FIELD EVALUATIONS OF CULTURAL PRACTICES IN SPICE PEPPERS (*CAPSICUM ANNUUM* L.)

BY

GREGORY LEE SCHOEN

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1980

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment for the requirements
for the Degree of
MASTER OF SCIENCE
May, 1982

FIELD EVALUATIONS OF CULTURAL

PRACTICES IN SPICE PEPPERS

(*CAPSICUM ANNUUM* L.)

Thesis Approved:

James E. Motes
Thesis Adviser

[signature]

Michael Smith

Lavoy I. Croy

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

The author wishes to express sincere gratitude to Dr. James E. Motes for his guidance and patience throughout the course of this study. Appreciation is also extended to the other members of my graduate committee, Dr. L. I. Croy, Dr. M. Smith, and Dr. H. G. Vest for their advisement and assistance in concluding this study, and also to Patty Kennedy for preparing the manuscript.

Special appreciation is expressed to the staff of the Oklahoma Agricultural Experiment Station for technical assistance, and to the Horticulture Department for housing and financial support.

Deepest gratitude is expressed to my mother, Marie Schoen, and my father, Lee Schoen, for their encouragement, support, and understanding throughout my college career, and to my friend and teacher, Audle Allison, whose advice and example during the past seven years have led me toward realizing the true meaning of education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

When a crop is being introduced into a new area, modifications of standard cultural practices may be necessary to adapt to the climate, soil, topography, and farming practices of that area. In addition, cultural methods that are new in themselves and still in the experimental stages can be evaluated in the location of the introduction.

Spice Peppers as a Crop

Two pepper (Capsicum annuum L.) crops adaptable to Oklahoma growing conditions were studied: 1) a type of paprika selected for its high concentration of lycopene and carotene pigments, which are extracted, primarily as oleoresins and used as commercial food coloring agents, and 2) the KSB chili, an introduction with a high concentration of capsaicin compounds which can also be extracted and used in processing where the hot chili flavoring is desired (12, 31).

Paprika is cultivated primarily in the Mediterranean region and in Mexico. Various types of hot chilies are grown in Africa, India, China, Southern Europe and Mexico. Imports from these areas of production have supplied most of the spice peppers used in the United States. However, recent changes in the world spice markets have encouraged the prospects of domestic production, and spice companies are beginning to fund research and contract growers for these crops in the South and Southwest.

Need for Cultural Studies

Studies in spice peppers have been carried out by the Oklahoma Agricultural Experiment Station since 1979, concentrating primarily on the screening of various paprika and chili selections, evaluating for yield, pigment content, pungency ratings and plant growth patterns (11). As the more promising types have emerged from these screenings, there has arisen a need to determine the cultural methods most applicable to this area, to inform prospective growers as to the practices to be recommended. Field studies in row width and in-row densities, and in various stand establishment practices have been designed and carried out to achieve part of this goal.

Background of Studies

Row Width and Plant Spacing

When nutrients and moisture are in adequate supply, the light interception by the crop canopy is of primary importance to the productivity within the stand. Changes in the planting pattern could allow a more complete utilization of the incoming sunlight, and could result in improved yields (27).

The planting arrangement has often been dictated by the planting, cultivation, and harvesting equipment used in the area. Such restrictions have limited the row widths in most cases to the 90-100 cm range. In spice peppers, as in other crops, the use of herbicides and more versatile harvest machinery has allowed closer row widths.

The row width and plant spacing studies in both pepper crops were designed to compare among different row widths and among in-row plant spacings, and their combinations, to find the particular regime(s) giving optimum production.

Stand Establishment Studies

Stand establishment involves bringing the planting from seeding or transplanting to the point at which it is no longer vulnerable to seed and seedling diseases or pests, and is better able to tolerate environmental stresses. The best method is one that is most likely to be initially successful and most profitable in terms of both costs and final yield.

Direct seeding with many crops is often an uncertain method of achieving a stand. Poor environmental conditions during or after the time of seeding, soil crusting, pests, and diseases can all drastically reduce the percent emergence. Overseeding to insure an adequate stand often requires thinning, a labor-intensive operation.

Sowing of germinated seed can be an alternative method for many crops, including the spice peppers. Seed germinated under controlled conditions, in amounts sufficient for large plantings can be suspended in a viscous gel material and sown with appropriately designed planters, a technique known as fluid drilling (6, 44). The advantages of this method over dry seeding are as follows:

1. Faster and more uniform emergence. Some seed takes 14-21 days or longer to germinate and emerge by the dry seeded method.

2. Germinated seed can be planted earlier, at lower soil temperatures that might inhibit germination of dry seed but not inhibit growth and emergence of seedlings from germinated seed.

3. Quick and uniform emergence means less time spent in the seed-

bed, thus avoiding some of the succeptibility to seed pathogens and pests, erosion and crusting, and the debilitating effects of moisture and temperature stresses.

4. Less seed is needed for planting, an advantage where seed costs are high.

5. Various materials can be added to the gel such as fungicides or insecticides to give localized protection. Fertilizer can be added to the gel as starter nutrients.

Variations on the germinated seed method include:

1. Treatment of germinating seed with gibberellic acid (GA_3) to improve uniformity in germination (42).

2. "Dry storage" in which seed in the early stages of radicle emergence (< 1 mm) is air dried and stored for later planting (41).

3. "Hardening" in which seed is stimulated, though not germinated, by leaching or treatments with gibberellic acid, followed by air drying (4,7).

Transplanting is the third principal means of establishing the stand. It consists of growing plants in individual containers, flats or open beds, then lifting them out and replanting them in the field. Its major advantage is earliness, and is practiced for many vegetable crops where the season is short, or where more than one crop is to be planted during the season. Transplants are grown either in greenhouses or in field beds, and where produced commercially on a large scale, with automation, their costs can often be competitive with the seeding methods. Transplanting also allows uniformity of plant size and spacing. Disadvantages of transplanting compared to seeding include:

1. high cost of plants, especially for higher planting densities.

2. initial labor cost for planting,

3. possibility of introducing diseases or pests, and

4. limited choice of cultivar.

Studies in stand establishment practices were designed to explore and evaluate the various techniques in spice peppers. These are listed as follows:

1. A comparison, among transplant types, between dry and germinated seed plantings, and between these two main methods in KSB chilies.

2. A seeding study with paprika dry seed, germinated seed, and various treatments of germinated seed.

3. A fluid drilling study with germinated paprika seed, involving a test of three synthetic planting gel preparations.

4. A fluid drilling study with paprika using various additives and combinations of additives to the planting gel.

All studies were carried out in 1980 and 1981 at the OSU Vegetable Research Station in Bixby, Oklahoma.

CHAPTER II

LITERATURE REVIEW

Row Width and Plant Spacing Studies

With the introduction of improved mechanization and through the use of herbicides, the standard wide row spacings used for crops such as corn, soybeans, and cotton are no longer necessary. Narrowing the row spacing has been suggested to increase seed yields in these three crops (13, 23, 30, 50). Increasing plant density within the rows at a given row width did not significantly affect yields in cotton but has had differing effects for soybeans (13, 23). It is generally observed that the plant canopy within limits will fill the space it is given to occupy (35, 50). It has been thought that the shape of that space may have some bearing on the productivity of the crop canopy as a whole.

Studies in plant arrangement patterns have been carried out with corn and soybeans to determine the advantage of equidistant (square or hexagonal) planting patterns over wide rows and close plant spacings at corresponding plant populations (2, 15, 35, 46). Some researchers indicate that the increases in yield may be due mostly to soil and moisture conditions and not due to any specific superior arrangement of plants (2, 35). A rather convincing study, however, involving dry beans in New York State, showed equidistant spacings consistently yielding 12 and 13 percent higher than more rectangular spacings at equal populations, indicating the planting pattern to be a specific factor for improved production (22).

Work by Shibles and Weber (34, 35), in soybeans has elucidated the basic principles of light interception and utilization and its relationship to productivity that may be applied to other crop species of similar architecture:

1. Both dry matter production and light interception vary in direct proportion to one another.

2. Percent solar radiation interception and dry matter production increase with increasing leaf area index, reach a maximum, then remain constant with further leaf area increase.

3. Dry matter production is a function of percent solar radiation interception over the life of the crop. Higher yielding planting arrangements are those that reach the 95 percent interception by the canopy at an earlier time. Although this includes equidistant planting patterns, Shibles (35) finds no evidence of planting patterns in themselves contributing to higher yield in these patterns. Narrow rows, and higher densities within rows also reach full (95 percent) canopy at an earlier time.

4. Dry matter produced during seed (fruit) formation is relevant to variations in seed (fruit) yield. If all spacings are at 95 percent interception at the onset of fruit development, differences in seed yield should be insignificant. Lower yields in wide row treatments may be the effect of a less than 95 percent interception during the early stages of fruiting (23, 35).

The above statements hold true if the crop in question does not exhibit a "critical" or "optimum" leaf area index (the ratio of canopy surface area to ground surface area) above which the lower leaves carry on respiration at a higher rate than photosynthesis, bringing down total net production of carbohydrate (25).

