1975

Influence of Cultivar, Pod Maturity and Fertilization on Quality of Okra (Abelmoschus Esculentus (L.) Moench.

Ramesh Sahasi Kakar

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INFLUENCE OF CULTIVAR, POD MATURITY AND FERTILIZATION
ON QUALITY OF OKRA (ABELMOSCHUS ESCULENTUS (L.) MOENCH)

A Dissertation
Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Horticulture

by
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ABSTRACT

Studies were conducted over a two-year period to investigate the influence of cultivar, maturity, and fertilizer on quality of okra (Abelmoschus esculentus (L.) Moench) pods. An anatomical study was designed to determine the effects of fertilizer, cultivar, maturity and section of pod samples on number of thick-walled (fiber) cells.

Effects of different cultivars on various quality factors were studied during the 1971 growing season. Cultivars selected were 'Clemson Spineless,' 'Emerald' and 'Louisiana Green Velvet.' Cultivar significantly affected pod weight and length. 'Clemson Spineless' had significantly lower dry matter, muscilage and fiber content (fresh weight basis) than 'Emerald' or 'Louisiana Green Velvet.' No differences between the cultivars 'Emerald' and 'Louisiana Green Velvet' were noted. Cultivar had no significant influence on pod color (O.D.) or fiber content (dry weight basis).

Age of pod (maturity) (5, 7, 9, and 11 days) significantly affected all the quality factors of the three cultivars. Both cultivar and stage of maturity significantly affected pod length, muscilage, fiber content (dry weight and fresh weight basis) and number of thick-walled cells. 'Clemson Spineless' had shortest pods, lowest amount of muscilage and the highest fiber content (dry
weight and fresh weight basis). 'Emerald' produced the longest pods, highest muscilage and medium fiber content (dry weight and fresh weight basis) and number of thick-walled cells among the three cultivars. 'Louisiana Green Velvet' produced medium length pods, highest muscilage and lowest fiber content (dry weight and fresh weight basis) and number of thick-walled cells. 'Emerald' and 'Louisiana Green Velvet' showed no significant difference in their muscilage or fiber content.

Fertilizer had no significant effect on quality factors during the years 1971 and 1972. Therefore, additional or extra nitrogen or complete fertilizers had no influence on quality. Fertilizer and pod tagging date both resulted in significant differences in the number of thick-walled (fiber) cells in 1971, and in muscilage content in 1972. These differences may be due to different environmental conditions.

Different fruit setting dates (also referred as tagging dates) on alternate days henceforth caused significant variations in weight, length, dry matter, muscilage, and pod color in 1971, and in weight, length, dry matter, muscilage, fiber (dry weight and fresh weight basis) and number of thick-walled cells in 1972.

An experiment was performed in the fall of 1972 with the cultivar 'Emerald' and fertilizer treatment (48-96-48 preplanting + 16-0-0 side-dressing) to determine the influence of fertilizer and pod parts on quality factors. Seven-day old pods were harvested and divided into three portions, i.e., butt, middle, and tip or end portion.
Pod part had significant influence on pod color. The end portion had better color than the butt or middle portion. Pod part had a highly significant effect on the number of thick-walled cells (No./quadrant of each objective’s field of view). The tip or end portion had the highest number of thick-walled cells and was harder than the butt or middle portion because of close concentration of thick-walled cells.

A study was conducted in the fall of 1972 with the cultivar 'Emerald' and fertilizer treatment (36-72-36 + 0-0-0) to investigate the influence of maturity and fertilizer on the number of thick-walled cells of different pod parts.

Stage of maturity (3 to 11 days old) influenced the number of thick-walled cells of different pod parts. On the 11th day, the highest number of thick-walled cells and hardest pods were obtained. The end portion of the pod had the highest number of thick-walled (fiber) cells and was harder than the butt or middle portion.
INTRODUCTION

Okra (Abelmoschus esculentus (L.) Moench) belongs to the Malvaceae family, and its importance as a vegetable is referred to by many workers (12, 13, 35, 69, 73, 91, 98).

Okra is a popular summer vegetable crop in the South since it lends itself well to fresh use as well as to canned and frozen products. Also, there is considerable interest in this crop from the standpoint of its oil, gum and fiber properties (19).

The production of okra is becoming of increasing importance in Louisiana. Much of this increase has been due to a rapid expansion of the okra freezing and canning industry. Okra ranks 2nd in value among vegetable crops processed in the state (60).

Preferences in the type of okra for freezing and canning have changed since the introduction of this product. At first, the commercial preference was based mainly on the morphological characters of the okra pod only. However, at present, the commercial preference for freezing and canning okra is shifting to the quality of the okra pod.

Although the quality of various vegetables has been recognized earlier and was the subject of investigation by various research workers (29, 30, 42, 45, 70, 74, 78), it is only recently that the quality of the okra pod has been recognized. Quality in okra refers to the desirable substances which are present in pods of okra. Quality in okra is concerned with length and diameter of pods, color (chlorophyll content), muscilage content and fiber content, etc. (69, 72, 73).
Much of the attention on okra research has been focused on studying the morphological characteristics of the plant and yielding ability, while very little attention has been given to the study of pod quality.

Although some workers (16, 17, 21, 44, 50, 51, 72, 73, 88, 96) studied the development of the okra pod and attempted to determine the best time for harvesting so far as the fresh market is concerned, yet they did not study the quality of the pod at various stages of development and maturity. It is, therefore, the purpose of this investigation to study certain quality factors of okra pods at various stages of development and maturity.

Since different cultivars of okra differ in morphological characteristics and total production, it is pertinent to evaluate the various cultivars of okra insofar as the quality is concerned.

Various workers have studied the effect of different fertilizers on the yield of okra pods (2, 4, 7, 11, 14, 18, 20, 67, 71, 80, 82, 92, 93); however, none of these workers had studied in detail the effect of fertilizers, especially nitrogen, phosphorus, and potassium on the quality of okra.

It is the purpose of the present investigation to study the influence of factors such as pod maturity, cultivar, and fertilization on quality of okra pods.
Beattie (10) first described the culture and uses of the okra plant in the United States. According to him, okra (*Abelmoschus esculentus* (L.) Moench) or Gumbo as it is commonly called, is a tropical annual belonging to the family Malvaceae which includes some very important economic plants, of which cotton and okra have the greatest commercial value.

Okra is a tropical annual native to Africa (12). The Egyptians grew this crop in the twelfth or thirteenth century. It was grown in Philadelphia in 1748 and quickly spread to the southern states (84).

According to Boswell (12), okra can be grown anywhere in the United States where vegetables are grown, except in the coolest, northern most parts of the country or at high altitudes, since it is easily injured by frost.

Miller (52) reported that okra has long been a favorite vegetable in the southern United States. It is frequently, but not extensively, cultivated in northern gardens. Although okra has long been a popular vegetable in home gardens in the South, it has become of considerable importance in recent years as a truck, market garden and canning crop.

Production in the United States is mostly confined to the South. In 1959, the South led in production with 19,235 acres out of the total U.S. production of 19,804 acres. In 1964, the proportion was 17,416
acres for the South out of a total of 17,818 acres. In both cases, the South produced more than 95 percent of the total okra grown in the United States (58, 86). In Louisiana, the main areas of production from 1959 until 1964 were St. Martin, Lafayette, St. Landry and Iberia Parishes. There was a definite increase in acreage from 1964 to 1969, from 1,761 to 7,500 acres (58, 87).

Okra is an important vegetable crop (12, 13, 35, 69, 73, 91). The most important use of okra is for food in the form of soups, stews and as a vegetable, both frozen or canned, and brined (10, 12). However, there are other uses for okra which are both real and potential in nature. The following is the list of these uses: for oil production, since okra oil is chemically comparable to cottonseed oil (25) and suitable for use in making soap, vegetable shortenings, and oleomargarine; for the manufacture of paper because the stems and mature pods contain fibers which can be used for such purposes (58, 62); for use as blood plasma substitute (58, 85); and for use as a livestock feed from which the residue as a result of oil extraction can be used. In the Philippines, the dry seeds are used as a substitute for coffee. In the far East, the leaves and the immature fruits are used in the preparation of poultices, as medication for sores, and for fermentation. The Turks use the leaves as demulcent, i.e., for soothing and protection of mucous membranes (58, 61). Finally, the United States imports tons of this dried product for use as flavoring (58, 84).

According to Boswell (12), the okra plant develops rapidly in areas to which it is suited in that it requires only 2 months from planting to harvesting of the first pods. Well-grown plants continue to bear for many weeks, especially if the young pods are all harvested
promptly, and none are allowed to mature. Similar results were pointed out by Miller et al. (50), demonstrating that plants which were harvested frequently bore pods continuously while those on which pods were allowed to mature exhibited alternate bearing or fruiting waves. Harvey (31) observed that okra plants in general appeared to possess an extremely delicate balance between vegetative and reproductive activity. This was confirmed by a similar report by Miller et al. (50) who concluded that seed maturation in okra caused a severe check in plant growth.

Woodroof (96) studied the flowering habits of the okra plant and observed that a flower bud appeared in the axil of each leaf above the 6th or 8th most basal ones. The crown of the stalk consisted of several undeveloped leaves and flowers, and during the period of most rapid growth, there may be as many as 10 undeveloped flowers in a single crown. As the stem elongates, the lowermost flower buds develop into flowers, one at a time. There may be a period of 1, 2, 3 or more days between the time of development of each flower, but never does more than one flower appear on a single stem on the same day. Purewal and Randhawa (62) made similar observations except that they could see more than one flower on a stem on the same day. The flowers open in the daytime only and for only a single day.

Srivastava (77) made a systematic study of the development of floral buds of okra. The whole process of development of the floral bud was divided into 7 stages. The seventh stage was considered to be the full bloom stage. It took 21 to 23 days for development of the buds to full bloom. Anthesis was observed in the morning between 9:00 A.M. and 10:00 A.M. during August. High temperature and low relative humidity were found to have some hastening effect on anthesis.
Chauhan (16) studied the blossom biology in 3 species of the genus *Abelmoschus*. He observed one continuous reproductive flush in all species, and maximum anthesis of flowers took place just before noon. Pod development was completed in 8, 9 and 10 days in *A. esculentus*, *A. panduriformis* and *A. moschatus*, respectively.

The fruiting period usually begins in early summer and continues until late in the fall. At any time during this period, a cluster of some 8-15 buds, varying in size from the smallest which can be distinguished with the naked eye to those which are ready to open, will be formed at the apex of each stem. Under good growing conditions, these buds open at the rate of one every 2 or 3 days. In cool weather, development may be much slower (51).

Woodroof (97) reported that okra is a rapidly growing vegetable which reaches the edible stage 3 days after blossom and becomes over-mature 5 days later. Fancy grade okra is picked on the 4th or 5th day, that of choice grade is picked on the 6th or 7th day, and the pods remaining on the stalk longer than 7 days are discarded as being too hard.

