stand of nutgrass 12/11/62. 73 days later, the aerial and underground plant material was removed from a 20" x 20" quadrat centrally placed within each plot. The vegetation was subdivided into annual grasses and nutgrass. The number and weight of each group are given in Appendix Table 40 and the mean values in Table 86 .

TABLE 86 : NUMBER AND WEIGHT (OZS) OF NUTGRASS AND ANNUAL GRASSES PER 20" x 20" QUADRAT.

TREATMENT	NUTGRASS			ANNUAL GRASSES		
	Weight	Number		Weight	Number	
		Actual	Sq.Root		Actual	Sq.Root
1. Hand forking	10.63	465	10.95	4.65	245	7.47
2. Hand hoeing	13.87	1048	16.04	5.62	287	8.41
3. Control (Undisturbed)	15.47	1213	17.29	5.09	651	11.95

The analysis of variance was carried out on the square root transformation of the number of nutgrass and annual grasses. Removal of the aerial and underground fractions(hand forking) gave significantly fewer plants than the plots which had received no cultivation or a hand hoeing treatment There were no significant differences among the treatments in respect of weight of nutgrass and number and weight of annual grasses. The weight per plant of annual grasses is higher for both cultivation treatments which could perhaps be attributed to reduced nutgrass competition. The survival and recovery potential of nutgrass,despite hand forking treatment, is borne out by the above results. It is clear that even where the aerial and attached underground fractions are manually removed, sufficient tubers remain in the soil to initiate a new infestation.

Summary of tillage trials.

As far as mechanical eradication of nutgrass is concerned, there appear to be two possible approaches to the problem. These include the exposure and desiccation of the nutgrass plant and tuber and, secondly, the prevention of tuber formation. Preceding results have demonstrated the susceptibility of the nutgrass plant to insolation. Early seasonal discing, prior to tuber formation, will tend to expose the nutgrass plants, whereas a disturbance late in the summer will subject both plants and newly formed daughter tubers to desiccation. The latter approach is the one therefore recommended by Du Preez (1944) and Hattingh and Sellschop (1955) because of the alleged twofold effect. The disadvantage of this delayed discing operation however, is the dispersal of a large percentage of newly formed tubers, many of which are not exposed to desiccation and therefore serve as a source of reinfestation.

From laboratory results it is evident that tubers 1/8" in diameter are capable of sprouting when divorced from the mother plant. A system involving the destruction or reduction of plant population and prevention of tuber formation would ultimately offer the grower the most efficient means of eradicating field infestations.

Observations made over a number of years on the Highveld have revealed that in infested arable fields, nutgrass presents a distinct late vernal or estival aspect, the appearance of which is dependent on the advent of the first summer rains. While the primary nutgrass population is removed by means of cultivation and the seeded crop exercises a shading effect on the second generation, the weed faciation changes and the annual grasses assume the dominant position. Where unshaded stands of nutgrass are left undisturbed, secondary invasion by annuals will ultimately shade out the nutgrass, reducing to a great extent the emergence of the weed during the subsequent summer. Such invasions appear to suppress regeneration from the dormant tubers but with subsequent cultivation nutgrass once again becomes the dominant species.

Based on the evidence already available, it is possible to calculate when the viable seed and tubers will be produced. In other words the timing of the summer discing operations should be related to the advent of the first rains, concentrating these operations in the period prior to tuber formation.



FIGURE 55: Puccinia canaliculata infecting autumn foliage.

8. BIOLOGICAL:

Observations made at numerous sites over a number of seasons revealed that nutgrass is highly susceptible to a particular pathogen and is frequented by a number of insect species. The pathogen and insect specimens were collected and identified. A description of both has been included in this section.

1. Pathogens

Undisturbed nutgrass appeared to be highly susceptible to late summer fungal infections, principally towards the end of the growing season, mid-February. Disease expression was particularly evident on undisturbed plants after seed formation. Infection was observed on numerous sites throughout the Highveld. Young, or frequently clipped plants were apparently not susceptible. For example, in the clipping trial at Frankenwald, (Page 99) disease symptoms were only observed on the unclipped plants. The causal pathogen was identified as Puccinia caniculata var.tenuis Doidge, which was sometimes found to be parasitized by Darluca filum (Figure 55).

2. Insects

The collection and identification of insect species occurring frequently, periodically or repeatedly in nutgrass infestations was undertaken. The purpose of these collections was to place on record those species which are associated with the weed, irrespective of whether this association is related to a biological interdependence or a direct cohabitation. Insect species, locations and occurrence frequencies are given.

(a) Aphididae : Saltusaphis scirpus Theob.

A pale cream coloured aphid frequenting dense stands of nutgrass, where due to a high plant population density, light has been excluded. Abundant in very large colonies on nutgrass stem bases, soil surfaces and lower leaves. Aphid infestations increase rapidly after inflorescence emergence, i.e. from beginning of January, reaching peak levels approximately mid-February and persisting till end-March in reduced numbers. Located at Bethal, Kriel and Sokhurg annually and also at Frankenwald on unclipped nutgrass plants growing in asbestos pots.

(b) Pentatomidae.

Collected at Bethal, Kriel and Frankenwald. Environmental conditions and collection sites similar to those for Saltusaphis scirpus above.

(i) Eysarconis inconspicuus H.S

(ii) Carbula trisignata Germ.

(iii) Dalecerqueila phalerata Stal.

(c) Nabidae

Predaceous on aphids. Collected in unclipped pots at Frankenwald.

Nabis capsiformis Germ.

(d) Coreidae.

Collected in unclipped pots at Frankenwald.

Cletus varius Dall.

(e) Coccinellidae. Predatory beetles. Found in association with aphid colonies. Environmental conditions and collection sites as for Saltusaphis scirpus above.

(f) Jassidae.

Frequently attacking nutgrass, especially when growing together with, or surrounded by, Gramineae.

Nutgrass planted in pots and kept in the glasshouse or open air was very susceptible to leafhopper. The insect principally attacks young, actively growing nutgrass, producing isolated necrotic zones on the foliage. Collected at Frankenwald in the glasshouse and open air experimental enclosures. January to February.

