Reprinted from
AGRONOMY JOURNAL, Volume 65
September-October 1973, p. 797-800

Influence of Straw Application Rates, Plowing Dates, and Nitrogen Applications on Yield and Chemical Composition of Sugarbeets[1]

J. H. Smith, C. L. Douglas, and M. J. LeBaron[2]

ABSTRACT

Fertilizer N applied at ever-increasing rates sometimes accumulates in the soil. The practice of fertilizing grain straw with N to stimulate decomposition is questionable, but decomposition of straw immobilizes N that must be compensated for in fertilizing the succeeding crop. Too much N decreases the sucrose content of sugarbeets and decreases sucrose recovery. Experiments were conducted to determine the relative value of early and late straw applications, plowing with N applied in the fall or spring, and the amount of N needed to compensate for straw applications in obtaining optimum beet and sucrose yields with maximum quality.

Sugarbeets (*Beta vulgaris* L.) were grown following winter wheat (*Triticum aestivum* L., var. 'Nugaines') in 1970 and 1971 on a Portneuf silt loam soil near Kimberly, Idaho. Straw was applied to the beet plots at rates of 6.7, and 13.4 metric tons/ha, and the plots were plowed either in early September or mid-November. Nitrogen was applied at 67 kg N/ha in the fall and at 67 and 134 kg N/ha in the spring. The treatments were arranged in a split-split plot design with 4 replications. Control plots were used with all experiments. N fertilization increased beet, top, and sucrose yields, as well as amino N, Na, K concentrations, and impurity index. It decreased the sucrose percentages of the beets. Straw applications decreased beet, top, and sucrose yields, Na and amino N concentrations, and impurity index, but they did not influence K content of the beets. Early plowing increased sucrose percentage and yield and decreased Na, K, and impurity index. Interactions between straw applications and plowing dates were significant for sugarbeet and beet top yields. Approximately 7.5 kg N fertilizer per metric ton of straw were required to compensate for the deleterious effects of the straw.

Additional index words: Sucrose percentage, K, Na, Amino N, Impurity index.

THE role of nitrogen in straw decomposition has been investigated extensively, and many papers have been published on the subject. Reviews by Allison (1), Bartholomew (2), and Harmsen and Van-Schreven (7) present the classic concepts relating C:N ratios to plant material decomposition and the immobilization and release of nitrogen during decomposition. Allison (1) cited references indicating that plant residues with C:N ratios greater than 25 to 30 require additional N for most rapid decomposition. Conversely, N may be available as fertilizer from plant residue with an initially wide C:N ratio after the residue has decomposed and lost enough carbon to narrow the ratio. Because of these immobilization theories, N is frequently applied to compensate for the addition of straw. Experimental and practical experience indicates that the concepts are basically correct. Increased N fertilization on many fields has increased soil fertility and residual nitrogen levels. James et al. (9) reported residual N fertilizer with nitrate concentrations up to 725 kg/ha in farmer's fields used for sugarbeet experiments. Many fields that they sampled had high residual nitrate. Crops grown under conditions of such fertility buildup will utilize residual fertilizer and may also have available considerable nitrogen from mineralization during decomposition of soil organic matter and crop residues.

Field studies by Smith and Douglas (15) showed that with normal straw applications in fertile soils, the addition of N does not hasten straw decomposition. Residual nitrogen fertilizer and mineralization will supply enough N under many field conditions to meet decomposition requirements. However, N will be immobilized during straw decomposition and will influence the availability of N to succeeding crops.

Sugarbeets (*Beta vulgaris* L.) grown following plowdown of grain straw may develop N deficiency. Several researchers have reported excellent responses to N fertilizer on sugarbeets treated with crop residues or manure (3, 5, 8, 16). Decreases in sucrose percentage in the sugarbeets with increasing N fertilization (12, 13) and increasing sucrose percentages resulting from straw applications have been reported (3, 4, 5). The amino N content of the beets is affected by N fertilizer (10) and influences sucrose recovery.

Because of increasing fertility levels in soil, it is necessary to evaluate established practices of fertilizing to enhance decomposition of crop residues. N immobilization that accompanies decomposition of low N crop residues must be compensated for adequately but without adding excess N that decreases sucrose content of sugarbeets. The experiments reported here were conducted to determine 1) the fertilizer value of N applied to 'Nugaines' wheat (*Triticum aestivum* L.) straw preceding early and late fall plowing, compared with spring N application, and 2) the N requirements of sugarbeets following incorporation of wheat straw.