Thompson and Kelly (84) recommended that harvesting of okra should be done while pods are still tender, usually from 4 to 6 days after blooming, since the table quality okra is rather high at this stage.

According to Boswell (12), okra pods usually reach a very good stage for consumption in 4 to 6 days after the flower opens. Harvested pods must be kept reasonably cool and well-ventilated. Pods kept in large or closely packed containers are likely to be spoiled by heat.

Chauhan et al. (17) studied pod development and seed germination
in okra and concluded that pods should be harvested for consumption at 6-9 days after flowering because they are tender and have maximum protein content (2.08 percent) and low crude-fiber at that time. For seed purposes, the best stage for harvest was 30 days after anthesis, when the pods were fully mature, dry, had started cracking, and the seed showed good germination (85-86 percent). Similar studies were conducted by Manoher (50). He reported that the pods developed rapidly for the first 11 days following the opening of the flowers, after which development slowed down. Seed matured about 21 days after opening of the flowers, after which development slowed down. Seed matured about 21 days after opening of the flowers and attained up to 97 percent germination.

Chatfield et al. (15) reported the approximate composition of fresh vegetables. Okra pod was reported to contain approximately 90 percent water, 2 percent protein, less than 0.5 percent fat and 1 percent fiber. Boswell (12) reported similar observations regarding the composition of okra pods. He also observed that at good edible stage, okra pods contained about 90 percent water, 2 percent protein, 7 percent carbohydrates and 1 percent of minerals. Like most other green vegetables, okra is low in calories. It is valuable as a food, chiefly for its bulk, minerals and vitamins. Okra is a good source of calcium and a fair source of iron. Fresh pods of green cultivars are rich in provitamin A. Dried okra contains no more than half of the provitamin A present in fresh pods. Fresh pods are fair to good as a source of vitamin B. Young pods 2.5 to 3 inches long are almost twice as rich in vitamin C as older pods 5.5 to 6 inches long.

Culpepper and Moon (21) discussed the effect of age of pod on
chemical composition. They observed that total and insoluble solids of the entire pod decreased up to the 14-day stage of maturity and then increased to the 34-day stage after which there was little change in the soluble solids. Total sugars were low but increased somewhat up to the 10-day stage after which there was a decline. The acidity and the total astringency made only slight changes which appeared to be of no great importance as the pods increased in size. The fresh weight of the entire pod increased slowly for the first few days after bloom, quite rapidly to the 14-day or 18-day stage, then more slowly to the 22-day stage, after which there was a decrease. Insoluble solids, total solids, and total nitrogen also accumulated in somewhat the same way except there was no decrease between the 22- and 34-day stage. Sugar accumulated up to the 14-day stage and remained nearly constant to the 22-day stage after which it decreased. Soluble solids increased to the 14-day stage and then decreased to the 34-day stage.

Moursi and Gomma (57) studies the changes in chemical composition of okra pods during maturation. They observed that the percentage of dry matter, total nitrogen, and phosphorus declined while the percentage of potassium did not change appreciably during the maturation process.

Shelor and Woodroof (69), in discussing the factors affecting quality of frozen okra, reported that there was a definite relation between age and increase in pod length, diameter, weight, and pressure to shear, a slight increase in moisture content, seed content, and crude fiber with age of pods, and a decided decrease in muscilagenous materials as the pods increased from 3 to 5 days of age, with a small decrease thereafter.
Culpepper and Moon (21) pointed out that table quality was judged to be rather high at the 4-day stage, increased somewhat to the 6-day stage, then slowly declined to the 12-day stage. After this time, the material quickly became so fibrous as to be unsuited for table use. The factor that was most important in determining culinary quality of the cooked material was texture. Texture was influenced or determined by chemical or physical changes, chiefly the tenderness of the material and the solid contents, and the nature of the changes in the matter or solids. They further observed that the material reached a degree of fibrousness that made it more or less undesirable for table use a short time before growth in length actually stopped.

Kramer et al. (45) pointed out that the important factors of quality in asparagus are color, flavor, and freedom from fibrousness. Smith and Kramer (74) presented a rapid method for determining fibrous materials in canned green asparagus and reported that fiber content increases rapidly beyond the naturally snapping point of the stalk.

Rowe and Bonny (65) have presented a tentative method for determination of quality in snapbeans, based upon measurement of total content of fibrous material in the sidewall of the pods. They gave no indication as to the type of tissue being extracted by their method, but it is reasonable to assume that the extracted material would include the strings, the "fiber of the sidewall," and the vascular bundles.

Woodroof (98) observed that okra pods were edible from the 3rd to the 8th day after blossoming, during which time there was a constant change from simple to complex compounds. As the pods grew there was a decrease in the amount of muscilage, an increase in fibers in the pod wall, and an increase in the weight of seed, markedly affecting the
texture and flavor. He further pointed out that muscilage of okra was found to be a gum which swelled in water. It was found to be produced in specialized cells of the pod wall and to be insoluble in most chemical reagents.

Amin (6) studied the chemistry of the muscilage of okra and observed that in water the minced pods yielded a muscilage indistinguishable in appearance from solutions of other plant gums and muscilages. On partial hydrolysis, the muscilage gave 3 galactobioses, one of which has been proved to be 4-O-D-galactopyranosyl-D-galactose. The following oligosaccharides were found as hydrolytic fragments, suggesting that the linkages involved are present in the polysaccharide: 2-O-(D-galactopyranosyluronic acid) → L-rhamnose, galactosyl → (galactosyluronic acid) → rhamnose and (galactosyluronic acid) → rhamnosyl → galactose. He extracted the muscilage with water at room temperature and purified it by precipitation with alcohol.

Whistler and Conrad (90) obtained a crystalline galactobiose which was shown to be 4-O-D-galactopyranosyl-D-galactopyranose. This was the first isolation of a crystalline galactobiose. The muscilage is located in pods and not in the seeds.

Kelkar et al. (43) also reported a method for isolation of muscilage from pods of okra.

According to MacGillivray (48), color is an important factor in connection with quality of horticultural crops. According to him, the spectrophotometer has been used to study the appearance of several agricultural products. Some workers report only reflection or transmission curves, and others describe the appearance of the product in color attributes.
While there are cultivars of okra that vary in color from deep green to cream, there is a definite preference for green okra for freezing purposes (69).

Woodroof (98) also pointed out that there was a color preference for pea green okra for freezing, brining and canning. Okra blackened along the ridges, and around the base and tip of pods, due to bruising lost greenness when held in hampers without refrigeration for more than a day and turned brown when brined warm or with insufficient salt.

Fishback and Newburger (28) made a spectrophotometric study of the green color of okra. They obtained transmission curves in the spectral region of 400-750 mu for the crude ether extract and the cold saponification product of the green pigment in fresh okra, canned fermented okra, canned unfermented okra, and canned fermented okra treated with zinc salts. The spectrophotometric data indicated that the addition of zinc salts to canned okra resulted in the synthesis of a pigment containing zinc. This new color was very similar chemically to the naturally occurring chlorophyll that it replaces.

According to Woodroof (98) the physical characteristics of okra pods varied with cultivar and age from the time of blossoming. Size of pods, hardness, dullness, shape, weight, and internal changes such as changes in resistance in shearing, percent of pod wall, percent placenta, percent seed, amount of mucilage, and flavor all were correlated with age.

Shelor (69) pointed out that of more than two dozen cultivars and strains tested color varied from cream to deep green; shape from very short and stubby with a maximum length of about 5 inches to long
and slender, reaching a maximum length of 12 inches; and surface contour from deeply ridged or star-type to perfectly smooth (round). 'Emerald' was a typical smooth pod-type and 'Dwarf Perkins' was a typical ridged, star-type.

Sistrunk and Jones (72) studied various cultivars of okra regarding their suitability for processing. They found that pods of all cultivars reached their maximum diameter, length and weight on the 8th or 9th day after bloom. 'Emerald' made the most rapid growth in length and remained in a good stage for freezing as whole okra for only 2 days while 'Louisiana Green Velvet' and 'Dwarf Velvet' were suitable for freezing as whole okra for 3 days. 'Louisiana Market' and 'Gold Coast' have short pods and never get too long for packing as whole pods. There was very little difference in the percentage of dry matter between cultivars throughout the test period. Examinations of frozen samples indicated that 'Emerald' had the most desirable dark green color, but its pods tended to collapse after blanching. 'Louisiana Market' had the most attractive shape. Color of 'Louisiana Market,' 'Louisiana Green Velvet' and 'Dwarf Velvet' was similar, being slightly lighter than 'Emerald.' 'Gold Coast' had a light green color, but the shape and size of pods were very desirable for freezing.

In a further study by Sistrunk et al. (73), there were only negligible differences at any given sampling date in dry matter content of pods of 3 cultivars and 2 lines of okra tested. The greatest increase in pod weight, length and diameter in all cultivars occurred during the 4th to 6th day after flowering. Pods of all cultivars grew rapidly until the end of the edible stage, at which time growth declined. Pods of all cultivars became so fibrous as to be inedible by the 10th day.
after flowering.

Results of their tests indicated that short-podded types such as 'Louisiana Market' and 'Gold Coast' may be frozen whole over a longer period than longer-podded cultivars such as 'Louisiana Green Velvet,' 'Dwarf Velvet,' and especially 'Emerald.' Pods 4 to 6 days old were found to be highest in quality for each cultivar.

Kolhe and Chavan (44) studied pod development and yielding capacity of various cultivars of okra. According to them (44) pod length, thickness, weight, specific gravity and dry matter were cultivar characters studied in relation to pod development, yield and quality. For a maximum yield of edible pods, it was recommended that the cultivar 'Pusa Sawani' be picked on the 7th or 8th day; 'Red Wonder' on the 6th or 7th day, and 'N412' on the 5th or 6th day after pollination.

Longo (47) studied and compared 4 Sicilian and 3 American cultivars of okra. He reported that although the number of pods per plant varied little, yield per plant differed considerably among cultivars, being high in 'Attica' and 'Clemson Spineless.' 'Emerald,' and 'C48' produced the best quality pods for fresh market and for canning.

Winton and Winton (94) reported on the macroscopic and microscopic structure of okra pods. According to them, at the edible stage the pericarp consists of 5 well-marked layers: (1) epicarp of thin-walled polygonal cells, stomata, unicellular hairs and multicellular hairs on unicellular bases; (2) hypoderm of thin-walled polygonal cells, some containing oxalate rosettes; (3) mesocarp of loose parenchyma cells, containing chlorophyll grains and small grains of transitory starch, often in twins and triplets, interspread with oxalate rosette cells as in the hypoderm, large muscilage cells and fibrovascular
bundles; (4) crystal layer, each cell with a single prismatic crystal; and (5) endocarp of fibers mostly transversely arranged, and stomata.