Harvest index, the ratio of seed or fruit yield to total dry weight may be lower in conditions of high population through close spacings in any direction (35). Here, the vegetative period encroaches upon the fruiting or reproductive period more than usual, with competition for available photosynthate. This condition may also lead to a lowering of actual seed yield, as suggested by Holliday (17) where seed yield increases to a point with higher population, then decreases with further increases in density. "Biologic yield", or dry matter production, increases to a point, at approximately the population which produced the optimum seed yield, then levels off to a constant thereafter. Determinate fruiting selections of a crop, as are the KSB chilies used in this study, may help shorten the period of vegetative production in higher densities.

The yield components, plants per area and yield per plant, generally vary in an inverse manner. It is hoped that the latter will decrease in a lower proportion than the population increase, to give an increase in area yield.

Branching decreases as spacing in either direction decreases (23). If the role of branches is relatively less important than main stems in fruiting, then the yield per plant component will hold up better under population increase. In soybeans, this balance may go either way depending on the variety and actual spacing, while in cotton production, closer spacing is proposed as a method to bring about maturity by increasing the potential number of early fruiting points (10, 23). Less branching can also assist in the efficiency of mechanical harvest.

Other Factors Influencing Spacing Effects

Factors other than light can be involved in population and spacing effects on production. In pimiento peppers, a crop similar to the paprika grown in this study, plant lodging was found to be higher in wide row plantings (1). Narrow rows and closer spacings in rows can create mutual support among the plants.

High night temperatures lead to flower drop in chili peppers possibly as a result of limited supply of carbohydrate to the reproductive growing points under conditions of elevated respiration (9). High planting densities allowing a full canopy and higher leaf area, may, through increased transpiration and shading reduce day temperatures enought to allow sufficient cooling at night. Increased density may, on the other hand, contribute to flower abortion by excessive shading, as has been found in soybeans (46).

Higher relative humidity may positively affect fruit set in chilies and seed set in sweet peppers (5). While this factor seems to indicate further support for modification of planting toward higher density in the spice pepper crops of this study, the higher incidence of disease, Bacterial leaf blight (*Xanthomonas vesicatoria*), observed in this species under conditions of high moisture, may warrant further considerations of spacing with respect to local climate.

Stand Establishment Studies

Direct Seeding

If successful, direct seeding can be the least expensive means of establishing vegetable crops. In Ohio, direct seeding of processing tomatoes, has increased interest due to the practice of once-over mechanical harvesting (36). The high plant populations desired for mechanical harvesting are far too costly to establish by transplanting. Precision seeding techniques to improve stand uniformity in various seeded vegetable crops have been studied (41).

The problem of soil crusting and low soil temperatures often reduce germination and emergence. Arndt (3) has described the soil crusting process as a result of disruption and rearrangement of surface structural units of the soil by rainfall or irrigation. The bonding and repacking results in a hard surface layer after drying that not only creates problems for seedling penetration (especially in seed with epigeal germination) but also interferes with gas and heat exchange as well. The use of anticrustant materials, such as vermiculite, perlite, sawdust, and various asphalt preparations with the seed has been shown to aid emergence of tomato seedlings in clay soils (36, 38). Low soil temperatures, which in may areas forces the use of transplants to obtain sufficient earliness, can be partially overcome by dark coloration of the asphalt preparations (38).

Seedling injury and death due to abrasion from wind-blown sand particles near the soil surface has been prevented by the use of interplanted windbreak material such as oats (37). This technique could also help protect seedlings from sheet erosion during heavy rains.

Alternative Seeding Methods

The seed of most crop plants, including vegetables, will not emerge as well in the field as in the laboratory or greenhouse, due in part to the unfavorable soil conditions mentioned earlier, and in part to soil pathogens. Setting transplants, or sowing seed at high rates and then thinning are often impractical and uneconomical.

Alternative methods to both dry seeding and transplanting have been investigated. Austin et al. (4) described a process of "hardening" seed which can promote earlier field emergence. Carrot seed was soaked for 24 hours in water at 20°C, then air dried. Three such cycles produced increases in embryo length due to both cell division and cell expansion. "Hardened" seed imbibed water more quickly in the field and emerged 3-4 days earlier than untreated seed.

Additional hardening studies with carrots showed that seedlings were significantly greater in fresh weight and earlier in field emergence than with dry seeded carrots. Greater uniformity of emergence was also observed (7). Similar studies in wheat and barley seed did not exhibit the same beneficial results (32).

Seed can be allowed to imbibe water and begin the early stages of germination in the "hardening" process, or they can actually be germinated to the point of radicle emergence. Planting equipment has been designed for the sowing of such germinated seed, in which the seed is suspended in a gelatinous material and extruded into the furrow, in such a way as not to injure the radicles (6, 44, 48). This technique is referred to as fluid drilling. In work with fluid drilling of carrot, lettuce and celery seed, Currah et al. (7) found significantly earlier and higher percentages of emergence for the germinated fluid drilled seed. An evaluation was also made by Taylor (47) of the emergence performance of various germinated vegetable seed. Sowing germinated seed of all kinds resulted in less time for 50 percent emergence than high moisture (imbibed) or dry seed. In asparagus and tomato, actual emergence percentages were significantly greater.

The gelatin mixture used by Currah et al. (6) was prepared with sodium alginate and calcium citrate in water. Since then, other gel preparations have been developed and evaluated (43). Petroleum derived and mineral based types have been successful. Absence of phytotoxicity, and the ability to maintain viscosity even in the presence of salts (as fertilizer additives to the mixture) are essential qualities of a good fluid drilling gel.

Germination of seed in aerated water columns is quite practical for use in fluid drilling field studies. Use of this method has been shown to produce uniform germination in even difficult species such as celery (8). By continuous replacement of water, or by manual changing at intervals, possible germination inhibitors leached from the seed can be removed. Use of the aerated water technique has been found to reduce the time required for actual germination of the slow-to-germinate vegetable seed to a fraction of the time required for dry seed in the field (47).

The addition of gibberellic acid (as GA_3) to the water has accelerated germination and improved uniformity of emergence in pepper seed (42). Such uniformity is essential so that a large percentage of the radicles are emerged, yet not too long to become broken in the planting process. Other growth regulators have been tested in vegetable seed. Lettuce seed with high temperature dormancy has been induced to sprout by a mixture of kinetin and ethephon (33).

Transplanting

Where earliness is critical and stand uniformity is desired, or where seeding methods are unreliable, the transplant method of establishment may be necessary.

Transplants are produced in greenhouses or cold frames, or are field seeded (49). Those grown in greenhouses in flats or plant bands that restrict root spread retain more of their root systems when transplanted than do field grown bare-root transplants and as a result suffer less shock when set in the field (28). With field or bed-grown plants, damage to or loss of that part of the root system most active in water and nutrient absorption means considerable transpiration stress that only the hardiest of transplant types can survive. Those plants that are more capable of replacing root structures in a shorter time are among the hardier types used for transplanting, and will resume growth more quickly after field setting (29). The cabbage group (Brassica spp.) and tomatoes are among the most tolerant to transplanting, whereas sweet corn and cucurbits require considerable care if they are to survive transplanting (26).

Greenhouse grown transplants that have been "spotted over" to other containers most often have had their primary root broken, which stimulates production of secondary roots. Production using open-bottomed "cells" or containers fosters air root-pruning that also breaks taproot dominance. Such plants have a high number of active root tips, that are efficient in water uptake and quick to resume growth in the field (28).

The term "hardening" in the transplant trade is applied to any treatments that render the plant more adaptable to chilling or freezing temperatures, moisture stress, or mechanical injuries from wind and abrasion. Hardening can be accomplished by any treatment that checks plant growth, and can be accomplished in 7 to 10 days (28). Over-hardened plants exhibit delayed growth after transplanting. Physiological changes that accompany the tissue changes characteristic to hardening have been described by Levitt (24). Conversion of carbohydrates to soluble forms, changes in proteins and phospholipids, and increased stomatal resistance all act to control cell dehydration caused from cold or dry conditions.

Clipping or topping of transplants is practiced to improve plant size uniformity and to reduce foliage as in overgrown plants (19, 20). This reduces excessive transpiration and can increase plant survival in shipping and in the field. Clipped plants have been found to withstand longer periods of field-holding when unfavorable weather delays planting (20).

The practice of using growth regulators as an alternative to clipping has been used in southern Georgia. Ethephon has been used to reduce stem length and early flowering and fruit set in tomato transplants, as well as to improve plant size uniformity (18). SADH has been found to concentrate fruit ripening, improving harvest quality in processing tomatoes (21).

Starter fertilizer solutions are commonly applied with field setting to aid in root and shoot growth and to overcome the effect of cold soils slowing phosphorus uptake in early season plantings (28).

Modernization of growing systems for transplant production, and improved mechanization for field setting have greatly helped to reduce the costs of materials and labor and will most likely continue to make transplanting a more economically feasible practice (28).

CHAPTER III

MATERIALS AND METHODS

Row Width and Plant Spacing Studies

Two kinds of spice peppers (Capsicum annuum L.) were used in this experiment. A hot chili introduction obtained from Kalsec, Inc. Kalamazoo, Michigan, was tested in 1980, and two separate selections of the introduction, 'KSB 6' and 'KSB 16', were used in 1981. Paprika selection 'KS-1', also from Kalsec, was used in 1980 and 1981.

