STUDY OF FIBER CONTENT IN ASPARAGUS CULTIVARS

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ABSTRACT

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By

Jorge Sosa-Coronel

Studies were performed to determine if the fiber content of spears produced by various cultivars and crowns of asparagus was different.

Nine cultivars and ten crowns selected from breeding plots were used. The cultivars were as follows: Mary Washington, N. J. 44 x 22, Michigan Select, N. J. 51 x 22, California 711, California 66, California 72, N. J. Improved and California 309. Of the selected crowns five were males and five were females. The spears used were 20.0 cm (8") long; they were divided into five sections and fiber content was determined in each of these sections. Spears from these different harvest dates were included in this study.

The results indicated that there were significant differences among cultivars in the fiber content of the spears they produce. The lowest in fiber were Michigan Select, Mary Washington, California 66 and California 72. Those with the highest fiber content were N. J. Improved and California 711. Cultivars that had low fiber content were usually high in marketable yield.

There also were significant differences in the fiber content of the five sections of each spear; the tip portion (10 cm) had the least fiber while the bottom section (17.5-20.0 cm) had the highest. There were no significant differences between the second (10.0-12.5 cm from the tip) and the third (12.5-15.0 cm from the tip) sections of the spear.

There were no differences in fiber associated with harvest dates and no interactions between harvest dates and cultivars. Within row spacing had no influence on fiber content.

There was a correlation between the fiber content in a given section of spear and the temperature at which the spear was produced. Low temperatures caused an increase in the fiber content in the tip 10.0 cm of the spear and a decrease in the other spear sections. High temperatures had the opposite effect, ie: low fiber in the tip section and an increase in the other sections.

The fiber content in the spears of the crowns selected from the breeding plots did not follow a definite trend across the three harvest dates. However, differences in fiber content between the crowns were observed. Of the nine crowns on May 17, the four lowest in fiber were females.

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Jorge Sosa-Coronel

A THESIS

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To

my wife

Rosalva Lopez de Sosa

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INTRODUCTION

Asparagus is one of the main vegetable crops grown in Michigan. The majority of the crop (93%) is processed. The remainder is sold for consumption as a fresh product (11, 12).

Fibrousness is the most important deterent of asparagus quality, because it determines the edibility of the product. If this fibrousness which results from thick lignified cell walls in the pericycle and vascular bundles of the spear is more than 0.25% of the fresh weight of the spear, it is classified as inedible (5, 15). This standard (0.25%) was obtained, by comparing the fiber content of spears using the blender method (17), and the percentage of objectionable segments obtained by using the "fork test", a method used by the industry (Herner, personal communication).

Studies have been done in Michigan an attempt to determine ways to avoid high amounts of fiber in spears (4, 5, 15). Years ago asparagus spears grown in Michigan were harvested at the ground level. It was then shown that bending the spear appropriately would cause it to break at the point where fiber cease to be objectionable, leaving in the yield the pieces of the spear highest in fiber.

This method now called "snapping" is the major method of harvesting asparagus in Michigan.

Studies (4, 5, 6, 9, 13, 15) have shown that fiber content in the spear decreases from the base to the tip. Long spears generally contain a lower percentage of fiber than short spears and spears of large diameter are usually less fibrous than thin ones.

A continual reduction of annual hand labor in Michigan, may encourage asparagus growers to use mechanical harvesters. Some of these are non-selective sled-type harvesters that cut the spears 5.0 to 6.25 cm (2.0 to 2.5 inches) above the ground, and allow the harvest of 60 to 80 acres in a half a day. Because of their non-selectivity, many tips of growing spears are harvested before the spear reaches the ideal marketable size. This lowers the yield of the sled harvested asparagus by about 30 to 50% compared to yields achieved by snapping (2, 3, 15).

Studies have been done in order to determine which height of the spear lends itself to the most efficient mechanical harvest while at the same time reducing to a minimum the losses in quality due to fiber when the product is processed (15).

The influence of environmental factors on fiber content in asparagus has also been studied. Both, temperature and rainfall have been reported to have an influence on fiber formation in the spear (4, 10, 15, 16).

So far, no one has reported comparisons on fiber content in different cultivars of asparagus.

Cultivars which are selected using parameters such as yield, resistance to insect and diseases, etc., could also be selected for fiber content of the spears produced. Combining yield and fiber content would allow the breeder to evaluate more precisely the potential of each cultivar, since the real yield is not known until the product reaches the processing plants, and grading has been accomplished.

The objective of this study was to evaluate the fiber content of nine asparagus cultivars and 10 selected crowns, with the purpose of obtaining information that could be useful as a basis for selection in a breeding program. In addition, identification of the best cultivars with low fiber content will allow the growers to obtain higher marketable yields, because their losses at the processing plants will be less at the time the product is graded. It will also be advantageous for the processors, because cultivars with less fiber will allow longer storage (when necessary), faster processing and a higher quality product.

REVIEW OF LITERATURE

Structurally, a cross section of an asparagus spear is divided into five anatomical regions: the epidermis, the cortex, the pericyclic fibers, the ground parenchyma and the vascular bundles (1).

Fiber cells, found mainly in the pericyclic fibers region are long, thick-walled cells with a flat surface. When these cells mature, the walls are filled with deposits of lignin which makes the tissue hard. The fiber cell walls at the tip of the shoot, however, are thin, because no lignin has been deposited in that region (1). Another area responsible for fibrousness is the region of the vascular bundles which contains thick-walled wood fiber in the xylem (1).

Bisson et al (1), showed that as the stem of the asparagus grows older, the outer wall of the epidermis becomes thicker and more cutinized, the fiber cells in the pericycle region become thicker and more heavily lignified and the number of lignified tracheal tubes also increases from the tip to the base of the spear.

Jacobs (6) showed that the lignin content of the asparagus stalks was only half as much at the tip (8.47 $\pm$ 0.49%) as at the middle (17.84 $\pm$ 0.49%) and basal portions (14.59 $\pm$ 0.25%).