MATERIALS AND METHODS

Nugaines wheat was grown in 1969 and 1970 on Portneuf silt loam soil near Kimberly, Idaho. Each crop was fertilized with 112 kg N/ha as ammonium sulfate. All of the straw was removed and plots 4.86 by 12.15 meters were established for growing sugarbeets. Straw from the area was applied to the plots by hand at rates of 6.7 and 13.4 metric tons/ha (3 and 6 tons/acre), and treated with 67 kg N/ha sprayed on the straw as urea-ammonium nitrate solution immediately before plowing. The straw contained an average of 0.47 and 0.36% total N in 1969 and 1970, respectively. The rates cover the range of expected straw yields for Nugaines wheat in this area. The plots were plowed either in early September or mid-November. Nitrogen was applied by hand to specified plots in the spring at rates of 67 and 134 kg N/ha as NH_4NO_3. The statistical design was a split-split block arrangement with four replications. Straw treatments comprised the major plots, plowing dates the split plots, and nitrogen treatments the split-split plots.

The sugarbeets were planted in rows 61 cm apart and were thinned by hand to an average spacing of 25 cm. The beets and previous wheat crop were irrigated in furrows according to a computer-scheduled irrigation program (11). Beet petiole sam-

[1] Contribution from the Agricultural Research Service, USDA, and the Idaho Agricultural Experiment Station. Presented at Agronomy Meeting, Miami Beach, Florida, Nov. 1, 1972. Received Feb. 3, 1973.

[2] Soil Scientists, Snake River Conservation Research Center, and Superintendent, Idaho Branch Agricultural Experiment Station, Kimberly, Idaho 83341.

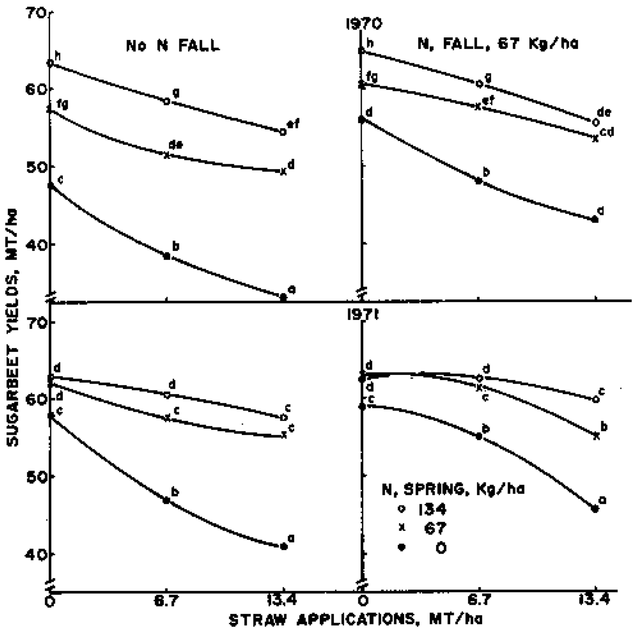

Fig. 1. Sugarbeet yields as influenced by straw applications and nitrogen fertilizer. Points on the curves with different letters are different at the 95% probability level for each individual graph. MT = metric tons.

ples were taken August 11, 1970, for nitrate analyses. For top and root yield determinations, four 10.6-m rows of beets were harvested from each plot. Beet samples were analyzed for sucrose, amino nitrogen, sodium, and potassium.[3] Beet and top samples were analyzed for total nitrogen by a Kjeldahl procedure modified to include nitrates; and soil samples composited from the surface 40-cm soil depth from each plot, taken before planting and after harvest, were analyzed for nitrate. Soil tests revealed that phosphorus was adequated. Laboratory nitrification studies on the plot soil in 1970 produced approximately 200 kg N/ha mineralized in 21 days. This is typical of many of the silt loam soils in this area and somewhat higher than the 159 kg N/ha utilized by the sugarbeets without added N.

RESULTS AND DISCUSSION

In the 1970 and 1971 experiments, beet yields, sucrose percentages, sucrose yields, and chemical analyses were similar. Statistical evaluation of the data for the 2 years also gave similar results. Significant interactions were observed between N fertilization and straw applications for sugarbeet yields (Fig. 1). Sugarbeet yield increased with N fertilizer and decreased with straw applications. Averages for the 2 years indicated that approximately 7.5 kg N would compensate for the addition of 1 metric ton of straw. Nitrogen never

[3] The authors express their appreciation to Amalgamated Sugar Co., Nyssa, Oregon, for the analyses.

