AN ABSTRACT OF THE THESIS OF

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Title: RELATIONSHIPS OF SWEET CORN (ZEA MAYS L.) AND CABBAGE (BRASSICA OLERACEA var CAPITATA L.) GROWING IN MIXED STANDS USING THE ADDITION SERIES APPROACH

Abstract approved: ______________________________

R. D. William

A sweet corn (*Zea mays* L.) and cabbage (*Brassica oleracea* var *capitata* L.) interplanting trial was conducted at the OSU Vegetable Research Farm in summer 1989. Four plant population densities representing 2, 4, 8, and 16 plants/m^2 were tested. Yield of corn and cabbage increased with density in both monoculture and interplanted treatments. Sweet corn ear length, ear diameter, kernel depth, and number of kernel rows per ear were reduced as density of corn increased. Cabbage density had no significant effect on sweet corn. Tillering and ear production also were reduced by increasing corn population. Cabbage yield, head circumference, and diameter were reduced by increases of either crop's densities.

Relative growth rate, net assimilation rate, and leaf area of either crop were reduced by density. Both land

equivalent ratio and area time ratio were less than or equal to 1 indicating a yield disadvantage for sweet corn and cabbage interplanting.

RELATIONSHIPS OF SWEET CORN (*Zea Mays* L.) AND CABBAGE (*Brassica oleracea* var *capitata* L.) GROWING IN MIXED STANDS USING THE ADDITION SERIES APPROACH

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Thomson G. Chilanga

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Head of Department of Horticulture

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INTRODUCTION

The practice of growing several crops on the same land within a growing season is an ancient strategy for crop production among worldwide farmers (Ruthenberg, 1971; Keswani and Ndunguru, 1980; Gomez et al., 1983; Francis, 1986). Multiple cropping may be categorized as sequential, double, or triple cropping within a season or may involve some degree of intercropping where two or more species are grown in a field at the same time. Traditionally, multiple cropping is practiced by farmers with limited resources to increase product diversity. As arable lands diminish globally, multiple cropping is a possible strategy for intensifying land use and absorbing excess farm labor. Efficiencies of scarce resource utilization could be increased. Multiple cropping increases the potential for interactions among crop species and reduces soil erosion.

The biological efficiency of intercropping is determined by comparing productivity within a given area of intercropping to the same area divided by the ratio of sole crops (Willey, 1979). The concept of land equivalent ratio (LER) defined as the total land area required under monocropping to produce yields in the intercropping, judges whether two crop species could be component crops. When LER = 1, there is no advantage or disadvantage to intercropping whereas LER >1 suggests an advantage to growing the crops in mixed stands. LER emphasizes land area without consideration of time a field is dedicated to production.

A modification of LER includes the duration of a crop was on the field from planting to harvesting. The modification is called the area time equivalent ratio (ATER). In regions where multiple cropping is practiced, a common problem is whether a crop will fit into the existing cropping system. To evaluate these aspects, a time weighted land use index or crop intensity index (CII) and its derivatives were developed (Menegay et al., 1978). The indices assess actual land use and time relationships for each crop or group of crops compared to the available land and time.

Plants in mixed stands interfere with or reduce yields of each other through environmental modification, allelopathy or competition (Harper, 1977; Radosevich and Holt, 1984; Radosevich, 1987). Competition among plants is influenced by environmental conditions, levels of resources, growth characteristics of interacting species, and proximity factors such as density, species proportion, and spatial arrangement. Experimental techniques that manipulate proximity factors could be used to identify competitive relationships between species. Growth analysis quantifies the effects of competition between crop species. Relative growth rate (RGR) of a plant expresses the dry weight increase in a time interval in relation to initial weight of a plant. Other indicators of competition among plants include the net assimilation ratio (NAR), leaf area, and dry matter accumulation.

In Malawi, corn and cabbage represent the staple grain and vegetable, respectively. Farmers sometimes ask about interplanting these crops to improve productivity, crop diversification, and possible profits. This research reported herin was conducted to determine the feasibility of intercropping sweet corn (Zea mays L.) and cabbage (Brassica oleracea var capitata L.) and eventually determining appropriate densities of sweet corn and cabbage.

LITERATURE REVIEW

Complex cropping systems that intensify land use are important in agriculture. In terms of land use, growing crops in mixed stands can be more productive than monocropping (Ruthenberg, 1971; Willey, 1979; Francis, 1986). Mixed, row, strip, and relay intercropping systems have been defined (Andrews and Kassam, 1976; Willey, 1979). In mixed intercropping common in Africa, component crops are simultaneously grown with no distinct row arrangement while row intercropping involves production in separate rows. Strip intercropping allows independent cultivation of crops in different strips, whereas relay intercropping allows overlap of crop growth cycles. Farmers often interplant maize with other crops including beans (*Phaseolus vulgaris* L.) and pumpkins (*Cucurbita* spp). Agricultural specialists, therefore, can increase production by conducting research on various types of intercropping existing in many countries.

Advantages of intercropping may include high yields, greater land use efficiency per unit area, risk aversion, pest protection, soil improvement, and reduced production costs (Horwith, 1985; Francis, 1986). Salter (1986) observed that intercropped brussel sprouts (*Brassica oleracea* L. var *gemmifera*) and cabbage produced 13 and 38t/ha, respectively compared with 15t of brussel sprouts and 45t/ha of cabbage when grown separately. Production costs also were reduced with intercropping. Sharaiha and Haddad (1986) reported greatest cabbage yields of 22kg/3m in a cabbage and maize row intercropping, whereas maize yield in both monocropped and intercropped treatments were similar. Brown et al. (1985) reported reduced production costs for tomatoes (Lycopersicon esculentum Mill) in a cabbage, muskmelon (Cucumis melo L.) and collards (Brassica oleracea L. var acephala) interplanting system. Monyo et al. (1976) observed modified environmental conditions when French beans (Phaseolus vulgaris L.), tomatoes, okra (Hybiscus esculentus L.) and cassava (Manihot esculentus L.) were interplanted. The modification permitted tomato production in summer.

Competition among plant species represents simultaneous demand by component crops for similar resources (Donald, 1963; Harper, 1977; Radosevich, 1987). Competition among plants involves interaction of biological and environmental factors. Plant growth reflects past use and potential exploitation of resources and its potential to compete. Growth analysis is one approach for insight into crop competition (Grime and Hunt, 1975; Patterson, 1982; Roush and Radosevich, 1985; Welden and Slauson, 1986).

Experimental techniques can be employed to manipulate proximity factors to identify competitive relationships between weed and plant species (Harper, 1977; Radosevich and Holt, 1984; Radosevich 1987). Similar techniques have been adopted by researchers to identify competitive relationships among crop species. One technique is the systematic design (nelders and addition series). The nelder approach is used to study interference among crop species. Plant density and arrangement are systematically varied. The design consists of a grid of points often in an arc or circle with each point representing a plant. The area available per plant changes consistently over the grid. The influence of another species is introduced into the design by overseeding the whole experimental area with a second species, whereas the interspecific effects could be determined by alternating placement of species along an arc (Radosevich and Holt, 1984). The design does not account for spatial arrangement because the distance between plants is held constant.

If all interference is assumed to be competition, relatitve competetive abilities of a species can be assessed with a model derived from the reciprocal yield law ($1/W = A + BN$), where $1/W$ is the reciprocal of individual plant weight, A is the constant equal to reciprocal of size of plant grown alone and B is the slope of the line reflecting the plant weight (W) and density (N) relationship.

Other approaches such as replacement or substitutive designs also provide some insight into interactions between two species. Total density remains constant in replacement designs but the density contributed by each species is varied. In contrast, additive experiments involve two species grown simultaneously with a constant density of one crop but varied densities of the other. The design, however, involves inadequate control of proximity factors. Interspecific and intraspecific competition of crops is difficult to determine.

Sweet corn

Increased yield of crops through greater densities are reported. A 55% increase in sweet corn yield was reported as plant population increased from 30,000 to 128,000 plants per hectare (Dolan and Christopher, (1952). Similar responses were reported by Freyman et al. (1972), Hoff and Mederiski (1960), Yao and Shaw (1964), and Tariah and Wahua (1985).

Chipman and Mackay (1960), Bleasedale (1967), Rutger and Crowder, (1967), and Downey (1971) reported that total dry matter and plant population were proportional. Sweet corn production, therefore, was a function of plant density. Mack (1972) using a constant rectangularity reported that

'Jubilee' reached a yield maximum 24t/ha at 14 plants/m^2 under adequate irrigation and nutrition conditions in Oregon.

Plant arrangement in a high density planting has an effect on growth performance and yield of individual plants. The more equidistant the plants are, the greater the yield potential due to reduced competition (Mack, 1968; Stang, 1975). Bleasedale (1966) and Suapon (1970) also stated that yield of many direct seeded vegetable crops is increased as plant spacing approaches a square configuration because interplant competition is equalized.

The production of sweet corn ears per plant is genetically controlled, although Downey (1971) noted that environment affects this trait. Vittum et al. (1959) and Eddowes (1969) found that increasing plant population decreased number of ears per plant. A decreasing plant population increases production of secondary ears (Enzie 1942). Unfavorable growing conditions such as moisture stress also reduce sweet corn ear production.

Plant density also alters plant height and leaf area. The partitioning of dry matter to various plant structures is affected. Fleming and Wood (1967), Suapon (1970), and Downey (1971) reported increased field corn plant height at greater densities. Lodging and density are positively related. Brown (1961), Fleming and Wood (1967), and Rutger and Crowder (1967) found that diameter of sweet corn stalks decreased as population increased, thus increasing chances of lodging. A 20% and 50% lodging at 20,000 and 50,000 plants per hectare, respectively, was observed. Similar observations were reported by Kohnke and Miles (1951), Long (1961), Giesbrecht (1969), and Whitaker et al. (1969). The ability of a plant to alter size, mass, or number in relation to density or other environmental stress is called plasticity (Radosevich and Holt, 1984).

Tillering in corn is responsive to plant population. Bailey (1941), and Dungan et al. (1958) reported greater tillering at minimal corn populations. Tillering may increase grain production of corn (Thompson et al., 1930; Dungan, 1931), thereby increasing yield.