Smith and Kramer (17) reported that fiber content was very low in the tip 11.25 cm (4.5"). They classified that portion as very tender (0.012 to 0.020% fiber), and called the adjacent section from 11.25 to 15.0 cm (4.5 to 6.0") where fibers were slightly noticeable (0.024% fiber) the tender portion. They observed that in the next section (15.0 to 18.75 cm), there was a big increase in fiber (0.14%) and in the last section (18.75 to 22.5 cm) the fiber content was so high (0.84%) that the section was considered inedible. This work supported by the work of Scott and Kramer (14) who reported the same distribution of the fiber in spears they studied. Gonzalez (4) found that fiber content decreased from the base to the tip of the spears, regardless of the temperature at which they were grown.

Scott and Kramer (13) showed that the percentage of fiber was less in spears 20.0 cm long than in those 7.5 cm in length. They compared three lengths of the spear, measured from the tip to the ground level: 7.5 cm (3"), 12.5 cm (5.0") and 20.0 cm (8"). All spears harvested were 21.25 cm (8.5") in length, which means that the 7.5 and the 12.5 cm lengths had to be harvested below the ground. They found the 15.0-18.75 cm (6.0-7.5") section of the 20.0 cm (8.0") harvested spears was very close to the objectionable fiber content, and the bottom section was very fibrous (more than 0.40%) and was considered unusable.

Gonzalez (4) showed that the percentage of fiber was higher in spears of small diameter and increased with spear length. The lowest percentage of fiber was found in

spears 20.0 cm (8") long and 8.9 to 9.4 mm in diameter. Small diameter (4.5 to 5.5 mm) spears and lengths of 30.0 to 35.0 cm (12.0" to 14.0") had the highest fiber content.

Segerlind and Herner (5, 15) showed that spears longer than 25.0 cm (10.0") had more fibrous portion at the base of the spear than shorter spears. They also found that spears of small diameter had higher fiber content than spears of larger diameters. Spears less than 1.0 cm (3/8") in diameter had three times as much fiber as those 1.9 cm (3/4") in diameter, at comparable distance from the tip. They pointed out that the principal causes of fibrous pieces in asparagus were spears longer than 18.75 cm (7.5") and spears harvested too close to the ground (5, 15).

Kaufmann (8) related the rate and duration of growth with fiber content in the asparagus spears. He observed that the amount of fiber increased with the duration of growth. This increment was particularly marked between the second and third day of development. He found that after the third day the fiber content so affected the quality of the spears, that it was necessary to peel the spear in order for it to be eaten. He suggested that the main factor involved in growth was temperature. He recomended that the growth rate of the spears be increased, in order for them to reach a harvestable length, in the minimum time possible. Heating the soil or cultivation under plastic or glass in order to increase the rate of growth, were some ways recomended to achieve this (8).

Gonzalez (4) showed that the growth rate per day of the cultivar Mary Washington, grown in the greenhouse, was lower (0.87 to 1.08 mm) at the temperatures of 10-15.5 °C than at 21.1-26.6 °C (2.47 mm to 4.55 mm) regardless of the spear diameter. But fiber content was lower at the temperatures of 21.1-26.6 °C. He attributed this to the rapid growth of the spears, leaving no time for fiber formation.

Smith and Kramer (14) found no significant effect of temperature upon the amount of fiber in spears in storage. However, fiber content seemed to be lower at high temperatures.

MacGillivray (10) found that as the number of days required to produce a seven inch spear increased, there was an increase in toughness. However, he did not find variations in fiber content due to temperatures. On the other hand, he observed that the tenderness of the spear increased as the rainfall increased.

Segerlind and Herner (15) reported that temperature may affect the fiber content of the harvested product. They recorded the minimum temperatures three days before harvest, and compared the average minimum temperature with the fiber content obtained in each harvest date. The results showed that asparagus produced at the lowest temperatures in the experiment (harvested on May 5, Ave. minimum temperature 2.2 °C) produced spears with a higher fiber content than spears harvested when the highest average minimum temperatures in the experiment was 18.8 °C.

This suggests that low temperatures may influence fiber content. However, the trend of their results was not consistent and the authors concluded that the fiber content of asparagus was influenced more by length and diameter of the spear than by average growing temperature.

Several methods for fiber determination have been developed; the most important are described as follows:

1. The blender method (Smith and Kramer, (17); this method gives very accurate values of fiber content. Spear sections are weighed, and cooked for 15 minutes in boiling water. Cooked sections are then macerated in a blender with 200 ml of water. The mixture is then transferred to a weighed 30 mesh screen, and dried for 2 hours at 100 °C in an oven. The main disadvantage of this method is the time (15 minutes) needed for the cooking step.

2. Lee (9) developed the Alcohol insoluble solids (A.I.S.) method, which consists of the evaluation of insoluable solids in the different segments of a 25 gm sample of a spear. The sample is ground up and the soluble solids are dissolved using heated 80% ethyl alcohol; the insoluble solids are then separated by filtration using a tared filter paper and Buchner funnel. The filter paper with the insoluble solids is dried in an oven at 95 °C overnight. Finally the weight of the paper with insoluble solids is substracted from the total weight. Samples having more than 4.35% A.I.S. are considered fancy (low in fiber) and those lower than 4.04%, are termed off grade. This method is not practical because of its very narrow range, and because solids have

been found to be high at the tip of the spear, which is the tender portion.

3. Wilder (21) developed the fiberometer for use in measuring fiber in canned asparagus. This instrument consists of a stainless steel wire to which a 3 pound weight is attached. A spear is considered tender to the point farthest from the tip that the wire will cut. The disadvantage of this instrument is that the values are influenced by the diameter of the spear.

4. Willey et al (22) developed the shear-press which permits elimination of influence of the diameter of the spear in the determination of fiber values. The shear-press consists of a single blade 6.9 cm (2-3/4") wide, 9.7 cm (3-7/8") long and 0.0925 cm (37/1000 of an inch) thick; the asparagus cell is 65.41 sq-cm (10.14 sq-in) and holds 12-20 spears. The blade must pass through all spears, sever each completely and pass through a bottom slit before being returned to the starting position. The spears are cut at a point 12.5-15.0 cm (5.0-6.0") from the tip.