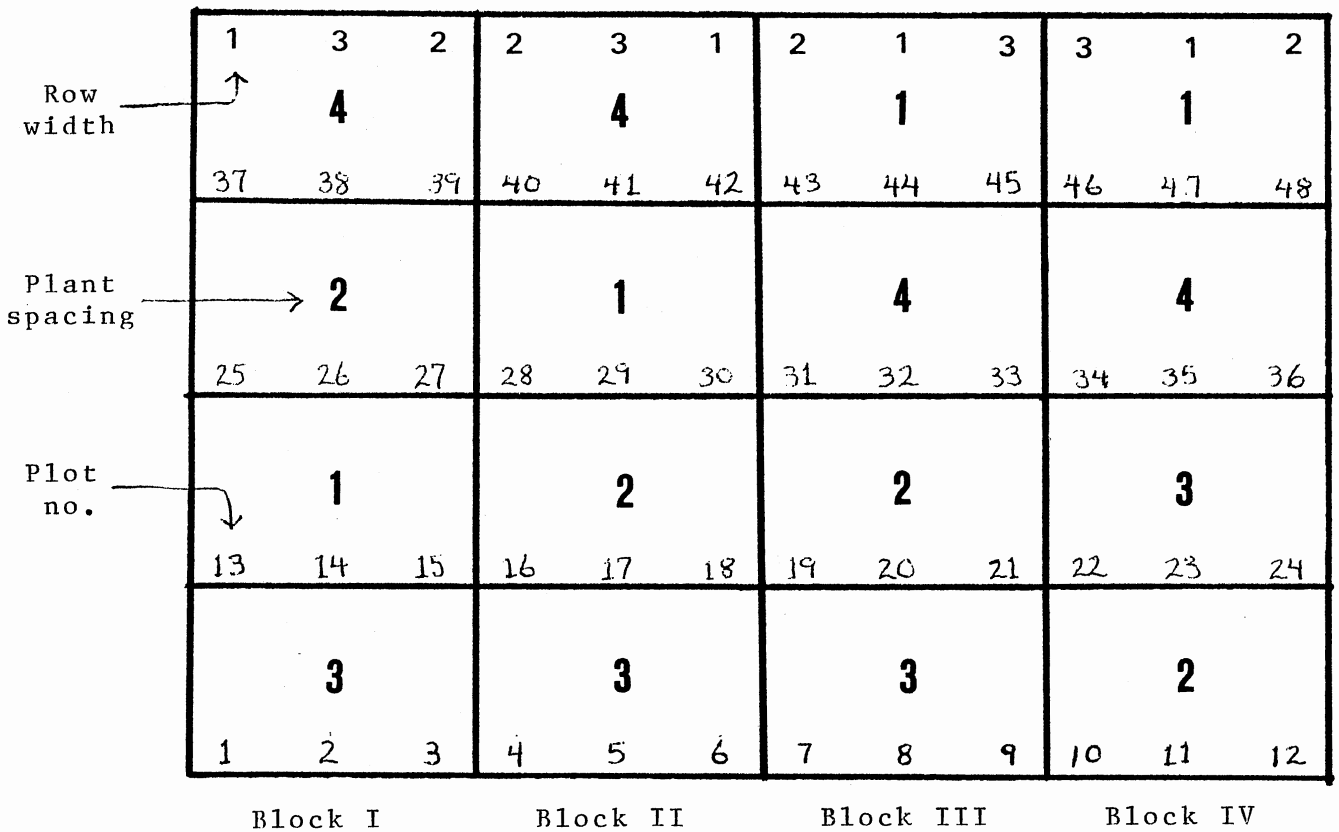
Field plots were laid out in a split-plot design, with between row spacing of 45 cm, 67.5 cm, and 90 cm as main plots. Main plots were quartered into 4.5 m sub-plots for plant spacing treatments (Fig. 1). Each plot consisted of a central treatment row bordered on each side by a guard row to create the desired row width effect. Rows were oriented north-south in 1980, and east-west in 1981.

Levels of major nutrients had been previously assessed by test. Fertilizer (12-12-12) at 450 kg/ha was applied broadcast, preplant, in 1980 and 1981. Napropamide (Devrinol) was applied preplant as a pre-emergence herbicide at 2.5 kg/ha.

Seeding was done with a Planet Jr. one-row planter, at a depth of 1-1.5 cm, with 30 seed/m for the chilies and 60 seed/m for the paprika.

In-row plant spacings were accomplished by hand thinning, beginning approximately three weeks after emergence. Spacings for the chilies

Fig. 1 Plot layout for row width and plant spacing studies.



Row width
Plant spacing
Plot no.
Block I
Block II
Block III
Block IV

were set at 20, 30, 40 and 50 cm between plants in 1980 and at 10, 20, and 30 cm in 1981. Paprika spacings were 3, 3.75, 5, and 7.5 cm between plants in 1980 and 3.75, 5, and 7.5 cm in 1981. Guard rows were thinned to correspond to their particular treatment row, to give the final arrangements for the studies.

At the onset of fruit development, NH_4NO_3 was topdressed at 40 kg/ha. Recommended pesticides were applied as needed for insect and disease control.

Plots were hand harvested in December of 1980 and 1981, after complete defoliation and pod drying had occurred. Chili plants were measured for height and width immediately before harvest. Plots 3.5 m long were harvested by cutting plants at ground level in 1980, and at 10 cm height in 1981. Plant material was evaluated to determine total dry weight, pod yield, percent weight pods in total top dry weight, and percent red pods. Pods separated from stem material contained about 10 per cent remaining trash by weight, including attached pedicels. Paprika studies were harvested as pods only, from 3 m of row in 1980 and 3.5 m of row per plot in 1981. Measurements were recorded for total pod yield, percent red pods, and red pod yield.

Data were analyzed by Trend Analysis for Factorial Treatment Combinations and by Analysis of Variance procedures (45). Comparisons of treatments at equal populations were analyzed by Duncan's Multiple Range Test (DMRT). All percentage values were adjusted by means of the Arcsine Transformation to bring them under the normal distribution tables, however, list results as true percent values (14).

Stand Establishment Studies

General Methods for Stand Establishment Studies

KSB chili selections and 'KS-1' paprika (Capsicum annuum L.) obtained through the Oklahoma Agricultural Experiment Station and Kalsec, Inc., were used in these studies in 1980 and 1981. Field preparations, additional fertilizer application, and pest and disease control procedures were carried out as in the spacing studies. Plots were laid out in a randomized complete block design with four replications, at 90 cm row widths and 10 m plot lengths. Studies were bordered with guard rows consisting of the respective control treatment. All treatments involving fluid drilling of germinated seed were prepared as follows:

1. Ten g seed was placed in 400 ml cylindrical glass columns, in a water bath (Fig. 2) filled with 350 ml distilled water.

2. Aeration by means of forced air through an aquarium air stone at the base of the column was maintained for a period 72-108 hours (depending on specific requirements) at a temperature of 27°C.

3. Water was changed periodically to avoid possible buildup of inhibitory compounds (40).

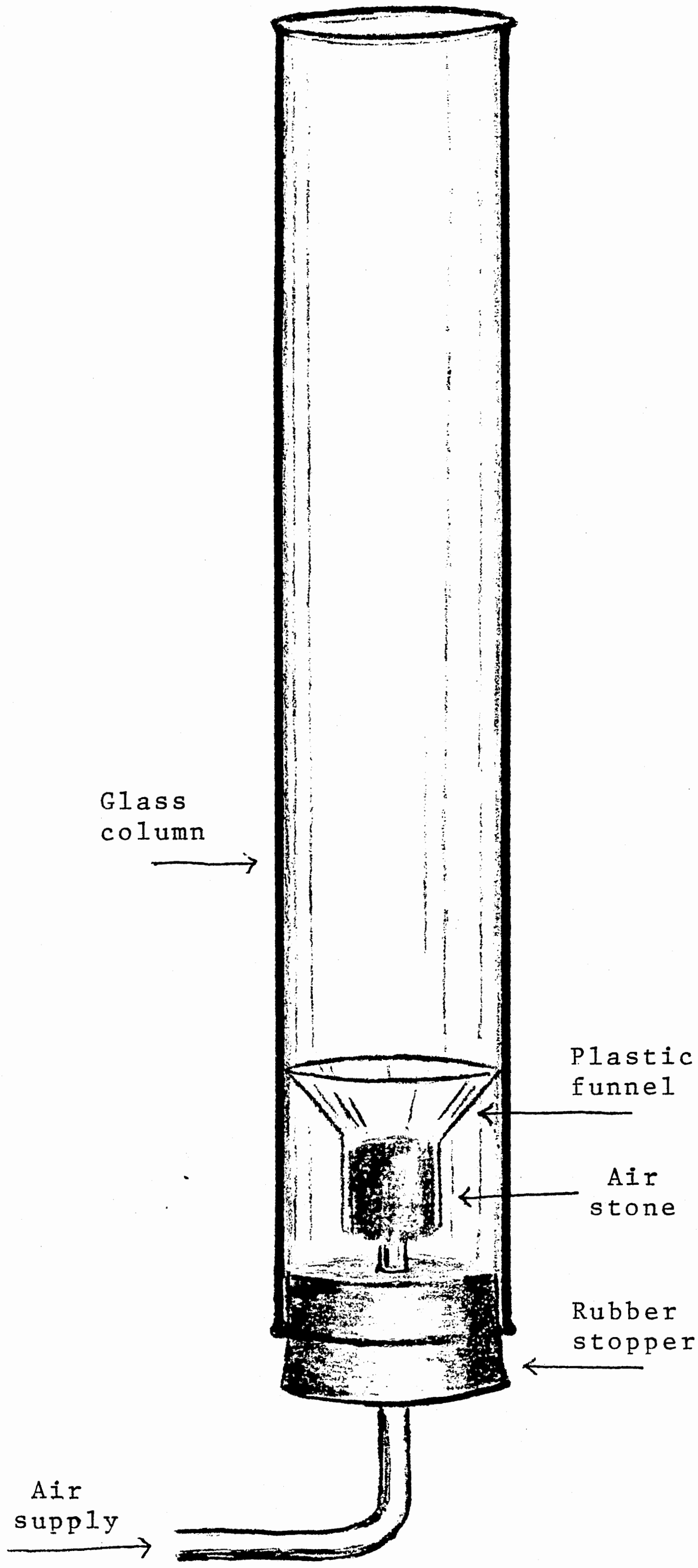
4. Seed was germinated to a radicle length approximately equal to seed diameter (2.5 mm for chilies, 3.0 mm for paprika).

