Evaluation of intercropped sugar beets Beta vulgaris L. with emphasis on competition for light

by Muammer Ozkan

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Crop and Soil Science
Montana State University

Abstract:
Sugar beets were grown with beans, barley, or corn in alternate single rows in 1969 and 1970 using four different spaeings. Alternate paired plantings were also studied in 1968 and 1969. Turnips were used as an intercrop in 1968 only. Sugar beets were also grown under four levels of light intensity at the Montana State University Experiment Station located at Huntley, Montana in 1969 and 1970.

Objectives were (1) to determine the competitive effects of other crops on the yield and sugar content of sugar beets, (2) to determine the effect of reduced light intensity on the yield, sugar content and nutrient composition of sugar beefs, (3) to compare the gross returns per acre from growing two crops in a mixed culture with returns from growing one crop in a monoculture, (4) to compare the yield and sugar content of intercropped sugar beets planted in alternate single versus alternate paired rows and (5) to determine the effects of a companion crop on the micro-climate of sugar beets.

Corn had the greatest and beans the least competitive effects on sugar beef yields. Barley was nearly as competitive as corn. The taller intercrops had a competitive advantage for light interception over beefs or beans. Corn reduced light intensities on the canopies of intercropped sugar beets by 94% and 74% for 11 and 22-inch spacings respectively. Barley reduced light intensities for sugar beets 11% and 6% in 11" and 22" spaeings respectively. Beans and turnips did not. reduce light intensities in the sugar beet canopies when planted in alternate rows. Increased air temperature in canopies of intercropped sugar beets may also have contributed to the reduction of sugar beef yields and sugar content.

Artificial shading of the sugar beet canopy decreased the overall growth and root weights, but caused an increase in the nitrogen and phosphorus content (percentage) of the leaves and roots.

Narrow spacing (11") of pure stand sugar beets gave a higher sugar content in 1969 and higher yield in 1970 than wide rows (33"). Growing sugar beefs in alternate rows with beans resulted in the largest gross return per acre.

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WITH EMPHASIS ON COMPETITION FOR LIGHT

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TABLE OF CONTENTS

Table of Contents

(Continued)

LIST OF TABLES

Context Tables

List of Tables

Context Tables
(Continued)

List of Tables

Context Tables
(Continued)

Appendix Tables

List of Tables

Appendix Tables (Continued)

LIST OF FIGURES

ABSTRACT

Sugar beets were grown with beans, barley, or corn in alternate single rows in 1969 and 1970 using four different spacings. Alternate paired plantings were also studied in 1968 and 1969. Turnips were used as an intercrop in 1968 only. Sugar beets were also grown under four levels of light intensity at the Montana State University Experiment Station located at Huntley, Montana in 1969 and 1970.

Objectives were (1) to determine the competitive effects of other crops on the yield and sugar content of sugar beets, (2) to determine the effect of reduced light intensity on the yield, sugar content and nutrient composition of sugar beets, (3) to compare the gross returns per acre from growing two crops in a mixed culture with returns from growing one crop in a monoculture, (4) to compare the yield and sugar content of intercropped sugar beets planted in alternate single versus alternate paired rows and (5) to determine the effects of a companion crop on the micro-climate of sugar beets.

Corn had the greatest and beans the least competitive effects on sugar beet yields. Barley was nearly as competitive as corn. The taller intercrops had a competitive advantage for light interception over beets or beans. Corn reduced light intensities on the canopies of intercropped sugar beets by 94% and 74% for 11 and 22-inch spacings respectively. Barley reduced light intensities for sugar beets 11% and 6% in 11" and 22" spacings respectively. Beans and turnips did not reduce light intensities in the sugar beet canopies when planted in alternate rows. Increased air temperature in canopies of intercropped sugar beets may also have contributed to the reduction of sugar beet yields and sugar content.

Artificial shading of the sugar beet canopy decreased the overall growth and root weights, but caused an increase in the nitrogen and phosphorus content (percentage) of the leaves and roots.