5. The tenderometer is an instrument which measures the fiber content and is not affected by the size of the spear. Correlations of 0.729 between tenderometer readings and crude fiber have been reported by Jenkins and Lee (7). The advantages of the tenderometer are its simplicity of operation, and rapidity and high degree of accuracy. It measures the force required to shear a spear through a standard grid; the shearing force is inversely proportional to

the tenderness of the product. The main disadvantage of the instrument is that the portion of the spear is completely macerated, rendering it unusable for other purposes.

MATERIALS AND METHODS

The cultivars studied were grown at M. S. U. Sodus Experiment Station. Nine cultivars were used: Mary Washington, N. J. 44 x 22, Michigan Select, N. J. 51 x 22, California 711, California 66, California 72, N. J. Improved and California 309. These cultivars were planted in 1967, and have been harvested for five years to date. They were planted at two spacing within the row, 22.5 cm and 45 cm (9" and 18"), with 120 cm (4') between rows.

The experimental plot as established is a split-plot design with 3 replications; spacing being the main plot and cultivars the subplot.

Random samples of five marketable spears from each replication, cultivar and spacing were collected from harvests on the following dates: May 10, June 17 and June 25, 1973. The spears from the first harvest date were snapped while those from the last two were cut at the ground level. Marketable spears were those more than 1.0 cm (3/8") in diameter and 20.0 cm (8") in length. The spears were frozen and kept in storage in plastic bags, until they were processed.

Each spear was divided into five sections for testing, as follows:

Section 1 0.0 - 10.0 cm from the tip (0 - 4").
" 2 10.0 - 12.5 cm " " " (4 - 5").
" 3 12.5 - 15.0 cm " " " (5 - 6").
" 4 15.0 - 17.5 cm " " " (6 - 7").
" 5 17.5 - 20.0 cm " " " (7 - 8").

Fresh weight was determined for each section of the spear.

The blender method (17) with slight variations was used to determine the fiber content. Spear sections were weighed then cooked for 15 minutes in boiling water; cooked sections were macerated for 2 minutes in a blender with 200 ml water. The mixture was then transferred to a 30 mesh screen in order to separate out the fiber. The screen was rinsed with water and the fiber was collected in filter paper (Whatman N° 1, qualitative) 7.0 cm in diameter, that had been dried in the oven at 100 °C for 2 hours and then tared. Fiber was collected in the filter paper by suction, using a Buchner funnel. The filter paper with the fiber on it, was dried in the oven at 100 °C for 2 hours, and then weighed. Fiber (in grams) for each treatment was obtained in this manner.

The percent of fiber was calculated comparing the fresh weight of each section with its corresponding amount of fiber.

Statistical analysis were done separately for each section of the spear from each harvest date.

Since spears harvested on May 10 were snapped and those harvested on June 17 and June 25, were cut at the

ground level, it was not possible to compare the three harvest dates in the same analysis. However, data from the last two harvest dates were compared statistically for their fiber content through the length of the spear.

Using data from the last two harvest dates and temperatures recorded daily for the three days before each harvest, correlation coefficients were calculated. The temperature data is presented in Table 1.

Additionally, fiber determinations were made on spears from 10 asparagus crowns which have been selected in the M. S. U. asparagus breeding program for characteristics such as color, vigor, spear size, branching, etc. These crowns (5 males and 5 females), were as follows : 103 ♂, 172 ♂, 417 ♂, 473 ♂, 751 ♂, 289 ♀, 382 ♀, 455 ♀, 587 ♀, and 660 ♀. They were sampled three times in May, 1973, cutting the spear at the ground level. The blender method was used for fiber determination.

Table 1. Average maximum and minimum temperatures at the M. S. U. Sodus Experiment Station, for three asparagus harvest dates, in 1973.

HARVEST DATE	Average temperature (°C).	
	MAXIMUM	MINIMUM
May 10	20.3 1/	11.1
June 17	28.8	18.6
June 25	22.5	12.5

1/ The average maximum and minimum temperatures were calculated from data recorded daily, during the three days preceding each harvest date.

RESULTS

Spears harvested on May 10 had lower fiber content at comparable section than spears from the other two harvest dates, however, this may have resulted because the spears were snapped rather than cut at ground level.

The results obtained from the spears harvested on May 10, are presented in Table 2 and Figure 1. There were no significant differences among cultivars in the amount of fiber in any of the top four sections of the spear. However, there were significant differences among cultivars in the fiber content in the bottom section (17.5-20.0 cm). Mary Washington and N. J. 51 x 22 had the lowest fiber content, followed by Michigan Select. The highest fiber content was found in N. J. Improved.

It can be seen in Figure 1, that with one exception, the fiber content for each cultivar in every section was below 0.25%, which is the limit of fiber considered acceptable for asparagus processing in Michigan. The one exception was the bottom section (17.5-20.0 cm) of N. J. Improved.

Table 3 and Figure 2 show the results obtained from the second harvest date. The first four sections from the tip showed differences in fiber content among cultivars. The bottom section did not show any differences. In general,

Table 2. Percentage of fiber in five sections and whole spear totals for nine asparagus cultivars, harvested May 10, 1973. 1/

CULTIVAR	Distance from the tip (centimeters).					TOTAL
	0.0–10.0 2/	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20.0	
Mary Washington	.032 a 3/	.072 a	.052 a	.056 a	.076 c	.052 ab
N. J. 44 x 22	.061 a	.090 a	.073 a	.087 a	.186 abc	.091 ab
Michigan Select	.027 a	.047 a	.053 a	.056 a	.107 bc	.022 b
N. J. 51 x 22	.052 a	.068 a	.085 a	.094 a	.071 c	.070 ab
California 711	.059 a	.101 a	.095 a	.108 a	.195 ab	.100 ab
California 66	.028 a	.067 a	.083 a	.094 a	.125 bc	.082 ab
California 72	.047 a	.096 a	.065 a	.069 a	.125 bc	.072 ab
N. J. Improved	.055 a	.105 a	.107 a	.102 a	.288 a	.114 a
California 309	.054 a	.092 a	.079 a	.084 a	.113 bc	.078 ab

1/ Spears were snapped.
2/ The statistical analysis was done separately for each section of the spear.
3/ Numbers in the same column followed by the same letter are not different at .05% level of significance (Duncan's multiple range test).