Plant density also influences the rate of maturity which is important in multiple cropping. A delay of maturity in densely populated sweet corn was reported by (Bailey, 1941; Enzie, 1942; Suapon, 1970). Early maturity is important in some multiple cropping systems (Moseman, 1966; Swaminathan, 1970) because it allows intensification of cropping over time; hence increasing agricultural productivity. With early maturity, planting dates can be adjusted to avoid environmental stress. In contrast, late maturing varieties are important in other multiple cropping systems. For example, studies on mung bean (Vigna radiata L.) showed that late maturing cultivars performed better than early ones under rainfed conditions with low light intensity and high temperatures (Poehlman, 1978).

Cabbage

Plant density has been shown to significantly affect marketable yield of cabbage (Vittum and Peck, 1956; Bowers and Mulkey, 1967; Miller et al., 1969; Knavel and Herron, 1981). Reduced head sizes were obtained from increased cabbage densities. For example, cabbage heads grown at 37 cm and 95 cm spacing weighed 2 and 4 kg, respectively. Greatest yields, however, were harvested from closely spaced plants because number of plants per hectare increased more than head size decreased. Greater cabbage densities also promote cabbage flavor,thereby suggesting a variation of population densities could influence flavor to suit market requirements.

Information on corn and cabbage intercropping is scarce. Salter et al. (1985) reported greater yields of brussel sprouts intercropped with cabbage than the respective monocrops. Such an intercropping system presented few agronomic or management problems because both crops had similar cultural and crop protection requirements. Other studies showed that winter peas (Pisum sativa L.) intercropped with winter wheat (Triticum aestivum L.) produced yields equal to those produced from monocropped peas (Murray and Swensen, 1985).

Increasing vegetational diversity is a cultural control technique which renders an ecosystem less favorable to pests (Nordlund et al., 1984). Considerable research has shown that crop diversification frequently results in reduced pest incidence. Various intercropping systems affect insect populations by interfering with movement and colonization or by increased herbivore mortality caused by natural enemies. Tahvanainen and Root (1975) reported that tomato and tobacco (Nicotiana tabacum L.) interplanted with collards interfered with orientation and feeding by Phyllotreta cruciferae (Goeze), an important chrysomelid flea beetle attacking cruciferous vegetables. Latheef et al. (1984) observed a reduced population of (Phyllotreta cruciferae Goeze) in collards intercropped with squash (Cucurbita spp), tomato, bean, cowpea, potato (Solanum tuberosum L.), eggplant (Solanum melongena L.), pepper (Capsicum annuum L.), corn, or soybean although collard leaf yield was reduced. Capinera et al. (1985) reported a decreased population of Mexican bean beetle (Epilachna varivestris Muls.) in a sweet corn and bean intercropping system. Beans trapped aphids, thereby decreasing the spread of rosette disease of groundnuts (Arachis hypogea L.) in mixed stands (Thresh, 1982). Radish mosaic decreased when radishes (Raphanus sativus L.) were sown between rows of rice (Oryza sativus L.). The findings identify intercropping as a potential insect pest control measure because mixtures of different crop species buffer against disease losses by delaying the onset of diseases, reducing spore dissemination, or modifying microenvironmental conditions including altering soil temperature and moisture (Olasantan, 1988).

Intercropping has also been reported to suppress weed growth (Ikeorgu et al., 1989; Chaudhary, 1981; Williams et al., 1973; William and Chiang, 1980).

MATERIALS AND METHODS

A sweet corn and cabbage interplanting trial was planted at the Oregon State University Vegetable Research Farm east of Corvallis on a Chehalis silt loam soil (haxizole), a recent alluvial type commonly found along the Willamette river. Four densities (2, 4, 8, and 16 plants/m^2) of 'Jubilee' sweet corn and 'Golden Acre' cabbage were systematically combined using the addition series approach. A total of 24 treatments were tested in the experiment. Treatments were assigned to 9 m^2 plots using a randomized complete block design wih 3 replicates.

A compound fertilizer, 12-29-10-10, was broadcast and disced at 672 kg/ha before sowing regardless of plant population or crop. Sweet corn was direct seeded on 26 and 27 June 1989, whereas cabbage was direct seeded on 28-30 June 1989. Plots were thinned to 1 plant per station 1 week after emergence. Overhead sprinklers supplied moisture every 10 to 14 days for all treatments beginning 30 June 1989. Regular hand weeding controlled weeds in all plots.

Single applications on 4 August 1989 of Disyston (0,0-diethyl S-[2-(ethylthio)ethyl] phosphorodithioate) and Diazinon (2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate controlled cabbage root maggot (<u>Hylemya</u>

brassicae Weidemann), cabbage aphid (Brevicoryne brassicae L.), and spotted cucumber beetle (Diabrotica undecimpunctata Mannerheim). Sweet corn plant height, dry matter, and leaf area were measured every two weeks after emergence,although data reported for growth analysis was collected from week 6 to 12 when plant growth was vigorous. One plant of each crop was sampled for the measurements. All leaves on the plant were measured for leaf area using the LI-3100 leaf area meter. The plant was then dried in a tunnel dryer at 110 ^{o}F for dry weight. A 1 meter ruler was used to take plant height measurements. Sweet corn was harvested on 16 October 1989 when kernel moisture was 68% to 71%. Sweet corn kernels from three ears of each treatment were dried in the tunnel dryer in order to obtain dry weight which was used for calculating the moisture percentage. Percent kernel moisture was calculated using the following formula:

Percent kernel moisture = (W1 - W2)/W1 * 100 where W1 was the wet weight and W2 was the dry weight of kernels.

Sweet corn measurements recorded at harvest included total yield of unhusked and husked ears, number of plants, and number of ears harvested. Ear characteristics measured from the main usable husked ears included ear length and diameter, kernel depth, kernel moisture, and number of rows per ear. Cabbage was harvested as heads matured beginning from 18 September and ending on 11 November 1989 with a total of four harvests. Maturity was determined by feeling the firmness of each head. Cabbage measurements recorded at harvest included head circumference, head diameter, number of heads harvested, and total head weight. A multiple regression analysis of the cabbage and sweet corn data was conducted to find interaction between densities of the two crops. A least significance difference test separated means of corn yield, cabbage yield, corn ear and cabbage head characteristics between treatment combinations. Land equivalence ratio (LER) and area time equivalence ratio (ATER) were calculated in order to determine the efficiency of the intercropping system using the following formulae:

$$LER = RY_c + RY_s$$

$ATER = (RY_c * t_c) + (RY_s * t_s)/T$ where RY_c = relative yield of cabbage and RY_s = relative yield of sweet corn = (Yield of intercrop/ha)/(Yield of monocrop/ha), t_c and t_s = duration (days) for cabbage and sweet corn, respectively. T = duration (days) of the intercrop system.

Relative growth rate (RGR), net assimilation ratio (NAR), dry matter (DM) content, and leaf area were calculated in order to quantify the competition between sweet corn and cabbage using the following equations:

$$RGR\ (g/day) = \frac{(\ln W_2 - \ln W_1)}{t_2 - t_1}$$

where W_1 and W_2 are plant dry weight (g) at time 1 (t_1 - days) and time 2 (t_2 - days), respectively,

$$NAR\ (g/cm2/day) = \frac{(W_2 - W_1)(\ln A_2 - A_1)}{(A_2 - A_1)(t_2 - t_1)}$$

where A_1 and A_2 are leaf areas (cm2) at the beginning and the end of the harvest interval.

DM = W2-W1

Leaf area = A2-A1

RESULTS

Cabbage response

As density increased, cabbage yield (kg/plot) also increased and then declined (Figure 1). Maximum yield of 82t/ha was observed at 8 plants/m^2 (Table 1). Cabbage head circumference (cm) decreased with increasing density (Figure 2). The minimum density of 2 plants/m^2 produced heads weighing 2 kg, whereas heads from 16 plants/m^2 weighed 0.5 kg each. A density of 8 plants/m^2 produced heads weighing 1.0 kg.

In sweet corn and cabbage intercropped treatments, only cabbage plants intercropped with corn density of 2 plants/m^2 produced firm heads (Table 1). Yields, however, generally increased with increasing density as in treatments where cabbage was growing alone reaching a maximum at a combination of 0 and 8 plants/m^2 sweet corn and cabbage, respectively. Average cabbage head weight was reduced by 0.3 kg at this maximum compared to the monocrop treatments. Days to cabbage harvesting were increased by density and species proportion. Cabbage monoculture (cabbage growing alone) at lower densities were harvested on 18 September 1989, whereas greatest densities of 16 plants/m2 treatments were harvested on 7 October 1989. Cabbage intercropped with 2 plants/m^2 sweet corn was harvested on 11 October and 19 November 1989. Cabbage intercropped with greater sweet corn densities (4, 8, 16 plants/m2) failed to form heads eight weeks after corn stalks were removed.

Sweet corn response

Monoculture sweet corn yield was proportional to density (Figure 3). The lowest density of 2 plants/m^2 produced 19t/ha sweet corn, whereas 26t/ha were harvested from 16 plants/m^2 (Table 2).

Sweet corn interplanted with cabbage showed a similar yield (kg/plot) response as monocultures (Figure 3). Densities of 16 plants/m^2 sweet corn and 8 plants/m^2 cabbage produced highest yield of 28t/ha sweet corn, whereas the lowest yield of 10t/ha was obtained from densities of 2 plants/m^2 and 16 plants/m^2 sweet corn and cabbage, respectively (Table 2).

Sweet corn yield increases were evaluated against relative growth rate (grams of dry matter/day), net assimilation ratio (grams of dry matter/cm2/day), plant height (cm), ear length (cm) and diameter (cm), kernel depth (cm), and moisture content (%).

Plant height increased with increasing sweet corn density. A density of 16 plants/m^2 produced tallest plants in contrast to those from 2 plants/m^2 population (Table 3). Corn stalks were thinner than those from lower densities. In contrast, less competition for horizontal space influenced tillering at 2 plants/m^2 where each plant produced 4 tillers (Figure 4). 'Jubilee' sweet corn has the potential of producing 2 ears per plant, but increasing densities resulted in a maximum of 1 tiller per plant and only 1 ear per plant (Table 4). In contrast, tillers from low densities produced at least a corn ear each.

Sweet corn ear length, diameter, number of kernel rows per ear, and kernel depth were reduced as population increased. There were significant differences between treatments (Tables 5, 6, 7, 8). Kernel moisture also was significant among treatments (Table 9).