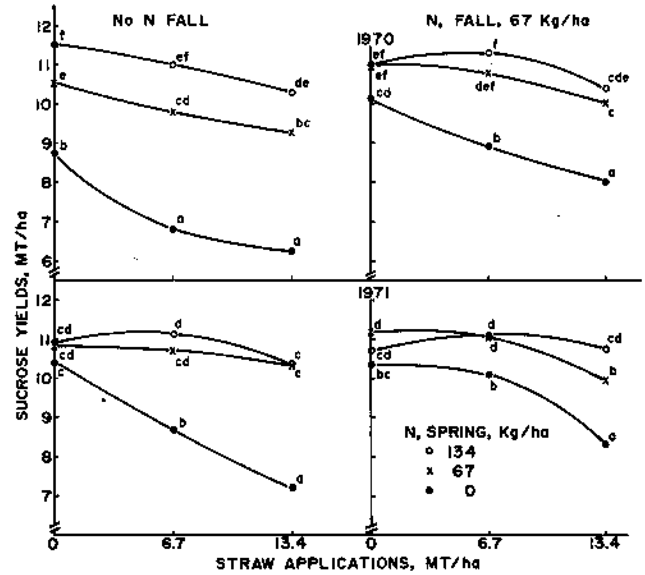

Fig. 2. Sucrose yields as influenced by straw applications and nitrogen fertilizer. Points on the curves with different letters are different at the 95% probability level for each individual graph. MT = metric tons.

completely compensated for the 13.4 metric ton straw rate. This lack of complete compensation may have resulted from toxic straw constituents, as was observed by Guenzi and McCalla (6).

Sucrose percentages in the beets were high in all treatments and were decreased only with 201 kg N/ha on the plots that received no straw (Table 1). The high sucrose percentages were probably brought about by cropping the previous year to wheat with moderate fertilization and the resulting low soil nitrate, which will be discussed. Sucrose yields were influenced by both nitrogen fertilization and straw applications (Fig. 2). Without N fertilizer, sucrose yields were decreased approximately 3 metric tons/ha by straw applications both years. Nitrogen fertilization compensated for the deleterious effects of 6.7 metric tons/ha of straw, and near-maximum sucrose yields were obtained at that rate. Other factors may have been influencing sucrose yields at the 13.4 metric tons/ha rate, but as just mentioned, N did not completely compensate for this treatment.

Excessive N fertilization increases amino N in the sugarbeet, resulting in decreased sucrose and decreased extraction efficiency. Impurity index values have been established relating amino N, Na, K, and sucrose (14) by the following formula:

$$\text{Impurity index} = [10(\text{N}) + 2.5(\text{K}) + 3.5(\text{Na})]/\%\ \text{Sugar}$$

Table 1. Effects of treatment on sugarbeet composition (1970 data).

N treatment, kg/ha		Sucrose % at			Impurity index at			N fertilizer		
Fall	Spring	0	6.7	13.4	0	6.7	13.4	Amino N	Na	K
		Straw applications, metric tons/ha						ppm in beets		
0	0	18.3*	18.1	18.8	484*	462	420	335 a†	72 a	1,869 a
0	67	18.4	18.8	18.7	460	470	458	378 b	74 a	1,914 ab
0	134	18.1	18.8	18.9	543	481	466	396 c	101 bc	1,956 bc
67	0	18.1	18.6	18.6	482	462	463	353 b	88 ab	1,950 bc
67	67	18.2	18.6	18.6	539	474	480	384 bc	104 c	1,989 bc
67	134	17.6	18.4	18.4	616	535	483	433 d	127 d	2,023 c
			* 6 means 0.5			* 3 means 61 6 means 64				

* For comparison of 3 means in the rows or 6 means in the columns, the differences indicated below each interaction block are needed for significance at the 95% probability.
† Duncan's Multiple Range Test, numbers followed by different letters are different at the 95% probability.

Table 2. Nitrogen uptake in sugarbeets and tops.