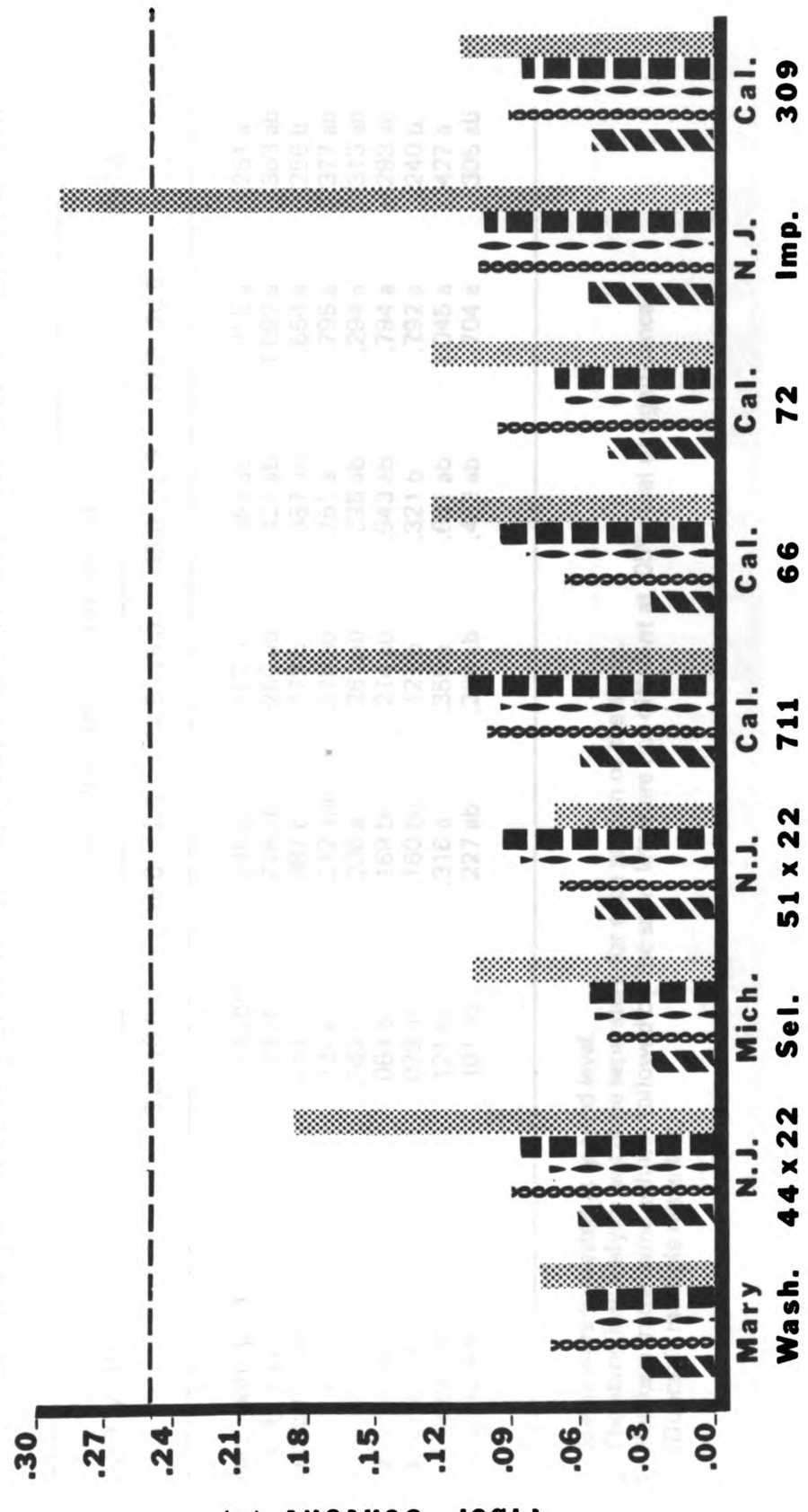

Figure 1. Percent of fiber through the length of the spear of nine asparagus cultivars, harvested in May 10, 1973. (Snapped).

Table 3. Percentage of fiber in five sections and whole spear totals for nine asparagus cultivars, harvested June 17, 1973. 1/

CULTIVAR	Distance from the tip (centimeters).					TOTAL
	0.0–10.0 2/	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20.0	
Mary Washington	.097 ab3/	.146 bc	.167 b	.353 ab	.755 a	.261 a
N. J. 44 x 22	.128 ab	.228 ab	.250 ab	.427 ab	1.092 a	.363 ab
Michigan Select	.054 b	.087 c	.173 b	.357 ab	.654 a	.256 b
N. J. 51 x 22	.124 ab	.212 abc	.275 ab	.751 a	.795 a	.377 ab
California 711	.163 a	.306 a	.261 ab	.398 ab	.294 a	.313 ab
California 66	.064 b	.169 bc	.214 ab	.543 ab	.794 a	.293 ab
California 72	.079 ab	.160 bc	.127 b	.321 b	.792 a	.240 b
N. J. Improved	.121 ab	.316 a	.355 a	.681 ab	1.045 a	.427 a
California 309	.101 ab	.227 ab	.238 ab	.483 ab	.704 a	.305 ab

1/ Spears were harvested at ground level.
2/ The statistical analysis was done separately for each section of the spear.
3/ Numbers in the same column followed by the same letter are not different at .05% level of significance (Duncan's multiple range test).