To judge whether sweet corn and cabbage should be grown as component crops, the concept of LER was explored. The four intercropped treatments in the experiment produced LERs ranging from 0.57 to 0.96 indicating a yield disadvantage. Another approach to calculating LER was pursued. Yields of monoculture treatments of both sweet corn and cabbage at 2 plants/m2 were each divided by 2. Assuming the quotients were yields harvested from the same plot whose half was planted to sweet corn and the other to cabbage, a LER was calculated in the same manner as before. All monoculture treatments were treated in the same manner. LERs obtained from this approach for all the treatments equaled 1 again indicating a yield disadvantage if the planted area was divided into two blocks, i.e. one for sweet corn and the other for cabbage. ATERs ranged from 0.51 to 0.76.

GROWTH ANALYSIS

Sweet corn RGR (g DM/day) decreased over time with density (Figure 5). A combination of 4 corn plants/m^2 and 16 cabbage plants/m^2 produced the highest corn RGR, whereas the lowest came from the monoculture sweet corn density of 16 plants/m^2. The corn NAR (g of DM/cm2/plant/day) also declined with density (Figure 6). A density of 4 corn plants/m^2 produced the maximum and 16 corn plants /m^2 the minimum.

Cabbage NAR and RGR declined with density and species proportion (Figures 7, and 8). Leaf area (cm2) for both crops declined with densities (Figures 9 and 10). Plant dry weights (g/plant) of both cabbage and sweet corn declined with increasing density (Figures 11, and 12).

DISCUSSION

The results have shown that density manipulation could be used as a management strategy to produce crops of different sizes for specific markets. Increasing cabbage density reduces head diameter and circumference. Similar findings were reported by Vittum and Peck (1956), Devey (1965), Halsey (1966), Bowers and Mulkey (1967), Miller et. al (1969), Alexander and Nussbaum (1976), and Knavel and Herron (1981). Small to medium cabbage heads are preferred by most consumers in many parts of the world, particulary those with inadequate or no cold storage facilities. Cabbage head sizes also are important in mechanized cabbage harvesting.

Sweet corn yield density relationship was similar to that of cabbage in that corn yield increased with density. This is in agreement with Vittum et al. (1959), Colville and McGill (1962), Brown et al. (1970), Mack (1972), and Moss and Mack (1979) who reported that sweet corn yield could be increased with higher densities. However, sweet corn ear characteristics were reduced as density increased. Reduced ear characteristics are sometimes important if the product is marketed for processing in which case a range of ear sizes is accepted.

The primary objective of multiple cropping is to increase agricultural productivity. It is, therefore, important that in selecting crops for intercropping, compatibility is considered. The results suggest that sweet corn and cabbage are not compatible because cabbage yield was seriously reduced when corn and cabbage were interplanted. Reduced yields were probably due to the shading and competition by corn. The intensity of competition should have been greater with increasing corn density because cabbage interplanted with sweet corn at densities greater than 2 plants/m^2 failed to form heads even after corn stalks were removed. The calculated LERs and ATERs were all less than 1 indicating that it was not efficient to interplant these two crops. Cabbage stems were etiolated, leaves senescenced earlier and in some treatments, cabbage mortality was greater. In contrast, cabbage density had no significant effect on sweet corn because corn dominated the competition for light, space, water and nutrients and, therefore, the relative growth rate, net assimilation rate, leaf area, and dry matter accumulation for sweet corn was greater than that of cabbage. A decline of RGR, NAR, and leaf area could be attributed to the competition and lack of available nitrogen for optimum growth since yellowing in some plots was observed but not quantified. Allen and Obura (1983) found similar responses when corn was interplanted either with cow pea (Vigna unguiculata L.) or soybean.

At greater densities, sweet corn responded by building a tall stem which may have contributed to suppression of cabbage. Monyo (1976) observed similar results where cassava suppressed okra and french bean yield in an intercropping system. Similarly, Cordero and McCollum (1979) harvested less soybean (Glycine max L.) in a corn interplanting system. Shultz et al. (1987) observed decreased tomato yield with increasing cucumber density.

Days to cabbage harvesting increased with density and species proportion. Low monoculture cabbage densities matured earlier than high density treatments. Cabbage interplanted with sweet corn matured towards the end of the intercropping duration. Sweet corn ear maturity also was delayed with corn density although sweet corn harvesting was completed the same time. Bailey (1941), Enzie (1942), and Suapon (1970) also reported that densely populated sweet corn delayed maturity. Delayed maturity, however, could spread the availability of a crop over time.

SUMMARY

An experiment whose objective was to evaluate advantage of interplanting sweet corn and cabbage at optimum densities was conducted at OSU Vegetable Research Farm. Results showed increased sweet corn yield with density in both monoculture and interplanted treatments. Sweet corn ear characteristics were reduced by density and species proportion. Greater densities reduced number of tillers and number of ears. Cabbage density had no significant effect on corn.

Similarly cabbage yield was proportional to density in both monoculture and intercropped treatments, although, cabbage yield was reduced by corn density. Cabbage yields were obtained only from treatments in which cabbage was interplanted with 2 corn plants/m2 although head sizes were reduced.

The primary objective of multiple cropping is to increase agricultural productivity for family needs. LER and ATER showed a yield disadvantage if corn and cabbage were intercropped. Therefore, in selecting crops for intercropping, compatibility should be evaluated.
Growth analysis results indicate that density and species proportion reduced the growth of sweet corn and

cabbage with the latter being the most affected.

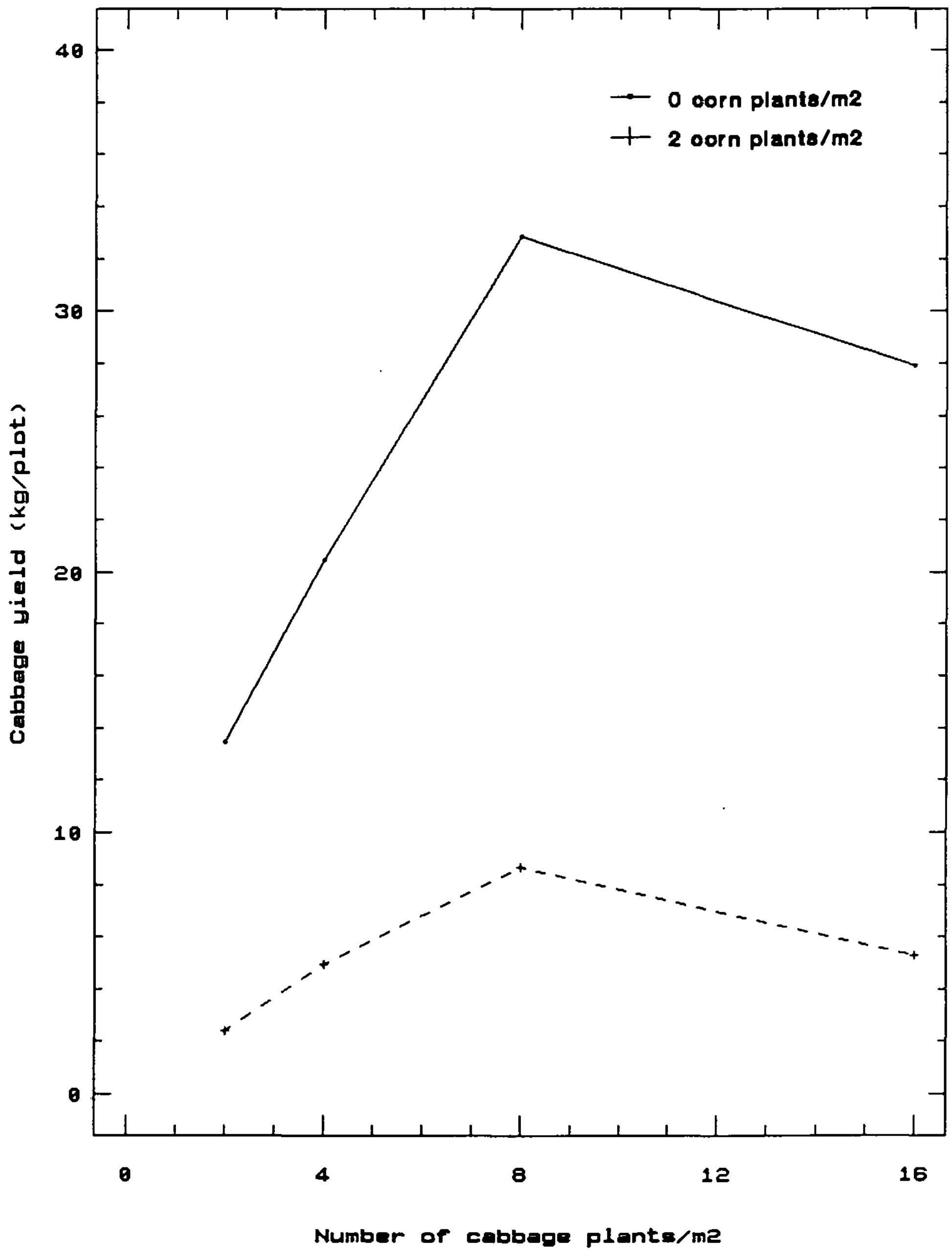

Figure 1. Effect of density and species proportion of sweet corn and cabbage on yield (kg/plot) of cabbage.