(g) Dasytidae : Astylus atromaculatus.

Very common on flowering nutgrass. Of the weeds infesting arable lands on the highveld, nutgrass is one of the first to flower during the early summer season, and serves as a suitable intermediary host plant prior to the emergence of the staminate maize flower. Infestations of Astylus on nutgrass during mid-December to early January are very common throughout the Highveld.

(h) Thripidae.

Found in mature or maturing nutgrass umbels at Bethel. Collected from mid-January onwards.

(i) Tettigoniidae.Conocephaloides longipennis Holt.

(j) Acarina.

Large numbers of spider mites present with thrips on immature or mature nutgrass seed. Very abundant at Jokaburg, mid-February. Also present at Bethel and Jokaburg with aphid-coccinellid complex.

C. CHEMICAL

Herbicidal tests were conducted over a number of seasons with a view to obtaining treatments which would give satisfactory nutgrass control without causing crop injury. In view of the restricted choice of candidate herbicides, the early field experiments were confined to the evaluation of pre-planting and directed basal contact treatments. With the advent of more effective and selective compounds, the emphasis in the final experiments was placed primarily on herbicidal efficacy. The latter experiments were designed as screening trials, in which a wide range of compounds and herbicidal mixtures were evaluated.

1. Pre-planting Applications of Three Soil-acting Herbicides.

Most compounds which had previously shown herbicidal efficacy in respect of nutgrass, were only effective at concentrations which produced severe crop injury. In an effort to overcome this problem, an experiment was conducted in which herbicides were applied at relatively high rates as pre-planting treatments.

The herbicidal efficacy against nutgrass and the residual toxicity to crops of three soil-acting herbicides were evaluated on a nutgrass-infested site at Bapefontein.

The duration of residual herbicidal toxicity in the soil was determined by means of three indicator crops seeded at two intervals after application of the herbicides. The three selected candidate herbicides were known to possess soil sterilizing properties when applied at high concentration levels. At these levels, crop injury is also very marked. Reduced rates were therefore applied, to establish critical toxicity levels in respect of the weed and indicator crops. The treatments consisted of the following:

a) Herbicides (Plot size 1/17th acre) Active ingredient.

	RATE PER ACRE
1. Monolinuron	4 lbs
2. "	8 lbs
3. Monuron	4 lbs
4 "	8 lbs
5. Sodium trichloracetate	25 lbs
6. " "	50 lbs
7. Control	

The main herbicidal treatments were arranged in 3 randomized blocks with 4 unsprayed control plots per block. Herbicidal plots were split for planting intervals.

b) Planting intervals.

1. 3 weeks after spraying.

2. 6 weeks after spraying.

c) Indicator crops.

1. Maize - SA 200

2. Beans - Small white Haricot.

3. Sunflower - Universal striped.

(d) Experimental Operations.

1. Preparation.

The site was disc-ploughed during the winter and again on on 13/11/59, after the area had become heavily infested with nutgrass. (6 - 8 leaf stage). Tandem discing and spike tooth harrowing was carried out 3 days later.

2. Herbicidal application:

Weedkiller treatments were applied on 19/11/59 onto a well prepared, moist seedbed. Heavy rain fell within 12 hours after applying the herbicides.

3. Seeding of Crops.

(i) 1st Planting Series.

3 weeks after spraying (9/12/59). Half of each block, 36' wide, was tandem disced across the full length of each block and seeded to the three crops. (See Figure 56).

(ii) 2nd Planting Series.

6 weeks after spraying (31/12/59). The remaining half of each block received 2 tandem discings. This treatment was sufficient to achieve a satisfactory seedbed on the weedkiller treated plots. Severe weed growth on the control plots during the interim period, coupled with adverse soil moisture conditions, necessitated additional offset ploughing of the control plots. This nevertheless still gave a poor seedbed. Sprayed and control plots received a final (3rd) tandem discing prior to seeding of the three crops.

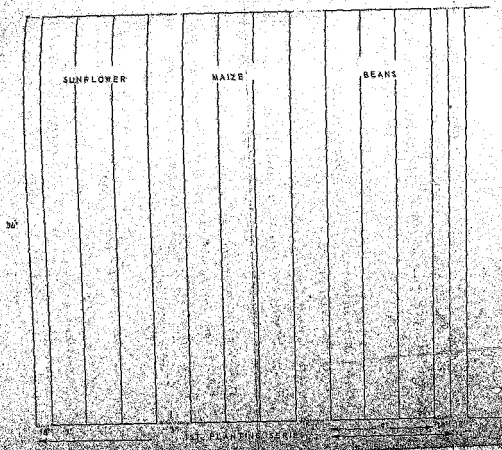


FIGURE 56.

PLOT SIZE AND ARRANGEMENT OF CROPS IN EXPERIMENTAL PLOTS.

PLOT SIZE – 36' × (24' × 2 PLANTING SERIES)

= 288 SQ. YDS.

= $\frac{1}{17}$ TH ACRE

4. Method of Seeding.

Crops were sown by means of a Massey Ferguson 4 x 3' row unit tractor-driven planter, fitted with "Turfmaster" press wheels. Maize and sunflowers were spaced at 6½" and beans at 8" in the row. Superphosphate (19% water soluble) was applied at planting at the rate of 250 lbs per acre.

5. Pest Control and Cultural Operations.

Routine cutworm baiting and granular stalkborer treatment of the maize were applied when necessary. Two mechanical inter row, and two intra row hand cultivations were carried out on the 1st Planting Series respectively. A nitrogen side dressing of 100 lbs Urea/acre was applied to the maize of the 1st Planting Series 7 weeks after planting.

(e) Assessment of results.

1. 1959/60 Weed Control Ratings - 11/12/59 and 23/12/59. 22 and 34 days after spraying. Results are given in Appendix Table 41 and the means in Table 87 .

2. Weed Counts - 23/12/59

34 days after spraying. The number of dicotyledons, nutgrass and annual grasses per 3 frames (18" x 18") sampled at intervals of 3 yards along the central line of each plot was recorded. Annual grasses were subdivided into 2 categories, namely, young grasses (2 - 4 leaf stage) and old grasses (4 - 8 leaf stage - tillering). Old grasses refer to the original weed flush and young grasses to the 2nd weed flush. Results are shown in Appendix Table 42 and the means in Table 88.