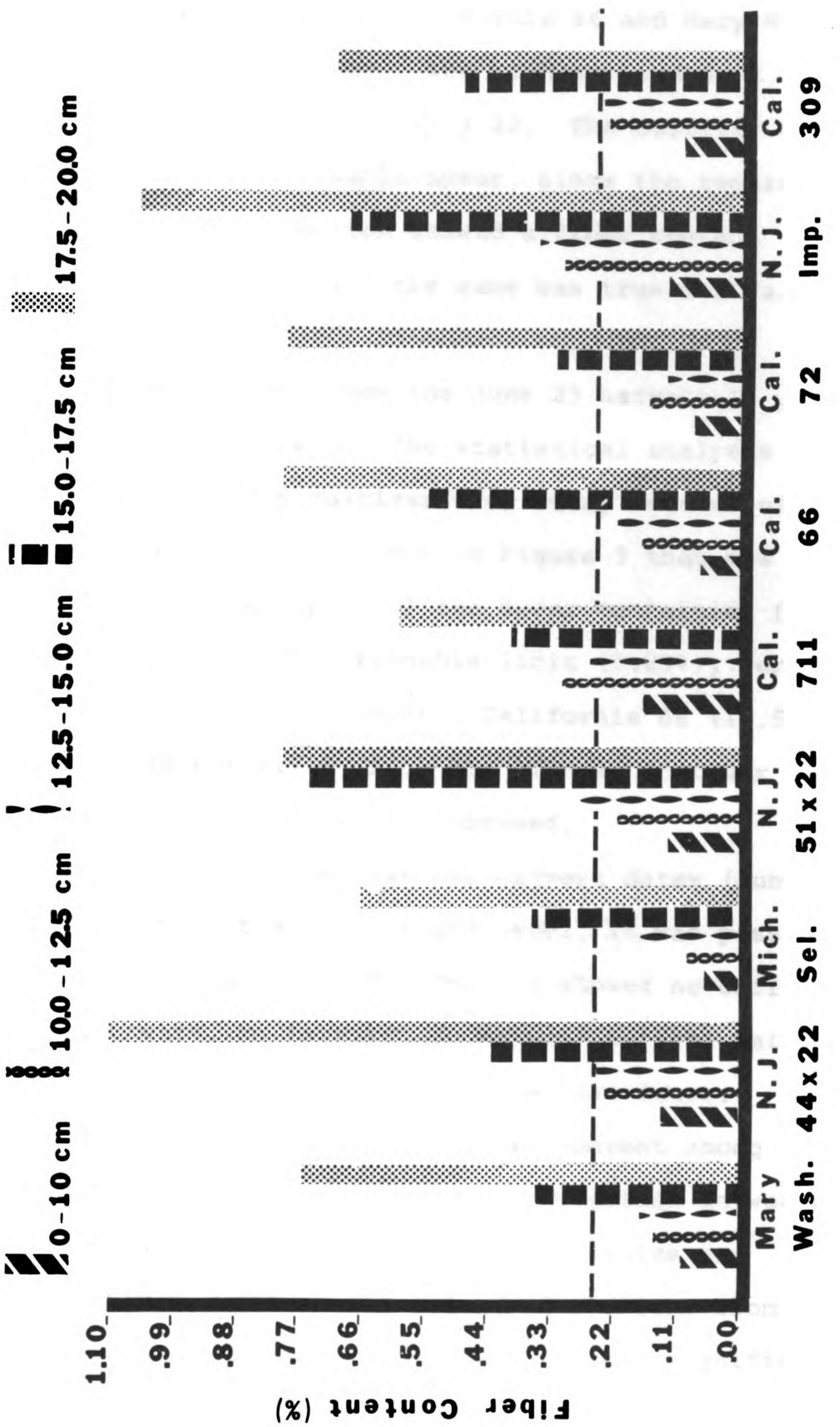

Figure 2. Percent of fiber through the length of the spear of nine asparagus cultivars, harvested in June 17, 1973.

Michigan Select, California 72, California 66 and Mary Washington were the lowest in fiber. The highest were N. J. Improved, California 711 and N. J. 44 x 22. The cultivar N. J. Improved had only 10 cm of usable spear, since the remaining four sections through the bottom showed a fiber content greater than the limit (0.25%); the same was true for California 711.

The fiber content from the June 25 harvest is presented in Table 4 and Figure 3. The statistical analysis did not show differences among cultivars for every section of the spear. However, it can be seen in Figure 3 that the cultivars with the longest part of the spear containing fiber percentage below the objectionable limit (0.25%), were California 72 (17.5 cm of the spear), California 66 (17.5 cm) and Michigan Select (17.5 cm). The highest in fiber content were California 711 and N. J. Improved.

Since spears in the last two harvest dates (June 17 and June 25) were cut at the ground level, it was possible to analize the data together. The results showed no differences among cultivars, no interaction between harvest date and cultivar and no differences between harvest dates. The analysis did show differences in fiber content among the sections of the spear and there was interaction between harvest date and section of the spear. The results are presented in Table 5. The second and third sections from the tip (10.0-12.5 and 12.5-15.0 cm) did not show significant differences. The tip (0-10.0 cm) showed the lowest

Table 4. Percentage of fiber in five sections and whole spear totals for nine asparagus cultivars, harvested June 25, 1973. 1/

CULTIVAR	Distance from the tip (centimeters).					TOTAL
	0.0–10.0 2/	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20.0	
Mary Washington	.108 a3/	.135 a	.163 a	.320 a	.805 a	.257 a
N. J. 44 x 22	.145 a	.216 a	.182 a	.288 a	.658 a	.278 a
Michigan Select	.079 a	.127 a	.126 a	.259 a	.563 a	.213 a
N. J. 51 x 22	.091 a	.134 a	.138 a	.292 a	.493 a	.213 a
California 711	.163 a	.218 a	.211 a	.360 a	.805 a	.280 a
California 66	.102 a	.149 a	.165 a	.231 a	.605 a	.224 a
California 72	.128 a	.159 a	.164 a	.190 a	.502 a	.217 a
N. J. Improved	.123 a	.157 a	.143 a	.378 a	.697 a	.271 a
California 309	.121 a	.195 a	.170 a	.276 a	.694 a	.266 a

1/ Spears were harvested at ground level.
2/ The statistical analysis was done separately for each section of the spear.
3/ Numbers in the same column followed by the same letter are not different at .05% level of significance (Duncan's multiple range test).

Figure 3. Percent of fiber through the length of the spear of nine asparagus cultivars, harvested in June 25, 1973.