Stark (78) made a histological study of the nature of the fibrous sheath in the edible pods of snapbeans. He presented information on time of formation of the fibrous sheath of the side wall in the pods, particularly in relation to edible quality.

As pointed out by Geraldine (29), nutrition is basic to the production of good quality and high yield, and it is of major importance in maintaining or improving quality of vegetables (29).

Dolan and Christopher (22) pointed out that not only the level of fertilization, but also the relative balance of the 3 main ingredients of complete fertilizer (Nitrogen, Phosphorous and Potash) must be given consideration in the nutrition of vegetable crops. Furthermore, it has been shown that crops respond differently to modifications of the ratio of the 3 main fertilizer materials.

Etzel (27) studied the effect of fertilizer on the oil content of okra seed. He reported that treatments with P₂O₅ and K₂O applied constantly at 80 lbs per acre and N at the rate of 30 lbs per acre produced a highly significant increase in oil content as compared to the treatment 60-80-80 which in turn produced significantly more oil than a 90-80-80 treatment.

Thompson and Kelly (84) pointed out that the usual fertilizer applications for okra in the South are 400 to 800 lbs of a 5-10-5 or 6-8-8 grade, broadcast before the seed is planted. After the harvest season is begun, nitrogen side dressings are usually applied. The harvest may be delayed if excessive amounts of nitrogen are used before the plant begins to fruit.
Spivy et al. (76), while discussing the production of okra in south Georgia, pointed out that a good fertilization program is 600 to 1200 lbs per acre of an 8-8-8 analysis, depending somewhat on the soil. Approximately one-half of this, in the case of heavier soils, should be applied prior to planting and the remainder 4-6 weeks after planting. In seasons of unusually heavy rainfall 25-30 additional lbs of nitrogen may prove profitable in the production of okra. In the micro- or minor element study, only magnesium was found to give increased yield.

The following are the fertilizer recommendations for production of okra in Louisiana (2).

(a) Alluvial Soils. Apply 300-600 lbs of 6-12-6 or equivalent per acre plus 15 to 30 lbs of nitrogen as side dressing if necessary to get good growth.

(b) Terrace Soils. Apply 400 to 800 lbs of 6-12-6 or equivalent per acre, plus 15 to 30 lbs of nitrogen as side dressing if necessary.

(c) Hill Soils. Apply 400 to 800 lbs of 5-10-10, 4-12-8 or equivalent per acre, plus 15 to 30 lbs of nitrogen as side dressing. It may be desirable to apply the side dressing in split applications, the first early in the harvest period and the second around the middle of the season.

Hester and Sheldon (32) reported that a combined weight of 11.5 tons (green weight) of pods, leaves and stems of okra contained 21, 10, 62 and 46 pounds of N, P₂O₅, K₂O and CaO, respectively. As compared with the chemical content of other vegetable crops, such as tomatoes and potatoes, okra has a relatively low content of these nutrients.

Sutton (80), studying the response of okra to nitrogen, phosphorus,
and potassium fertilization, found that relatively high initial rates of nitrogen in combination with the higher rates of phosphorus reduced early yield of okra. Higher rates of potassium had no beneficial effects on yield. The treatment combination that resulted in the highest early yield did not supply enough nitrogen to maintain a relatively high yield over a long harvest period. It appears that it would be beneficial to side dress okra with nitrogen even if leaching is not a problem.

Singh and Singh (71) studied the effect of 4 different sources of nitrogen, viz. urea, calcium ammonium nitrate, ammonium sulphate and ammonium chloride on okra production. Plants of the cultivar 'Pusa Sawani' grown on a clay loam soil, with urea as the source of nitrogen produced better growth with higher yields per acre than the other sources. Calcium ammonium nitrate proved the second best source of nitrogen for okra.

Sarin and Saxena (67) studied the influence of zinc and manganese deficiency on the growth of okra. When okra plants were subjected to zinc deficiency, a depression in leaf production and leaf size appeared within about 3 weeks, and a leaf mottling developed about 2 weeks later, and the stem diameter was reduced. The rate of increase in dry weight and the rate of phosphorus uptake were also depressed within 3 weeks whereas ribonuclease activity was increased.

They (67) further observed that with manganese deficiency, a reduction in internode length was noted in 5 weeks. There was, however, no effect on leaf growth, phosphorus uptake or ribonuclease activity. It was tentatively concluded that the zinc deficiency symptoms were induced by the increase in ribonuclease activity and a consequent decrease in protein synthesis.
Windham (92) studied the rates of fertilizer for okra production. In his trials with 'Clemson Spineless' plants grown on 2 different soil types and treated with various levels of nitrogen, phosphorus and potassium no relationship was found between pod size and treatment. Results showed that a well drained soil with ample amounts of organic matter should receive N, P$_2$O$_5$ and K$_2$O at the rates of 24, 48, and 48 lbs per acre, respectively. On lighter soils, the N rate may be increased to 48 lbs per acre.

Sutton (81) studied the effect of nitrogen, phosphorus and potassium on yield of okra. Four experiments were conducted with okra to determine the effect of rates and ratios of nitrogen, phosphorus, and potassium on marketable yields. In all cases, a fertilizer ratio of 1-1.3-1.3 (N, P$_2$O$_5$, K$_2$O) resulted in the highest yields of marketable okra.

Tai et al. (83) carried out a spacing and fertilizer trial with okra. The fertilizer treatments consisted of basic fertilizer with and without added dressings of 1.5 cwt. Calnitro per acre 4 and 8 weeks after planting, applied singly or combined. The differences between fertilizer treatments were small; however, the plants at the closest spacing gave the highest yield.

Ahmad and Tullock-Reid (4) investigated the responses of okra to various levels of nitrogen (0-336 kg/ha), phosphorus (0-280 kg/ha), potassium (0-280 kg/ha) and magnesium (0-112 kg/ha) fertilization together with adequate basal levels of the other 3 elements. Best yields were obtained with 112 kg magnesium/ha. The effect on leaf composition of nitrogen, phosphorus, potassium and magnesium at 3 stages of growth of the crop and the amount of these nutrients removed in the pod was
also studied.

Windham (93) studied the effect of nitrogen, phosphorus and potassium on the yield of okra and reported that the addition of 20 lbs N, 40 lbs P$_2$O$_5$ and 40 lbs of K$_2$O per acre increased the yield by 0.4 tons/acre. Rates above this level had no further influence on yield.

A similar study was carried out by Randhawa and Pannun (64) regarding row spacing and fertilizer trials on okra. They employed row spacings of 30, 45 and 60 cm and nitrogen levels of 33, 66, and 99 kg/ha. The number of branches, flowers and fruits per plant increased with the spacings of 60 cm. The highest yield was obtained from the close spacing of 30 cm. The maximum height, the greatest number of leaves, branches, flowers, fruit per plant and the highest total yield of fruit were obtained with the application of 66 kg nitrogen/ha. Fruit weight was not affected by different nitrogen levels.

Kamlanathen et al. (40) carried out spacing and fertilizer trials on the okra cultivar 'Pusa Sawani' over 3 seasons. They reported that at the closest spacings of 60 x 20 cm, yield/ha was greatest and yield/plant least compared with spacing of 60 x 30 and 60 x 40 cm. The response to nitrogen at 40 and 80 kg/ha was linear, but only the lower rate was economically feasible. Potassium at 30 kg/ha increased the yield but reduced it at 60 kg/ha. Nitrogen application delayed maturity and phosphorus induced earliness. There was no yield response to phosphorus.

Verma et al. (89) studied the effect of different levels of nitrogen, phosphorus and potassium on vegetative growth and yield of okra. Nitrogen was applied at 30, 60, 90 or 120 kg/ha, and phosphorus
at 60 or 80 kg/ha, and potassium at 40 kg/ha. The best quantitative and qualitative response came from 90 kg nitrogen + 80 kg phosphorus. Potash applications caused some increase in leaf number but had no effect on pod size or yield.

Sutton (82) studied the effect of fertility and plant populations on the yield of okra. He conducted 3 experiments on scrotan fine sand to determine the effect of 1,000, 2,000, and 3,000 lbs/acre of a 6-8-8 fertilizer and plant spacing at 2, 4, 6, and 8 inches on the row on marketable yield. The 3,000-lb rate of fertilizer maintained a more favorable total soluble salt content in the 0-6 inch layer of soil; however, in only 1 experiment was the linear effect of fertilizer more significant on marketable yield. In most cases, the 2-inch spacing resulted in the highest yield.

Sainbhi and Padda (66) studied the effect of nitrogen and phosphate fertilization on growth and yield of okra. They reported that nitrogen applications of up to 134 kg/ha increased plant height and pod yield. Higher nitrogen levels were not beneficial, and there were no significant responses to phosphorus applications at 34 or 67 kg/ha.

Chandrasekharan (14) studied the effect of nitrogen-phosphorus-potassium in combination with trace elements on the yield of Bhindi (okra). Application of nitrogen-phosphorus-potassium at levels above 84, 112 and 56 kg/ha, respectively, did not increase yield significantly. There was no response to a trace-element formulation, sparitin A, applied at 336 kg/ha.

Hipp and Cowley (33) discussed the importance of the phosphorus-zinc interaction in okra production. They reported that zinc deficiencies in field-grown okra were induced with band phosphorus applications
of 29 and 58 kg/ha. Okra yields were slightly increased with these elements applied alone, but phosphorus and zinc in combination resulted in the highest yields. Yields of okra were seriously reduced when phosphorus and zinc concentrations in 10-15 day old plants were less than 0.30 percent and 40 ppm, respectively.

Bid et al. (11) studied the efficiency of nitrogenous and phosphatic fertilizers on growth and yield of Bhindi (okra). Nitrogen, phosphorus and potassium were applied at 60, 30, and 30 kg/ha, respectively, and in various other combinations. The best growth was obtained when all 3 elements were applied. Of the 2-nutrient combination, nitrogen-potassium was most effective, followed by nitrogen-phosphorus and phosphorus-potassium. Of the single nutrient applications, the highest yields were obtained with nitrogen. Differences in results among various nitrogen sources were slight.

Chiotan et al. (18) studied the effect of chemical fertilizer applications on okra production. Comparing the effects of various levels and combinations of nitrogen and phosphorus, the highest yields were obtained with N\textsubscript{96} P\textsubscript{96} kg/ha, followed by N\textsubscript{48} P\textsubscript{96}. The highest return per unit of nutrient applied was obtained from N\textsubscript{48} P\textsubscript{48} and N\textsubscript{48} P\textsubscript{96}.

Asif and Greig (7) studied the effects of nitrogen, phosphorus, and potassium fertilization on pod yield, macro- and micro-nutrient levels and nitrate accumulation in okra. Maximum yield was obtained from 120 lbs nitrogen/acre, while phosphorus and potassium had no favorable influences on yield.