Narrow spacing (11") of pure stand sugar beets gave a higher sugar content in 1969 and higher yield in 1970 than wide rows (33"). Growing sugar beets in alternate rows with beans resulted in the largest gross return per acre.

INTRODUCTION

Variations in the external environment affect not only photosynthesis but also all other physiological processes through the supply of substrate for energy and biosynthesis. Photosynthesis and subsequent plant growth are influenced by the light intensity, the carbon dioxide concentration and the temperature of the external environment in which the plant is growing. Sunlight is the primary energy source of a natural environment and it can be considered as the pre-eminent factor of the environment. Variation in light intensity and quality cause morphological changes in plant growth.

Light is an important factor in intra-plant and/or inter-plant competition. The wide fluctuations which occur in light intensity and quality in different locations and growing seasons suggest that competition for light may affect the competive ability of plants.

The research reported here was set up to study the relationship between competitive ability of different genotypes and availability of light. This study had the following objectives:

(1) to determine the competitive effects of other crops (barley, corn, beans, or turnips) on the yield and sugar content of sugar beets, (2) to determine the effect of reduced light intensity on the yield, sugar content and composition of sugar beets, (3) to compare the gross returns per acre from growing two crops in a mixed-culture with returns from growing one crop in a monoculture, (4) to compare the yield and sugar content of intercropped sugar

beets planted in alternate single versus alternate paired rows, (5) to determine the effects of a companion crop on the micro-climate (We planned to measure light intensity, soil and air temperatures.) and composition of sugar beets.

The information obtained should provide a better understanding of the physiology of sugar beets and information on the economic feasibility of intercropping sugar beets.

LITERATURE REVIEW

Competition may occur among plants for water, nutrients, light, CO_2 and oxygen. The components of the environment for which adjacent plants compete most are light, mineral nutrients, and water (15). Adequate application of fertilizer and timely irrigation can minimize competition for nutrients and water so that production is primarily limited by light (15,4,14,26,). According to Clements et al., cited by Donald (15), two plants do not compete with each other so long as water nutrients, and light are in excess of the needs of both. When the immediate supply of a single necessary factor falls below the combined demands of the plants, competition begins. It is assumed that in these experiments light is the main factor limiting the yield of intercropped plants. Therefore, this review of literature will emphasize the effect of competition for light upon the yield and sugar content of sugar beets. Since artificial shading of sugar beets affected both temperature and composition of sugar beets the effects of temperature and of sugar beet nitrogen, phosphorus and potassium content on sugar beet yield and sugar content will also be discussed here.

I. The Effect of Competition for Light on Sugar Beet Yield and Sugar Content

Competition for light can occur whenever one plant shades another plant or within a plant, when one leaf shades another leaf. Blackman and Black (3) and Evans and Hughes (17) have measured the effect of artificial shading on growth of several species in the early vegetative phase. They showed that the net assimilation rate was dependent on the amount of light received while the leaf-area ratio (total leaf area/ ground area) rose as the level of shading was increased. They also concluded that during the season of active growth the quantity of light reaching the individual plants was limiting photosynthesis. Blackman and Black (4), in another experiment, found that shading (50% of daylight) reduced the relative growth rate of twenty-one out of twenty-two species, and concluded that the growth rate of many species is restricted even in midsummer by the lack of sufficient light energy.

Thomas and Hill (39) have investigated the photosynthesis of crops in the field where there was a high degree of self-shading as in sugar beets. They established that the net photosynthesis did not attain a maximum value for sugar beets until the intensity reached 4,400 foot-candles. In contrast Went (47) recorded that for seedlings of sugar beets under conditions where there was no self-shading, light saturation in environmental chambers occurred at 1,000 foot-candles. Watson (45) also showed that in normal stands of Beta mantima self-shading depresses photosynthesis.