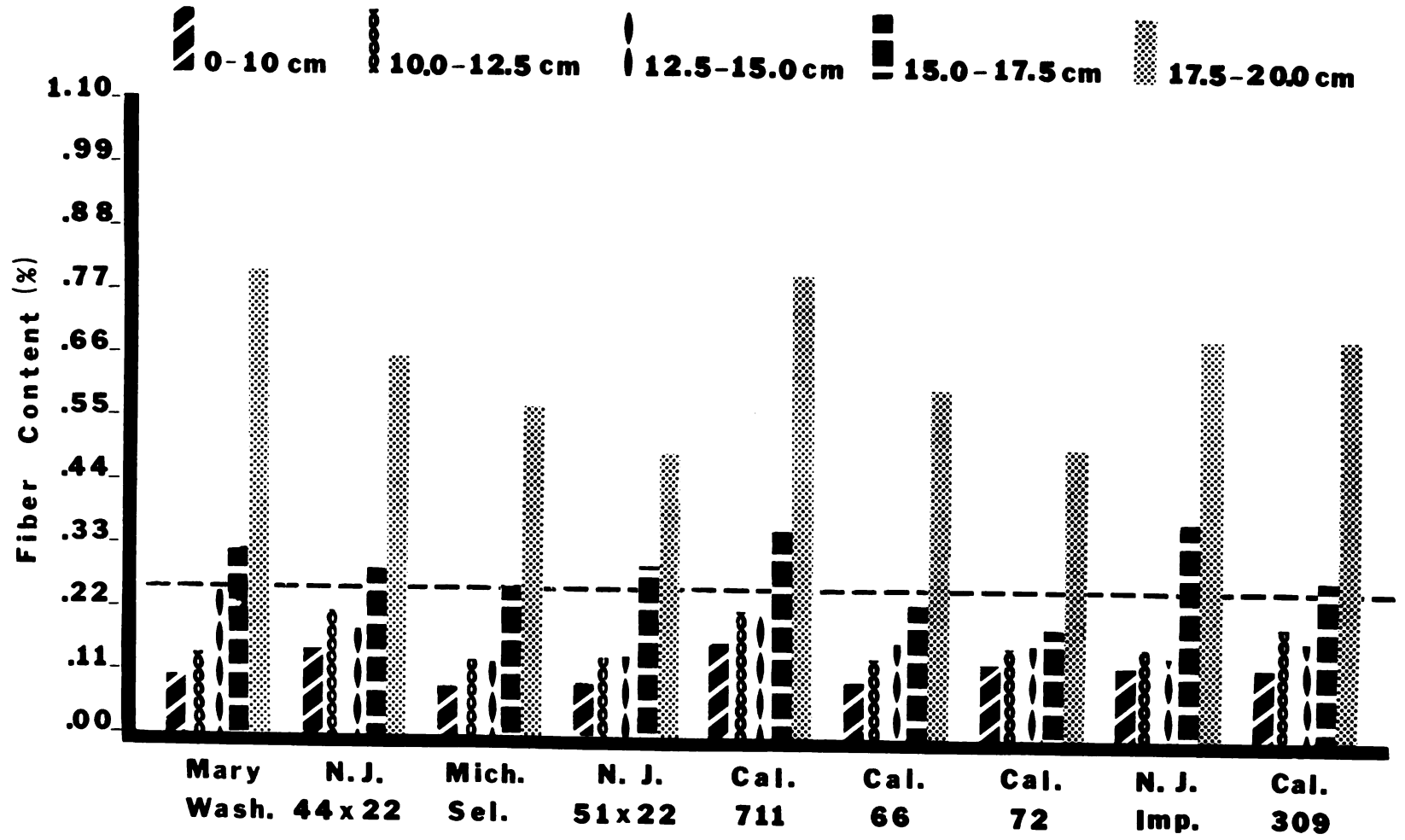

Table 5. Average percentage of fiber in five sections of the spear of nine asparagus cultivars, harvested on two dates, in 1973.

HARVEST DATE	Distance from the tip (centimeters)				
	0.0-10.0	10.0–12.5	12,5–15.0	15.0–17.5	17.5–20.0
June 17	.104 g[1/]	.206 e	.229 de	.480 c	.803 a
June 25	.118 g	.165 f	.162 f	.288 d	.647 b
MEAN[2/]	.111 D	.186 C	.196 C	.384 B	.725 A

1/ Duncan's multiple range test at 0.05% level was used.
2/ Significances for the mean of the section must be read separately from the rest.

fiber content, whereas the bottom section of the spear (17.5 -20.0 cm) was the highest in fiber, regardless the harvest date.

Crown spacing did not influence the fiber content.

The correlation coeficients between fiber content and temperatures are shown in Table 6. Fiber content at the tip (0-10.0 cm) increased with low temperatures and decreased with high temperatures. On the other hand, it can be seen in Table 6, that as far as the other sections of the spear was concern, all the cultivars except Michigan Select in section 2 (10.0-12.5 cm) showed positive correlations; in other words, as the temperatures increased, the fiber content also increased. Fiber content in the cultivar N. J. 51 x 22 was positively correlated with temperatures in all sections of the spear.

The results obtained from spears from the selected crowns are presented in Tables 7, 8 and 9, which show the data for three harvest dates: May 10, May 17 and May 31, respectively.

The fiber content in the spears of each crown was variable depending on the harvest date; the relationship of the fiber content of each crown regarding the other crowns, was not the same in each harvest date. For example, 455♀ and 382♀ were remarkable low in fiber when harvested on May 17 (20.0 cm of usable spear), whereas 455♀ had only 12.5 cm of usable spear on May 31. On the other hand, 751 ♂ was the lowest in fiber on May 10 (17.5 cm of usable spear)

and on May 31 (20.0 cm of usable spear), while it had 12.5 cm of usable spear on May 17.

Four female crowns (455, 382, 289 and 587) were the best (20.0 cm to 17.5 cm usable spear) on the second harvest date. Three males (751, 473 and 172) were also among the lowest in fiber.