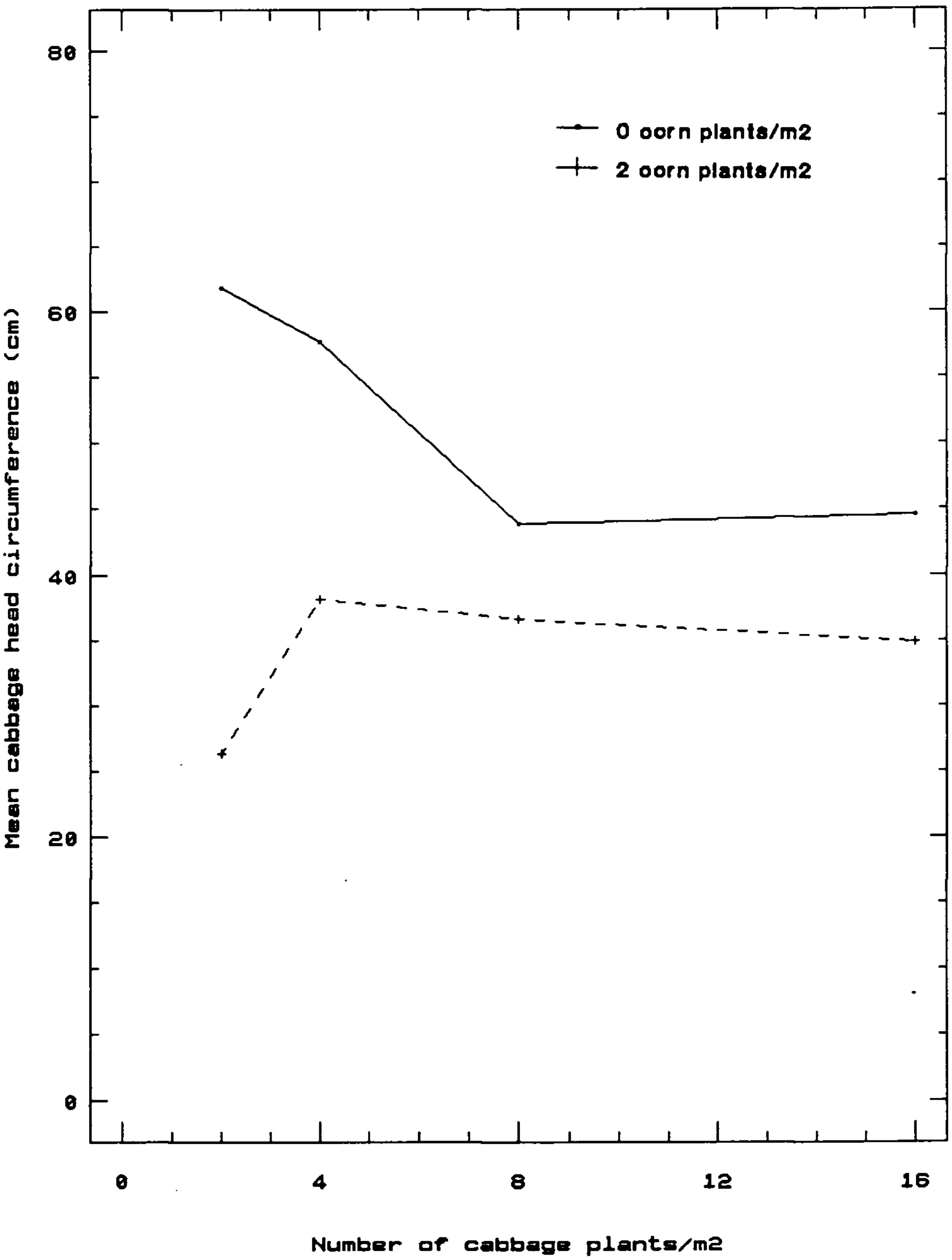

Figure 2. Effect of density and species proportion of sweet corn and cabbage on cabbage head circumference (cm) per plot.

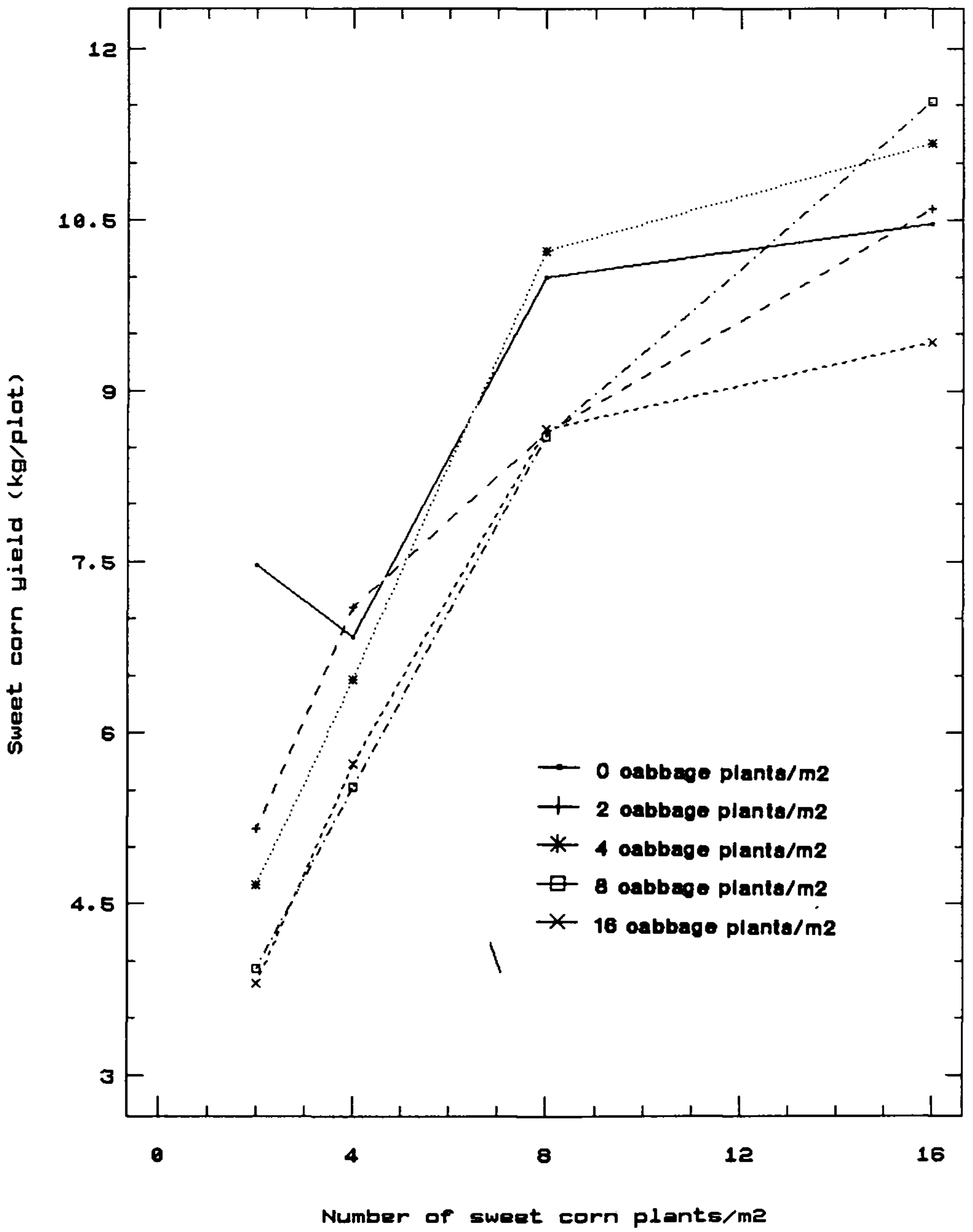

Figure 3. Effect of density and species proportion of sweet corn and cabbage on sweet corn yield (kg/plot).

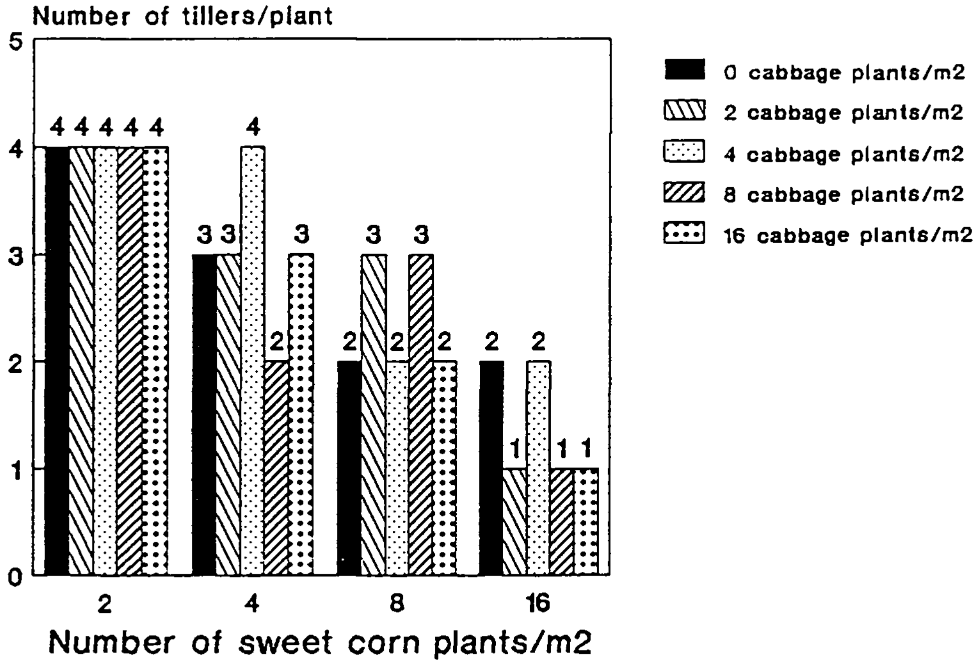

Figure 4. Effect of density and species proportion of sweet corn and cabbage on number of sweet corn tillers per plant per treatment.