Treatment		1970					1971				
		Total N %		N uptake, kg/ha			Total N %		N uptake, kg/ha		
Fall	Spring	Tops	Beets	Tops	Beets	Total	Tops	Beets	Tops	Beets	Total
N, kg/ha											
0	0	1.47 a*	0.51 a	62 a	45 a	107 a	1.57 a	0.60 a	95 a	64 a	159 a
0	67	1.51 ab	0.61 b	95 b	72 c	167 c	1.61 a	0.66 b	119 b	85 c	204 c
0	134	1.58 b	0.70 c	121 c	92 d	213 e	1.82 a	0.75 c	150 c	100 d	250 d
67	0	1.54 ab	0.58 b	85 b	64 b	149 b	1.65 a	0.66 b	118 b	77 b	193 b
67	67	1.57 b	0.68 c	112 c	86 d	198 d	1.61 a	0.69 b	131 b	91 c	222 c
67	134	1.71 c	0.76 d	150 d	102 e	252 f	1.89 b	0.81 d	159 c	110 e	269 e
Straw, metric tons/ha											
0		1.62 a	0.70 b	132 b	92 b	224 b	1.86 b	0.76 b	161 b	102 c	263 b
6.7		1.51 a	0.63 ab	92 ab	75 a	167 a	1.63 a	0.68 a	118 a	86 b	204 a
13.4		1.56 a	0.60 a	90 a	65 a	155 a	1.60 a	0.64 a	106 a	75 a	181 a
Plowing dates											
September 5		1.56 a	0.65 a	103 a	78 a	181 a	1.68 a	0.70 a	132 a	88 a	220 a
November 13		1.57 a	0.63 a	105 a	75 a	180 a	1.70 a	0.69 a	124 a	86 a	210 a

* Numbers followed by different letters are different at the 95% probability.

Amino N, K, and Na are expressed in parts per million in this formula. The impurity index is related to ease of sucrose recovery in sugarbeet processing; a high impurity index is undesirable. Nitrogen fertilizer increased the amino N, Na, K, and impurity indexes of the sugarbeets (Table 1). However, all of the impurity indexes in this experiment were within the range for good sucrose recovery. There was a significant interaction between straw application, N fertilizer, and impurity index, with N increasing and straw decreasing the impurity index.

In the interaction of straw and N fertilizer and its effect on sucrose percentages, trends for sugar percentages were approximately opposite of those for sugarbeet yields. When no straw was applied, the highest rates of N fertilizer decreased sucrose percentages. Straw applications at each N treatment level increased sucrose percentage.

Even though trends in sugarbeet yields and sucrose percentages were opposite those produced by N and straw, the increases in sugarbeet yields with N were great enough to overcome sucrose percentage declines, and sucrose yields followed beet yields closely. The 201 kg N/ha application did not increase sucrose yields significantly above either the 134 kg N applied in spring or split between fall and spring. When no straw was used, spring and fall applications of 67 kg N produced similar sucrose yields. Spring application of 67 kg N produced an average of 8.5% more sucrose than the fall-applied 67 kg N/ha with the 6.7 metric ton/ha straw rate and an average of 17% more sucrose when 13.4 metric tons/ha straw was applied. Sucrose yields from all plots receiving adequate fertilizer were excellent and demonstrated that certain N treatments compensated for immobilization of N in straw decomposition and did not provide the excess N late in the season that contributed to decreased sucrose content of the beets.

In 1970, September plowing produced beets with 18.6 percent sucrose and 10,976 kg/ha of sucrose, compared with November plowing with 18.2 percent sucrose and 10,668 kg/ha of sucrose. In 1971, the sucrose percentage for both plowing dates was 18.0 percent. September plowing produced 10,370 kg/ha of sucrose, and November plowing 10,100 kg/ha of sucrose. These differences in sucrose yield are relatively small but significant at the 95% level.

Nitrogen percentages of tops and beets were increased by N fertilizer (Table 2). Nitrogen percentages in the tops and beets were not different for equivalent N fertilizer rates regardless of time of application in 1970, but showed a small increase for the 134 kg N rate in the spring 1971. Nitrogen uptake by the tops was also proportional to N fertilizer rate in both years. Nitrogen uptake by the beets and total N uptake by beets and tops were greater for the spring application of 67 kg N/ha than for the fall application. Total N uptake was greater for the spring application of 134 kg N/ha than for the split fall and spring application of 134 kg N/ha.