Table 6. Correlation coefficients between average maximum[1/] temperatures and percent of fiber in five sections of spear of nine asparagus cultivars, harvested June 17 and June 25, 1973. [2/]

CULTIVAR	Distance from the tip (centimeters).				
	0.0–10.0	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20.0
Mary Washington	-1.00	1.00	1.00	1.00	1.00
N. J. 44 x 22	- .97	1.00	.99	1.00	1.00
Michigan Select	- .99	- 1.00	1.00	.99	1.00
N. J. 51 x 22	.99	.99	1.00	1.00	1.00
California 711	- .33	1.00	1.00	1.00	1.00
California 66	- .99	1.00	.99	1.00	1.00
California 72	-1.00	1.00	1.00	1.00	1.00
N. J. Improved	-1.00	.99	1.00	1.00	1.00
California 309	-1.00	1.00	1.00	.99	1.00

1/ The same results were obtained when average minimum temperatures were used.
2/ Spears were harvested at ground level.

Table 7. Percentage of fiber in five sections and whole spear totals of seven selected asparagus crowns, harvested May 10, 1973.

CROWN	Distance from the tip (centimeters).					TOTAL
	0.0–10.0	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20.0	
103 ♂	.010	.022	.039	.264	1.236	.208
172 ♂	.014	.062	.196	.337	.443	.174
289 ♀	.008	.061	.120	.313	.470	.139
417 ♂	.004	.020	.148	.340	.603	.175
473 ♂	.008	.029	.009	.330	.083	.082
660 ♀	.025	.014	.049	.362	.020	.092
751 ♂	.013	.000	.016	.081	.286	.068

Table 8. Percentage of fiber in five sections and whole spear totals of nine selected asparagus crowns, harvested May 17, 1973.

CROWN	Distance from the tip (centimeters).					TOTAL
	0.0–10.0	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20.0	
172 ♂	.051	.100	.605	2.150	2.520	.540
289 ♀	.061	.023	.064	.057	.768	.035
382 ♀	.052	.111	.057	.082	.182	.086
417 ♂	.028	.118	.097	4.560	1.311	.980
455 ♀	.035	.029	.059	.025	.024	.034
473 ♂	.015	.038	.055	.552	.495	.204
587 ♀	.050	.099	.076	.143	.425	.142
660 ♀	.055	.125	.107	.348	1.127	.304
751 ♂	.012	.034	.038	.307	.647	.187

Table 9. Percentage of fiber in five sections and whole spear totals of six selected asparagus crowns, harvested May 31, 1973.

CROWN	Distance from the tip (centimeters).					TOTAL
	0.0–10.0	10.0–12.5	12.5–15.0	15.0–17.5	17.5–20.0	
172 ♂	.018	.030	.049	.228	.349	.115
289 ♀	.062	.193	.208	.524	.237	.198
455 ♀	.037	.197	.290	.368	.309	.189
473 ♂	.066	.271	.285	.234	.196	.166
587 ♀	.081	.241	.329	.276	1.273	.371
751 ♂	.076	.140	.122	.129	.231	.127

DISCUSSION

The cultivars with least fiber were Michigan Select, California 66, California 72 and Mary Washington. The highest in fiber were N. J. Improved and California 711. The cultivars low in fiber were those that had the highest yield of marketable spears per acre, in 1972 (19) and in 1973 (20).

Since cellulose and lignin in the spear are formed from the sugars in the crown (1, 6, 18, 23), the low yield of the cultivars high in fiber may be due to the use of the sugars stored as food reserves for the formation of fiber, reducing the food reserves available for the growth of new spears in the same season.

Cultivars showed differences in the distribution of the fiber through the length of the spear. Thus, some cultivars had 17.5 cm of usable spear while other cultivars had only 10.0 or 12.5 cm (Tables 3 and 4, Figures 2 and 3). This fact is very important, because it makes it possible to select those cultivars with the greatest portion of usable spear, which will consequently produce more marketable spears per acre.

Most of the information obtained in this study regarding fiber content through the length of the spear agrees

with the findings of other investigators (4, 5, 13, 14, 15, 17). The fact that the second and third sections of the spear (10.0-12.5 and 12.5-15.0 cm) did not show significant differences in fiber content indicates that the same changes are taking place in both sections; this could help in future work, saving time in the process of fiber determination by the blender method (17) because fewer number of sections need be used to analyze fiber in a 20.0 cm spear.

The striking differences in fiber content observed in the spears harvested on May 10, compared with those of the the other harvest dates, were probably due to the different method of harvest, since use of the "snapping" method leaves the basal portion of the spear and most of the fiber in the field.

The simple correlations showed that in the tip section (0-10 cm) fiber increased with low temperatures and decreased with high temperatures. In the other sections the trend was just the opposite. These results agree in part with the idea of other investigators (4, 5, 15). However, none of them (5, 15) indicated whether the total fiber content or the fiber content in a given section was used to correlate with temperature. Gonzalez (4) used the total fiber content in the spear to indicate the tendency of increasing fiber content with low temperatures. He did, however, report fiber for sections of the spear. By observing his data for spears 20.0 cm long, it can be seen that the fiber content of each section in relation with the temperature studied, followed the same trends as did the

results presented herein.

Spears growing at high temperatures probably have less fiber at the tip but more fiber in the sections below the tip than spears growing at low temperatures. This points out the importance of controlling the frequency of the harvests during periods of high temperatures, in order to have spears of the appropriate length with the greatest usable portion possible. At high temperatures the growth rate of the spear will increase; if the periods between harvests are long, the spears will increase in length rapidly, and the zone high in fiber at the bottom sections will increase in length toward the top of the spear, producing long spears with high fiber content in the basal sections (5).

According to Working (23) and Downes et al (3), cell division, elongation and enlargement in the tip 8 cm of a spear proceed from the apex to the base in progressively decreasing rates. The most active area of cell division, elongation and enlargement was found to be in a zone 2.5 to 3.0 cm from the tip. In the 8 cm just below the tip to the bottom of the spear, growth no longer occurred. The fiber content in the 8 cm tip of the spear, may be low because food reserves (mainly sugars) are used to supply energy for cell division and elongation, leaving no reserves and energy for the formation of high quantities of cellulose and lignin. On the other hand, in the area below 8 cm, cell division and elongation no longer occur and cell walls begin to thicken, as lignin formed from the sugars stored in the crown and roots is deposited.