Nitrogen and copper levels of plants increased, but phosphorus, calcium, and zinc levels decreased with nitrogen applications. Applied
phosphorus-potassium increased only phosphorus and potassium levels of plants. Nitrogen applications increased nitrate accumulation in the pod. Phosphorus and potassium concentrations were maximum in the pods; nitrogen, zinc and manganese were high in the leaves, and calcium and magnesium concentrations were higher in the green stems than in other tissues. Roots contained maximum iron, suggesting that okra plants tend to accumulate iron in the roots without translocating much of it to above-ground plant parts.

Albregts and Howard (5) recently studied the effect of fertilization and mulching on responses of okra and peppers. They reported that germination of okra and early growth and seasonal marketable yield of both vegetables were greatest with the full bed mulch treatment. They also observed that yields were always higher with higher fertility levels, but differences were usually not significant. They concluded that pepper and okra both respond to moderate rates of fertilizer.
MATERIALS AND METHODS

A study of three cultivars of okra was conducted in 1971 at Baton Rouge on Mississippi River Terrace soil (Hill Farm). The 3 cultivars selected for this study were 'Clemson Spineless,' 'Emerald' and 'Louisiana Green Velvet.' These 3 cultivars are commonly grown commercially in Louisiana. Three adjacent rows, 150 ft long were planted to each cultivar. Recommended cultural practices were followed.

Flowers were tagged during early morning hours on blooming day to ensure that the blooms were of the same physiological age. Different tagging dates were referred to as different fruit setting dates throughout the text. Blooms were tagged on 6 alternate days. Pods were harvested for quality studies on the 7th day after tagging. Four replications of 20 pods from each cultivar were utilized for quality measurements. Quality variables studied included weight and length of the pods, color (optical density), percent dry matter, percent muscilage and percent fiber.

Two different okra maturation studies were conducted for 2 consecutive years (1971 and 1972) at the L.S.U. Hill farm and at the Ben Hur Farm, (Mississippi River Alluvial soil), Baton Rouge, Louisiana.

The first maturity study was conducted at the Hill farm with 3 cultivars, 'Clemson Spineless,' 'Emerald' and 'Louisiana Green Velvet.' For this study flowers were tagged 2 times on blooming day and pods were harvested on the 5th, 7th, 9th, and 11th day after tagging, thus each time producing pods of 4 maturities. This experiment was repeated 2 times in 1971 and also in 1972. Quality measurements listed above in the cultivar study and anatomical study were conducted.
For the second maturity study only one cultivar, 'Emerald,' was utilized at the Ben Hur Farm because of its desirability for processing. An interaction between stage of maturity and type of fertilizer was studied to determine the effect on the growth and quality variables of okra pods. This experiment was repeated for 2 consecutive years (1971 and 1972) at the Ben Hur Farm.

There were 4 fertilizer treatments replicated 5 times in a randomized block design. Each plot consisted of 3 rows 4 feet apart 35 feet in length with 12-inch spacing between the plants and 5-foot alleys per treatment with the center row being harvested for research. Field replications 1 and 2 were combined as were 3 and 4, to obtain 2 laboratory replications for quality analysis as well as for anatomical study. This was necessary due to a small number of pods per field plot. Forty pods of each treatment were harvested every 7th day. This entire experiment was repeated 3 times in 1971 and 7 times in 1972. The fertilizer treatments utilized in 1971 were as follows:

1. Check (control) 0 - 0 - 0
2. 36 - 0 - 0 + 16 - 0 - 0 lbs/Acre (33.5%N) Ammonium Nitrate
3. 36 - 72 - 36 + 16 - 0 - 0 lbs/Acre (6-12-6)
4. 48 - 96 - 48 + 16 - 0 - 0 lbs/Acre (6-12-6)

Treatments were the same in 1972 as those in 1971 with the exception of treatment number three, where the nitrogen side dressing was not applied in 1972. Fertilizers were applied 6 inches deep in the drill row approximately 2 weeks before planting and nitrogen side dressing was applied to the top of the row by hand when plants were about knee high.

The soil type at Ben Hur Farm was a commerce silt loam (Mississippi River Alluvial Soil). In 1972 soil samples by treatment were
taken. Two borings about 8 inches deep in the center of the plot were taken for a total of 10 borings/treatment/sample for soil analysis. Results of the soil analysis are shown in Table 1.

Quality Studies

The following aspects of growth and quality were studied during the 2 years, 1971 and 1972.

1. **Weight**—Fresh weight of the individual pods was determined. A total of 80 pods of each cultivar were brought to the laboratory and divided into 4 groups of 20 pods which represented a replication.

2. **Length**—Length of the pods from basal cap to pod tip was measured in centimeters.

3. **Dry Matter**—Pods were divided into two equal lots.

   One lot of the pods was cut into small pieces and mixed thoroughly to obtain uniform and homogeneous samples. The percent dry matter was determined by drying 20 to 60 grams of cut okra at 70°C for 24 hours in a forced-air oven.

4. **Mucilage**—The remaining lot of pods were cut longitudinally through the center into equal halves. After seed removal, one half was saved for color determination and the other half of the pods was cut into small pieces and mixed thoroughly to obtain uniform samples. Twenty-five gram samples of each replication was minced or blended with 100 ml of distilled water in a Waring blender for 2 minutes and allowed to stand overnight. The following day these viscous samples were pressed through a thick cloth or muslin, and the filtrate was weighed. Four parts
<table>
<thead>
<tr>
<th>Fertilizer Treatments</th>
<th>Depth Inches</th>
<th>Extractable Nutrients, Parts per Million</th>
<th>O.M. %</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Control 0-0-0</td>
<td>0-8</td>
<td>P: 177 K: 110 Ca: 1070 Mg: 270 pH: 6.3</td>
<td>0.62</td>
<td>Commerce Silt Loam</td>
</tr>
<tr>
<td>2. 36-0-0 + 16-0-0</td>
<td>0-8</td>
<td>P: 177 K: 120 Ca: 1070 Mg: 272 pH: 6.3</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>3. 36-72-36 + 0-0-0</td>
<td>0-8</td>
<td>P: 165 K: 130 Ca: 1130 Mg: 284 pH: 6.2</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>5. 48-96-48 + 16-0-0</td>
<td>0-8</td>
<td>P: 196 K: 150 Ca: 1180 Mg: 297 pH: 6.3</td>
<td>0.94</td>
<td></td>
</tr>
</tbody>
</table>

1 Ben Hur Farm, Baton Rouge, La.
2 Series - Commerce Silt Loam.
of 95% ethyl alcohol by volume were added to one part of this muscilage filtrate (1:4). The muscilage, which was precipitated by addition of 95% ethyl alcohol, was then separated as a sticky mass on No. 15 Whatman filter paper by filtering under forced suction pressure through a Buchner funnel. This muscilage material along with filter paper was dried in a forced-air oven at a temperature of 50°C for 3 hours. The modified method for muscilage isolation (Kelkar, Ingle and Bhide, 1962) was adopted to obtain the actual weight of muscilage in the pods (43).

5. Color--Ten gram samples of okra, free from seeds, were used for color determination. Care was taken to get homogeneous samples representing butt, middle, and tip or end portion of the pods. Forty cc of 95% ethyl alcohol were added and blended with a Virtis homogenizer for 3 minutes. Samples were then filtered through No. 15 Whatman filter paper. The residue was washed twice with 95% ethyl alcohol to remove the remaining chlorophyll. Five cc of filtrate were mixed with the same quantity of absolute ethyl alcohol giving a final diluted volume of 10 cc. Optical densities (O.D.) were determined at 665 mp wave length by using a Beckman DBG recording spectrophotometer.

6. Fiber content--The 4 dried samples from the dry matter determination were utilized in determining the fiber content of the pods. All dried samples of each cultivar were massed and ground through a Wiley mill to pass through a 20-mesh screen and were submitted to the Louisiana State Feeds and Fertilizer Laboratory for crude fiber analysis according to A.O.A.C. procedure (8).
7. **Anatomical Studies**—The middle portion from 2 pods of each cultivar or treatment were cut into small sections approximately 1.27 cm, preserved and fixed in Formalin-acetic acid-alcohol (F.A.A.) solution. The formula for F.A.A. solution was as follows: Formaldehyde, (40%) 5cc; Glacial acetic acid, 5 cc; and Ethyl alcohol, 70%, 90 cc. The method for preparation of paraffin blocks and microtomy (Sharma and Sharma, 1965) was adopted to determine the number of lignified or thick-walled cells in okra pods (68).

Samples preserved in F.A.A. solution were dehydrated with a series of Tertiary-Butyl alcohol (TBA), then embedded in paraffin blocks. Paraffin blocks containing pod samples were cut into very thin sections (approximately 16 microns) with the Spencer 820 Rotary microtome and mounted on slides by using a drop of Haupt's adhesive. Later these sections were stained with safranin 0 and fast green stain.

In the cultivar study at the L.S.U. Hill farm, 4 sections were selected from each sample. Each cultivar provided 2 samples, therefore 8 sections of each cultivar were selected to study the fibrous or lignified cells. The 3 cultivars had 6 samples, giving a total of 24 sections for each date or stage of maturity.

The first maturity study was conducted at the L.S.U. Hill farm with 3 cultivars harvested at 4 maturity dates (5th, 7th, 9th, and 11th day after blooming). Each cultivar at each maturity date provided 2 samples, therefore 8 sections were selected for each maturity date or cultivar. The 3 cultivars had 6 samples at each maturity date, giving a total of 24 sections. For 4 maturity dates a total of 96 sections
were selected to study lignified cells which were counted in a quarter size of each objective's field of view near the periphery of the pod. This study was conducted in 1971 and 1972.

The second maturity study was conducted at the Ben-Hur Farm with only the 'Emerald' cultivar. An interaction effect of stage of maturity and type of fertilizer on the lignification of cells was studied.

Each fertilizer treatment furnished 2 anatomical samples, therefore 4 treatments had a total of 8 samples. From each sample 4 sections were selected, and the fibrous cells or lignified cells were counted from the quarter size of each microscope objective's field of view. This study was conducted for 2 years in 1971 and 1972.

In 1972, at the Ben Hur Farm, an anatomical study was conducted with only one fertilizer treatment No. 4 and the cultivar 'Emerald.' Pods were harvested on the 7th day from blooming and cut into 3 parts (butt, middle and end or tip part). All quality variables were studied. The forty pods were harvested and 2 field replications were made which were used as 2 laboratory replications.

Each part (butt, middle and end) had 2 samples, and from each sample 4 sections were selected; therefore, for 2 samples, 8 sections were selected for each date or part. The 3 pod parts had 6 samples so 24 sections were selected to determine the number of thick-walled cells. This experiment was repeated 3 times in the same year.