Davidson and Philip (12), Davidson and Donald (11), and Watson (45) have shown that the degree of mutual shading of leaves which depends on the leaf area per unit area of land (the Leaf-Area Index or LAI) is related to the rate of dry-matter production per unit time (the Crop Growth Rate). Watson and Witts (46) compared wild beets and sugar beets under experimental conditions and found out that early in the season (LAI = 1), the net assimilation rate was equal in wild and cultivated beets. This suggested that "There was no difference in the leaf physiology". When the LAI rose to 2, the net assimilation rate fell for both, but much more steeply for wild beets. They attributed the fall to mutual shading in the wild beet because it has a rosette of horizontally disposed foliage. Cultivated beets have leaves at steeper angles and with less vertical separation between leaves. Therefore, a greater proportion of leaves in cultivated plants received a favorable light intensity. In general, with high solar elevations, light is better utilized by crops with erect leaves than by crops with horizontally placed leaves (14).

Researchers (5, 9, 22, 29, 36) have shown that the reduction in yield and leaf area per plant and the loss of leaf efficiency has been attributed, at least in part, to the reduction of incident light around the lower leaves of the plants.

Rate of photosynthesis in crop plants is highly correlated with light intensity from a low intensity to light saturation of the leaves (22, 29, 38).

Kruger and Wimmer cited by Ulrich (44) found that yields of sugar beets were limited by light rather than by the nutrient deficiencies which restricted growth in direct sunlight. Borden (6) showed that shaded sugar cane plants grown in pots produced less sugar than unshaded plants regardless of the nitrogen or potash treatments used.

II. The Effect of Temperature on the Yield and Sugar Content of Sugar Beets

Ulrich (41) and Went (47) have shown that both day and night temperatures have pronounced effects on sugar beets. But the effect of night temperature is more pronounced. The optimum night temperature for growth lies between 20 and 23 C, whereas the optimal day temperature is 23 C. They also showed that the sugar content of the beets was inversely proportional to the temperature, again night temperature being slightly more important than daytime temperature. According to Ulrich (41) and Went (47) sugar content of sugar beets reached the highest value at 2 C to 4 C (night temperature) whereas at 30 C the sugar content was the lowest. Increasing the day temperatures from 20 to 23 or to 26 C during 8-hour day periods also decreased the sucrose concentration of the beets, but the effects were not nearly as great as for the night temperatures (41).

Ulrich et al. (44) showed that beets grown at a higher temperature gave lower yields and lower sugar percentages than obtained in a cooler climate.

Ulrich (42) found that petioles of sugar beets were high in nitrogen, phosphorus and potassium when night temperatures were kept at a high level.

Loomis (27) showed that the temperature of a leaf exposed to sunlight is often well above that of the air. Under conditions of high insolation and high humidity, leaf temperatures of 10 to 15 C above air temperatures (37) have been recorded (24, 37). Linacre (25) noted that when plants were exposed to the sun but without suffering from water stress, the difference between air and leaf temperatures was usually small. Linacre also reported a tendency for equality of air and leaf temperature at about 33 C (91.5 F). Below that temperature, leaves tended to be warmer than the air; above that temperature, the reverse was observed. According to Priestley (32) the maximum temperature of a plant canopy should be about 92 F. He also concluded that leaves whose surface temperature exceeds 92 F suffer from water deficit. Ansari and Loomis (1) found that leaves shaded from direct sunlight were usually about 1 C warmer than the air temperature.

There is not much information available on the effect of soil temperature on the growth of sugar beets. The percent emergence of sugar beet seedlings at soil temperatures of 13, 18, and 24 C was significantly higher than at 6 C and the speed of emergence increased as the temperature increased (16). Nielsen et al. (30, 31) found that the yield of roots and foliage of lucerne increased with increase in temperature to at least 19.4 C. The phosphorus content of the roots and foliage tended to increase with increasing temperature. Oats produced higher yields (30) of grain and straw when soil temperature was increased from 41 to 67 F (19.4 C). They also showed that there was a trend toward increased concentration of phosphorus in the oat plants with increasing temperature. Low soil temperature depressed the growth and phosphorus percentage of corn seedlings (23).