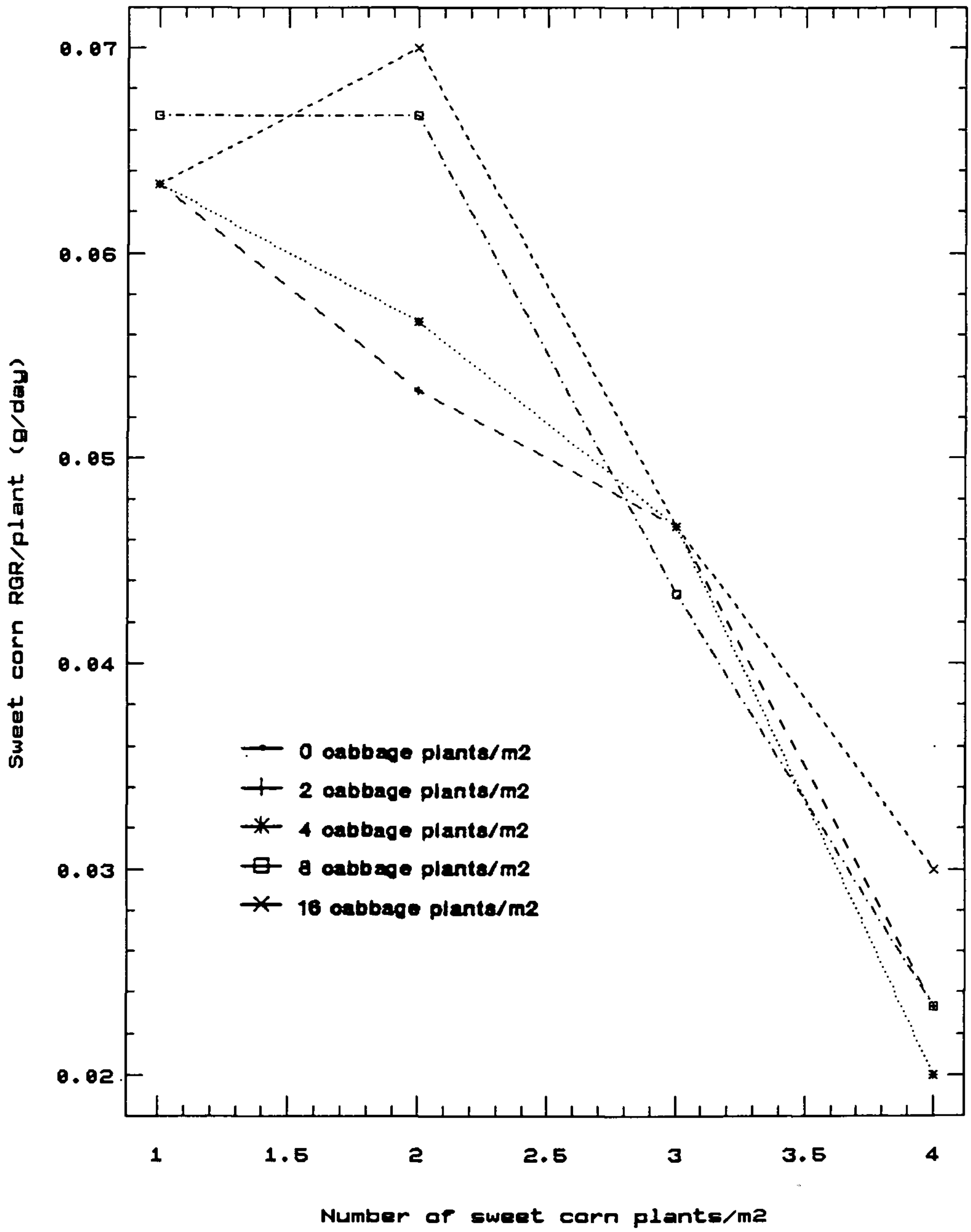

Figure 5. Effect of density and species proportion of sweet corn and cabbage on sweet corn RGR (g/day) per plant/plot.

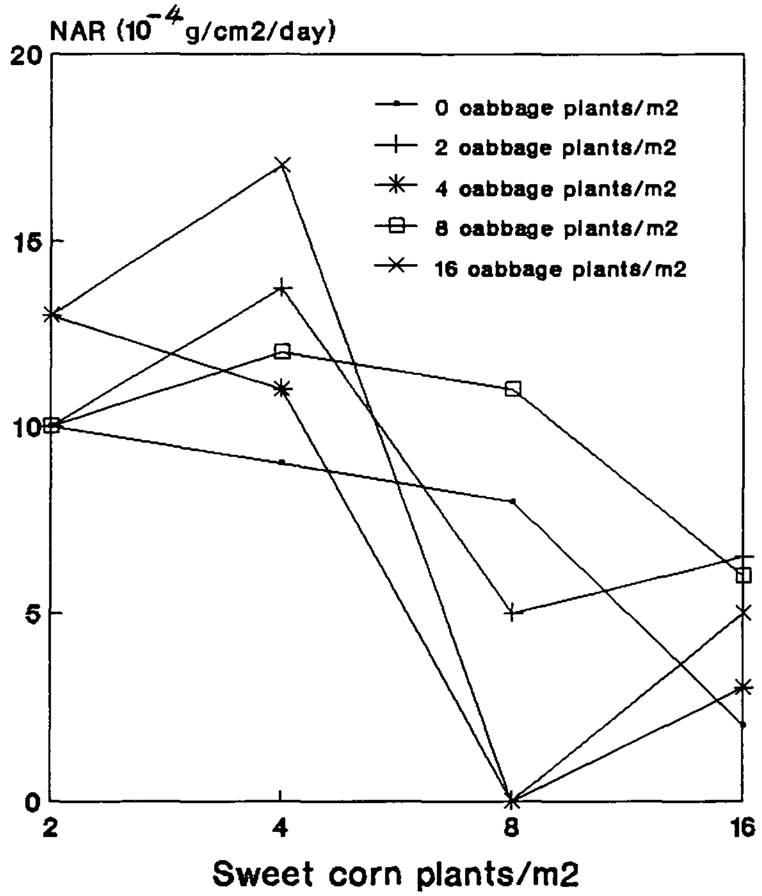

Figure 6. Effect of density and species proportion of sweet corn and cabbage on sweet corn NAR (10^{-4} g/cm2/day) per plant per plot.

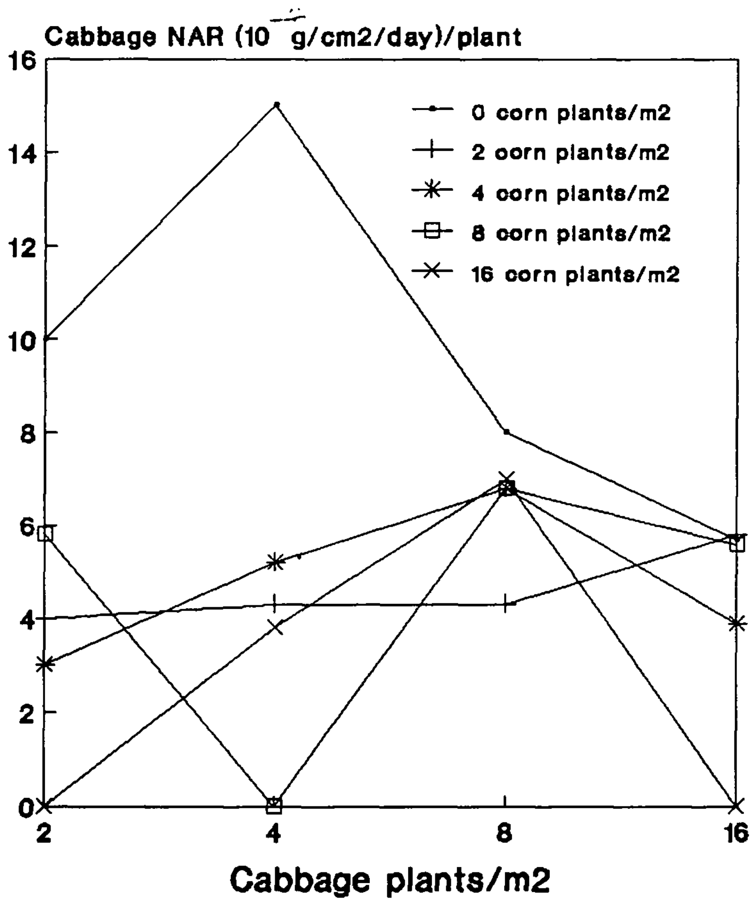

Figure 7. Response of cabbage NAR (10^{-4} g/cm2/day) per plant per plot to density and species proportion of sweet corn and cabbage.

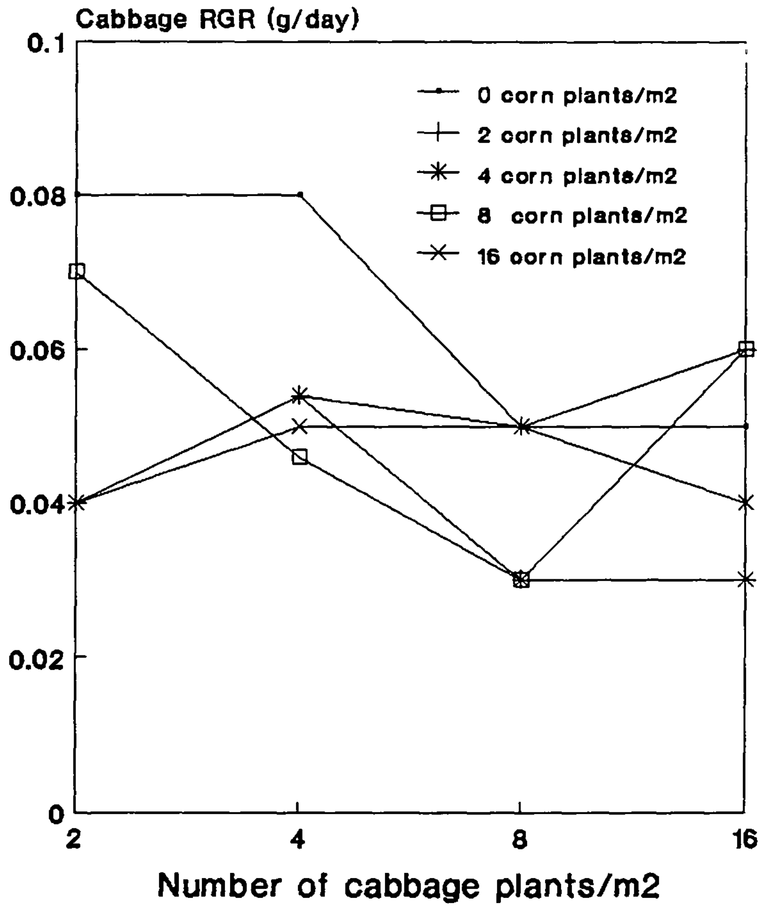

Figure 8. Effect of density and species proportion of sweet corn and cabbage on cabbage RGR (g DM/day) per plant per plot.

