Developing an Effective Southernpea and Sweet corn Intercrop System

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Summary. Southernpea and sweet corn can be intercropped effectively. When simultaneously planted, sweet corn appears to be the dominant crop in the mixture, with intercropped southernpea producing a supplemental yield to intercropped sweet corn. Increasing intercrop plant densities increased the amount of sweet corn yield and reduced the amount of southernpea yield. The reduction in light intercepted by southernpea and sweet corn in the intercrop situation probably contributed to the reduction in yield by these component crops as compared to the yield of these crops as monocrops. The total system LER ($LER_{\text{southernpea}} + LER_{\text{sweetcorn}}$) for the high-population intercropping system, where plant densities for each crop were comparable to the densities of these crops as monocrops, was 1.26. This suggests that intercropping southernpea and sweet corn at this density gave a yield advantage of 26%, or that 26% more land planted in equal proportion of each component crop would be required to produce the same yield as the intercrop. A N application rate of 125 lb/acre (140 kg·ha⁻¹) was optimum for intercropped sweet corn, and there was no advantage of a 2-week delayed planting of sweet corn in this intercrop system.

Advantages of intercropping

There has been an increase in grower interest in using intercropping—the growing of two or more crops simultaneously on the same land—in the development of new cropping systems for their land. Intercropping could reduce management inputs and result in sustainable systems that more effectively use and even potentially replenish natural resources used during crop production for long-term management of farm land. While intercropping has been practiced to a limited degree in developed countries such as the United States (Lewandowski, 1987), it has been practiced more widely in the developing countries of Central America, Asia, and Africa (Andrews and Kassam, 1976; Chowdbury and Misangu, 1979; De and Singh, 1979; Jodha, 1979; Krantz, 1979; Okigbo, 1979; Willey and Osiru, 1972). Some benefits of intercropping to the grower are risk minimization, effective use of available resources, efficient use of labor, increased production per unit area of land, erosion control, and food security (De and Singh, 1979; Okigbo, 1979; Wien and Smithson, 1979). These advantages have resulted in more grower requests for reliable information on cultural practices (such as plant spacing, fertilizer rates, and planting dates) to use in these systems.

One example of two types of crops that have been intercropped successfully is a cereal (such as corn or wheat) with a legume (such as beans and peas). Several researchers have suggested that crop yields can be increased by intercropping with a legume (Elmore and Jacobs, 1986; Keswani et al., 1977; Natarajan and Naik, 1992; Ntare and Williams, 1992; Reddy et al., 1992), presumably by the transfer of biologically fixed nitrogen (N) in the roots of the legume to the root zone of the companion crop (Agboola and Fayemi, 1972; Singh et al., 1986). This biologically fixed N can reduce the need for N from commercial fertilizers (Elmore and Jacobs, 1986; Hensz and Vallis, 1977; Shirvastava et al., 1983).

Some factors that will determine whether or not two crops can be successfully intercropped include plant height (Trenbath, 1979), the size of the leaves, and the orientation and distribution of these leaves in the plant

canopy (Trenbath, 1976). These variables affect the amount of sunlight that passes through the canopies (Gardiner and Craker, 1981; Kasperbauer, 1971), which could influence the photosynthetic rates of the leaves within the canopy. In intercropping systems with differences in canopy height, the crop in the understory needs to be shade-tolerant for the plant to be productive (Trenbath, 1976).

Intercrop systems with vegetable crops

Most intercropping studies have been on agronomic crop production systems. Limited studies have been conducted in vegetable crop production systems, even though vegetable crops have high income-generating potential and are of dietary importance.

Intercropping vegetables with field crops has been encouraged in Central America as a means of producing additional farm income (Hilderbrand, 1976). In these systems, vegetables such as cabbage, cucumber, radish, snap bean, and broccoli are intercropped into double rows of field corn planted on raised soil beds. Intercropping two vegetable crops with different architecture and nutritional value, such as beet and okra, pepper and onion, and okra and onion is practiced widely in tropical Asia (Prabhakar et al., 1983). In some areas of Africa, vegetable cropping systems such as maize and pumpkin, maize and bean, and maize and cowpea often are practiced (Magaguda et al., 1979).

Land Equivalent Ratios (LER)—a method of determining the effectiveness of intercropping systems

Land Equivalent Ratio (LER) is the most widely used index for measuring the advantages of using intercropping systems on combined yield of both crops (Mead and Willey, 1980). LER is calculated as the relative yield of a crop in an intercrop system to the yield of that crop in a monocrop system (i.e., intercrop yield/monocrop yield). A major advantage in using LER analysis is that it provides a standardized basis for comparing systems under different situations and different crop combinations.