III. The Effects of Nitrogen, Phosphorus and Potassium on Sucrose Content and Yield of Sugar Beets

Researchers (19, 28, 34, 35) indicated that mineral nutrient content and balance in plant tissue strongly affect yield and quality. Gardner and Robertson (18) analysed petioles of sugar beets and found it useful in determining fertilizer needs as regards nitrate, phosphate and potassium.

Ulrich and Hill (43) and Tolman and Johnson (40) conducted experiments with sugar beets, and studied yield and quality in regard to fertilizer practices. They found a negative relation between levels of nitrate nitrogen in the petioles and percentage sucrose of the roots.

Hoddock et al. (20) found that nitrogen fertilization and nitrogen plant composition are closely associated with sucrose storage in beet roots and sugar recoveries from extract juice.

Baver (2) showed that nitrogen was the major factor affecting the quality of sugar crops both sugar beets and sugar cane.

Ulrich and Hill (43) have proposed and used the theory of "Critical Concentrations" of nitrogen, phosphorus, and potassium in sugar beet petioles as a guide to crop fertilization. They proposed 1,000 ppm of nitrate-nitrogen, 750 ppm phosphorus, and 10,000 ppm potassium as "Critical levels" in sugar beet petioles.

MATERIALS AND METHODS

Experimental Area

The experiments were conducted on the Huntley Branch of the Montana Experiment Station at Huntley, Montana in 1968, 1969 and 1970. The soil texture was silty clay, pH values were 6.9; 7.5; 8.1; 8.1 and 8.3 for soil depths of 0-6; 6-12; 12-24; 24-36 and 36-48 inches respectively. Conductivity was 2.0-4.0 mmhos/cm (slightly salty) for the surface soil but subsoil was 0.0-2.0 mmhos/cm (33). Organic matter was medium in the surface soil but low below 12 inches. Available phosphorus was high in the surface soil but low below 12 inches. Available potassium was high at all soil depths (Appendix Table 26).

A. Interseeding Experiment

Experimental Design and Methods

The design of the interseeding experiment was a randomized split-plot with four replications. Four different row spacings (11", 16½", 22" and 33") were randomly assigned to main plots, 77 feet long and 30 feet wide.

Four pure stand and three interseeding treatments were randomly assigned to subplots, 11 feet wide and 30 feet long within each main plot.

The experimental fields were uniformly fertilized with 500 pounds of 16-20-0 per acre. Plots were irrigated by furrow irrigation between rows in 1968 and 1970, and by sprinkler irrigation in 1969.

Each year spring barley (*Hordeum vulgaris L.*) variety (Vantage), corn (Zea mais L.) variety (Trojan TX68) or beans (Phaseolus vulgaris L.)variety (Pinto UI114) were planted in alternate rows with sugar beets (Beta vulgaris L.) variety (Great Western Hybrid size 3). Turnips (Brassica rapa L.) variety (Purple top white globe) were also planted with sugar beets in 1968. Rows were east-west oriented. Sugar beets were planted with a 6-row John Deere Flexi-planter May 10, 1968, April 23, 1969 and June 4, 1970. In 1968, the other crops were planted at the same time as the sugar beets. In 1969, the other crops were planted at one week intervals in order to give the sugar beets an adequate growing season and to use conventional planting times for barley, corn, and beans. These three crops were planted May 5, 12 and 19, 1969 respectively. In 1970, wet weather delayed seeding until June 4 and 5, and all crops were planted on the same date. Plots were maintained weed free by hand weeding and cultivating.

Measurement of Light

The percent penetration of photosynthetically useful radiation (visible light) through crop canopies of four crops was measured.