3. Plant Populations and Indicator Crops. 1st Planting Series 30/12/59 (21 days after planting). 2nd Planting Series - 18/1/60 (18 days after planting).

The plant population of each crop was established. Only normal plants were recorded. Stunted or malformed plants were excluded. For beans and sunflowers only the middle three rows were counted. The plants in all four maize rows were recorded. Results are given in Appendix Table 43 and the means in Tables 88 and 90.

4. Yields of Indicator Crops.

Beans, sunflower and maize were harvested 2/5/60, 10/5/60 and 15/5/60, respectively. Results are given in Appendix Table 44 A&B and the means in Table 91 . 92.

Bean yields refer to weight of pods + stems, while sunflower yields refer to weight of seedheads + stover.

(f) 1960/61 (Residual Effect).

The entire experimental block was disc ploughed twice, (12/8/60 and 5/10/60), disced twice (12/10/60 and 27/10/60) and seeded to maize on 4/11/60. The experimental site was repegged and hand-hoed 1/12/60. Residual crop phytotoxicity and herbicidal activity against nutgrass was evaluated by means of the following:-

1) Weed Counts.

8 quadrat frames measuring 18" x 18" were sampled within each plot 29/11/60, namely, 4 within the original 1st Planting Series and 4 within the original 2nd Planting Series. Weed populations were recorded on the basis of nutgrass and other weeds, the latter consisting principally of annual grasses. Results are given in Appendix Tables 46 A & B and the means in Table 93 .

2) Maize population counts:

The maize population per centre 4 rows of each plot, within the original planting series, was recorded on 22/12/60. Results are given in Appendix Table 47A and the means per row in Table 94 .

3) Plant Heights were measured from ground level to the top of the maize funnels on 23/1/61. 25 plants per plot were measured in the 1st Planting Series, the results of which are given in Appendix Table 47B and the means in Table 94.

(g) Statistical Analysis.

Analysis of variance was applied to a number of variates but only in respect of the 6 herbicide treatments. Control data was excluded from the analysis. Data on counts and ratings have been transformed as indicated. Analysis of variance tables are listed in Appendix Table 45.

(h) Observations.

a) Weed Control - Nutgrass. Notwithstanding the severe nutgrass infestation at the commencement of the trial, re-emergence after the final mechanical soil preparation prior to spraying, was markedly reduced. Nutgrass emergence after the completion of the 2nd Planting Series seeding (31/12/59), was very poor.

Annual Grasses: Owing to extremely favourable soil moisture conditions at the time of spraying, all the herbicides, at both rates of application, gave excellent annual grass control.

(ii) Crop emergence - 1st Planting Series. Emergence of all crops was initially uniform and apparently unaffected. Phytotoxic symptoms were evident within 10 days after emergence.

1. Of the three compounds, monolinuron appeared to be the least phytotoxic, causing moderate foliar damage to the beans at the 8 lb application level.

2. Monuron at the 8 lb level was highly toxic to maize and beans, both crops revealing foliar phytotoxicity patterns, symptomatic of typical substituted urea herbicide damage. The latter consisted of an initial foliar chlorosis, followed by a necrosis of the leaf apex and a general disappearance of chlorophyll. The symptoms were evident on both crops. In the final stages, especially maize, the leaf becomes transparent prior to the complete deterioration of the plant.

3. TCA induced severe whipstick formation in the maize at both application levels, whilst beans also showed considerable sensitivity to this chemical. Maize plants suffering from herbicidal toxicity were more susceptible to Helminthosporium infection. Due to late planting, crop yields, especially maize, were very low.

Beans growing on the control plots matured very rapidly, shedding their leaves and consequently ripened earlier. On the sprayed plots, however, beans matured very much later.

2nd Planting Series. Apart from one light shower which fell shortly after seeding, soil moisture conditions remained poor shortly after germination and throughout the growing season. Crop emergence was consequently somewhat retarded, especially on the control plots where, due to the poor soil moisture conditions, crop stands were irregular. There appeared to be a marked differential crop response to the three compounds tested. Sunflowers appeared to be highly tolerant of TCA, while monolinuron was highly selective on beans and maize.

Results.

TABLE 87 : MEAN RATING OF WEED CONTROL 22 AND 34 DAYS AFTER SPRAYING.

TREATMENTS		RATINGS AFTER SPRAYING					
		22 DAYS				34 DAYS	
		NUTGRASS		ANNUAL GRASSES		GENERAL	
		*Transfd	Actual	*Transfd	Actual	*Transfd	Actual
Monolinuron	4	38.8	4	51.1	6	46.8	5.3
Monolinuron	8	67.8	8	80.7	9.3	77.4	9.3
Monuron	4	51.1	6	63.4	8	57.6	7.0
Monuron	8	50.7	6	80.7	9.3	77.4	9.3
TCA	25	63.4	8	54.9	6.7	57.7	7.0
TCA	50	80.7	9.3	89.4	10	83.4	9.7
L.S.D p=0.05				17.5		24.4	
CONTROL			1.7		1.7		1.3

* Ratings converted to percentage of maximum control - Angular transformation.

TABLE 88 : MEAN WEED POPULATIONS. NUMBER OF WEED SPECIES PER 18" x 18" FRAME(34 DAYS AFTER SPRAYING).

TREATMENTS		NUTGRASS		YOUNG AN. Grasses Actual	OLD AN. Grasses Actual	BROADLEF. Species Actual
		*Transfd	Actual			
Monolinuron	4	1.9875	37.3	33.6	0	0
Monolinuron	8	1.1003	10.6	0.6	0	0
Monuron	4	1.5474	12.0	0.3	0	0
Monuron	8	0.7253	3.2	0	0	0
TCA	25	0.6513	1.4	22.3	0	0
TCA	50	0.6777	1.4	5.1	1.7	0.2
L.S.D p = 0.05		0.8021				
CONTROL			35.22	38.1	36.72	5.8

* Log (Total number + 1)

1. Weed Control Ratings.

a) Percent rating nutgrass 22 days after spraying - Angular transformation.