5. Seed was suspended in 15.0 g per liter distilled water of Laponite (synthetic gel-forming powder from Laporte Industries, Ltd., Hackensack, New Jersey). Other gels were used, also, in the Gel Type Studies.

6. Seed-gel mix was sown into the planting furrow by extrusion from a caulking gun with 30 ml per m of row and a seed rate of 30 seed/m for the chilies, and 60 seed/m for the paprika studies. Seeding depth was 1-1.5 cm.

Dry seed was treated with thiram (Arasan) and treatments were sown at the rates and depth of the fluid drilling treatments.

Fig. 2 Aeration column apparatus for seed germination.


Glass
column
Plastic
funnel
Air
stone
Rubber
stopper
Air
supply

All seeded treatments in these studies were hand-thinned after seedling establishment, to a spacing of 5-10 cm between plants in the paprika studies and to 30 cm between plants in the chili studies.

KSB Chili Planting Method Studies

A field-run KSB chili introduction was used in 1980; selection 'KSB 8' was used in 1981.

Three treatments consisted of 5-week old transplants. They were:

1. Local greenhouse-grown plants with 5 x 5 cm spacing in flats, using Cornell mix planting medium at an 8 cm depth, with weekly fertilization with soluble 20-20-20 at a 4 g/l rate.

2. Speedling 100A transplants, commercially grown by Speedling, Inc., Sun City, Florida, using inverted pyramidal cells at a plant spacing of 2.5 x 2.5 cm, in a Cornell mix medium.

3. Speedling 080 transplants, at a 2.0 x 2.0 cm spacing. Plants were set in plots at a 30 cm spacing.

The remaining two treatments consisted of: 1) dry seed; and 2) germinated seed, both prepared and sown as described above. Seeded treatments were planted the same day as transplant treatments. (Note: 1980 fluid drilling treatment was done in "plugs" of 5-7 seed each at 30 cm spacings.

At setting, transplants were watered in with 300 ml of starter solution consisting of soluble 20-20-20 at 7.5 g/l and diazinon at 1.0 g/l. Seeded treatments were given a comparable amount of starter solution at each planting site or 30 cm of row length.

Paprika Seeding Studies

In 1980, 'KS-1' paprika seed was sown with the following treatments:

1. Dry seed.

2. Germinated seed.

3. Seed imbibed for 24 hours in distilled water, followed by the addition of GA_3 in the aerated germination solution (as Pro-Gibb, product of Abbott Laboratories) at 400 ppm, and germination for an additional 24 hours. Seed was then aerated in distilled water alone for the remaining time to adequate germination.

4. Seed germinated to the point of first radicle emergence (< 1 mm), then air-dried for 24 hours before planting ("dry storage" technique) (41).

5. GA_3-treated and air-dried germinated seed.

Treatments 2 through 5 were suspended in Laponite gel and sown. Treatments for this study in 1981 differed by replacing the 400 ppm GA_3 treatment with two GA_3 treatments (200 ppm and 800 ppm) and the omission of the GA_3-treated dry storage treatment.

Gel Type Studies - Paprika

KS-1 paprika seed germinated as above was added to the following gel preparations, and sown:

1. Laponite, 15.0 g/1, as a control.

2. Viterra 2 (Schering, Inc., Minneapolis, Minnesota) at 4.0 g/1.

3. Natrosol 250 H (Hercules, Inc., Wilmington, Delaware) at 15.0 g/1.

Seed was sown and plants thinned as in the previous study.

Gel Additive Studies - Paprika

Germinated 'KS-1' paprika seed was sown in 15.0 g/1 Laponite with the following additive treatments in 1980 and 1981:

1. Gel only - control.

2. Fertilizer - 1.0 g/1 soluble 20-20-20.

3. Fungicide - 100 ppm a.i. terbumiton (Captan).

4. Insecticide - 100 ppm a.i. diazinon.
5. Fertilizer and fungicide.
6. Fertilizer and insecticide.
7. Fungicide and insecticide.
8. Fertilizer, fungicide and insecticide.

General Harvest and Evaluation Procedures

Plots were hand harvested after frost and complete defoliation and pod drying had occurred. In the Chili Planting Method Study, measurements for plant height and plant width were taken, after which two observations of 10 plants each were taken from each plot. Plants were removed by cutting at ground level and bagged. Plants were later evaluated for top dry weight, pod yield, percent weight pods, and percent red pods.

In 1980, only red pods were harvested from 6.5 m plots in the paprika studies and evaluated for yield only. In 1981, all pods were harvested from 4 m plots and evaluated for yield, percent red pods and red pod yield.

Data were analyzed by Analysis of Variance procedures and mean separation by DMRT. Percentage values were adjusted as in the spacing studies. (Tables list results as true percentage values).

CHAPTER IV

RESULTS AND DISCUSSION

Plant Spacing and Row Width Studies

KSB Chili Studies

Differences in yield and top dry weight across row widths were not significant for the 1980 chilies (Table 1). Severe heat stress during the summer of 1980 may have masked the treatment effects. Wider in-row plant spacings in 1980 may have set the populations into a range low enough to mask the advantages gained by the narrow row widths. A quadratic response for the plant spacings in top dry weight in 1980 was reflected by nearly constant values for the three closest spacings followed by a reduction at the 50 cm spacing where canopy filling was not complete. The effect of the plant spacings in these chilies for pod yield was not significant. The north-south row orientation of the 1980 study may also have been a factor preventing greater treatment effects, through less efficient capture of sunlight, a possibility described by Stoskopf (46). The 1981 orientation (east-west rows) may have allowed better light interception.

Top dry weight and pod yield in the 1981 KSB chili studies, however, were affected by row width (Table 1). Significant linear trends in both KSB selections indicated increased productivity with narrowing row widths. Differences between the two KSB selections with

Table 1. Top dry weight and total pod yield of KSB chilies as influenced by plant spacing and row width.

Chilies (1980)				'KSB 6' (1981)				'KSB 16' (1981)			
Plant spacing (cm)	Means (kg/ha)	Row width (cm)	Means (kg/ha)	Plant spacing (cm)	Means (kg/ha)	Row width (cm)	Means (kg/ha)	Plant spacing (cm)	Means (kg/ha)	Row width (cm)	Means (kg/ha)
				Top dry weight							
--	--	45.0	7269	10	6434	45.0	6869	10	6001	45.0	6673
20	6772	67.5	6561	20	6351	67.5	6288	20	5695	67.5	5183
30	6814	90.0	6227	30	5493	90.0	5121	30	5182	90.0	5022
40	6988										
50	6156										
Linear	NS[z]		NS		NS		**		*		**
Quadratic	*		--		--		--		--		--
				Pod yield							
--	--	45.0	3113	10	3091	45.0	3545	10	3325	45.0	3815
20	2883	67.5	2627	20	3257	67.5	3140	20	3190	67.5	2715
30	2776	90.0	2720	30	2949	90.0	2610	30	2874	90.0	2860
40	2860										
50	2943										
Linear	NS		NS		NS		**		NS		**
Quadratic	NS		--		--		--		--		--

[z]*,**,NS - indicates significance of F values at 5%, 1% or nonsignificant, respectively.

respect to the responses to row width should be considered. 'KSB 6' is a taller and somewhat wider plant, where 'KSB 16' is a compact and shorter type. 'KSB 6' may develop a full canopy in a shorter time than 'KSB 16', behaving as if it were in narrower rows than the smaller 'KSB 16'. Stoskopf (46) has stated that small statured plants such as 'KSB 16' are adapted for higher populations, as would be created by proportionately narrower row widths.

My results seem to be in agreement with Shibles' (35) conclusions that greatest production takes place in arrangements that allow full canopy for the longest period of time, falling off where full interception is not reached until later in the life cycle. The parallel response for both dry matter and fruit production is not in conflict with Holliday (17). The optimum pod yield for both selections lies within the narrow rows, and would probably begin to decrease with further narrowing, while top dry weight would thereafter tend to be constant.