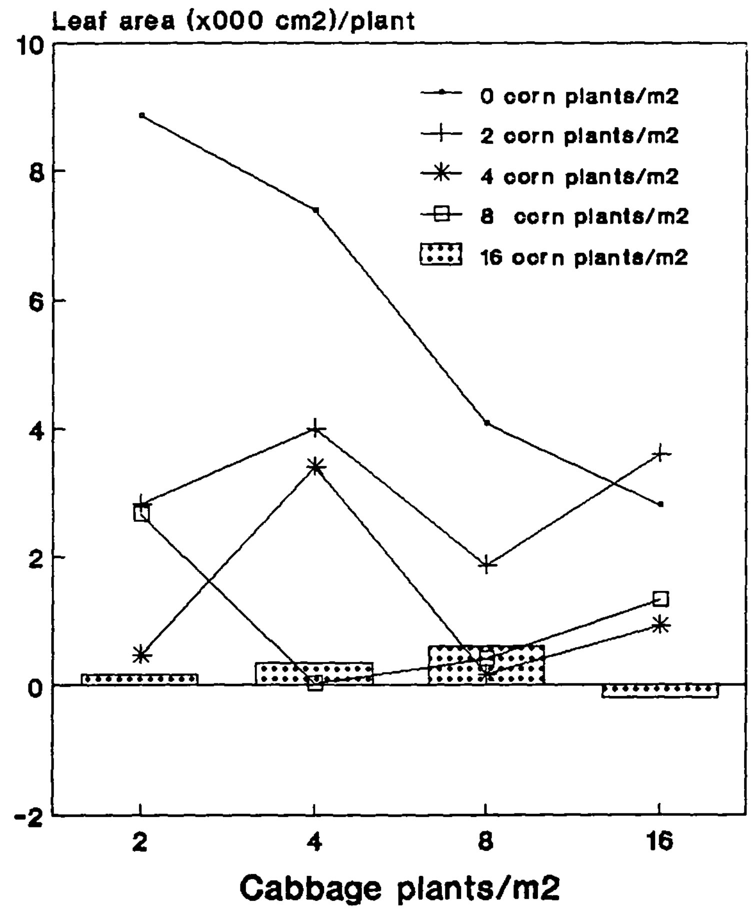

Figure 9. Effect of density and species proportion of sweet corn and cabbage on cabbage leaf area (cm2) per plant per plot.

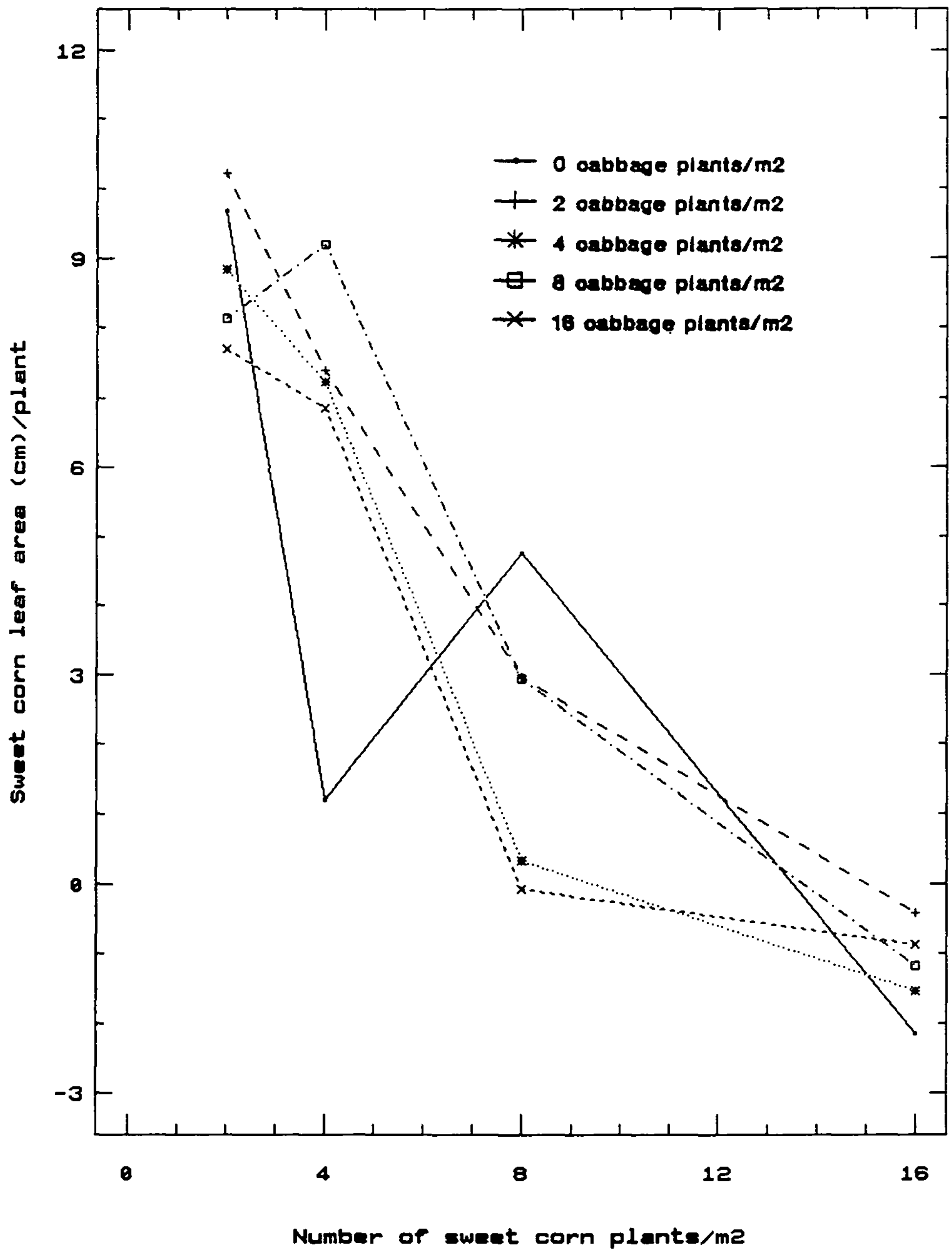

Figure 10. Sweet corn leaf area (cm2) per plant per plot as affected by density and species proportion of sweet corn and cabbage.

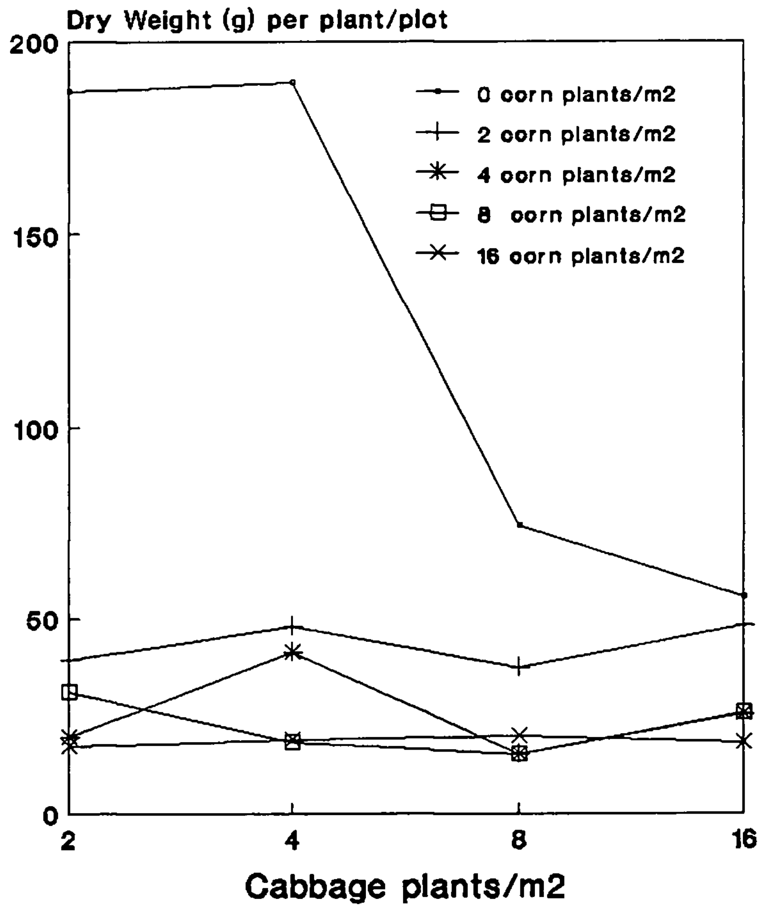

Figure 11. Cabbage dry weight (g) per plant per plot as affected by density and species proportion of sweet corn and cabbage.

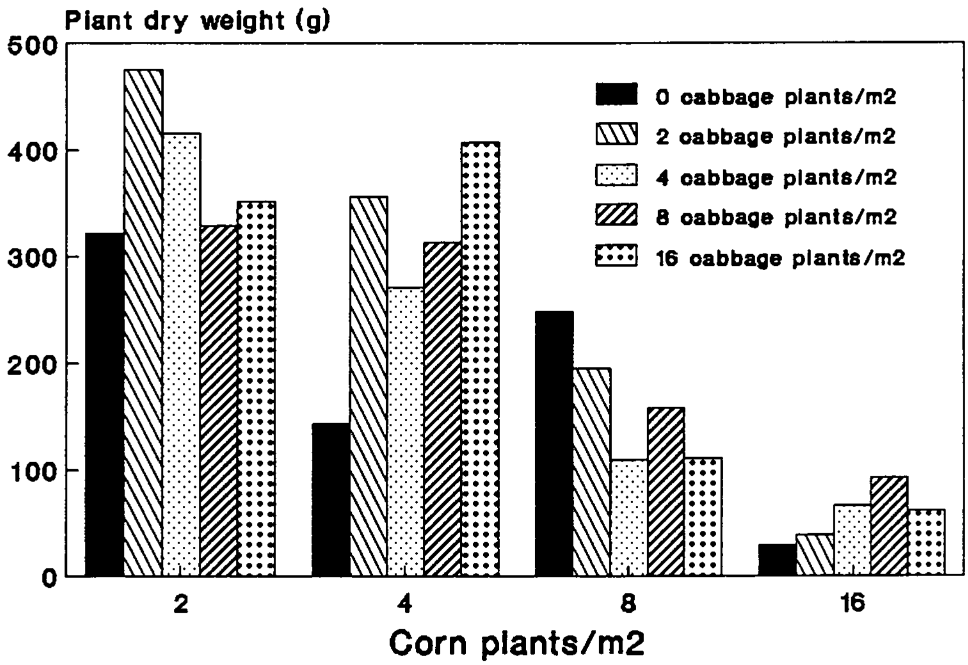

Figure 12. Sweet corn dry weight (g) per plant per plot as affected by density and species proportion of sweet corn and cabbage.