The overall treatment effect was not significant. The variation was high, so that accurate comparisons are not possible. The results do indicate that both rates of TCA and the higher rate of monolinuron had successfully suppressed the weed.

b) Percent rating annual grasses 22 days after spraying - Angular transformation.

The higher levels of monolinuron and TCA gave significantly better ratings than the corresponding lower levels.

The difference between the two levels of monuron just failed to reach significance. There were no differences between weedkillers when comparing either high or low level.

c) Percent general rating 34 days after spraying - Angular Transformation.

There were no significant differences between the higher levels of the three weedkillers or between the lower levels. The higher levels of monolinuron and TCA gave better ratings than the lower levels. With monuron this difference is also substantiated but not significant.

2. Weed Counts.

a) Log number of nutgrass plants 34 days after spraying.

The lower levels of monolinuron and monuron gave significantly larger numbers of nutgrass plants than both levels of TCA and the higher level of monuron. The higher level of monuron gave a significantly smaller number of nutgrass plants than the lower level.

b) Control of annual grasses and broadleaf species 34 days after spraying.

All the herbicidal treatments gave excellent control of the primary grass and broadleaf complex. With regard to the secondary annual grass problem, it was evident that the lower rates of monolinuron and TCA failed to give complete protection of this invasion 34 days after spraying.

TABLE 89 : MEAN POPULATIONS OF NORMAL PLANTS PER PLOT

1ST PLANTING SERIES

TREATMENT	BEANS		SUNFLOWER		MAIZE	
	*Transf'd	Actual	*Transf'd	Actual	*Transf'd	Actual
Monolinuron 4	14.80	220	13.02	170	12.39	154
Monolinuron 8	10.16	109	8.86	94	10.11	107
Monuron 4	3.68	14	5.88	37	9.60	93
Monuron 8	2.37	6	4.50	21	7.60	60
TCA 25	9.79	102	6.91	82	11.15	125
TCA 50	5.41	31	9.72	98	6.35	42
L.S.D p=0.05	3.58	-	5.27	-	2.81	-
CONTROL		236		236		156

TABLE 90 : MEAN POPULATIONS OF NORMAL PLANTS PER PLOT

2ND PLANTING SERIES

TREATMENT	BEANS		SUNFLOWER		MAIZE	
	* Transf'd	Actual	*Transf'd	Actual	*Transf'd	Actual
Monolinuron 4	13.27	185	12.70	181	13.58	185
Monolinuron 8	12.82	166	15.36	246	12.24	153
Monuron 4	8.34	78	10.20	105	11.68	139
Monuron 8	6.50	56	8.41	94	7.15	68
TCA 25	13.16	179	16.76	290	14.86	231
TCA 50	9.92	99	17.47	331	12.91	166
L.S.D p=0.05	-	-	-	-	3.66	-
CONTROL		68		167		77

* Square Root Transformation.

TABLE 91 : CROP YIELDS - 1ST PLANTING SERIES

TREATMENT	BEANS WEIGHT	SUNFLOWER WEIGHT	MAIZE		
			COB NO.	COB WEIGHT	STOVER WEIGHT
Monolinuron 4	13.1	6.4	20	3.0	10.7
Monolinuron 8	14.9	6.1	28	5.5	9.0
Monuron 4	5.2	4.8	19	2.7	7.7
Monuron 8	2.1	3.0	10	1.7	6.4
TCA 25	0.3	6.6	8	1.1	12.4
TCA 50	0.5	4.2	1	0.1	2.9
L.S.D p=0.05					4.73
CONTROL	9.6	5.7	20.5	3.1	

TABLE 92 : CROP YIELDS - 2ND PLANTING SERIES

TREATMENT	BEANS WEIGHT	SUNFLOWER WEIGHT	MAIZE		
			COB NO.	COB WEIGHT	STOVER WEIGHT
Monolinuron 4	7.9	2.7	5	1.4	13.3
Monolinuron 8	7.9	3.5	18	2.1	11.6
Monuron 4	4.8	4.0	13	1.4	11.3
Monuron 8	2.1	2.5	4	0.3	5.8
TCA 25	0.2	4.0	0	0	12.6
TCA 50	0.0	2.4	0	0	8.6
CONTROL	1.4	2.3	4.8	0.3	6.5

N.B. L.S.D's have only been calculated in respect of certain crops and Planting Series. L.S.D's for crop yields of the 2nd Planting Series have been omitted because of the ill,itad growing season.

3. Plant Populations of Indicator Crops.

a) Number of normal plants.

The square root transformation was applied to all plant numbers.

(i) 1st Planting Series.

Beans: The low level of monolinuron gave significantly more normal plants than all other treatments. Both levels of monuron and the high level of TCA gave significantly fewer normal plants than the high level of monolinuron.

Sunflower: The F-value just reached significance and the variation was very high. It does appear as if both levels of monuron affected the growth of sunflower plants adversely in comparison with the low level of monolinuron. No conclusions with regard to the effects of TCA and of the high level of monolinuron can be made.

Maize: The high levels of monuron and TCA decreased the number of normal plants significantly.

(ii) 2nd Planting Series.

Beans: The treatment effect is not significant.

Sunflowers: The treatment effect is not significant.

Maize: The high level of monuron gave a significantly lower number of normal plants than all other treatments.

4. Crop Yields of Indicator Crops.

(i) 1st Planting Series.

Beans: Yields were unaffected by the application of both levels of monolinuron. TCA and monuron were highly toxic to the crop and suppressed growth very drastically.

Sunflowers: There were no significant differences between treatments. The results in Table 91 suggest that both levels of monuron and the high rate of TCA reduced the yields.

Maize: Cob weights were reduced by both levels of TCA and the high rate of monuron.

Stover weights: The treatment effect is highly significant. The higher levels of monuron and TCA affected the yields very adversely in comparison with both rates of monolinuron.

(ii) 2nd Planting Series.

Beans. Monolinuron at both levels gave the highest yields. Yields from the unsprayed plots were very low.