Top dry weight and pod yield in the 1981 selections were not significantly affected by plant spacing in the rows. The range of spacings used may simply have not been wide enough to show a true varying response in this crop.

Measurements of percent pods in total top dry weight and percent red pods in total pod yield were intended to determine the effects of the row width and plant spacing on reproductive vs. vegetative production and on the earliness of maturity.

The chilies showed varying results with respect to both percent weight pods in total top dry weight and per cent red pods in total pods (Table 2). Row width effects for percent red pods were not significant.

Table 2. Percent weight pods and percent red pods of KSB chilies as influenced by plant spacing and row width.

Chilies (1980)				'KSB 6' (1981)				'KSB 16 (1981)			
Plant spacing (cm)	Means (%)	Row width (cm)	Means (%)	Plant spacing (cm)	Means (%)	Row width (cm)	Means (%)	Plant spacing (cm)	Means (%)	Row width (cm)	Mean (%)
				Percent weight pods							
--	--	45.0	42.9	10	47.9	45.0	52.1	10	55.4	45.0	57.2
20	42.0	67.5	39.7	20	51.6	67.5	50.1	20	55.6	67.5	52.4
30	40.9	90.0	43.8	20	53.5	90.0	50.9	30	55.4	90.0	56.9
40	37.9										
50	47.7										
Linear	NS[z]		NS		**		NS		NS		NS
Quadratic	*		--		--		--		--		--
				Percent red pods							
--	--	45.0	47.1	10	47.2	45.0	47.7	10	56.2	45.0	50.1
20	43.8	67.5	47.3	20	51.4	67.5	51.7	20	56.2	67.5	54.8
30	47.4	90.0	45.3	30	49.5	90.0	48.7	30	53.0	90.0	60.6
40	39.4										
50	55.7										
Linear	*		NS		NS		NS		NS		**
Quadratic	*		--		--		--		--		--

[z]*,**,NS - indicates significance of F values at 5%, 1% or nonsignificant, respectively.

A quadratic response was found for plant spacing in both percent weight pods and percent red pods in 1980. The 50 cm spacings in both resulted in the highest values. This data shows, at least in plant spacing, some support for the hypothesis of lower plant density resulting in a higher percent pods in total dry weight and earlier maturity. Row width effects for percent red pods in 1980 were not significant.

A significant linear trend for plant spacing in 'KSB 6' appears for percent weight pods also supporting the case favoring lower density. No other significant differences, however, appeared for the two variables in this selection. The smaller 'KSB 16' shows a significant linear trend across row widths for percent red pods indicating the earlier maturity for the wider rows. No significant plant spacing effects were found for either variable in this selection.

The differing response of the two chilies in 1981 may again be explained by their distinctive growth habit, and also to their differences in earliness. The larger 'KSB 6' matures pods later than 'KSB 16' and may also be more sensitive to close in-row plant spacings, thus producing relatively more vegetative matter. The smaller 'KSB 16' seems to show the advantage of the wide rows in early pod ripening. 'KSB 6' would most likely require a proportionately wider row to show the same effect.

In 1980, there was a linear trend for plant height (Table 3) for the in-row spacing, with the closer spacings being tallest. This agrees with the observation that plants in higher densities are often taller due to greater elongation of internodes under the influence of competition for light (23). Row width effects for height were not significant

Table 3. Plant height and plant width of KSB chilies as influenced by plant spacing and row width.

Chilies (1980)				'KSB 6' (1981)				'KSB 16' (1981)			
Plant spacing (cm)	Means (cm)	Row width (cm)	Means (cm)	Plant spacing (cm)	Means (cm)	Row width (cm)	Means (cm)	Plant spacing (cm)	Means (cm)	Row width (cm)	Means (cm)
--	--	45.0	57.9	10	60.2	45.0	60.0	10	49.9	45.0	45.2
20	58.6	67.5	55.8	20	60.6	67.5	60.1	20	49.2	67.5	48.3
30	58.6	90.0	58.1	30	57.5	90.0	58.2	30	46.1	90.0	51.6
40	57.6										
50	54.4										
Linear	*[z]		NS		NS		NS		NS		*
Quadratic	NS		--		--		--		--		--
					Plant width						
--	--	45.0	35.8	10	47.2	45.0	37.0	10	43.1	45.0	36.1
20	45.2	67.5	45.5	20	45.5	67.5	47.8	20	43.1	67.5	44.0
30	45.8	90.0	54.0	30	44.9	90.0	52.8	30	41.6	90.0	47.8
40	45.1										
50	44.2										
Linear	NS		**		NS		**		NS		**
Quadratic	NS		--		--		--		--		--

[z]*,**,NS - indicates significance of F values at 5%, 1% or nonsignificant, respectively.

in 1980. 'KSB 16' showed a quite different response. Although no in-row significance was found, the more compact plants in this case tended to retain their overall shape across the changing row widths, and the increases in height may have been simply in proportion to specific plant width increases described below. 'KSB 6' was taller than 'KSB 16' under all conditions, with no significant differences due to the treatments.

Plant width (Table 3) was affected by the row widths, and a significant linear trend describes the direct variation of plant and row width in all three chili studies. In-row density, on the other hand, did not significantly affect plant width.

It should be noted that the height and width measurements were made on dry, defoliated plants, underestimating actual plant height and canopy width; but relative differences among these dimensions are nonetheless preserved.

The appearance of a mosaic virus on many of the 'KSB 6' and 'KSB 16' plots resulted in a temporary general chlorosis where present and raised concern as to the effects on yield and plant development. Analysis of Variance, however, between the healthy and affected plants showed no significant differences for any of the variables, nor did it result in increased coefficients of variation in the overall analysis.

'KS-1' Paprika Studies

No significant effects were shown by Trend Analysis with either the 1980 or the 1981 paprika study (Tables 4 and 5). Although heat stress and phenotypic variability may have contributed to the masking of treatment effects in 1980, the lack of effects in 1981 show that, at least

Table 4. Total pod yield and percent red pods of paprika as influenced by plant spacing and row width.

KS-1 paprika (1980)				KS-1 paprika (1981)				Combined studies			
Plant spacing (cm)	Means (kg/ha)	Row width (cm)	Means (kg/ha)	Plant spacing (cm)	Means (kg/ha)	Row width (cm)	Means (kg/ha)	Plant spacing (cm)	Means (kg/ha)	Row width (cm)	Means (kg/ha)
				Total yield							
3.0	2092	45.0	2082	--	--	45.0	2196	--	--	45.0	2131
3.75	1968	67.5	1800	3.75	2047	67.5	1697	3.75	2008	67.5	1744
5.0	1917	90.0	2074	5.0	2190	90.0	2312	5.0	2053	90.0	2153
7.5	1965			7.5	1967			7.5	1966		
Linear	NS[z]		NS		NS		NS		NS		NS
Quadratic	NS		--		--		--		--		--
				Percent red pods							
	(%)		(%)		(%)		(%)		(%)		(%)
3.0	51.8	45.0	49.9	--	--	45.0	67.7	--	--	45.0	57.8
3.75	42.3	67.5	54.1	3.75	65.2	67.5	62.2	3.75	53.7	67.5	53.6
5.0	53.0	90.0	52.0	5.0	67.8	90.0	69.3	5.0	60.4	90.0	60.6
7.5	48.8			7.5	64.2			7.5	56.0		
Linear	NS		NS		NS		NS		NS		NS
Quadratic	NS		--		--		--		--		--

[z]NS -indicates nonsignificance of F values at 5% level.

Table 5. Yield of red paprika pods as influenced by plant spacing and row width.

KS-1 paprika (1980)				KS-1 paprika (1981)				Combined studies			
Plant spacing (cm)	Means (kg/ha)	Row width (cm)	Means (kg/ha)	Plant spacing (cm)	Means (kg/ha)	Row width (cm)	Means (kg/ha)	Plant spacing (cm)	Means (kg/ha)	Row width (cm)	Means (kg/ha)
Yield of red pods											
3.0	1095	45.0	1044	--	--	45.0	1462	--	--	45.0	1229
3.75	830	67.5	828	3.75	1353	67.5	1056	3.75	1092	67.5	949
5.0	1048	90.0	1085	5.0	1491	90.0	1605	5.0	1270	90.0	1308
7.5	971			7.5	1279			7.5	1125		
Linear	NS[z]		NS		NS		NS		NS		NS
Quadratic	NS		--		--		--		--		--

[z]NS indicates nonsignificance of F values at 5% level.

in the range of the treatments used, row width and plant spacing do not influence paprika pod production and ripening.

Combining the two years of paprika studies also showed no significant effects. In any case, results from such a combination of data are questionable, due to an apparent genetic difference between the 1980 and the 1981 material, and to a difference in growing conditions between the two years.

Plant Arrangement Effects of Equal Populations

No interactions between the main effects of plant spacing and row width were found in either the KSB chilies or the 'KS-1' paprika studies.

The experiments of this study were not designed to test plant population as a main effect, as was done in much of the research cited. As designed and analyzed, these experiments showed variation due to main effects only. It was decided nonetheless to perform an analysis of variance on each individual study, comparing those particular combinations of plant spacing and row width that contained identical plant populations (Tables 6 and 7). Such analysis served to compare the more equidistantly spaced combinations with the more rectangular combinations.