High temperatures possibly increase the rate of the biochemical reactions related to growth and development at the tip of the spear, while they favor those reactions related to the conversion of sugars into cellulose and lignin in the sections beyond the tip, where no growth takes place.

As can be seen from the results presented herein, all cultivars had sufficient fiber in the portions lower than 15.0 cm (6") of the spear to render them inedible. This supports the results of Segerlind and Herner (15), that fiber content is high in the basal section of spears harvested too close to the ground and in spears longer than 18.75 cm (7.5"). This is also an indication that in mechanically harvested asparagus, the calibration of the level of the cutting bar is very important, in order to harvest the spears at the proper length, to ensure the longest edible spear possible.

Although the fiber content of the 10 crowns selected from the breeding plots was not consistant over the three harvest dates (Tables 7, 8 and 9) there were indeed differences in fiber content of the spears from the various crowns. It is interesting to observe that four female crowns were the lowest in fiber (17.5 to 20 cm of usable spear) on the second harvest date; two of them (455 and 382) had a remarkable low fiber content. It has been observed that the fern of these crowns are easily blown over by the wind. This indicates that besides the limit of fiber content imposed by the industry, as far as the edibility of the product is concern, the

plant breeder should establish a minimum limit of fiber content in the plant, in order to allow the fern to remain upright. The system of grading the breeding material for its tendency to fall over and its fiber content in different years in a given region, will provide a good indication of that limit for selection.

It is important to point out that in the evaluation of asparagus cultivars, or in the selection of materials to be used in the breeding program, it will be important to take into account the distribution of fiber through the length of the spear, rather than consider only the total fiber content of the whole spear. The distribution of fiber in the spear indicates the actual length of the spear that is edible (portion with less than 0.25% fiber). Two cultivars could show the same total fiber percentage, but one of them could have 17 cm of usable spear and the other 20 cm (Tables 3 and 4).

LITERATURE CITED

1. Bisson, C. S., H. A. Jones and W. W. Robbins. 1926. Factors influencing the quality of fresh asparagus after it is harvested. Calif. Agr. Exp. Sta. Bul. 410. 28 pp.

2. Downes, J. D. 1961. Growth characteristics of asparagus in relation to yields from mechanical harvesting. Mich. Agr. Exp. Sta. Quart. 44 (2): 272-281.

3. _____, Donald P. Watson and R. R. Dedolph. 1962. Stem elongation of Asparagus officinalis L. Mich. Agr. Exp. Sta. Quart. Bul. 44 (4): 772-780.

4. Gonzalez, R. A. 1970. Effect of growth temperature and diameter of asparagus on the amount of fiber and growth rate. Unpublished data.

5. Herner, R. C. 1973. Fiber determination. In "Progress report of asparagus research". Research report 217. Michigan State University, Agr. Exp. Sta. p 11-12.

6. Jacobs, M. B. 1951. Foods. XXVII. Vegetables and mushrooms. In "The chemistry of food and food products". Vol. 2, p 1310-1317. Interscience Publishers, Inc. N. Y.

7. Jenkins, R. R. and F. A. Lee. 1940. Tenderometer readings as an index of quality of fresh asparagus. A preliminary paper. Food Res. 5: 161-166.

8. Kaufmann, F. 1967. Der einfluss der wachstumsgeschwindigkeit unddaver auf faserigkeit von grünen spargeltrieben. (The effect of the rate and duration of growth on the amount of fibre in green asparagus spears.). Arch. Gartenb., 15: 89-100. (Hort. Abstr. 38 (2): ref. 3107).

9. Lee, F. A. 1943. Determination of toughness of frozen asparagus. Food Res. 8: 249-253.

10. MacGillivray, J. H. 1933. Seasonal variation in the tenderness of asparagus. Proc. Amer. Soc. Hort. Sci. 30: 558-560.

11. Michigan Crop Reporting Service. 1972. Michigan asparagus Survey, acreage, production and marketing 1972. Michigan Department of Agriculture. U. S. D. A.

12. _____. 1973. Acreage, production and value. Statistics on vegetables, berries, mint 1959-1972. Michigan Department of Agriculture. U. S. D. A.

13. Scott, L. E. and A. Kramer. 1954. Yield and quality of asparagus as affected by height of spear above ground at harvest. Food Packer 35 (4): 46-48.

14. _____ and _____. 1949. Physiological changes in asparagus after harvest. Amer. Soc. Hort. Sci. 54: 357-366.

15. Segerlind, L. J. and R. C. Herner. 1972. On the fiber content problem of processed asparagus. Amer. Soc. of Agr. Eng. Paper N° 72-882, 15 pp.

16. Segerlind, L. J. 1973. Physical measurements of toughness. In "Progress report of asparagus research". Research Report 217. Michigan State University, Agr. Exp. Sta. p 12-14.

17. Smith, H. R. and A. Kramer. 1947. The fiber content of canned green asparagus. Canner 104 (18): 15-16.

18. Tiedjens, V. A. 1924. Some physiological aspects of asparagus officinalis. Amer. Soc. Hort. Sci. 21: 129-140.

19. Vest, H. G. 1973. Asparagus breeding program and cultivar evaluation. In "Progress report of asparagus research". Research Report 217. Michigan State University, Agr. Exp. Sta. p 3-4.

20. Vest, H. G. 1973. Asparagus yield trials-sodus 1973. In "Annual Progress Report 1973". Sodus Hort. Exp. Sta. M. S. U. Dept. of Horticulture and Southwestern Mich. Gro. Ass. p 16-17.

21. Wilder, H. K. 1948. Instructions for use of the fiberometer in the measurement of fiber content in canned asparagus. Res. Lab. Rep. N° 12313-C Natl. Canners Assoc. San Francisco. June 16, 1948.

22. Willey, R. C. N. Elehwany, and A. Kramer. 1956. The shearpress an instrument for measuring the quality of foods. IV. Applications to asparagus. Food Technol. 10: 439-443.

23. Working, E. B. 1924. Physical and chemical factors in the growth of asparagus. Univ. Ariz. Agr. Exp. Sta. Bul. 5. 38 pp.