Sunflowers. There were no significant treatment differences

Maize. There were no significant differences between treatments with regard to stover weight. High levels of TCA and monuron did appear to produce lower stover weights. Due to the late planting, cob weights were very low. Treatment comparisons are thus not valid.

TABLE 93 : MEAN NUMBER OF NUTGRASS AND ANNUAL GRASSES PER 18" x 18" FRAME (RESIDUAL EFFECT)

TREATMENT		1ST PLANTING SERIES			2ND PLANTING SERIES		
		NUTGRASS		ANNUAL GRASSES	NUTGRASS		ANNUAL GRASSES
		Transf	Actual		Transf.	Actual	
Monolinuron	4	5.60	12	3	6.24	11	3
Monolinuron	8	3.99	6	3	3.11	4	3
Monuron	4	5.68	8	2	4.61	6	2
Monuron	8	4.80	8	3	4.44	7	5
TCA	25	5.40	7	2	4.58	6	2
TCA	50	3.62	4	3	4.45	5	3
Control			12	3		9	5

TABLE 94 : MEAN NUMBER AND HEIGHT OF MAIZE PLANTS (RESIDUAL EFFECT)

TREATMENT		NUMBER PER ROW *				MAIZE HEIGHTS**
		1ST PLANTING SERIES		2ND PLANTING SERIES		1ST PLANT.SERIES
		Transf.	Actual	Transf	Actual	
Monolinuron	4	15.63	61	16.07	65	55.1
Monolinuron	8	15.14	58	14.83	63	62.0
Monuron	4	15.19	58	1 .84	63	54.5
Monuron	8	15.10	57	14.29	66	56.8
TCA	25	15.26	58	15.93	64	59.0
TCA	50	15.36	59	16.26	66	53.1
Control			56		64	54.6

* Number - Square Root Transformation

** Height in inches

Residual Effect

Mean heights of the maize plants, the number of maize and nutgrass plants per plot were not significantly affected by the herbicidal treatments applied to the soil during the preceding summer season. The results suggest that toxic residues of the three compounds applied, irrespective of concentration do not persist from one summer season to the next.

Summary of Results.

Pre-planting herbicidal treatments for the control of nutgrass proved to be a relatively selective method of controlling nutgrass, provided a herbicide with a short residual action was used. Monuron and TCA were highly toxic to most of the indicator crops, while monolinuron showed considerable selectivity. The rates of application of all three chemicals, however, were of a non-economic level, and would therefore be commercially restricted.

2. Monolinuron as a Pre-emergence Treatment in Maize.

Early trials conducted with monuron had indicated that on sandy soils, this herbicide was highly effective in controlling nutgrass, but phytotoxic to maize (Fisher 1957). The appearance of a substituted urea compound with an alleged wider spectrum of selectivity merited field evaluation. In view of the promising results obtained in the preceding experiments, monolinuron 80% wettable powder was compared with monuron 80% wettable powder. Both compounds were applied as pre-emergence single row treatments on a band 12" wide. The treatments were as follows:. (Rates of active ingredient per acre refer to row treatment only).

1.	Monolinuron	0.4 lbs	6.	Monuron	0.4 lbs
2.	"	0.6 "	7.	"	0.6 "
3.	"	0.8 "	8.	"	0.8 "
4.	"	1.0 "	9.	"	1.0 "
5.	"	1.2 "	10.	"	1.2 "

A randomised block design with 3 replicates and 2 controls per block (Treatments 11 and 12) was used. Plot~~lengths~~ were 60 yds x 12". Herbicides were applied at Bethal on 8th November immediately behind mechanically planted maize (SA 4). The tilth was poor and the seedbed surface uneven and dry. Heavy rain fell 5 hours after application of the herbicides. The plots were kept weed-free in order to assess the relative crop safety factor of each compound. Germination was uniform, but incipient herbicidal phytotoxicity became evident some 14 days after germination, especially on the monuron-treated rows. Total number of germinated maize plants were counted in each plot 27 days after planting. A second plant population survey was carried out 63 days after planting.

Total plant population was recorded and subdivided into unaffected (normal) and affected (stunted) plants. Maize cobs were harvested in July and the weights recorded.

The total number of maize plants in each row recorded 27 and 63 days after planting are shown in Appendix Table 48 . The mean values are given in Table 95 . Weights of cobs are given in Appendix Table 49 and the respective means in Table 95 .

TABLE 95 : MEAN NUMBER OF MAIZE PLANTS AND COB WEIGHTS PER PLOT.

TREATMENT		TOTAL PLANTS AFTER 27 DAYS	TOTAL PLANTS AFTER 63 DAYS		COB WEIGHT
			ACTUAL	SQ.RT.TRANS.	
1.Monolinuron	0.4	107	98	9.88	41.0
2. "	0.6	129	109	10.41	40.3
3. "	0.8	116.3	103	10.13	36.4
4. "	1.0	122	96.6	9.79	30.7
5. "	1.2	120.6	105.6	10.24	24.8
6.Monuron	0.4	129	115.6	10.74	29.3
7 "	0.6	114.3	96.6	9.78	34.9
8. "	0.8	100.6	69	8.32	18.0
9. "	1.0	89.6	56	7.46	10.3
10 "	1.2	73.3	54.3	6.76	8.7
11 Control	A	127	125.6	11.18	44.4
12 Control	B	119	115.3	10.73	43.9
L.S.D				2.07	14.6

Counts made 27 days after planting reveal that the high levels of CDU reduced the maize population. An analysis (square root transformation) of the counts made 63 days after planting confirms a highly significant treatment effect. Treatments 9 and 10 (1.0 and 1.25 of monuron gave significantly lower numbers of plants than all levels of monolinuron and the control. The lowest concentration of monuron did not affect the stand significantly. The treatment effect for weight of cobs is highly significant at $p = 0.05$. The control produced a significantly higher weight of cobs than 1.2 lbs of monolinuron and 0.8 lb, 1.0 lb and 1.2 lbs of monuron per acre. Yields decreased with increasing dosages of monolinuron and monuron. The results indicated that monolinuron when applied as a pre-emergence herbicide to maize was less injurious to the crop even at rates equivalent to 3.6 lbs of active per acre blanket treatment (1.2 lbs a.i row treatment). The latter treatment is equivalent to an application rate of 7.2 lbs of a 50% wettable powder which is approximately 2 - 3 times higher than the current field recommendation for this herbicide.