In all the chili studies, significant differences in plant width appeared, an artifact of the comparison of the wider rows with narrower rows as main effects. Significant responses for pod and dry weight yield and percent red pods appeared in 'KSB 6' and 'KSB 16', respectively, at the population of 111,111 plants/ha but both of these may be row width main effects. A significant difference in dry weight in the

Table 6. Comparison of variables at equal populations of KSB chilies.

Population (plants/ha)	Plant spacing (cm)	Row width (cm)	Top dry weight (kg/ha)	Pod yield (kg/ha)	Percent weight pods	Percent red pods	Plant height (cm)	Plant width (cm)
				1980 chilies				
37,037	30	90	6340a[z]	2715a	44.3a	45.8a	56.8a	53.8a
37,037	40	67.5	6209a	2288a	37.0a	45.7a	54.5a	45.5a
55,555	20	90	6218b	2692a	44.7a	43.8a	59.8a	55.0a
55,555	40	45	8251a	3091a	38.2a	39.3a	59.2a	36.2b
73,964	20	67.5	6845a	2835a	42.6a	48.8a	56.2a	45.5a
73,964	30	45	6965a	2931a	43.9a	56.3a	59.2a	36.2a
				'KSB 6'				
73,964	20	67.5	6262a	3191a	53.7a	60.5a	62.5a	47.5a
73,964	30	45	6261a	3469a	58.8a	48.9a	61.5a	35.2b
111,111	10	90	4859b	2192b	47.0a	45.4a	54.8a	56.2a
111,111	20	45	7237a	3653a	53.2a	49.8a	59.0a	37.8b
				'KSB 16'				
73,964	20	67.5	5367a	2801a	54.8a	62.8a	51.0a	43.5a
73,964	30	45	6287a	3560a	60.1a	54.5a	44.5a	35.0a
111,111	10	90	5350b	3349a	62.6a	67.3a	55.5a	50.5a
111,111	20	45	6502a	4142a	63.7a	50.9b	45.7a	38.0a

[z]Mean separation by DMRT, $\alpha = 0.05$.

Table 7. Comparison of variables at equal populations of paprika plants.

Population (plants/ha)	Plant spacing (cm)	Row width (cm)	Row yield (kg/ha)	Percent red pods	Yield of red pods (kg/ha)
		'KS-1' paprika (1980)			
296,030	7.5a	45	2105a[z]	49.0a	988a
296,030	5.0a	67.5	1993a	58.6a	1150a
296,030	3.75a	90	2036	50.3a	967a
		'KS-1 paprika (1981)			
296,030	7.5	45	1950a	65.2a	1191a
296,030	5.0	67.5	1712a	65.7a	1019a
296,030	3.75	90	2131a	75.2a	1463a

[z]Mean separation by DMRT, =0.05.

1980 chilies at 55,555 plants/ha may favor the equidistant spacing, also appears as a valid effect of the equidistant spacing, but lack of interactions as mentioned above indicate that such as effect did not show up in these studies. In order to clarify this matter, future plant spacing studies should be pursued with plant populations as principle treatments, to more closely investigate the matter of equidistant spacing.

Stand Establishment Studies

KSB Chili Planting Method Studies

The two effects most pronounced in the Chili Planting Method Studies were: 1) the differing performance between the transplants as a group and the seeded treatments, and 2) the influence of climate stress in 1980 as compared with the effects of mild conditions in 1981 with respect to the relative behavior across treatments.

The advantage of earliness in the transplants over the direct seeded methods (Table 8) was obvious in 1980. Significant differences between the two groups appeared for top dry weight and pod yield, with values for the transplants nearly double those of the seeded treatments. In 1981, the differences were not nearly so great. Mean separation by DMRT in dry weight showed significant separation of the Speedling 080 transplants over the dry seeded plants, with other treatments intermediate. In pod yield, the two Speedling transplant types were significantly higher than the two seeded treatments.

Plant height and width in 1980 were also affected by the planting method, with the transplants significantly larger in both dimensions. In 1981, by contrast, no significant differences in plant height

Table 8. KSB chili planting method studies, 1980 and 1981.

Treatment	Top dry weight (kg/ha)	Yield (kg/ha)	Percent wt. pods	Percent red pods	Height (cm)	Width (cm)
		1980				
1. Dry seed	4444b[z]	1932b	43.4a	58.6a	53.4b	47.1b
2. Local transplant	9360a	3697a	39.9a	54.2ab	67.2a	67.9a
3. Seedling 100A	8777a	3435a	39.1a	48.1bc	65.4a	69.1a
4. Speedling 080	8850a	3483a	39.2a	45.3c	66.6a	66.1a
5. Germinated seed	4738b	2071b	43.6a	60.1a	51.4b	47.8b
		1981				
1. Dry seed	5889b	3381c	56.9b	72.1a	51.0a	48.6b
2. Local transplant	6407ab	3899abc	60.8a	48.1c	48.8a	50.4ab
3. Speedling 100A	6823ab	4180ab	61.3a	52.5c	49.4a	52.4ab
4. Speedling 080	7314a	4543a	62.2a	59.8b	49.4a	51.4ab
5. Germinated seed	6461ab	3712bc	57.4b	73.5a	52.1a	53.2a

[z]Mean separation by DMRT, $\alpha = 0.05$.

occurred. Germinated seed produced significantly wider plants than dry seed. No other significant differences between the two seeded treatments or among the transplants were found for top dry weight, pod yield, height or width, in either 1980 or 1981.

Greater differences between the two treatments types in 1980 are clearly a result of the unusual heat and drought stress during the summer of that year. Although ample irrigation water was available, the prevailing conditions may have strained the water transport and photosynthetic systems of the plants, with greater adverse affects on the growth and development of the smaller seeded plants. In addition, the more highly branched root systems of the transplants may have been more efficient in water uptake than the taproot systems of the seeded plants. At any rate, the seeded plants were never able to recover from the delay, even during the more favorable growing conditions of early autumn.

Hot days and warm nights, causing flower abortion, as described earlier in the section on plant spacing, prevented summer fruit set until early August. By that time, however, the larger transplanted chilies were in position for greater pod production capacity upon the arrival of the milder weather. Some early season fruit set in the transplants also contributed to their overall greater yield.

The 1981 crop showed much less contrast between the two groups due to the better growing conditions of that year. A steadier growth pattern across all treatments through the summer, and earlier onset of fruit production in the seeded plantings compared with those of the previous year, allowed the seeded plants to approach and equal the transplants in plant size, weight, and pod production.

Results for percent weight pods (harvest index) seemed to show the opposite tendencies between the two years compared to the other evaluations. In 1980, no significant treatment effects were found. On the other hand, the 1981 transplants were shown as significantly higher for percent weight pods in total top dry weight than the seeded plants. During that year, early season fruit set, and the more or less continuous fruit set through the season could have raised the ratio of pods to vegetative matter in the transplants. In 1980, the larger transplants were aborting flowers, though still increasing the number of internodes, adding a larger amount of vegetative mass than the smaller direct seeded plants, thus lowering percent pods of the transplants down to a level with the seeded treatments.

Values for percent red pods favored the seeded treatments in both years. Such an indication of greater maturity in the younger plants is in contradiction to the assumption that the transplants would mature pods earlier, owing to their greater development and size. Even though the larger, older plants set pods earlier and in greater numbers, the greater amount of pods in the transplant situation may have resulted in a greater load upon the plants. A longer time might have been required to develop and ripen the larger yield, resulting in a higher proportion of pods not reaching full red coloration by the first killing frost.

Differences in the chilies themselves may have also caused the variation between the years, as seen among the selections in the spacing studies. Distinctions between the field-run KSB chilies used in 1980, and specific selection 'KSB 8' used in 1981 may have been great enough to account for some of the responses not easily explained due to climate effect alone.

Paprika Seeding and Fluid Drilling Studies

No treatment differences were found for pod yield, percent red pods, or red pod yield in the Paprika Seeding Studies for either year, (Table 9) with the exception of a significantly reduced pod yield in the GA_3-treated dry storage seed treatment in 1980. Poor emergence of this seed resulted in a thin stand and the low production.

The Gel Type Studies (Table 10) showed no significance across the treatments. Some depression of emergence was observed in both years in the Natrosol treatment, but with thinning of plants to the proper spacing after establishment, uniform population across plots was achieved.

In the Gel Additives Studies in 1980, the 'Fertilizer and Insecticide' treatment produced greater yield than the 'Fungicide' and the 'Fungicide and Insecticide' treatments (Table 11). No such significance was shown in 1981, nor in a combined analysis of this study (Table 12). Elevation of the yield value in 1980 cannot be explained in terms of stand quality, as all plots were thinned to the same spacing, nor was earlier emergence observed in any of the treatments. Reduced stands in three plots in 1980, due to poor water drainage, may have created the reductions sufficient to give significant separation from the highest values.

Table 9. Paprika seeding studies, 1980 and 1981.