In 1972, another anatomical study was conducted with only one fertilizer treatment No. 3 and the cultivar 'Emerald.' Pods were harvested daily from the 3rd day to the 11th day of maturity. Pods were cut into 3 parts (butt, middle, and end part). Each part had 2
samples, therefore the 3 parts had 6 samples and from each sample 4 sections were selected. Thus, 24 sections were selected and studied for each maturity date. This study was repeated twice in the same year.
RESULTS AND DISCUSSION

The data were subjected to analysis of variance, and the F test was used to determine significant differences. Mean separations were tested by Duncan's Multiple Range Test (Duncan, 1955) (24). These were done by Fortran computer program.

CULTIVAR STUDY:

Quality factors for the cultivars studied in 1971 are presented in Table 2.

There were highly significant differences among the cultivars in pod weight. 'Clemson Spineless' produced the heaviest pods (24.2 gm), followed by 'Emerald' (19.4 gm), and 'Louisiana Green Velvet' (17.1 gm) (Table 2). Also, tagging of freshly opened blooms on alternate days resulted in highly significant variation among tagging dates (Figure 1). The maximum average weight was recorded on the 4th tagging date for all the cultivars, indicating that environmental conditions were significantly causing variations in pod weight at different tagging dates.

Weight appeared to be correlated with the length of the pods. 'Clemson Spineless' proved to be a short but thick-podded cultivar; whereas, 'Emerald' was rated intermediate in weight but produced longer pods than 'Clemson Spineless' and 'Louisiana Green Velvet.'
### TABLE 2

**QUALITY FACTORS OF THREE CULTIVARS OF OKRA AS AN AVERAGE OF SIX TAGGINGS**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Weight (gm)</th>
<th>Length (cm)</th>
<th>Dry Matter (%)</th>
<th>Muscilage (%)</th>
<th>Color* (O.D.)</th>
<th>% Fiber (Dry wt. basis)</th>
<th>% Fiber (Fresh wt. basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Clemson Spineless'</td>
<td>24.2 a</td>
<td>12.7 a</td>
<td>9.0 a</td>
<td>0.71 a</td>
<td>0.24 a</td>
<td>8.6 a</td>
<td>0.76 a</td>
</tr>
<tr>
<td>'Emerald'</td>
<td>19.4 b</td>
<td>16.5 b</td>
<td>10.5 b</td>
<td>1.33 b</td>
<td>0.29 a</td>
<td>9.0 a</td>
<td>0.94 b</td>
</tr>
<tr>
<td>'Louisiana Green Velvet'</td>
<td>17.1 c</td>
<td>14.7 c</td>
<td>10.3 b</td>
<td>1.52 b</td>
<td>0.25 a</td>
<td>8.8 a</td>
<td>0.91 b</td>
</tr>
</tbody>
</table>

*Color—Optical density of 10 g of okra pods mixed in 40 ml. ethanol (diluted 1:1) at 665 nm.

Mean separation in columns by Duncan's Multiple Range Test, 1% level. Means having the same letter are not significantly different from each other.
Figure 1. The average pod weight of 3 cultivar of okra which had been tagged on different dates and harvested on the 7th day after tagging.
'Louisiana Green Velvet' produced thin pods but shorter pods than 'Emerald' in length, which resulted in lighter weight pods than the other cultivars.

On the average, 'Emerald' produced the longest pods (16.5 cm) over the entire experiment, and 'Louisiana Green Velvet' was rated intermediate for length (14.7 cm). 'Clemson Spineless' had the shortest pods (12.7 cm). Pod lengths of the cultivars were significantly different from each other at the 1% level (Table 2). This is in agreement with Jones, Sistrunk and Miller (73), who reported that 'Emerald' had the longest pods, with 'Louisiana Green Velvet' and 'Dwarf Velvet' ranking as intermediate, and 'Louisiana Market' and 'Gold Coast' being characterized as short-podded cultivars.

The pod length varied significantly during the season for all cultivars as shown by tagging on alternate days (Figure 2). The maximum length was recorded on the 4th tagging and minimum length on the 1st tagging for all cultivars, indicating that this may be due to growing conditions which were causing variations in pod length at the different taggings.

On the average, 'Emerald' produced the highest dry matter content (10.5%) followed by 'Louisiana Green Velvet' (10.3%). These 2 cultivars were not significantly different from each other in their dry matter content. 'Clemson Spineless' produced the lowest dry matter content (9.0%) (Table 2), which is significantly lower than the other 2 cultivars.

Tagging dates were associated with significant differences in dry matter, as an average of all 3 cultivars (Figure 2).

On the average 'Louisiana Green Velvet' produced the highest
Figure 2. The average pod length and dry matter content of 3 cultivars of okra which had been tagged on different dates and harvested on the 7th day after tagging.
amount of muscilage (1.52%). 'Emerald' rated intermediate in muscilage content (1.33%), and 'Clemson Spineless' produced the lowest amount (0.71%) (Table 2). 'Louisiana Green Velvet' and 'Emerald' were not significantly different from each other in muscilage content; however, 'Clemson Spineless' was significantly lower than the other 2 cultivars.

The muscilage content varied significantly among the cultivars at each different tagging date. The interaction between cultivars and tagging dates for muscilage content was significant (Figure 3).

On the 2nd tagging date the 'Emerald' and 'Clemson Spineless' cultivars decreased in muscilage content. Later on, the 3rd tagging of all cultivars was accompanied by the highest percentage of muscilage. The cultivars then decreased in muscilage production on the 4th tagging date. 'Clemson Spineless' decreased further on the 5th tagging date; whereas, 'Louisiana Green Velvet' and 'Emerald' increased continuously in their percent of muscilage content. 'Clemson Spineless' again increased in percent muscilage on the 6th tagging date, indicating environmental influences.

There were no significant differences among the cultivars in pod color. 'Emerald' pods had the best color, on the average (0.29 O.D.) followed by 'Louisiana Green Velvet' (0.25 O.D.) and 'Clemson Spineless' (0.24 O.D.) (Table 2). Jones, Sistrunk and Miller (73) also found that 'Emerald' showed the most intense green color among the cultivars. The color of 'Louisiana Market,' 'Louisiana Green Velvet' and 'Dwarf Velvet' was similar, being slightly lower than 'Emerald.'

Highly significant interaction for pod color (O.D.) among cultivars and tagging dates was present. The cultivars did not respond the same on each tagging date (Figure 4).
Figure 3. The average muscilage content of 3 cultivars of okra pods which had been tagged on different dates and harvested on the 7th day after tagging.
Figure 4. The average pod color of 3 cultivars of okra which had been tagged on different dates and harvested on the 7th day after tagging.
There were no significant differences among the cultivars and tagging dates for fiber content when expressed on a dry weight basis. 'Emerald' had the highest fiber content (9.0%), 'Louisiana Green Velvet' had an intermediate amount of fiber (8.8%) and 'Clemson Spineless' had lowest fiber content (8.6%) (Table 2).

Tagging date was not associated with fiber content of the 3 cultivars when expressed on a dry weight basis. However, 'Clemson Spineless' had significantly less fiber than the other 2 cultivars when expressed on a fresh weight basis.

'Emerald' had the highest fiber content (0.94%), followed by 'Louisiana Green Velvet' (0.91%), and 'Clemson Spineless' (0.75%), respectively, when expressed on a fresh weight basis (Table 2).

The maximum fiber content (fresh weight basis) was produced on the 6th tagging date, and the minimum amount on the 3rd tagging date in all the cultivars.

MATURITY STUDY

In the maturity study with 3 cultivars, the data of 2 years' results was pooled, and combined analyses of variance were calculated. The F test was used to determine significant differences.

The effect of maturity on the average development of pods and on quality variables of each cultivar in 1971 and 1972 are presented in Table 3 and Figures 5-13.

Highly significant interactions between cultivars and maturity were noted for all quality factors except weight, dry matter and color in both years (Figures 7, 10, 13). Cultivars did respond differently at each stage of maturity and influenced the quality of the pods.
### TABLE 3
QUALITY FACTORS OF THREE CULTIVARS OF OKRA AS AN AVERAGE OF FOUR MATURITIES (1971-72)

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Weight (gm)</th>
<th>Length (cm)</th>
<th>Dry Matter (%)</th>
<th>Muscilage (%)</th>
<th>Color (O.D.)</th>
<th>% Fiber (dry wt. basis)</th>
<th>% Fiber (fresh wt. basis)</th>
<th>Thick-walled (fiber) cells (No.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Clemson Spineless'</td>
<td>30.5</td>
<td>11.6</td>
<td>9.9</td>
<td>1.33</td>
<td>0.38</td>
<td>12.4</td>
<td>1.33</td>
<td>119.0</td>
</tr>
<tr>
<td>'Emerald'</td>
<td>24.9</td>
<td>15.5</td>
<td>11.2</td>
<td>2.43</td>
<td>0.53</td>
<td>10.3</td>
<td>1.15</td>
<td>97.7</td>
</tr>
<tr>
<td>'Louisiana Green Velvet'</td>
<td>19.4</td>
<td>13.4</td>
<td>10.9</td>
<td>2.62</td>
<td>0.40</td>
<td>10.0</td>
<td>1.10</td>
<td>84.7</td>
</tr>
</tbody>
</table>

*, **F values significant at 5% (*) and 1% (**) levels, respectively.

N.S. = Non-Significant.
Highly significant differences among cultivars in pod weight were observed. In 1971 and 1972, the average weight of the pods of the cultivar 'Clemson Spineless' was found to be highest (30.5 gm) and also the highest in fiber content (dry weight and fresh weight basis). The cultivar 'Emerald' produced pods weighing 24.9 gm and had a medium amount of fiber (dry weight and fresh weight basis). 'Louisiana Green Velvet' produced the lightest pods, weighing 19.3 gm, which had the lowest amount of fiber (dry weight and fresh weight basis) (Table 3).

The quality variables of the pods varied from cultivar to cultivar when harvested on the 5th, 7th, 9th and 11th day after tagging. Effects of stage of maturity on pod weight were highly significant. Initial pod weight was lowest on the 5th day after blooming, then it increased linearly on the 7th, 9th and 11th days of maturity in all 3 cultivars (Figure 5). Woodroof and Shelor (98) reported that the physical characteristics of okra pods varied with cultivar and age from the time of blossoming. The size of pods, hardness, dullness, shape, weight, and amount of muscilage was correlated with age. The weight of the pods increased as the pods grew older. Similar observations were also reported by Jones, Sistrunk and Miller (73).

Highly significant differences among the cultivars for pod length were noted. In 1971 and 1972, 'Emerald' produced the longest pods (15.5 cm), followed by 'Louisiana Green Velvet' (13.4 cm) and 'Clemson Spineless' (11.6 cm) (Table 3). Jones, Sistrunk and Miller (73) observed that the 'Emerald' had the longest pods, with 'Louisiana Green Velvet' and 'Dwarf Velvet' ranking as intermediate, and 'Louisiana Market,' 'Gold Coast' being characterized as short-podded cultivars.

The effect of stage of maturity on pod length was highly
Figure 5. Effects of maturity on average pod weight and dry matter content of 3 cultivars of okra.
significant. Pod length did vary significantly among different stages of maturity.