Table 1. Effect of density and species proportion of sweet corn and cabbage on mean yield (t/ha) of cabbage per plot.

Number of plants/m2		Mean yield
Sweet corn	Cabbage	(t/ha)
2	2	6 a
2	16	8 a
2	4	10 a
2	8	17 a
0	2	34 ab
0	4	51 bc
0	16	70 d c
0	8	82 d

LSD = 11.4

Means underscored by the same letter are not significantly different at 5% according to LSD.

Table 2. Effect of density and species proportion of sweet corn and cabbage on the yield (t/ha) of sweet corn per plot.

Number of plants/m2 Sweet corn	Cabbage	Mean yield of corn (t/ha)	
2	16	10	a
2	8	10	ab
2	4	12	abc
2	2	13	abcd
4	8	14	abcd
4	16	14	abcd
4	4	16	bcde
4	0	17	f cde
4	2	18	f cde
2	0	19	fg de
8	8	22	fgh e
8	2	22	fgh e
8	16	22	fgh e
16	16	24	fghi
8	0	25	ghi
8	4	26	hi
16	0	26	hi
16	2	27	hi
16	4	28	hi
16	8	28	i

LSD = 2.6

Means underscored by the same letter are not significantly different according to LSD at 5% level.

Table 3. Effect of density and species proportion of sweet corn and cabbage on the sweet corn plant height (cm) per plot.

Number of plants/m2		Mean plant height (cm)	
Sweet corn	Cabbage		
2	16	214.5	a
2	8	218.5	ab
4	0	219.0	ab
2	4	225.2	abc
4	16	225.5	abc
2	2	226.0	abc
8	16	231.8	abcd
2	0	232.7	abcd
4	2	234.0	abcd
16	16	234.3	abcd
4	4	235.0	abcde
8	8	236.8	abcde
4	8	238.7	bcde
8	2	239.7	bcde
16	0	241.2	bcde
16	4	245.8	cde
8	0	246.0	cde
8	4	252.0	f de
16	8	258.5	f e
16	2	270.0	f

LSD = 23.6

Means underscored by the same letter are not significantly different according to LSD at 5% level.

Table 4. Number of sweet corn tillers per plot, plants, and number of ears harvested/plot.

Plants/m^2		Tillers	Plants harvested	Ears harvested
Sweet corn	Cabbage	per plot	per plot	per plot
		(no.)	(no.)	(no.)
2	0	4	10	25
4	0	3	16	27
8	0	2	37	37
16	0	2	63	63
2	2	4	7	21
4	2	3	16	31
8	2	3	31	32
16	2	1	61	61
2	4	4	7	19
4	4	4	16	26
8	4	2	36	37
16	4	2	61	61
2	8	4	7	16
4	8	2	17	23
8	8	3	34	36
16	8	1	65	65
2	16	4	10	16
4	16	3	17	22
8	16	2	39	39
16	16	1	60	60

Table 5. Effect of density and species proportion of sweet corn and cabbage on sweet corn ear length (cm) per plot.

Number of plants/m2 Sweet corn	Cabbage	Mean ear length (cm)	
16	0	14.5	a
16	2	14.7	a
16	8	15.0	a
16	16	15.7	ab
2	8	15.2	ab
16	4	15.5	abc
8	16	16.7	bcd
2	16	17.1	cd
8	8	17.1	cd
2	2	17.4	d
4	16	17.5	d
8	2	17.5	d
4	4	17.6	d
8	4	17.6	d
2	4	17.7	d
4	2	17.8	d
4	8	17.8	d
8	0	17.9	d
2	0	18.2	d
4	0	18.3	d

LSD = 1.6

Means underscored by the same letter are not significantly different at 5% probability level according to LSD.

Table 6. Effect of density and species proportion of sweet corn and cabbage on the diameter (cm) of sweet corn ear per plot.

Number of plants/m2		Mean ear diameter (cm)
Sweet corn	Cabbage	
16	16	4.9 a
16	0	4.9 a
16	2	4.9 a
16	4	5.0 ab
16	8	5.0 ab
8	16	5.1 bc
8	2	5.2 dbc
8	8	5.2 dbce
8	4	5.3 d ce
8	0	5.3 d ce
2	2	5.3 d ce
2	8	5.3 d ce
2	16	5.3 d ce
4	4	5.3 d ce
4	16	5.3 d ce
4	8	5.4 d e
4	2	5.4 d e
2	4	5.4 e
2	0	5.4 e
4	0	5.4 e

LSD = 0.20

Means underscored by the same letter are not significantly different from each other at 5% level according LSD.

Table 7. Effect of density and species proportion of sweet corn and cabbage on the number of sweet corn kernel rows per ear per plot.

Number of plants/m2		Mean rows/ear
Sweet corn	Cabbage	(no.)
2	8	16 a
4	2	16 a
16	8	16 a
2	16	16 a
4	8	16 a
4	4	16 a
16	16	18 ab
16	2	18 ab
4	16	18 ab
4	0	18 ab
8	8	18 ab
8	0	18 ab
2	4	18 ab
2	0	18 ab
8	16	18 ab
16	0	18 ab
16	4	18 ab
2	2	18 ab
8	2	18 ab
8	4	18 ab

LSD = 2.2

Means underscored by the same letter are not significantly different at 1% level of significance according to LSD.

Table 8. Effect of density and species proportion of sweet corn and cabbage on the sweet corn kernel depth (cm) per ear per plot.

Number of plants/m2		Mean kernel depth
Sweet corn	Cabbage	(cm)
16	16	1.3 a
16	0	1.3 a
16	4	1.3 a
16	8	1.3 ab
2	8	1.3 abc
8	8	1.3 abc
8	16	1.3 abc
8	2	1.3 abc
16	2	1.3 abc
2	16	1.4 abc
8	0	1.4 abc
4	8	1.4 abc
2	4	1.4 abc
2	0	1.4 bc
4	16	1.4 bc
2	2	1.4 bc
8	4	1.5 c
4	0	1.5 c
4	4	1.5 c
4	2	1.5 c

LSD = 0.13

Means underscored by the same letter are not significantly different at 5% probability level according LSD.

Table 9. Effect of density and species proportion of sweet corn and cabbage on the sweet corn kernel moisture (%) per plot.

Number of plants/m2		Mean kernel moisture (%)	
Sweet corn	Cabbage		
16	7	68	a
8	0	68	a
8	16	69	ab
16	0	69	ab
16	8	69	ab
8	8	69	ab
8	2	69	ab
2	0	70	abc
2	8	70	abc
2	16	70	abc
8	4	70	abc
16	4	70	abc
4	2	70	abc
16	16	70	abc
4	16	70	abc
2	4	70	abc
4	8	71	bc
4	4	71	bc
2	2	71	bc
4	0	72	c

LSD = 2.5

Means underscored by the same letter are not significantly different according to LSD at 1% level.

LITERATURE CITED

Alexander, J. M, and M. Nussbaum. 1976. The effects of different horticutural practices on the chemical flavor composition of some cabbage cultivars. Phytochemistry. 16:861-865.

Allen, J.R., and R.K. Obura. 1983. Yield of corn and soybean under different intercropping systems. Agron. J. 75:1005-1009.

Andrews, D.J., and A.H. Kassam. 1976. The importance of multiple cropping in inreasing world food supplies. In M. Stelly, L.C. Eisele, and J.H. Nauself (eds.). Multiple cropping. Amer. Soc. Agron., Madison, Wisc.

Bailey, R.M. 1941. The effect of plant spacing on yield, ear size, and other characters in sweet corn. Proc. Amer. Soc. Hort. Sci. 38:546-553.

Bleasedale, J.K.A. 1966. Plant growth and crop yield. Ann. Appl. Biol. 57:173-182.

Bleasedale, J.K.A. 1967. The relationship between the weight of a plant part and total weight as affected by plant density. J. Hort. Sci. 42:51-58.

Bowers, J.L., and W.A. Mulkey. 1967. Cabbage variety trials. Ark. Farm Res. 16(1):9.

Brown, B.A. 1961. Lodging is a problem in thick corn forage. Crops and Soils. 14(2):20.

Brown, R.H., E.R. Beaty, W.J. Ethredge, and D.D. Hayes. 1970. Influence of row width and plant population of two varieties of corn (Zea mays L.). Agron. J. 62:767-770

Brown, J.E., W. E. Splittsoesser and J, M. Gerber. 1985. Production and economic returns of three vegetable double cropping systems. J. Amer. Soc. Hort. Sci. 110(3):414-417.

Capinera, J.L., T.J. Weissling, and E.E. Schweizer. 1985. Compatibility of intercropping with mechanized agriculture: effects of strip intercropping of pinto beans and sweet corn on insect abundance in Colorado. J. Econ. Ent. April. 78:354-7.

Chaudhary, A.H. 1981. Effects of population and inter-row spacing on yields of maize and control of weeds with herbicides in the irrigated savanna. Expl. Agric. 1981(17):389-397.

Chipman, E.W., and D.C. Mackay. 1960. The interactions of plant populations and nutritional levels on the production of sweet corn. Proc. Amer. Soc. Hort. Sci. 76:442-447.

Colville, W.L., and D.P. McGill. 1962. Effect of rate and method of planting on several plant characters and yield of irrigated sweet corn. Agron. J. 54:235-238.

Cordero, A., and R.E. McCollum. 1979. Yield potential of interplanted annual food crops in southern U.S. Agron. J.71:834-842.

Devey, J.B. 1965. Spacing cabbages to regulate head size. Queensland Agr. J. 91:394-395.

Dolan, D.D. and E.P. Christopher. 1952. Plant spacing of sweet corn. Univ. of Rhode Island Agric. Expt. Sta. Bul. 316.

Donald, C.M. 1963. Competition among crop and pasture plants. Adv. Agron. 15:1-118.

Downey, L.A. 1971. Plant density-yield relations in maize. J. Aust. Inst. Agr. Sci. 37:138-146.

Dungan, G.H. 1931. An indication that corn tillers may nourish the main stalk under some conditions. J. Amer. Soc. Agron. 23:662-670.

Dungan, G.H., A.L. Lang, and J.W. Pendleton. 1958. Corn plant population in relation to soil and productivity. Advances in Agronomy. 10:435-473.