Light measurements were determined by the method of Bula et al. (7) in 1969 and by a modification of the method of Daynard et al. (13) in 1970. No light measurements were made in 1968. In 1970, eight selenium photo cells were connected in parallel and mounted on a 33 x 4 x 4 cm wooden block. Photocells were painted with white paint and covered with opal plexiglass which in turn was covered with black paint and black electrician's tape. A slit through the black paint was varied so that all cells gave the same micro ampere output in full sunlight intensity. Each block of eight photo cells was called a station. All stations were connected to a timer and a stepping switch assembly that provided successive readings to a 50 μA Rustrak recorder (Model 288).

Two stations were used in each interseeded plot of one replication. One was at the top of the sugar beet canopy, the other at the bottom of the sugar beet canopy (at ground level). Plots with pure stands had one station at the bottom of the crop canopy. Stations were oriented the same direction as the crop rows. Percent reduction of light intensity was calculated by comparison with another station above the barley, corn and bean canopies. Heights were adjusted as the crops grew. Readings were taken 5 times a day (8 AM, 10 AM, 12:30 PM, 3 PM and 5 PM) in full sunlight every 10 to 15 days. Solar noon was approximately 12:45 PM.

Measurement of Air and Soil Temperatures in Cropped Areas

Thermocouples were used to measure temperatures. Temperatures within intercrop canopies were compared with temperature taken in the canopies of pure stand sugar beets. Thermocouples were connected to a stepping switch assembly and a Rustrak Model 157C amplifier and Model 288 recorder.

Sampling Procedure

Yields were calculated from one 20-foot row sample taken from each plot. Nitrogen was determined by the Macro Kjeldahl method and phosphorus and potassium were determined with a spectrophotometer and atomic absorption spectrophotometer respectively. The Great Western Sugar Company in Billings, Montana determined sugar content of the sugar beets.

B. Shading Experiment

The shading experiment was conducted in 1969 and 1970 in an area immediately adjacent to the experimental area used for the Interseeding Experiment. The design used in the shading experiment was a randomized complete block with four replications. Plots were 22-feet long and 11-feet wide. The sugar beets were planted in 22 inch spaced rows on April 23, 1969 and June 4, 1970. Four shading intensities were created with saran shade cloth that was used by Cooper et al. (10) at Montana State University. Cloths were suspended at a height of 36 inches on July 7, 1969 and July 27, 1970. Intensities of shading were: (a) full sunlight, (b) 51% shade, (c) 76% shade, and (d) 92% shade.

Cultivation and irrigation were done at the same time as Interseeded Experiment.

Air and soil temperatures (4-inch depth) were recorded by thermocouples under the shading cloths in 1970. Temperatures were not measured in 1969.

C. Alternate VS Paired Rows Experiment

This experiment, conducted in another area adjacent to the Interseeded Experiment, compared plantings of barley, corn or beans grown in alternate single rows with sugar beets with alternate double rows (paired rows). The experimental design was a randomized split-plot with four replications. Two different row spacings (11" and 22") were randomly assigned to main plots, 77 feet long and 30 feet wide. Pure sugar beet stand and two different planting patterns (alternate single and alternate paired rows) with three interseeding treatments were randomly assigned to subplots, 11 feet wide and 30 feet long within each main plot.

All plots were planted, cultivated and irrigated at the same time as the Interseeded Experiment.

RESULTS AND DISCUSSION

Weather, experimental designs and planting patterns differed in 1968, 1969 and 1970. In 1969, each crop was planted at the normal planting time but a snowfall and frost occurred on June 12 and 13th, causing light damage to corn. Center rows of beans were covered by plastic to prevent damage. After June 13, temperatures warmed gradually and remained warm through September. Precipitation throughout the growing season was higher than normal (see Appendix Table 27). These conditions resulted in a high yield and sugar content of sugar beets in 1969. A cold and wet spring in 1970 preceded a wet growing season (see Appendix Table 28). The wet spring in 1970 delayed planting and thereby reduced yields. Because of differences in weather and planting dates, each year's results will be discussed separately.