Straw applications decreased N percentage in the beets both years, and the decrease in the tops was significant in 1971. N uptake by the beet tops was decreased by straw application as was N uptake in the roots and total N in both tops and roots. Plowing dates did not influence N percentage or uptake by the beet tops or roots.

Nitrate concentration of the sugarbeet petioles increased very significantly with nitrogen fertilization, decreased with straw applications, and there was a highly significant interaction between the two factors (Table 3). Plowing in September produced lower petiole nitrates than plowing in November, with the 134 kg spring and the 201 kg split N application. Interaction between plowing dates and nitrogen fertilization was also significant. Carter[4] reported that petiole nitrates below 1,000 ppm N on August 10 would depress yield of sugarbeets. He also suggested that nitrate values above about 1,500 ppm N on that date would depress sucrose percentage in the beets. The petiole nitrates resulting when N fertilization was not used were too low and reflected decreased beet and sucrose yields. Some of the other low nitrates may also have reflected this condition. Most of the intermediate petiole nitrate values were in a near-optimum range, and only the 4,250 ppm nitrate N value obtained with the highest N fertilization and

[4] Carter, J. N. Personal communication. Snake River Conservation Research Center, Kimberly, Idaho.

Table 3. Nitrate-N (ppm) in sugarbeet petioles sampled August 11, 1970.

N treatment, kg/ha		Straw applications, metric tons/ha			Plowing dates	
Fall	Spring	0	6.7	13.4	Sept.	Nov.
0	0	200*	250	160	230	170
0	67	450	270	300	390	290
0	134	2,160	1,060	530	960	1,540
67	0	1,360	330	200	690	560
67	67	2,620	620	310	1,100	1,250
67	134	4,250	2,180	1,240	2,230	2,880

* The difference required for significance because of straw-nitrogen interactions is 585 for 3 and 614 for 6 means. When comparing plowing dates and nitrogen treatments, the differences required are 435 for 2 and 480 for 6 means.

without straw decreased sucrose percentages. At the lower rates of N application, plowing dates had no influence on petiole nitrate and all of the values were relatively low. When 134 kg N were applied in the spring, however, either with or without fall N fertilization, petiole nitrates were high enough for differences to be observed. With November plowing they were higher than with September plowing. The November plow-down probably delayed decomposition of the straw. Therefore, the N released during the following summer occurred at a later date and caused a higher petiole NO_3-N content than did comparable N rates in the early fall plow-down treatment.

Soil nitrate analyses of the top 40 cm of soil taken in the spring before the sugarbeets were planted reflected the N utilization by wheat and indicated that residual N was low. In 1970, the spring samples contained 7 ± 3 ppm nitrate N, compared with the 1971 spring samples of 11 ± 3 ppm nitrate N. The fall sampled soils contained 5 ± 2 ppm nitrate N for both years. Two of the plots were sampled in the spring of 1971 at 30-cm intervals to 180 cm. One plot contained nitrate N in the successive 30-cm sampling depths as follows: 9, 11, 9, 6, 6, and 5 ppm. The second plot was slightly higher with nitrate N in the successive depths of 12, 15, 10, 6, 5, and 6 ppm. The plot land had a lime-cemented hardpan at a depth of approximately 40 cm. The hardpan had little influence on water penetration, but was restrictive of root penetration, therefore much of the nitrateN below the hardpan probably was not readily accessible to the sugarbeets.

Rainfall from September to April in 1969 to 1970 and in 1970 to 1971 amounted to 18 and 21 cm, respectively. Most of the individual storms applied less than 1.5 cm of water. While some leaching of nitrate-N could have occurred over winter, it is unlikely that the loss from leaching was appreciable.

Smith and Douglas (15) showed that much less N is immobilized by straw decomposing in the field than would be anticipated in laboratory experiments. Decomposition proceeds in the field at a maximum rate for existing conditions. Straw decomposition proceeds to a great enough extent as a result of early fall plow-down that N immobilization is essentially complete in the fall and when N is applied the following spring for the sugarbeet crop after N immobilization has subsided, much of the N is utilized by the beets.