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Developing a southernpea and sweet corn intercrop system

The objective of the vegetable intercropping program at Clemson Univ. was to develop an effective intercrop system using a relatively low-growing legume, southernpea [*Vigna unguiculata* (L.) Walp. 'Colossus'], and a relatively tall-growing cereal crop, sweet corn (*Zea mays* L. 'Merit'). Research on developing a southernpea and sweet corn intercropping system was conducted at the Calhoun Field research site, Clemson, S.C., in 1988 and 1989.

Southernpea seeds were inoculated with Nitragin inoculant (Nitragin Co., Milwaukee), a N-fixing *Rhizobium* bacteria, prior to planting. All experimental plots were 16 ft (4.9 m) long and consisted of two adjoining raised beds. Each raised bed was 4 ft wide × 6 inches high. There was 6 ft (1.8 m) between the centers of the beds. This spacing between the center of beds is common in the southern United States for field production of vegetable crops. Border plots consisted of one raised bed that separated each treatment plot and were planted to monocrop southernpea. Prior to planting, representative soil samples were analyzed to determine soil nutrient status. The soil type was a Riverview silt loam (fine loamy, mixed, thermic fluventic dystrochreets).

Monocropped southernpea plots contained two rows per bed. Each row was 24 inches (61 cm) apart with intrarow spacing of seedlings 6 inches (15 cm) apart, resulting in a population density of ≈31,800 plants/acre (78,600 plants/ha). Monocropped sweet corn plots contained one row located in the center of the bed. Intrarow spacing of seedlings was 8 inches, resulting in a population density of ≈11,900 plants/acre (29,400/ha).

The planting geometry of intercrop plots was one row of sweet corn located in the center of the bed, and two rows of southernpea, each 18 inches (45 cm) from the corn row. The population density and planting configuration of intercrop southernpea were equivalent to the monocrop southernpea population.

All plots were overseeded and then thinned to achieve the desired plant spacing. Weeds were controlled by

applying metolachlor (2-chloro- *N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)-acetamide at a rate of 1.0 lb a.i./acre preplant. Recommended pesticides were applied as needed, and natural rainfall was supplemented with overhead irrigation.

Yields of monocrops and intercrops were determined from 8 ft (2.4 m) of row from each plot. Southernpea yields were determined by recording fresh weight of pods from successive harvests. Pea pods were harvested at ≈90% physiological maturity. Yield components such as pod length, number of pods per plant, number of seeds per pod, and branch formation also were recorded. Sweet corn yield was measured by recording the number and fresh weight of marketable and nonmarketable ears (as graded according to USDA standards) from successive harvests.

Population density and nitrogen rate evaluation

For vegetable intercropping systems to be successful in a geographical

location, effective cultural practices must be determined. The influences of plant population density and N rate were evaluated on the southernpea and sweet corn intercrop in 1988. The desired intercrop population densities were achieved by in-row spacing of sweet corn seedlings at 8, 10, and 12 inches (20, 25, and 30 cm), to give relative plant population densities of high [11,900 plants/acre (29,400 plants/ha)], medium [9500 plants per acre (23,400 plants/ha)], and low (6700 plants/acre [16,500 plants per ha]). N fertilizer (urea, 46% N) was applied 21 days after planting to only the sweet corn plants at rates of 0, 62, 125, and 214 lb N/acre (0, 70, 140, and 240 kg·ha⁻¹) in soil-covered furrows 2 inches (5 cm) deep, located ≈4 inches (10 cm) from both sides of the corn row. Phosphorus (from P₂O₅) and potassium (from K₂O) at 54 and 91 lb/acre (61 and 102 kg·ha⁻¹), respectively, were uniformly broadcast 3 days prior to planting and incorporated in the soil to a depth of 6 inches (15 cm). Southernpea and sweet corn

Fig. 1. The influence of density of sweet corn population in a southernpea and sweet corn intercrop on plant growth (dry mass accumulation) of the southernpea (A) and sweet corn (B) components of the intercrop system.

were planted to all plots on 14 May.

A randomized complete-block design investigating population densities and N fertilizer rates was used. Population densities evaluated at all N fertilizer rates included the three intercrop densities and monocrop sweet corn. An additional treatment of monocrop southernpea with no N also was included. All treatments each year were replicated four times.