1968 Experiment

One preliminary experiment was conducted in 1968 to study competition between sugar beets and different interseeded crops. Each cultivated crop was planted in alternate single or alternate paired rows. Gross returns per acre, yields, and sugar content were determined. Neither light intensities nor temperatures were measured in 1968.

The data presented in Tables 1 and 2A shows that sugar beets grown alone yielded 19.0 tons per acre compared to 8.1; 9.1; 15.9; or 13.9 tons per acre of sugar beets when grown in alternate single rows (11 inches apart) with barley, corn, beans or turnips, respectively. Barley had the greatest and beans the least competitive effect on sugar beet yields. Corn was nearly as competitive as barley and turnips were only slightly more competitive than beans. Percent reductions in yield of sugar beets were 57.4; 52.1; 16.3; or 26.8 when barley, corn, beans or turnips respectively were grown between 22 inch beet rows resulting in 11" spacings between adjacent rows.

The effects of alternate 22" rows of barley, corn, beans or turnips on sugar beets were essentially identical to 11" rows. Barley had the greatest and beans the least competitive effect as indicated by sugar beet yields.

Yields of sugar beets were 9.9; 8.8; 12.9; or 12.4 tons per acre when grown in alternate paired rows with 22 inches between adjacent rows with barley, corn, beans or turnips respectively. The competitiveness of intercrops on sugar beet yield decreased in the order corn, barley, turnips and beans.

Percent sugar was not significantly affected. Means ranged from 17.7 to 16.4.

Competitive effects of sugar beets upon the other crops can also be observed (Table 2A). The beets had a greater effect upon the yield of beans and barley than on corn and turnips. The percent yield reductions of corn, beans, or turnips were 22.4; 69.7; or 17.9 respectively in alternate single rows with 11" spacing.

The relative competitiveness of the different intercrops was the same for alternate paired 22" rows as for alternate single 22" rows.

Table 1. The effect of the competition of barley, corn, pinto beans, and turnips upon the yield and sugar content of sugar beets at Huntley, Montana in 1968.

Row Spacing	Crops	% Sugar (Averages)	Root Yield Tons/Acre (Averages)	% Yield Reduction (Averages)
22"	Beets alone	17.7	19.0	
11"	Beets in alternate single rows with barley	17.3	8.1	57.4
11"	" " " " " " corn	17.6	9.1	52.1
11"	" " " " " " beans	17.9	15.9	16.3
11"	" " " " " " turnips	17.8	13.9	26.8
22"	" " " " " " barley	17.5	8.1	
22"	" " " " " " corn	16.4	9.7	
22"	" " " " " " beans	16.8	15.6	
22"	" " " " " " turnips	16.9	14.0	
22"	Beets in paired rows with barley	17.1	9.9	
22"	" " " " " corn	17.4	8.8	
22"	" " " " " beans	16.3	12.9	
22"	" " " " " turnips	16.2	12.4	

Table 2A. The yield and gross returns for barley, corn, beans, and turnips grown alone and intercropped with sugar beets at Huntley, Montana, in 1968.

Row Spacings inches	Crops	Yield: Sugar Beets T/A Roots	Tops	Interseeded Crops: Barley Cwt./A	Corn T/A	Beans Cwt./A	Turnips T/A	Yield Reduction by Inter-Crop (%)	Gross Return per Acre
22"	Sugar beets alone	19.0	14.2						382.00
11"	Barley alone (grain)			26.0					63.20
22"	Corn alone (silage)				17.0				119.00
22"	Beans alone (seed)					14.5			100.40
22"	Turnips alone (roots)						8.4		63.30
11"*	Beets w/barley	8.1	7.2	10.5					194.50
11"	" w/corn	9.1	5.8		13.2			22.4	271.23
11"	" w/beans	15.9	15.1			4.4		69.7	375.22
11"	" w/turnips	13.9	7.6				6.9	17.9	325.69
22"*	Beets w/barley	8.1	4.2	7.2					173.41
22"	" w/corn	9.7	8.3		10.7				274.33
22"	" w/beans	15.6	14.4			7.3			382.00
22"	" w/turnips	14.0	10.8				4.6		320.83
22"**	Beets w/barley	9.9	6.9	8.0					217.60
22"	" w/corn	8.8	7.7		10.3				253.73
22"	" w/beans	12.9	10.5			7.7			322.18
22"	" w/turnips	12.4	12.5				4.2		299.60