Early, E.B., R.J. Miller, G.L. Reichert, R.H. Hagemann, and

R.D. Sief. 1966. Effects of shade on maize production under field conditions. Crop Sci. 6:1-6.

Eddowes, M. 1969. Physiological studies of competition in Zea mays L. III. Competition in maize and its practical implications for forage maize production. J. Agr. Sci. Camb. 72:203-215.

Enzie, W.D. 1942. The relation of spacing to yield and to plant and ear development of some yellow sweet corn hybrids in New York. N.Y. State Agr. Expt. Sta. Bul. 700.

Fleming, A.A., and E.H. Wood. 1967. Effect of soil moisture and plant population on corn hybrids at high fertility level. Agron. Abstr. Div.C-3:35-36.

Francis, C.A. 1986. Multiple cropping systems. Macmillan Publishing Company. N.Y.

Freyman, S., M.S. Kalddy, G.C. Kozub, S. Dubetz, and W.T. Andrew. 1972. Spacing and fertilization studies on sweet corn and irrigation in Southern Alberta. Can. J. Plant Sci. 52:881-886.

Giesbrecht, J. 1969. Effect of population and row spacing on the performance of four corn (Zea mays L) hybrids. Agron. J. 61:439-441.

Gomez, A.A., and A.K. Gomez. 1983. Multiple cropping in the humid tropics of Asia. Ottawa Ont. IDRC, 1983. 248pp.

Grime, J.P., and R. Hunt. 1975. Relative growth rate, its range and adaptive significance in a local flora. J. Ecol. 63(2):393-422.

Halsey, L.H. 1966. Influence of variety and spacing on yield of cabbage from a single harvest. Proc. of Florida State Horticultural Society. 70:194-201.

Harper, J.L. 1977. Population biology of plants. Academic Press N.Y. 892pp.

Hiebsch, C.K. 1980. Principles of intercropping: Effects of nitrogen fertilization, plant population, and crop duration on equivalency ratios in intercrop versus monoculture comparisons. Ph.D. Diss. North Carolina State Univ., Raleigh, N.C. (Diss. Abstr. 41B:4337.

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

Horwith, B. 1985. A role for intercropping in modern agriculture. BioScience 35(5):286-291.

Ikeorgu, J.E.G., T.A.T. Wahua, H.C. Enzumah. 1989. Effect of melon (Citrulis lunatus Thumb), and okra (A. esculentus L) on the soil moisture and leaf water status of intercropped cassava/maize in Nigeria. Tropical Agriculture. January. 66:78-82.

Keswani, C.L., and B.J. Ndunguru (eds). 1980. Proceedings of the second symposium on intercropping in semi arid areas held at Morogoro, Tanzania. Aug.

Knavel, D.E., and J.W. Herron. 1981. Influence of tillage system, plant spacing, and nitrogen on head weight, yield, and nutrient concentration of spring cabbage. J. Amer. Soc. Hort. Sci. 106(5):540-545.

Kohnke, H., and S.R. Miles. 1951. Rates and patterns of seeding corn on high fertility level land. Agron. J. 43:488-493.

Lang, A.L, J.W. Pendleton, and G.H. Dungan. 1956. Influences of population and nitrogen levels on yield and protein and oil contents of nine corn hybrids. Agron. J. 48:284-289.

Latheef, M.A., J.H. Ortiz. 1984. Influence of companion herbs on Phyllotreta cruciferae (Coleoptera:chrysomelidae) on collard plants. J. Econ. Ent. Feb. 77:80-82.

Long, O.H. 1961. Nitrogen and plant population in corn production. Tenn. Agr. Exp. Sta. Bul. 337.

Nordlund, D.A., R.B. Chalfant, W.J. Lewis. 1984. Anthropod populations, yield, and damage in monocultures and polycultures of corn, beans, and tomatoes. Agric. Ecosy. Env. Nov. 11:353-67.

Mack, H.J. 1968. Effects of plant arrangement and population density on yield of bush beans. Proc. Amer. Soc. Hort.Sci.

92:418-425.

Mack, H.J. 1972. Effects of population density, plant arrangement and fertilizers on yield of sweet corn . J. Amer. Soc. Hort. Sci. 97(6):757-760.

Menegay, M.R., J.N. Hubbel, and R.D. William. 1978. Crop intensity index: A research method of measuring land use in multiple cropping. HortScience 13(1):8-11.

Miller, C.H., W.E. Splinter, and F.S. Wright. 1969. The effect of cultural practice on the suitability of cabbage for once-over harvest. J. Amer. Soc. Hort. Sci. 94:67-69.

Monyo, J.H. 1976. Intercropping in semi arid areas. ADR Ker and Marilyn Campbell Ed. IDRC. pp72.

Moseman, A.H. 1966. International needs in plant breeding research. In Plant breeding. Iowa State Univ. Press. Ames. Iowa.

Moss, J.D., H.J. Mack. 1979. Effect of plant density and nitrogen fertilizer on sweet corn. HortScience 14:176-177.

Murray, G.A., and J.B. Swensen. 1985. Seed yield of Austrian field winter peas intercropped with winter cereals. Agron. J. 77:913-916.

Olasantan, F.O. 1988. The effects of soil temperature and moisture content and crop growth and yield of intercropping maize with melon (Colocynthis vulgaris). Exptl. Agric. January. 24:67-74.

Patterson, D.T. 1982. Effects of light and temperature on weed/crop competition. Biometeorology in IPM. Academic Press. New York.

Poehlman, J.M. 1978. What we have learned from the international mung bean nurseries. First international mung bean symposium. AVRDC, Tainan, Taiwan.

Radosevich, S.R., and J.S. Holt. 1984. Weed ecology: Implications of vegetation management. John Willey and Sons. New York.

Radosevich, S.R. 1987. Methods to study interactions among crops and weeds. Weed Technol. 1:191-198.

Roush, M.L., and S.R. Radosevich. 1985. Relationships between growth and competitiveness of four annual weeds. J. Appl. Ecol. 23:895-905.

Roush, M.L., and S.R. Radosevich. 1987. A weed community model of germination, growth and competition of annual weed species. WSSA abstracts. St. Louis.

Rutger, J.N., and L.V. Crowder. 1967. Effect of high plant density on silage and grain yields on six corn hybrids. Crop Sci. 7:182-184.

Ruthenberg, H. 1971. Farming systems in the tropics. Oxford University Press. London. pp366.

Salter, P.J., Akehurst, M. Jayne, G.E.L. Morris. 1985. An agronomic and economic study of intercropping brussel sprouts and summer cabbage. Exptl. Agric. 21:153-157.

Salter, P.J. 1986. An alternative method of cutting production costs. National Vegetable Research Station Wellesbourne UK. Growers 105:(4):24-26.

Schultz, B., H. McGuinness, B. Horwith, J. Vandermeer; C. Phillips, I. Perfecto, P. Rosset, R. Ambrose and M. Hansen. 1987. Effects of planting densities, irrigation, and hornworm larvae on yields in experimental intercrops of tomatoes and cucumbers. J. Amer. Soc. Hort. Sci. 112(5):747-755.

Sharaiha, R.K. and N.I. Haddad. 1986. Potential of row intercropping of cabbage, broad bean and corn under Jordan valley conditions. Hort. Abstr. 56:745.

Stang, J.R. 1975. Response of bush snap bean cultivars (Phaseolus vulgaris L) to plant population densities. PhD Thesis. O.S.U.

Stinson, H.T. Jr., and D.N. Moss. 1960. Some effects of shade upon hybrids tolerant and intolerant to dense planting. Agron. J. 52:482-484.

Suapon, O. 1970. High population planting patterns for maximum yield of field corn. MS Thesis. O.S.U.

Swaminathan, M.S. 1970. New varieties for multiple cropping. Indian Farm. 20:9-13.

Tahvanainen, J.O., and R.B. Root. 1975. The influence of vegetational diversity on the population ecology of specialized herbivore , Phyllotreta cruciferae (Coleoptera: Chrysomelidae). Oecologia (Berl) 10:321-346.

Tariah, N.M., and T.A.T Wahua. 1985. Effects of component populations on yields and land equivalent ratios of intercropped maize and cowpeas. Field Crops Research 12:81-89.

Tetio-Kagho, F., and F.P. Gardner. 1988. Response of maize to plant population density. II. Reproductive development, yield, and adjustments. Amer. Soc. Agron. 80(6):935-940.

Thompson, H.C., H.S. Mills, and P.H. Wessels. 1930. Results of sweet corn suckering experiments on Long Island. Cornell Univ. Agr. Exp. Sta. Bul. 509.

Thresh, J.M. 1982. Cropping practices and virus spread. Ann. Rev. Phytopathol. 20:193-218.

Vittum, M.T., N.H. Peck, and A.F. Carruth. 1959. Response of sweet corn to irrigation, fertility level and spacing. N.Y. State Agric. Expt. Sta. Bul. 786.

Vittum, M.T., and N.H. Peck. 1956. Response of cabbage to irrigation, fertility level and spacing. N.Y. State Agr. Expt. Sta. Bul. 777.

Welden, C.W., and W.L. Slauson. 1986. The intensity of competition versus its importance: an overlooked distinction and some implications. Quart. Rev. Biol. 61:23-44.

Whitaker, F.O., H.G. Heinemann, and W.E. Larson. 1969. Plant population and row spacing influences on maximum corn yield. Mo. Agr. Exp. Sta. Bul. 961.

Willey, R.W. 1979. Intercropping its importance and research needs. Parts 1 and 2 Field Crop Abstr. 32:1-10 and 73-83.

Williams, C.F., G. Crabtree, H.J. Mack, and W.D. Lewis. 1973. Effect of spacing on weed competition in sweet corn, snap beans, and onions. J. Amer. Soc. Hort. Sci.98(6):526-529.

Wit de C.T., and J.P. van der Burgh. 1965. Competition among herbage plants. Neth. J. Agric. Sci. 13:212-221.

Yao, A.Y.M., and R.H. Shaw. 1964. Effect of plant population and planting pattern of corn on water use and yield. Agron. J. 56:147-152.

Yassen, A.A. 1985. Effect of nitrogen, row spacings, and population densities on yield and ear characteristics of sweet corn. MS Thesis. O.S.U.