A significant interaction for pod length between cultivar and maturity was noted. It was found that the length of the pods varied according to cultivar and physiological maturity (Figure 6). All 3 cultivars had different length pods at different physiological ages. Pod length of all 3 cultivars increased continuously with maturity. The shortest pods were recorded on the 5th day, and longest pods on the 11th day of maturity in all 3 cultivars. The rate of growth in length of all 3 cultivars was rapid from the 5th day to the 9th day, and then growth slowed down considerably from the 9th to 11th day in both years. The cultivar 'Emerald' had the longest pods, 'Louisiana Green Velvet' was intermediate, and 'Clemson Spineless' had the shortest pods at each stage of maturity. Cultivars varied significantly for pod length at each different stage of maturity (Figure 6).

Significant differences in dry matter content were found among the cultivars. In 1971 and 1972, the highest dry matter content was found in the 'Emerald' cultivar (11.2%), followed by 'Louisiana Green Velvet' (10.9%), and the lowest was present in 'Clemson Spineless' (9.9%) (Table 3).

The effect of stage of maturity on the dry matter content of the pods was highly significant. The dry matter content of the pods varied significantly among different stages of maturity. The dry matter content of all 3 cultivars was higher in the young pods 5 days old and decreased to a minimum level in 9 days after flowering, then gradually increased (Figure 5). The lowest dry matter content occurred on the 9th day after flowering, the level varying with cultivars. There were
Figure 6. Effects of maturity on pod length and muscilage content of 3 cultivars of okra.
only slight differences among the cultivars in dry matter content at
the various stages of maturity during both years, which indicates that
the dry matter of all cultivars was comparable at any given stage of
maturity, insofar as pod quality is influenced by dry matter content
(Figure 5). These findings, however, are in full agreement with Jones,
Sistrunk and Miller (73), who reported that the dry matter percentage
of all cultivars studied was high in the young pods. The lowest dry
matter content occurred on the 8th to 10th day after flowering, then
increased gradually to a high level, varying with cultivar. They also
concluded that the edible stage of the pods was closely related to an
early decline in the dry matter content.

Highly significant differences among cultivars for muscilage
content were observed. In 1971 and 1972, the highest amount of musci-
lage was produced by 'Louisiana Green Velvet' (2.62%), followed by
'Emerald' (2.43%) and 'Clemson Spineless' which had the lowest amount
of muscilage (1.33%) (Table 3).

The effects of stage of maturity on muscilage content were
highly significant.

Highly significant interactions were found for muscilage con-
tent between cultivar and maturity and also between year and maturity.
Muscilage contents were higher in 'Emerald' and 'Clemson Spineless' on
the 5th day of maturity when the pods were younger. Then it decreased
continuously as the pods became physiologically older or more mature.
In 'Louisiana Green Velvet' the highest amount of muscilage was recorded
on the 7th day of maturity, after which it decreased continuously
(Figure 6). Shelor and Woodroof (69) reported a decided decrease in
muscilangeneous materials as the pods grew from 3 to 5 days of age,
with a small decrease thereafter, markedly affecting the flavor.

Highly significant variation for pod mucilage content between the year and maturity were noted. The amount of mucilage was significantly higher in 1972 than in 1971 except on the 9th day of maturity, where it was higher in 1971 (Figure 8).

There were highly significant differences among cultivars for pod color (O.D.). 'Emerald' had the best color (0.53 O.D.), followed by 'Louisiana Green Velvet' (0.40 O.D.) and 'Clemson Spineless' (0.38 O.D.) (Table 3).

The effects of stage of maturity on pod color were highly significant. The pod color of all cultivars did vary with stage of maturity. Average best color was recorded on the 5th day of maturity when the pods were youngest, then it gradually decreased as maturity progressed (Figure 7).

A highly significant interaction for pod color between the year and maturity was present. The color was darker in 1972 than in 1971 at all pod ages (Figure 8). Color varied significantly between the years at all stages of maturity, being darker in the younger pods (5 days old) and decreasing to a minimum level when pods were 11 days old (Figure 8).

A significant interaction between year and cultivar was present for pod color. When the average of separate years was compared 'Emerald' had the best color, with 'Louisiana Green Velvet' ranking intermediate and 'Clemson Spineless' having the poorest color. In 1955 Jones, Sistrunk, and Miller (72) reported that the 'Emerald' showed the most intense green color among the cultivars. 'Louisiana Market,' 'Louisiana Green Velvet' and 'Dwarf Velvet' were similar, being slightly
Figure 7. Effect of maturity on average pod color of 3 cultivars of okra.
Figure 8. Effects on maturity on muscilage and pod color as an average of 3 cultivars of okra (1971-72).
lighter than 'Emerald.' In 1972 all 3 cultivars had more color than in 1971 (Figure 9).

Highly significant differences among cultivars for fiber content (dry weight basis) were found. The cultivar 'Clemson Spineless' had the highest amount of fiber (12.4%), followed by 'Emerald' (10.3%) and 'Louisiana Green Velvet' (10%) (Table 3).

The effects of stage of maturity on the fiber content (dry weight basis) were highly significant. The fiber content of the pods varied at different stages of maturity. The lowest amount of fiber (dry weight basis) was present on the 5th day of maturity, and it gradually increased up to the 9th day of maturity; then there was a marked increase of fiber (dry weight basis) from the 9th to 11th day of maturity.

A highly significant interaction was found between cultivar and maturity for fiber content. On the average, in 1971 and 1972 the fiber content (dry weight basis) for 'Emerald' and 'Clemson Spineless' increased as maturity progressed, whereas 'Louisiana Green Velvet' contained the same amount of fiber (dry weight basis) on the 5th and 7th days of maturity and increased continuously thereafter with maturity of pods (Figure 10). Shelor and Woodroof (69) presented data showing that there was a definite relation between pod age and crude fiber content. A similar study was reported by Jones, Sistrunk and Miller (73). Fiber developed in pods on maturity, destroying their edibility. All cultivars studied by them became so fibrous as to be inedible by the 10th day after flowering.
Figure 9. Yearly variations in pod color of 3 cultivars of okra (1971-72).
Figure 10. Effect of maturity on fiber content of 3 cultivars of okra.
A highly significant interaction between year and maturity for fiber content (dry weight basis) was also present. In 1971, the fiber content (dry weight basis) did not increase regularly with maturity in all 3 cultivars. Fiber had increased slightly by the 9th day and markedly by the 11th day (dry weight basis). The 9-day old pods had more fiber than 5 and 7-day old pods, and 11-day old pods had by far the highest amount of fiber. In 1972, the fiber content (dry weight basis) in all 3 cultivars increased linearly as the physiological maturity of pods increased (Figure 11).

There were no significant differences among cultivars for fiber content (fresh weight basis). The highest amount of fiber on a fresh weight basis was found in 'Clemson Spineless' (1.33%), followed by 'Emerald' (1.15%), and 'Louisiana Green Velvet' (1.10%) (Table 3).

Effects of stage of maturity on the fiber content (fresh weight basis) were highly significant. A higher fiber content was found in 5-day old pods than in 7-day old and 9-day old pods. The 11-day old pods definitely had the highest amount of fiber (Figure 10).

A significant interaction between cultivar and maturity for fiber content (fresh weight basis) was found. Highly significant differences were noted among cultivars at different maturity stages for fiber content (fresh weight basis). 'Louisiana Green Velvet' and 'Emerald' decreased in their fiber content continuously from 5 to 9 days after blooming, whereas in 'Clemson Spineless' 7-day old pods had the lowest amount of fiber (fresh weight basis). Nine-day old pods had more fiber than 5-day old pods, and 5-day old pods had more fiber than 7-day old pods. Eleven-day old pods of all cultivars consistently had by far the highest amount of fiber (fresh weight basis) (Figure 10).
Figure 11. Effect of maturity on fiber content (dry weight basis) as an average of 3 cultivars of okra (1971-72).
Highly significant differences were found among the cultivars for number of thick-walled (fiber) cells in both year (1971 and 1972) (Table 3). There were highly significant differences observed at the different stages of maturity for the number of thick-walled cells. It was noted that there was a significant relationship between the number of thick-walled cells and the physiological maturity of the pods. Cultivars varied significantly in the number of thick-walled cells at each stage of maturity. The number of thick-walled cells increased continuously in pods from the 5th to the 11th day as maturity progressed (Figure 12).

During 1971 and 1972 'Clemson Spineless' had the highest number of thick-walled cells (119.0, No./quadrent of each objective's field of view), 'Emerald' was ranked intermediate (97.7), and 'Louisiana Green Velvet' had the lowest number of thick-walled cells (84.7) (Table 3) (Appendix 1, 2, 3). It was noted that differences in the number of thick-walled cells appeared to be a cultivar characteristic, since these cultivars were grown under the same environmental conditions.

Highly significant differences between the year 1971 and 1972 were observed for number of thick-walled cells. The number of thick-walled cells was higher in 1971 (105.7) than in 1972 (95.1). This might have been due to differences in environmental conditions. Stark and Mahoney (78) reported that external factors appeared to be responsible for the amount of thickening in cell walls of the inner mesocarp of two cultivars of snapbean, with cool temperatures and high rainfall having a depressing effect on increased cell wall thickness. An influence of external factors was also reported by Kaldy (39). 'Tenderlong 15' and 'Tendercrop' cultivars of green snapbeans were grown in
Figure 12. Effect of maturity on number of thick-walled cells of 3 cultivars of okra.
greenhouse under warm (25°C) conditions and lower humidity and under cool (21°C) conditions. 'Tenderlong 15' beans were significantly more fibrous when grown at the warmer than under cooler conditions, but there was no difference in the fiber content of 'Tendercrop' grown under the two conditions. The fiber content of green snapbeans appeared to be a cultivar characteristic that was greatly influenced by temperature and humidity.

A highly significant interaction between cultivars and maturity existed. The number of thick-walled cells of all 3 cultivars were minimal in the young pods (5 days old) and increased gradually with maturity. There was a rapid increase in the number of thick-walled cells in pods from 7- to 9-days old of the cultivars 'Emerald' and 'Louisiana Green Velvet', whereas in 'Clemson Spineless', a rapid increase was noted in 9- to 11-day old pods (Figure 12).
FERTILIZER STUDY

There were no significant differences among fertilizer treatment effects on pod weight, pod length, percent dry matter, color (O.D.), fiber content, or number of thick-walled (fiber) cells of the cultivar 'Emerald' in 1971 or 1972 (Tables 4 and 5). In addition, there were no significant differences in muscilage content in 1971 (Table 4). All treatments resulted in similar responses, therefore the addition of extra nitrogen or complete fertilizer did not influence pod quality. These investigations were partially in agreement with results of studies involving fertilization reported by Asif and Greig (7). They found that maximum yield was obtained from 120 lb N/A, while applying phosphorus and potassium had no favorable influence on yield. Kamalanathan et al. (40) reported similar results with phosphorus and potassium. Sambhi and Padda (66) observed that there were no significant responses to phosphorus applications. Sutton (80) and Verma et al. (89) reported similar results with potassium. Windham (93) and Chandrasekharan and George (14) added that the highest nitrogen-phosphorus-potassium levels had no beneficial influence on yield.