Treatment	(Red pods only) Pod yield (kg/ha)
	1980
1. Dry seed	1385a[z]
2. Germinated seed	1572a
3. Germinated seed (GA_3, 400 ppm)	1333a
4. Dry storage	1659a
5. Dry storage (GA_3, 400 ppm)	798b

Treatment	Pod yield (kg/ha)	Percent red pods	Yield of red pods (kg/ha)
		1981	
1. Dry seed	2067a	67.2a	1395a
2. Germinated seed	1931a	65.1a	1263a
3. Germinated seed (GA_3, 200 ppm)	1808a	65.5a	1186a
4. Germinated seed (GA_3, 800 ppm)	1666a	61.0a	1018a
5. Dry storage	2055a	63.4a	1303a

[z]Mean separation by DMRT, $\alpha=0.05$.

Table 10. Paprika gel type studies, 1980 and 1981.

Treatment	(Red pods only) Pod yield (kg/ha)
1980	
1. Laponite, 15.0 g/l	916a[z]
2. Viterra 2, 4.0 g/l	1064a
3. Natrosol 250H, 15.0 g/l	918a

Treatment	Pod yield (kg/ha)	Percent red pods	Yield of red pods (kg/ha)
1981			
1. Laponite, 15.0 g/l	1839a	68.0a	1250a
2. Viterra 2, 4.0 g/l	1904a	64.5a	1228a
3. Natrosol 250H, 15.0 g/l	1808a	63.2a	1142a

[z]Mean separation by DMRT, $\alpha = 0.05$.

Table 11. Paprika gel additive studies, 1980 and 1981.

Treatment	(Red pods only) Pod yield (kg/ha)
1980	
1. Control	1114ab[z]
2. Fertilizer	1119ab
3. Fungicide	1044b
4. Insecticide	1114ab
5. Fertilizer and fungicide	1194ab
6. Fertilizer and insecticide	1520a
7. Fungicide and insecticide	1041b
8. Fertilizer, fungicide and insecticide	1191ab

Treatment	Pod yield (kg/ha)	Percent red pods	Yield of red pods (kg/ha)
1981			
1. Control	2003a	62.4a	1250a
2. Fertilizer	1920a	61.8a	1187a
3. Fungicide	1973a	61.8a	1219a
4. Insecticide	1900a	59.6a	1132a
5. Fertilizer and fung.	1957a	63.4a	1241a
6. Fertilizer and ins.	2395a	65.2a	1561a
7. Fungicide and ins.	2170a	67.2a	1458a
8. Fertilizer, fungicide and insecticide	2113a	27.9a	1435a

[z]Mean separation by DMRT, $\alpha=0.05$.

Table 12. Paprika gel additive studies, combined data.

Treatment	Pod yield (kg/ha)
1. Control	1559a[z]
2. Fertilizer	1519a
3. Fungicide	1509a
4. Insecticide	1507a
5. Fertilizer and fungicide	1576a
6. Fertilizer and insecticide	1958a
7. Fungicide and insecticide	1606a
8. Fertilizer, fungicide and insecticide	1652a

[z]Mean separation by DMRT, $\alpha = 0.05$.

CHAPTER V

SUMMARY AND CONCLUSIONS

Increased productivity was apparent from narrowing the row widths in both KSB chili selections in 1981. Closer rows allow the formation of a full crop canopy in a shorter time, permitting full light interception early in the life of the crop. With the range of widths used in these studies, the crowding of rows in the chilies did not seem to be detrimental to pod yields by increasing the ratio of vegetative to pod production. Crowding did result in a higher trash ratio in the close row spacings with the relatively larger 'KSB 6'. This indicates that a further increase in row density may possibly lower the pod yield in this selection, while dry weight production would level off. 'KSB 16', being a smaller plant, did not yet begin to show this effect.

Pod ripening was earlier for the wider rows in 'KSB 16', in agreement with the hypothesis that wider spacing can promote earlier maturity (37), as all sides of the plants were illuminated and perhaps induced toward earlier reproductive growth. This selection, then, was apparently small enough to register such an effect due to later canopy filling across the rows.

Plant widths were clearly affected by row widths. At the end of the season, canopy filling had become continuous regardless of row width; the resulting plant widths were in a direct linear proportion to the row widths.

Response differences in the 1980 chilies were reduced, primarily by the severely hot dry summer of 1980, but possibly in part as a result of greater genetic variability in the material used. The selections used in 1981 were taken from the gene pool of the 1980 chilies, and are in themselves more phenotypically uniform.

No significant treatment effects were found in either year for paprika row width and plant spacing studies. A further study, using both narrower and wider row widths, and additional population or spacing treatments may lead to more definite conclusions for this crop.

In-row plant spacings generally had little influence on either crop. Among the spacings used, canopy filling probably occurred at nearly the same time, even at the greatest in-row spacings. Consequently, no differences in earliness of canopy ever occurred to fully capture the sunlight falling between plants. Yield per plant and plants per row distance varied in an inverse manner. In light of this fact, the more open in-row spacings should be recommended, especially in more humid growing areas, as a means to reduce disease problems. Likewise, if the wide row spacings in paprika continue to show yields comparable to narrow rows as they did in this study, this too should be advised.

Much of the research conducted in plant arrangements differs from these in that, although row widths are varied incrementally, plant populations over the given area are tested as the other main variable; plant spacings in themselves are not tested as such. This type of experimental method would probably be of greater value in further cultural studies in the spice peppers.

The transplant method for KSB chilies was obviously superior to both dry and germinated seeding, especially when the harsh conditions of

1980 put the latter at a greater disadvantage. Earliness is the main incentive to use transplants, but if growing conditions are favorable, as in 1981, seeded plantings can catch up with the transplants and equal them in production, an effect observed in that year for top dry weight, pod yield, and plant size.

In 1981, the transplants produced a higher percent of pod weight, a characteristic aiding harvest and improving the quality of the harvested product, especially if forage choppers are to be used. The benefits of using transplants held up even during a year that increased the growth and yield in seeded stands.

Pod maturity across treatments was not significantly different in 1980, but in 1981, the seeded plots ripened a significantly higher percent of the pods than did the transplants. This factor does not appear at this time to be a detriment to the crop value. Further selections in KSB chilies, and studies in nutrition will quite possibly lead to improvements in pod ripening.

The studies in seeding and fluid drilling in paprika did not show any substantial problems or benefits with any specific treatments. Sowing of germinated seed does not seem to show an advantage over dry seeding in paprika. Since no observable earliness or improved percentages in emergence with the former were seen, and since paprika has a shorter germination time compared with some other peppers, the practice of planting paprika as germinated seed is probably not beneficial.

Techniques such as "dry storage" need to be re-evaluated for ways to increase longevity and vigor of seed so treated. Undoubtedly, the destruction of the radicle tip and the subsequent need for the initiation of secondary roots taxes the carbohydrate reserves of the seed, renders it less able to continue development. In those seed that do succeed in developing into healthy seedling, the dominant taproot is not present, and the resulting more highly branched root system (as in transplants) may have some ramifications as to drought tolerance and efficiency in nutrient uptake.

Various types of gels have been evaluated and some have been shown in the laboratory to cause necrosis of the radicle tip in a percentage of the germinated seed. This problem did not arise in the Gel Type Studies, and although some skips appeared in the "Natrosol 250H" plots, no such effects on emergence were found with the gel when germinated paprika seed were sown in the greenhouse.

The addition of materials to the gel type had no effect on seedling emergence in any of the treatments. Seedlings, once established, also performed equally. Greenhouse studies also showed no effects, even at 2X rates of the additives. Further studies in gel additives could open an entire area of study. Buffering agents, absorbing materials as protectants against possible herbicide injury, and supplemental nutrient salts or organic compounds can be added to replace vital substances leached from the seed during the germination process.

No cultural experiments are complete after two or three years. Innovations in farming, new cultivars and selections, and new growing areas will all continue to create opportunities for further study.

LITERATURE CITED

1. Anonymous. 1973. Production practices for pimiento pepper. Ala. Agr. Exp. Sta. Bull. 444.

2. Anonymous. 1976. Soybeans planted equidistantly increase yields. Crops and Soils. 29:26.

3. Arndt, W. 1965. The nature of the mechanical impedance to seedlings by soil surface seals. Aust. J. Soil Res. 3:45-54.

4. Austin, R. B., P. C. Longden, and J. Hutchinson. 1969. Some effects of "hardening" carrot seed. Ann. Bot. 33:883-895.

5. Baer, J., and L. Smeets. 1978. Effect of relative humidity on fruit set and seed set in pepper (Capsicum annuum L.). Neth. J. Agr. Sci. 26:59-63).

6. Currah, I. E., D. Gray, and T. H. Thomas. 1974. The sowing of seed using a fluid drill. Ann. Appl. Biol. 76:311-318.

7. Currah, I. E., and P. J. Salter. 1973. Some combined effects of size grading and "hardening" seed on the establishment, growth, and yield of four varieties of carrot. Ann Bot. 37:709-719.

8. Darby, R. J., and P. J. Salter. 1976. A technique for osmotically pre-treating and germinating quantities of small seed. Ann. Appl. Biol. 83:313-315.

9. Dorland, R. E., and F. W. Went. 1947. Plant growth under controlled conditions VIII: growth and fruiting of chili pepper (Capsicum annuum L.). Am. J. Bot. 34:393-401.

10. Fowler, J. L., and L. L. Ray. 1977. Response of two cotton genotypes to five equidistant spacing patterns. Agron. J. 69:733-738. (abstr.)