3. Evaluation of Directed Basal Contact Herbicides in Maize

Two contact herbicides applied as directed basal sprays to maize were evaluated in nutgrass infested sites. These experiments were conducted on young maize (Bathal)and on well-established plants at Hope-/fontein, (c) Bothaly. In a preliminary screening test, emulsifiable oils fortified with DNBP (20% and 50%) and PCP (5%) were applied at increasing rates to young maize, 4 - 6" high (6 leaf stage) heavily infested with nutgrass of almost equal height. The treatments were non-replicated and applied as directed basal contact sprays to the rows only. The maize was planted 11/10/60 and the sprays were applied 19 days later, by which time the maize had almost been smothered by the nutgrass,thus making directed herbicidal spraying difficult. Air temperature and humidity during application were 35°C and 29% respectively at 3 p.m. Inter-row mechanical cultivation was carried out when necessary. Plot size was 60 yds x 1 yd (1/80th acre). The treatments (expressed as row treatments per acre), with respective pre- and post- treatment maize population counts and herbicidal ratings, recorded 7 days after spraying, are given in Table 96 .

TABLE 96 : PRE-AND POST TREATMENT MAIZE ROW POPULATIONS AND HERBICIDAL RATINGS FOR NUTGRASS

TREATMENT		MAIZE COUNTS		HERBICIDAL
		PRE-TMT	POST-TMT	RATING
A.DNBP 20%	2 pints	85	84	1
" "	4 "	121	107	6
" "	6 "	70	69	8
" "	8 "	114	112	9
" "	10 "	89	73	9
B.DNBP 50%	2 "	102	100	2
" "	4 "	104	99	6
" "	6 "	116	105	8
C. PCP 5%	10 "	114	104	3
" "	20 "	119	111	7
" "	30 "	104	103	8
" "	40 "	91	83	9
" "	50 "	64	62	9
Control A		119	117	0
Control B		117	109	0
Control C		126	123	0

High applications of both DNBP and PCP formulations gave excellent initial kill of nutgrass. At these concentrations, toxicity to maize was only slight when applied as directed row treatments. The duration of control however, was very short. Within 16 days of spraying the nutgrass had completely recovered and the maize, despite the absence of phytotoxic foliar symptoms, appeared to be retarded when compared to the

unsprayed plants.

b) Bapefontain.

Two contact herbicides, PCP and DNBP fortified emulsifiable oils, were applied at various concentrations as directed basal contact sprays to established maize infested with a mixture of nutgrass and Eleusine indica. The maize received inter-row cultivation and the weedkiller sprays were confined to a 12" band, (6" on both sides of the row). The weed population was approximately 6 - 8" tall and the maize 12 to 15" tall. The treatments were as follows: (Rates expressed as row treatments per acre).

1. 4 pints DNBP 50%
2. 6 " "
3. 8 " "
4. 10 " "
5. 12 " "
6. 8 " PCP 5%
7. 40 " "

Plot size was 12" x 60 yards. Treatments were arranged in randomised blocks and alternated with untreated rows of maize. The herbicides were applied 4/1/60. Fifteen days later, the weed growth in each plot was sampled by removing 3, 6" x 36" clip quadrats per row. The green weed weight for each treatment with adjacent control, are shown in Appendix Table 50 and the means given in Table 97 .

TABLE 97 : MEAN GREEN WEIGHTS OF WEED GROWTH PER QUADRAT 6" x 36" IN OZS PER QUADRAT.

TREATMENT	WEIGHT OF WEED
1. 4 pints DNBP 50%	20.6
2. 6 " "	20.0
3. 8 " "	14.6
4. 10 " "	8.7
5. 8 pints PCP 5%	16.5
6. 40 " "	10.0
7. Control	30.1

There were no significant differences in green weed weights between the treated plots. The treated plots gave an average of 15 ozs in comparison with a mean of 30 ozs for the controls. The latter difference can be regarded as significant.

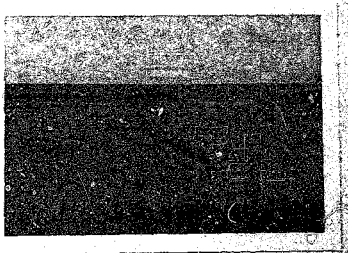


FIGURE 57: Screening trial at Bethel

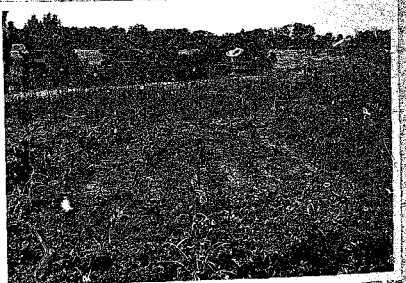


FIGURE 58: Control of nutgrass with Linuron plus surfactant

Suppression of weed growth was only evident at the high herbicidal dosage levels, rendering this treatment uneconomical. At these high concentrations, phytotoxicity (foliar scorch) to the maize was severe. Residual herbicidal effect was of a transitory nature. Regrowth of weeds was very rapid.

The results of the two directed contact spraying experiments, using PCP and DNBP formulations, showed that both compounds gave a short residual effect against nutgrass, and were highly toxic to maize, especially when applied to young plants.

4. HERBICIDE SCREENING TRIAL.

The toxicity of a number of herbicides and certain herbicidal mixtures to nutgrass were evaluated in two field trials at Bethal. The site was poorly drained, very heavily infested with nutgrass plants and a high dormant tuber population. The screening of a wide range of compounds would therefore furnish information, not only in respect of direct phytotoxicity to aerial growth, but would also indicate which herbicides exercised a residual toxicity. A replicated screening trial was conducted during the first season, followed by a non-replicated confirmatory test in the subsequent year.

a) Screening trial (1963/64).

20 herbicides or herbicidal mixtures were applied(6/11/63)to nutgrass in the 10 - 12 leaf stage. Details of the treatments are given in Table 98 . (Figure 87). Rates expressed as active material per acre.