Highly significant differences were noted for all quality factors except fiber and the number of thick-walled cells/quadrant of each objective's field of view in all fertilizer treatments due to tagging date in 1971 (Figures 13, 14). Highly significant differences due to tagging date were noted for all quality factors other than pod color (O.D.) in 1972 (Figures 16, 17, 18, 19). Pods were tagged one
TABLE 4

EFFECTS OF FERTILIZER ON QUALITY FACTORS OF THE 'EMERALD' CULTIVAR (1971)

<table>
<thead>
<tr>
<th>Fertilizer Treatments</th>
<th>Weight (gm)</th>
<th>Length (cm)</th>
<th>Dry Matter (%)</th>
<th>Muscilage (%)</th>
<th>Color (O.D.)</th>
<th>% Fiber (Dry wt. basis)</th>
<th>% Fiber (Fresh wt. basis)</th>
<th>Thick-walled (fiber cells) (No.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Control 0-0-0</td>
<td>18.8</td>
<td>15.5</td>
<td>10.2</td>
<td>3.2</td>
<td>.33</td>
<td>8.6</td>
<td>.88</td>
<td>70.6</td>
</tr>
<tr>
<td>2. 36-0-0 + 16-0-0</td>
<td>20.0</td>
<td>16.0</td>
<td>10.2</td>
<td>2.9</td>
<td>.34</td>
<td>8.7</td>
<td>.90</td>
<td>62.2</td>
</tr>
<tr>
<td>3. 36-72-36 + 16-0-0</td>
<td>19.9</td>
<td>16.1</td>
<td>10.1</td>
<td>1.9</td>
<td>.34</td>
<td>8.4</td>
<td>.84</td>
<td>72.2</td>
</tr>
<tr>
<td>4. 48-96-48 + 16-0-0</td>
<td>20.4</td>
<td>16.1</td>
<td>10.1</td>
<td>2.7</td>
<td>.34</td>
<td>8.3</td>
<td>.84</td>
<td>66.2</td>
</tr>
</tbody>
</table>

N.S. = Non-Significant F test at the 1% level.
<table>
<thead>
<tr>
<th>Fertilizer Treatment</th>
<th>Weight (gm)</th>
<th>Length (cm)</th>
<th>Dry Matter (%)</th>
<th>Muscilage (%)</th>
<th>Color (O.D.)</th>
<th>% Fiber (Dry wt. basis)</th>
<th>% Fiber (Fresh wt. basis)</th>
<th>Thick-walled (fiber) cells (No.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Control 0-0-0</td>
<td>7.7</td>
<td>9.2</td>
<td>12.3</td>
<td>3.8</td>
<td>.85</td>
<td>8.0</td>
<td>.99</td>
<td>70.8</td>
</tr>
<tr>
<td>2. 36-0-0 + 16-0-0</td>
<td>8.0</td>
<td>9.5</td>
<td>13.3</td>
<td>3.8</td>
<td>.87</td>
<td>7.8</td>
<td>1.04</td>
<td>59.2</td>
</tr>
<tr>
<td>4. 36-72-36 + 0-0-0</td>
<td>8.4</td>
<td>9.7</td>
<td>12.0</td>
<td>3.8</td>
<td>.80</td>
<td>8.1</td>
<td>1.06</td>
<td>67.9</td>
</tr>
<tr>
<td>5. 48-96-48 + 16-0-0</td>
<td>7.8</td>
<td>9.2</td>
<td>11.8</td>
<td>3.6</td>
<td>.82</td>
<td>7.8</td>
<td>.99</td>
<td>65.8</td>
</tr>
</tbody>
</table>

N.S. = Non-Significant F test at the 1% level.
week apart, and harvested when 7-days old. It revealed that significant variation existed for these quality factors at the same stage of maturity among different tagging dates. The quality factors varied among different dates when harvested at the same physiological stage of maturity, probably because of varying environmental variations.

On the average, fertilizer applications produced heavier and longer pods in 1971 than in 1972. Culpepper and Moon (21) reported that fruit growth was more than doubled for each 18°F increased in temperature.

According to Jones' (37) data, pod yields for all 4 fertilizer treatments were higher in 1970 than in 1971. The differences in pod yield from year to year might have been due to differences in climatic conditions. In 1971, the season was a bit wet with fluctuating temperatures. Thus, higher temperatures and relatively dry conditions with moderate rainfall were more favorable for okra production in 1970 than lower temperatures and additional moisture of 1971. This observation is also supported by Jones' (34) theory that the temperature, moisture supply, light, and relative humidity had a greater influence on pod quality and growth rate than various levels of fertilizer application.

The dry matter content, muscilage content, pod color (O.D.), and fiber content (fresh weight basis) were found to be higher in 1972 than in 1971. The fiber content (dry weight basis) and number of thick-walled cells were higher in 1971, except in fertilizer treatment No. 1 (control), which produced higher numbers of thick-walled cells in 1972 (Table 5). This was probably because of cooler temperatures during the 1972 season. These results were in full agreement with
Figure 13. The pod weight, length, dry matter and muscilage content of 'Emerald' okra pods which had been tagged at weekly intervals and harvested at 7 days of age - 1971.
Figure 14. The color of 'Emerald' okra pods which had been tagged at weekly intervals and harvested at 7 days of age 1971.

Figure 15. The effects of fertilizer treatment on the number of thick-walled (fiber) cells of 'Emerald' okra pods which had been tagged at weekly intervals and harvested at 7 days of age -- 1971.
Figure 16. The pod weight and length of 'Emerald' okra pods which had been tagged at weekly intervals and harvested at 7 days of age -- 1972.
Figure 17. The dry matter and muscilage content of 'Emerald' okra pods which had been tagged at weekly intervals and harvested at 7 days of age -- 1972.
Figure 18. The fiber content of 'Emerald' okra pods which had been tagged at weekly intervals and harvested at 7 days of age, 1972.
Figure 19. The number of thick-walled (fiber) cells of 'Emerald' okra pods which had been tagged at weekly intervals and harvested at 7 days of age — 1972.
results of the maturity study of both years (1971 and 1972). Stark and Mahoney (78) reported that cool temperatures and high rainfall had an adverse effect on increased cell wall thickness of 2 cultivars of snapbean. Similar observations were also reported by Kaldy (39) with 2 cultivars of green snapbeans.

A significant interaction between fertilizer treatments and tagging date for the number of thick-walled cells was present in 1971 (Figure 15). Fertilizer treatments produced varying numbers of thick-walled (fiber) cells at different tagging dates. Fertilizer treatment No. 2 (36-0-0 + 16-0-0) produced the minimum number of thick-walled cells (52.5 No./quadrant). Treatment No. 3 (36-72-36 + 16-0-0) produced the highest number of thick-walled cells (79.8) on the 1st tagging date. On the 2 tagging date, fertilizer treatment No. 4 (48-96-48 + 16-0-0) produced the minimum number of thick-walled cells, and highest number of thick walled cells was produced by treatment No. 3, on the 3rd tagging date. The minimum number of thick-walled cells were produced by fertilizer treatment No. 3, and highest number by fertilizer treatment No. 1 (control, 0-0-0 + 0-0-0) (Table 4). This may be due to environmental factors.

A highly significant interaction for muscilage content between fertilizer treatments and tagging date was present in 1972 (Figure 20). Fertilizer treatments did not produce the same response at each tagging date. Fertilizer treatment No. 1 produced the lowest muscilage content on the 2nd tagging date. Fertilizer treatments No. 2 and No. 3 produced pods with the most muscilage on the 1st tagging date; whereas, fertilizer treatment No. 4 produced the lowest amount of muscilage on the 6th tagging date. All fertilizer treatments produced the highest
Figure 20. The effects of fertilizer treatment on the mucilage content of 'Emerald' okra pods which had been tagged at weekly intervals and harvested at 7 days of age—1972.
amount of muscilage on the 7th tagging date. Increasing nitrogen or complete fertilizer application had no influence on pod muscilage content (Table 5). This indicates that environmental factors probably played a larger role in muscilage production than fertilizer application. Janes et al. (34) came to the same conclusion, that the climatic factors associated with different locations or seasons exert a greater influence on the relative vitamin content of collards, broccoli and carrots than cultivar, soil type or fertilizer application. They also claimed that the intensity of light to which the particular plant part--fruit or leaf--is subjected influences the ascorbic acid content. High light intensity is associated with high ascorbic acid content.

POD PARTS STUDY

The average weight and length of the whole pods were 10 gm and 11 cm, respectively. Pod weight appeared to be correlated with length of the pods of the cultivar 'Emerald.' The 1st tagging produced the heaviest and longest pods; whereas, other taggings produced lighter and shorter pods (Table 6), indicating that this may be due to environmental conditions.

Statistically, there were no significant differences in dry matter content, muscilage, or fiber content among pod parts of the cultivar 'Emerald.' But there was a variation among the pod parts in muscilage content and also in fiber content, when expressed on a fresh weight basis. The butt portion of the pod had the highest muscilage and fiber (fresh weight basis) contents, and the end portion produced the lowest muscilage content, while the middle portion had the lowest fiber content (fresh weight basis).
<table>
<thead>
<tr>
<th>Pod Parts</th>
<th>Dry Matter (%)</th>
<th>Muscilage (%)</th>
<th>Color (O.D.)</th>
<th>% Fiber (Dry wt. Basis)</th>
<th>% Fiber (Fresh wt. Basis)</th>
<th>Thick-walled (Fiber) cells No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt</td>
<td>12.1 a</td>
<td>4.07 a</td>
<td>0.65 a</td>
<td>8.4 a</td>
<td>1.02 a</td>
<td>69.2 a</td>
</tr>
<tr>
<td>Middle</td>
<td>12.1 a</td>
<td>3.56 a</td>
<td>0.99 b</td>
<td>7.6 a</td>
<td>0.93 a</td>
<td>70.9 a</td>
</tr>
<tr>
<td>End (Tip)</td>
<td>11.9 a</td>
<td>3.48 a</td>
<td>1.12 b</td>
<td>8.1 a</td>
<td>0.96 a</td>
<td>87.5 b</td>
</tr>
</tbody>
</table>

Mean separation in columns by Duncan's Multiple Range Test, 1% level. Means having the same letter are not significantly different from each other.
In the pod parts, no significant differences were noted in quality factors due to tagging date when the pods were tagged on alternate days and harvested on the 7th day after tagging.