Fertility practices that will produce low residual nitrate and low impurity indexes with associated high sucrose percentages in the beets are desirable. As indicated in the introduction, soil fertility is high in many fields, and the residual nitrate levels are also high. Growing wheat on the land with moderate N fertilization before growing sugarbeets when the straw is plowed early in the fall appears to be an excellent practice, because the wheat has an extensive root system and high N requirement and removes a large amount of nitrogen. Of course, when extremely high residual N exists, more than one year may be required to remove the excess N. The removal of much of the residual N, the immobilization of mineralized N by straw, and a soil test to determine residual N, which is considered in fertilizer recommendations, enables fertilizing at a rate to obtain high yields and high sucrose content of the sugarbeets, as well as low impurity indexes.

Based on comparisons of sugarbeet yield curves as influenced by N fertilizer and straw applications, N response and immobilization were estimated. The average immobilization for 2 years' data was approximately 7.5 kg N per metric ton of straw. Immobilization appears to decrease slightly per unit of straw with increasing straw applications.

In conclusion, sugarbeets can be grown following wheat with excellent results. The wheat crop decreases residual N. Nitrogen immobilization can be compensated for with approximately 7.5 kg N per metric ton of straw. Working from a predictable fertility base, applying N at the rate recommended of 7.5 kg N per ton for straw compensation, and fertilizing with N at the proper rate for the crop can produce an excellent yield of beets with high sucrose content.

LITERATURE CITED

1. Allison, Franklin E. 1966. The fate of nitrogen applied to soils. Advan. Agron. 18:219-258.
2. Bartholomew, W. V. 1965. Mineralization and immobilization of nitrogen in the decomposition of plant and animal residues. *In* W. V. Bartholomew and F. E. Clark (ed.) Soil nitrogen. Agronomy 10:285-306. Amer. Soc. of Agron., Madison, Wis.
3. Boguslawski, E. V., and J. Debruck. 1970. Effect of application and plowing-in of straw on yield and sugar content of sugar beet. Zucker 13:377-384. (Abstr. in Soils Fert. 34: 1587.)
4. Eghbal, K. 1970. Effect of straw fertilizing on sugarbeet in Iran. Bodenkultur 21:325-334. (Abstr. in Soils Fert. 34:3424.)
5. Golus, H. M., and W. R. Schmehl. 1969. Yield and quality of sugar beets as affected by residual nitrogen, nitrogen fertility, and crop residue. Colo. State Univ. Agr. Exp. Sta. Prog. Rep. 69-35.
6. Guenzi, W. D., and T. M. McCalla. 1962. Inhibition of germination and seedling development by crop residues. Soil Sci. Soc. Amer. Proc. 26:456-458.
7. Harmesen, G. W., and D. A. VanSchreven. 1955. Mineralization of organic nitrogen in soil. Advan. Agron. 7:299-398.
8. Holmes, J. C., and E. A. Hunter. 1971. Trials on the manuring of sugar beet in South-east Scotland 1962-1966. J. Int. Inst. Sugar Beet Res. 5:136-145.
9. James, D. W., A. W. Richards, W. H. Weaver, and R. L. Reeder. 1971. Residual soil nitrate measurement as a basis for managing nitrogen fertilizer practices for sugarbeets. J. Amer. Soc. Sugar Beet Technol. 16:313-322.
10. Koch, K., and K. Mengel. 1970. Effect of varied nitrogen and potassium supply on the amino-acid content and yield of sugar beet. Landwirt. Forsch. 23:353-362. (Abstr. in Soils Fert. 34:4369.)
11. Jensen, M. E. 1969. Scheduling irrigations with computers. J. Soil Water Conserv. 24:193-195.
12. Milford, G. F., and D. J. Watson. 1971. The effect of nitrogen on the growth and sugar content of sugar beet. Ann. Bot. (London) 35:287-300. (Abstr. in Soils Fert. 34:4370.)
13. Reuss, J. O., and P. S. C. Rao. 1971. Soil nitrate nitrogen levels as an index of nitrogen fertilizer needs of sugarbeets. J. Amer. Soc. Sugar Beet Technol. 16:461-470.
14. Ryser, George K., and J. C. Theurer. 1971. Impurity index selections on individual sugarbeets. J. Amer. Soc. Sugar Beet Technol. 16:399-407.
15. Smith, J. H., and C. L. Douglas. 1971. Wheat straw decomposition in the field. Soil Sci. Soc. Amer. Proc. 35:269-272.
16. Snyder, F. W. 1970. Effect of leaf area and nitrogen on root weight and sucrose of sugarbeets. J. Amer. Soc. Sugar Beet Technol. 16:8-25.