11. Govindarajan, V. S., S. Narasimhan, and S. Dhanaraj. 1977. Evaluation of spices and oleoresins II: pungency of capsicum by Scoville heat units-a standardized procedure. J. Food Sci. Tech. 14:28-34.

12. Hartman, K. T. 1970. A rapid gas-liquid chromatographic determination for capsaicin in capsicum spices. J. Food Sci. 35:543-547.

13. Hawkins, B. S., and H. A. Peacock. 1973. Influence of row width and population density on yield and fiber characteristics of cotton. Agron. J. 65:47-51.

14. Helwig, J. T., and A. K. Council, eds. 1979. SAS User's Guide, 1979 Edition. SAS Institute, Inc., Cary, NC.

15. Hoff, D. J., and H. J. Mederski. 1960. Effect of equidistant spacing of corn yield. Agron. J. 52:295-297.

16. Hoggard, A. L., J. G. Shannon, and D. R. Johnson. 1978. Effect of plant population on yield and height characteristics in determinate soybeans. Agron. J. 70:1070-1072.

17. Holliday, R. 1960. Plant population and crop yield: part I (review article). Field Crop Abstr. 13:159:167.

18. Jawarski, C. A., S. C. Phatak, and A. Liptay. 1980. Differential cultivar responses of tomato transplants to ethephon. Hort-Science. 15:647-648.

19. Jawarski, C. A., and R. E. Webb. 1967. Preliminary tests on the performance of clipped tomato transplants. Proc. Amer. Soc. Hort. Sci. 91:550-555.

20. Jawarski, C. A., and R. E. Webb. 1971. Pepper performance after transplant clipping. HortScience. 6:480-482.

21. Jawarski, C. A., R. E. Webb, S. A. Garrison, E. L. Bergman and S. Shannon. 1970. Growth-retardant-treated tomato transplants. HortScience. 5:255-256.

22. Kueneman, E. A., et al. 1979. Effect of plant arrangements and densities on yield of dry beans. Agron. J. 71:419-424.

23. Lehman, W. F., and J. W. Lambert. 1960. Effects of spacing of soybean plants between and within rows on yield and its components. Agron. J. 52:84-86.

24. Levitt, J. 1956. The Hardiness of Plants. Academic Press, Inc., New York, NY.

25. Loomis, R. S., and W. A. Williams. 1963. Maximum crop productivity: an estimate. Crop. Sci. 3:67-72.

26. Lorenz, O. A., and D. N. Maynard. 1980. Knott's Handbook for Vegetable Growers, Second Edition. John Wiley and Sons, New York, NY, p. 38.

27. Mitchell, R. L. 1970. Crop Growth and Culture. Iowa State University Press, Ames, IA, pp. 103-123.

28. Motes, J. E. 1982. Stand establishment of vegetable crops--transplanting. HortScience. (in press).

29. Myers, C. E. 1916. Experiments with cabbage. Penn State College Agr. Exp. Sta. Bull. 137.

30. Nunez, R., and E. Kamprath. 1969. Relationships between N response, plant population, and row width on growth and yield of corn. Agron. J. 61:279-282.

31. Rosebrook, D. D. 1971. Collaborative study of a method for extractable color in paprika and paprika oleoresin. Assoc. Official Analyt. Chem. J. 54:37-38.

32. Salim, M. H., and G. W. Todd. 1968. Seed soaking as a pre-sowing, drought hardening treatment in wheat and barley seedlings. Agron. J. 60:178.

33. Sharples, G. C. 1973. Stimulation of lettuce seed germination at high temperatures by ethephon and kinetin. J. Am. Soc. Hort. 98:209-212.

34. Shibles, R. M., and C. R. Weber. 1965. Leaf area, solar radiation interception, and dry matter production by soybeans. Crop Sci. 5:575-577.

35. Shibles, R. M., and C. R. Weber. 1966. Interception of solar radiation and dry matter production by various soybean planting patterns. Crop Sci. 6:55-59.

36. Short, T. H., and J. E. Henry. 1971. Direct seeding of tomatoes for processing. Ohio Ag. Res. Develop. Ctr. Res. Sum. 49:59.

37. Short, T. H., and D. W. Kretchman. 1973. Windbreaks for direct-seeded tomatoes. Ohio Ag. Res. Develop. Ctr. Res. Sum. 72:7-8.

38. Short, T. H., and D. W. Kretchman. 1973. A prelimary study of liquid-spray anticrustants for direct-seeded tomatoes. Ohio Ag. Res. Develop. Ctr. Res. Sum. 72:11.

39. Sims, R. E. 1974. Precision seeding techniques. New Zealand J. Agric. 128:50-53.

40. Singh, H., and G. S. Khattra. 1977. Germination-inhibitor in chili fruit and seed extract. Indian J. Agric. Sci. 47:445-447.

41. Sosa-Coronel, J. 1981. Studies of seed germination and storage of germinated seed of different pepper (Capsicum sp.) cultivars-their applications in fluid drilling. (unpub. Ph.D. dissertation, Oklahoma State University, 1981.)

42. Sosa-Coronel, J., and J. E. Motes. 1982. Effect of gibberellic acid and seed rates on pepper seed germination in aerated water columns. J. Am. Soc. Hort. (in press).

43. Sosa-Coronel, J., A. G. Taylor, and J. E. Motes. 1978. Evaluation of gels for fluid drilling on pregerminated seed. HortScience. 13:20 (abstr.).

44. Spinks, J. L., L. O. Roth, and J. E. Motes, 1979. A combination fluid drill and dry seed planter for vegetable plot research. HortScience. 14:170-171.

45. Statistical Analysis System. 1979. Oklahoma State University, Stillwater, OK.

46. Stoskopf, N. C. 1979. Understanding Crop Production. Reston Pub. Co., Reston, VA.

47. Taylor, A. G., 1977. Comparative performance of pregerminated, high moisture content, and dry vegetable seed in greenhouse and field studies. J. Seed Tech. 2:52-61.

48. Taylor, A. G., S. W. Searcy, J. E. Motes, L. O. Roth. 1981. Separation, singulation, and precision planting of germinated seed. HortScience 16:198-200.

49. Ware, G. W., and J. P. McCollum. 1975. Producing Vegetable Crops. Second Edition. The Interstate Publishers and Printers, Danville, IL.

50. Wiggans, R. G. 1939. The influence of space and arrangement on the production of soybean plants. J. Am. Soc. Agron. 31:314-321.

APPENDIX

Table 13. Pungency readings in Scoville units from KSB chili planting method studies.

Treatment	Pungency (Scoville units)
1980 (Field-run KSB chilies)	
1. Dry seed	186,000
2. Local transplants	181,500
3. Speedling 100A	210,750
	161,320[z]
4. Speedling 080	186,750
	147,260
5. Germinated seed	178,500
1981 ('KSB 8')	
1. Dry seed	174,000
2. Local transplants	153,750
3. Speedling 100A	132,300
4. Speedling 080	134,550
5. Germinated seed	140,100
Trash free samples from combined 1981 material	
1. Red pods	167,250
2. Orange pods	120,375
3. White pods	101,625

[z]Second sampling (lower readings due to volatilization).

Table 14. Pungency readings in Scoville units from KSB chili row width and plant spacing studies, 1981.

Sample	Pungency (Scoville units)
KSB 6, narrow rows, close spacing	181,500
KSB 6, narrow rows, wide spacing	194,250
KSB 6, wide rows, close spacing	184,500
KSB 6, wide rows, wide spacing	169,500
KSB 6, red pods (no trash)	191,250
KSB 6, orange pods (no trash)	168,750
KSB 6, white pods (no trash)	189,750
KSB 6, from healthy plants	192,750
KSB 6, from virus-affected plants	193,500
KSB 16, narrow rows, close spacing	141,075
KSB 16, narrow rows, wide spacing	153,750
KSB 16, wide rows, close spacing	162,750
KSB 16, wide rows, wide spacing	157,500
KSB 16, red pods (no trash)	152,850
KSB 16, orange pods (no trash)	154,500
KSB 16, white pods (no trash)	149,775
KSB 16, from healthy plants	170,250
KSB 16, from virus-affected plants	155,250

VITA

Gregory Lee Schoen

Candidate for the Degree of

Master of Science

Thesis: FIELD EVALUATIONS OF CULTURAL PRACTICES IN SPICE PEPPERS (CAPSICUM ANNUUM L.)

Major Field: Horticulture

Biographical:

Personal Data: Born at Tinker Air Force Base, Oklahoma, April 25, 1956, the son of Lee G. Schoen and Marie E. Schoen.

Education: Attended primary schools in Lompoc, California, and Midwest City, Oklahoma, 1961-1971; Graduated from Midwest City High School, May, 1974; attended the University of Oklahoma, Norman, Oklahoma, 1974-1976 and 1977-1978; received Bachelor of Science degree in Botany from Oklahoma State University, Stillwater, Oklahoma, in May, 1980. completed requirements for the Master of Science Degree at Oklahoma State University in May, 1982.

Professional Experience: Student Research Technician, Department of Plant Pathology, January 1979 to December 1979; Graduate Student, Department of Horticulture, January 1980 to May 1982, Oklahoma State University, Stillwater, Oklahoma.