Highly significant differences were noted among the pod parts in color. On the average, the end portion of the pod had the best color (1.12 O.D.), the middle portion of the pod produced medium color (0.99 O.D.), and the butt portion of the pod had the lowest color (0.65 O.D.) (Table 6). There were no significant differences between the end and middle portion of the pods when the means were compared by Duncan's Multiple Range Test (24); however, the butt part was significantly lower in color (O.D.) than the end part or the middle part of the pods.

Highly significant differences were found among the pod parts for the number of thick-walled cells. The tip or end part of the pod had the highest number of thick-walled (fiber) cells (87.5 No./quadrant), followed by the middle part of the pod (70.9), and butt part of the pod (69.2). The number of thick-walled cells of the middle and butt parts did not vary significantly; however, the tip part was significantly higher in its number of thick-walled cells than the butt and middle parts of the pods (Table 6). High concentration of thick-walled cells resulted in harder portion. The end portion became more fibrous and harder than the butt and middle portions, due to the high concentration of thick-walled cells in the end portion of the pod.

ANATOMICAL STUDY

Highly significant differences in the number of thick-walled (fiber) cells among pod parts were observed. The tip or end part of
the pod had the highest number of thick-walled cells (73.4 No./quadrant) followed by the middle part (68.8) and butt part of the pod (60.3).

The effects of maturity on the number of thick-walled (fiber) cells of the pod parts were highly significant. The minimum number of thick-walled (fiber) cells were observed when the pods were youngest (3-day old), whereas the highest number of thick-walled (fiber) cells were observed when pods were 11-days old (Appendix 4, 5, 6, 7, 8, 9, 10, 11, 12).

A highly significant interaction in the number of thick-walled cells between pod parts and maturity was noted. Pod parts varied significantly in their number of thick-walled cells at each stage of maturity. The number of thick-walled cells increased as maturity progressed in every pod part. There was a rapid increase in the number of thick-walled (fiber) cells from 8- and 11-day old pods in the middle and tip parts, whereas in the butt part, a rapid increase occurred in 8- to 10-day old pods. On the 11th day, the number of thick-walled cells had not increased (Figure 21).
Figure 21. Effects of maturity and pod part on the number of thick-walled fiber cells of 'Emerald' okra pods.
SUMMARY

The main objective of this study was to investigate the influence of cultivar, stage of maturity and level of fertilizer on certain variables of okra pods. An anatomical study was also designed to determine the stage of fibrousness or number of thick-walled cells in different cultivars and the influence of fertilizer level, stage of maturity, and pod part on the number of thick-walled cells.

Cultivar significantly affected pod weight and length, and these findings are in agreement with Sistrunk and Jones (73). In the cultivar study, pod weight appeared to be negatively correlated with muscilage content. 'Clemson Spineless' produced the heaviest pods with the lowest muscilage content; whereas, 'Louisiana Green Velvet' produced the lightest pods with the highest muscilage content.

Average pod length, dry matter content, color (O.D.), and fiber content of all three cultivars appeared to be directly correlated with each other.

On the average the 'Emerald' cultivar produced the longest pods with the highest dry matter content, the best color, and the highest fiber content. The longer and harder pods usually had a higher fiber content.

'Louisiana Green Velvet' produced pods that were medium in length, with medium dry matter content, medium color (O.D.), and medium fiber content. "Emerald" and 'Louisiana Green Velvet' did not differ in dry matter content, muscilage, or fiber content (fresh weight basis).
'Clemson Spineless' produced the shortest pods with the lowest dry matter content, least color (O.D.), lowest muscilage, and lowest fiber content. Cultivar had no effect on pod color or fiber content (dry weight basis).

Tagging on alternate days caused significant differences in pod weight and length, dry matter and muscilage content, and pod color (O.D.). Tagging of blooms before opening should result in pods of the same physiological maturity. However, significant differences were noted, indicating that environmental factors may be playing a major role in pod development.

This environmental influence may help to account for differences reported in the literature concerning optimum maturity and harvest for best quality.

Cultivar and stage of maturity influenced the quality factors, i.e., pod length, muscilage, fiber content (dry weight and fresh weight basis) and number of thick-walled cells. These quality variables varied significantly at each stage of maturity. Pod length, fiber (dry weight basis), and number of thick-walled cells increased as maturity progressed in both year (1971 and 1972). This is in agreement with Shelor and Woodroof (69) and Jones, Sistrunk and Miller (73). In the present study, pod fiber content (fresh weight basis) decreased to a minimum level at 11 days.

Pod muscilage content of the different cultivars decreased with maturity, markedly affecting the quality of pods. This is in agreement with the findings of Woodroof and Shelor (64). The younger (5-day old) pods of the cultivar 'Emerald' and 'Clemson Spineless' produced the highest amount of muscilage, while the older (11-day old) pods produced
the lowest amount of muscilage in both years and in both cultivars. 'Louisiana Green Velvet' contained the highest amount of muscilage on the 7th day of maturity in both years.

Differences between years, at each stage of maturity were rated in muscilage content, pod color (O.D.), and fiber content (dry weight basis). Differences between years and cultivars in pod color (O.D.) were probably caused by different environmental conditions.

The cultivars showed significant differences in quality factors, i.e., pod weight, length, dry matter content, muscilage content, color (O.D.), fiber content (dry weight basis) and number of thick-walled cells in both years (1971 and 1972). Cultivar did not influence the fiber content (fresh weight basis). These findings are in partial agreement with the cultivar study, pod color (O.D.) and fiber content (dry weight basis) were not affected by cultivar, in contrast with the study of cultivar and maturity.

'Clemson Spineless' produced the heaviest and shortest pods. It had the lowest dry matter content, muscilage content, and least color (O.D.). This is in agreement with the cultivar study. 'Clemson Spineless' produced pods with the highest fiber content (dry weight and fresh weight basis). These results are in contrast with the cultivar study. This cultivar also produced the highest number of thick-walled (fiber) cells.

'Emerald' had the longest but intermediate weight pods of the 3 cultivars studied. This cultivar had the highest amount of dry matter and best pod color among 3 cultivars. It ranked intermediate for muscilage content. These findings are in full agreement with the cultivar study. 'Emerald' also contained an intermediate amount of
fiber (dry weight and fresh weight basis). The number of thick-walled cells was not significantly different between the cultivar 'Clemson Spineless' and 'Emerald.'

'Louisiana Green Velvet' had the lightest pods, with intermediate length. It had a medium amount of dry matter and highest muscilage content, pod color (O.D.), which was in full agreement with the cultivar study. It also had the lowest fiber content (dry weight and fresh weight basis) and number of thick-walled cells.

Thus, maturity significantly affected all quality factors of the 3 cultivars studied. There was a significant relationship between quality factor of the cultivars and stage of maturity.

None of the fertilizer treatments had any influence on the quality factors of the 'Emerald' cultivar during 1971 or 1972. These results are in agreement with other reported data (7, 14, 34, 37, 66, 89, 93). So, it was concluded that addition of extra nitrogen or complete fertilizer had no beneficial effect on quality of pods.

Tagging date influenced all of the quality factors significantly except fiber (dry weight and fresh weight basis) and the number of thick-walled cells during 1971 and pod color (O.D.) in 1972. Tagging date was associated with variations in quality factors in pods harvested at different dates at the same stage of maturity. Differences in quality factors may be due to different environmental conditions preceding the time of harvest (during the pod growth period), which is in agreement with reports of many researchers (21, 34, 37).

In 1971, different fertilizer treatments and tagging dates produced pods with varying numbers of thick-walled cells. In 1972, fertilizer treatments and tagging dates produced pods with different
muscilage contents. These investigations suggested that addition of nitrogen or complete fertilizers (nitrogen, phosphorus, and potassium) did not affect the quality of pods. Differences in the number of thick-walled cells and pod muscilage were due to different weather conditions (7, 14, 66).

Fertilizer treatment No. 4 (48-96-48 + 16-0-0) influenced pod color (O.D.) and number of thick-walled cells significantly of all pod parts of cultivar 'Emerald.' The end or tip portion of the pod produced the best color and the highest number of thick-walled (fiber) cells. This resulted in harder end portions than butt or middle portions. The butt and middle portions did not differ significantly from each other in the number of thick-walled cells and hardness. The color (O.D.) of the middle and end portions did not differ from each other, however, the butt part was rated poor in color (O.D.).

Neither pod part nor tagging date caused any difference in dry matter, muscilage, or fiber content (dry weight and fresh weight basis).

Pod parts of cultivar 'Emerald' treated with fertilizer treatment No. 3 (36-72-36 + 0-0-0) varied in the number of thick-walled (fiber) cells. The end or tip portion produced the highest number of thick-walled cells, followed by the middle and butt portions. These investigations are in full agreement with the pod part study done with fertilizer treatment No. 4 (48-96-48+16-0-0). Pod part and stage of maturity (from 3 to 11 days, daily) affected the number of thick-walled cells. Younger (immature, 3rd day) pods produced a minimum, and older (mature, 11th day) pods produced the highest number of thick-walled cells. The end portion of the pod was the oldest portion which became fibrous earlier than the butt and middle portions with maturity. This
suggests that the number of thick-walled cells and hardness of every pod part increased with maturity; therefore, pods should be harvested when they are tender and have the best quality.
BIBLIOGRAPHY


Appendix 1. Thick-walled (fiber) cells of the cultivar 'Clemson Spineless' on the 11th day of maturity.
Appendix 2. Thick-walled (fiber) cells of the cultivar 'Emerald' on the 11th day of maturity.
Appendix 3. Thick-walled (fiber) cells of the cultivar 'Louisiana Green Velvet' on the 11th day of maturity.
Appendix 4. Thick-walled (fiber) cells in butt part of 3 days old okra of the cultivar 'Emerald'.
Appendix 5. Thick-walled (fiber) cells in middle part of 3 days old okra of the cultivar 'Emerald'.
Appendix 6. Thick-walled (fiber) cells in end (tip) part of 3 days old okra of the cultivar 'Emerald'. 
Appendix 7. Thick-walled (fiber) cells in butt part of 7 days old okra of the cultivar 'Emerald'.
Appendix 8. Thick-walled (fiber) cells in middle part of 7 days old okra of the cultivar 'Emerald'.
Appendix 9. Thick-walled (fiber) cells in end (tip) part of 7 days old okra of the cultivar 'Emerald'.
Appendix 10. Thick walled (fiber) cells in butt part of 11 days old okra of the cultivar 'Emerald'.
Appendix 11. Thick-walled (fiber) cells in middle part of 11 days old okra of the cultivar 'Emerald'.
Appendix 12. Thick-walled (fiber) cells in end (tip) part of 11 days old okra of the cultivar 'Emerald'. 
VITA

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EXAMINATION AND THESIS REPORT

Candidate: Ramesh S. Kakar

Major Field: Horticulture

Title of Thesis: Influence of Cultivar, Pod Maturity and Fertilization on Quality of Okra (Abelmoschus esculentus (L.) Moench).

Approved:

[Signatures]

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