* Planted in alternate single rows.

** Planted in alternate paired rows.

Table 2B. The yield and gross returns for barley, corn and beans grown alone and intercropped sugar beets at Huntley, Montana in 1969.

Treatments	Yield (T/A) Sugar Beets	Beans	Barley	Corn	Gross Crop Value/Acre ($)
Sugar beets 22" spacing alone	25.54				434.18
Sugar beets 22" spacing between rows beans	25.88	.05			440.00 + 6.50 = 446.50
Sugar beets 22" spacing between rows barley.	9.76		1.66		165.92 + 69.16 = 235.08
Sugar beets 22" spacing between rows corn	8.94			14.62	151.98 + 102.34 = 254.32
Sugar beets 33" spacing alone	24.58				417.86
Sugar beets 33" spacing between rows beans	15.82	.25			268.94 + 32.50 = 301.44
Sugar beets 33" spacing between rows barley.	15.10		1.35		256.70 + 56.25 = 312.95
Sugar beets 33" spacing between rows corn	8.46			19.50	143.82 + 136.50 = 280.32

Corn and barley were almost equally competitive in alternate and paired rows but beans and turnips were less competitive to sugar beets in alternate rows than in paired rows.

Total gross crop values per acre, using local prices at harvest, are presented in Table 2A and Table 2B. Sugar beets grown alone and sugar beets grown in alternate 22-inch rows with beans produced the largest gross of $382 per acre in 1968 (Table 2A) and $446.50 per acre in 1969 (Table 2B). Turnips were not planted in the 1969 and 1970 experiments because no market was available for turnips. Although beets grown with beans produced the same gross return per acre as beets alone, net income with beans as an intercrop should be more than beets grown alone because labor and machinery expenses were reduced when sugar beets were planted with beans in alternate rows.

1969 and 1970 Experiments

Although the same drill, the same planting pattern, and the same seed type were used both years, some results differed. This was partly due to the climatic conditions described above. Therefore, it is impractical to discuss the results from the two years together. The data obtained and calculated "F" values in 1969 and 1970 are presented in Table 3.

I. Interseeded Experiment

A. The Effects of Row Spacing and Intercrops on Sugar Beets:

1. Yield and % Sugar

Row spacing significantly affected yields and sugar content of beets (fresh weight basis) in 1969 but only yields were affected in 1970 (Table 3 and 4). Narrow (11") spacing of pure stand sugar beets gave a higher sugar percentage in 1969 and a higher yield in 1970. The higher yield and sugar content in narrow rows can be attributed to the increased population (smaller beets) and possibly to the more erect leaves that can use light more efficiently than the more horizontal leaves obtained with wider rows. These concepts are supported by other researchers.

Root yields and sugar content were generally lower in 1970 than in 1969 because of the shorter growth period in 1970 (164 days in 1969 vs 144 days in 1970). On the other hand, late planting in 1970 adversely affected the photosynthesis attained in the period from June 1 to July 10. The "Maximum photosynthesis possible" for this period was calculated by Campbell and Viets (8) to be 17.6 tons per hectare (7.3 T/A). Most of this photosynthetic potential was lost since plants were too small to intercept light efficiently.

Growing barley or corn, in alternate rows with beets decreased sugar beet yields in both years (Table 5). Percent reductions in yield of beets were 65 and 62 when corn or barley respectively were grown