TABLE 98 : HERBICIDES AND HERBICIDAL MIXTURE PER ACRE.

1.	TCA	- 100 lbs.
2.	Dinoseb	- 5.52 lbs DNBP
3.	Dinoseb	-11.4 lbs DNBP
4.	2,4-D	- 8 lbs acid equivalent (2 gallons).
5.	Atrazine	- 8 lbs + Agral* 15 fl.oz.
6.	Linuron	- 5 lbs + Agral - 15 fl.oz.
7.	Monolinuron	- 5 lbs + Agral - 15 fl.oz.
8.	Monuron	- 8 lbs + Agral - 15.fl. oz.
9.	Atrazine	- 4 lbs + Amitrole - 9.6 lbs
10.	Monolinuron	- 2.5 lbs + Amitrole - 9.6 lbs.
11.	Monuron	- 4 lbs + Amitrole - 9.6 lbs
12.	Atrazine	- 4 lbs + Paraquat - 1 lb + Agral - 15 fl. oz.
13.	Monolinuron	- 2.5 lbs + Paraquat - 1 lb + Agral - 15 fl. oz.
14.	Monuron	- 4 lbs + Paraquat - 1 lb + Agral - 15 fl.oz.
15.	Monolinuron	- 2.5 lbs + Dinoseb - 5.52 lbs.
16.	Monuron	- 4 lbs + Dinoseb - 5.52 lbs.
17.	Atrazine	- 4 lbs + Dinoseb - 5.52 lbs.
18.	Amitrole	- 9.6 lbs
19.	Paraquat	- 1.5 lbs
20.	Dalapon	- 33 lbs
21.	Control	- Unsprayed
22.	Control	- Unsprayed
23.	Control	- Unsprayed
24.	Control	- Unsprayed.

*Agral 90 - Surfactant containing 92% w/w Alkylated phenolyethylene oxide condensate.

4 unsprayed controls were included in each replicate. The treatments were arranged in 3 randomised blocks. To ensure thorough wetting of the plants, the water volume was increased to 100 gallons per acre. Plot size was 1/100th acre. The prevailing weather conditions during spraying were,

Relative humidity - 54%
Shade temperature - 25°C

Soil moisture conditions were favourable during spraying.

Results

The experimental plots were rated for control of nutgrass on 5 different occasions following herbicidal application. These results are given in Appendix Table 5 and the mean values in Table 99. At the final assessment, two clip quadrats ($\frac{1}{4}$ sq. metre) were removed from each plot centre and the green nutgrass herbage weighed. Results are given in Appendix Table 52 and means in Table 99.

R.T. Ratings after 6 and 47 days respectively were converted to percentages of maximum nutgrass control and then to angular transformation. Analysis of variance are given for the two ratings only and for weights of clipped quadrats. Control plots were excluded from the analysis.

Herbicidal Ratings.

Herbicides differed significantly on both assessment dates. Treatments 1, 2, 3, 14 and 16 were among the first ten on both assessment dates. Treatments 12, 13, 15, 17 and 19 were among the first ten on the first date but not on the second. Treatments 9, 10, 11, 18 and 20 were among the first ten on the second date of assessment but not on the first. Variation was extremely high in the second assessment so that any conclusions can only be very tentative.

In general the contact herbicides, e.g. dinoseb and paraquat gave excellent initial top kill within 6 days after treatment. The effect was of short duration and had practically disappeared one week later. Combinations of soil acting herbicides, i.e. substituted urese and atrazine with amitrole gave good control of nutgrass when rated 23 days after spraying. These plots however became reinfested one month later.

The high application rate of TCA and to a lesser extent the dalapon treatment gave the best control of nutgrass both in respect of kill and residual action. These results are also confirmed by the green clip quadrat weights. The analysis of variance reveals no significant differences. The results in Table 99 show that the lowest weights of green nutgrass herbage were produced on the TCA and dalapon sprayed plots.

TABLE 99 : MEAN RATINGS OF NUTGRASS CONTROL AND GREEN AERIAL WEIGHT OF NUTGRASS (OZS PER CLIP QUADRAT)

TREATMENTS	CONTROL RATINGS AFTER						WEIGHT PER CLIP QUADRAT
	6 days 12/11/63		13 days 19/11/63	23 days 29/11/63	47 days 23/12/63		59 days 24/1/64
	A.T *	Actual			A.T	Actual	
1. TCA	41.1	4.3	4.3	8.0	42.7	6.7	7.3	7.9
2. Dinoseb - 5.52 lbs	41.0	4.3	3.7	1.0	36.1	3.7	0	15.9
3. Dinoseb - 11.04 lbs	71.5	9.0	7.7	4.7	34.9	4.0	2.7	19.4
4. 2,4-D	41.1	1.3	1.0	4.0	21.1	1.7	0	14.7
5. Atrazine + Agral	18.4	1.0	1.3	1.0	29.9	3.3	0.7	16.5
6. Linuron + Agral	18.4	1.0	2.0	1.3	6.1	0.3	2.0	17.4
7. Monolinuron + Agral	18.4	1.0	2.0	1.0	6.1	0.3	0.0	16.2
8. Monuron + Agral	14.9	1.0	2.0	2.0	17.6	1.3	2.0	13.1
9. Atrazine + Amitrole	18.4	1.0	3.7	8.3	38.8	4.0	3.3	14.1
10. Monolinuron + Amitrole	18.4	1.0	6.0	8.3	36.9	3.7	1.3	18.0
11. Monuron + Amitrole	21.1	1.3	5.7	9.0	61.1	7.7	3.3	16.0
12. Atrazine + Paraquat + Agral	37.2	3.7	1.7	1.0	12.2	0.7	0.0	18.4
13. Monolinuron + Paraquat + Agral	36.9	7.3	3.0	1.0	0	0	0.0	19.0
14. Monuron + Paraquat + Agral	46.8	5.3	4.0	3.7	41.1	4.3	3.7	16.2
15. Monolinuron + Dinoseb	34.9	3.3	3.3	1.0	0	0	0.0	16.4
16. Monuron + Dinoseb	54.9	6.7	4.3	2.0	38.1	4.0	1.3	18.4
17. Atrazine + Dinoseb	61.1	7.7	4.7	2.3	6.1	0.3	0.3	16.5
18. Amitrole	23.8	1.7	2.0	7.7	30.9	2.7	0.7	13.1
19. Paraquat	61.1	7.7	3.7	1.7	19.2	1.7	0.7	17.5
20. Dalapon	21.1	1.3	1.3	6.7	48.7	5.0	3.7	9.0
21. Control	0	0	0	0	0	0	0	24.9
22. Control	0	0	0	0	0	0	0	16.9
23. Control	0	0	0	0	0	0	0	18.8
24. Control	0	0	0	0	0	0	0	19.1
L.S.D p = 0.05	10.8				29.1			

* Angular Transformation

b) Screening Trial 1964/65

In this trial, several of the most promising treatments included in the 1963/64 screening trial, as well as a number of more recent herbicides and herbicidal combinations were screened. The action of repeated applications of the same treatment was also examined. Treatments were applied in 100 gallons of water per acre to single plots (1/100th acre) as follows :- (Rates expressed as active material per acre).

1) Initial spray 25/11/64

2) Initial spray 25/11/64 + repeat spray 2/2/65

3) Initial spray 2/2/65.

The nutgrass plants were approximately 8" high on 25/11/64 and 12" high on 2/2/65.

Results. Results were assessed by visual ratings. The relative efficiency of the treatments are given in Table /DD.

TABLE 100 :RATING OF NUTGRASS CONTROL

TREATMENTS	PERIOD AFTER APPLICATION			
	3 Days	3 weeks	10 weeks	14 weeks
1. Application 25/11/64				
1. 2,4-D ester - 0.5 lb a.e + NaFl - 30 lbs + TCA 5 lbs	2	2	0	0
2. 2,4-D ester - 1 lb a.e + NaFl 30 lbs + TCA 10 lbs	2	2	2	0
3. Amitrole - 4.8 lbs + Dalapon 15 lbs	2	7+	4	0
4. Bromacil - 3.2 lbs	1	4	7	6
5. Bromacil - 6.4 lbs	2	8	9+	9
6. Bromacil - 4.8 lbs + Amitrole 4.8 lbs	2	8+	9+	9
7. TCA - 100 lbs	3	8	9	5
8. Dalapon - 40 lbs	3	7	8	5
9. Iriuron - 100 lbs	3	9	9+	8
10 Paraquat - 1 lb - Agral 0.05%	4	6	0	0
11 Paraquat - 1.5 lb + Agral 0.05%	8	8	1	0
12 Paraquat - 1.5 lb + diuron 4 lbs + Agral 0.5%	8	9	5	0
13 Paraquat - 1.5 lb +monolinuron 2.5 lbs + Agral 0.5%	8	9	1	0
14 Paraquat - 1.5 lbs + Linuron 2.5 lbs + Agral 0.5%	9	9+	0	0
15 Calcium nitrate - 600 lbs	0	0	0	0
16 Calcium nitrate - 1200 lbs	0	0	0	0
17 Dinoseb - 5.52 lbs	8	2	0	0
18 Dinoseb - 11.04 lbs	9	3	0	0
19 Dinoseb - 22.08 lbs	9+	5	0	0
2. Applications 26/11/64 and 2/2/65	4 weeks after 2nd application			
1. Bromacil 3.2 lbs			10 8+	
2. Dalapon - 40 lbs			9+	
3. Paraquat - 1.5 lbs + diuron 4.0 lbs +Agral 0.5%				
3. Application 2/2/65	4 weeks after 2/2/65.			
1. Diuron - 8 lbs + Agral 0.5%			10 9+	
2. Linuron - 5 lbs + Agral 0.5%			9+	
3. Linuron 10 lbs + Agral 0.5%				

Agral - 0.5% - Based on final spray volume, i.e. 4 pints per 100 gallons

*The 2,4-D, NaFl, TCA combinations as described by Tamos & Olmons (1963).

Of the single applications, the high rate of bromacil (6.4 lbs. per acre) gave excellent control of nutgrass, followed by the mixture of bromacil (4.8 lbs) + amitrole, Triuron, the low bromacil treatment (3.4 lbs), TCA and dalapon. Combinations of paraquat + soil acting herbicides + Agral gave good initial control, but the residual effect was of short duration (3 weeks). Repeated applications of 3.2 lbs bromacil + diuron + Agral at intervals of 68 days gave excellent control of nutgrass, whereas split dalapon applications gave only 85% control.

5. Linuron as a Post-emergence Treatment in Maize.

According to Hill et al. (1964), linuron, when applied in conjunction with a surfactant, is highly toxic to a number of annual broadleaf and grass species. The effect of linuron, when combined with a surfactant on yellow nutgrass has already been described by Shear (1965) and Goenell (1965b). To test the efficacy of post-emergence linuron treatments against nutgrass in maize, two new trials were conducted at Frankenwald on a nutgrass dominated weed flora, using various rates of linuron with a constant concentration of surfactant. The treatments were as follows:- (Per acre)

Trial (a)

1. Linuron 1 lb + Agral 90 (0.5%) - 2 pints per 50 gallons/water
2. Linuron 2 lbs + Agral 90 (0.5%) - 2 pints per 50 gallons/water.
3. Unsprayed control.

Trial (b)

1. Linuron 1 lb + Agral 90 (0.5%) - 4 pints per 100 gallons/water.
2. Linuron 1.25 + Agral 90 (0.5%) - 4 pints per 100 gallons/water.
3. Linuron 1.5 lbs + Agral 90 (0.5%) - 4 pints per 100 gallons/water.
4. Linuron 2.0 lbs + Agral 90 (0.5%) - 4 pints per 100 gallons/water.
5. Unsprayed control.

Both trials were conducted on adjacent sites. Treatments were arranged at random, in a continuous block and replicated three times. Plots were 1/200th of an acre. Trial (a) (See Fig. 56) was sprayed on 12/1/65. The maize plants were approximately 15" tall, and the nutgrass 5" high.

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