Collection of plant growth data began 28 days after planting (DAP) and continued until 1 week prior to final harvest. Plant growth measurements were recorded for two plants per plot of each component plant that were randomly selected and collected from the first 8 ft (2.4 m) of each row of the plots every 10 days. Southernpea plants were separated into leaves, branches, and stems. Plant samples were dried in a forced oven at 160F for 7 days.

Southernpea plant growth was affected adversely by intercropping system beginning by 38 DAP (Fig. 1A). Population density and fertilizer rate did not affect southernpea plant growth (data not presented). Sweet corn appears to be the dominant crop in the southernpea and sweet corn intercrop, since intercropping had no significant effect on the growth and development of sweet corn (Fig. 1B). Growth of sweet corn also was not affected by population density or fertilizer rates (data not shown).

Total pod yield of southernpea was reduced by intercropping (Fig. 2). Intercropped southernpea averaged a

LER value of 0.57 (i.e., the intercrop yield was 57% of monocropped southernpea yield). Southernpea yield in the high-density treatment was affected most severely by intercropping, with a 52% relative yield reduction (LER = 0.48), as compared to 39% relative yield reduction (LER = 0.61) for the medium- and low-density intercropping systems. This suggests that southernpea yield was affected by interspecific competition within the intercrop system. These results are similar to those reported by Gardiner and Craker (1981) and Reddy and Willey (1981), who reported that increased populations of cereals intercropped with legumes resulted in reduced legume yields. Cropping system also affected the number of pods and branches produced per southernpea plant, with monocropped southernpea producing 30% more pods and 20% more branches than intercropped southernpea (data not shown). There were no cropping system or planting-density effects on pod weight or the number of seeds per pod.

Yields of sweet corn (as measured by total ear weight) were affected by intercropping, with monocropped sweet corn producing an average of 29% more earweight than intercropped sweet corn (Fig. 2). Intercropped sweet corn in the high population density resulted in a LER of 0.78, and intercropped sweet corn in the medium and low densities resulted in LER values of 0.71 and 0.63, respectively. The total system LER ($LER_{\text{southernpea}} + LER_{\text{sweet corn}}$) for the high-population

intercropping system, where plant densities for each crop were comparable to the densities of these crops as monocrops, was $0.48 + 0.78 = 1.26$. This suggests that intercropping southernpea and sweet corn at this density gave a yield advantage of 26%, or that 26% more land planted in equal proportion of each component crop would be required to produce the same yield as the intercrop.

The greater yields in the higher intercrop densities were primarily due to the greater number of sweet corn plants in this treatment, as the number of ears per plant was not affected by cropping system or planting density. These results are similar to those reported by Lima and Lopes (1979) and Willey and Osiru (1972), who observed that, in a bean and maize mixture in which the population of maize was varied, increased maize yields were attributed to increasing plant population densities of maize. Plant density and N fertilizer did not influence the number of ears produced per plant (data not presented).

Future research on intercropping southernpea and sweet corn should evaluate other varieties of these crops for suitability for inclusion into the intercrop system. Additional considerations need to be given to alternative growth habit types of these crops. For example, a determinate bush-type cultivar of southernpea may perform better in an intercrop than the indeterminate cultivar Colossus. Also, a shorter season and less-tall sweet corn cultivar than 'Merit' may be better in an intercrop because it may reduce the level of competition of intercropping on southernpea.

Light interception in the southernpea/sweet corn intercrop

Light interception previously had been implicated as a major factor affecting plant growth and yield in a cereal and legume intercrop (Gardiner and Craker, 1981). Light interception by the southern pea and sweet corn intercrop was determined in 1988 by measuring photosynthetic photon flux (PPF) from above, within, and below the plant canopies with a LI-COR Quantum Sensor (191S A) (LI-COR, Lincoln, Neb.) attached to a Campbell CR21X micrologger. The PPF measurements above the canopy were ob-

Fig. 2. The influence of density of sweet corn population in a southernpea and sweet corn intercrop on yield and resulting land equivalent ratios (LER) of the southernpea (A) and sweet corn (B) components of the intercrop system.

Fig. 3. Location of crops and irradiance measurements in the intercropping system. SC = sweet corn; SP = southernpea; I = location of measurements for incoming irradiance above the cropping system canopy; CL and CR = locations of irradiance measurements within the canopy; BL and BR = locations of irradiance measurements taken below the cropping system canopy.

tained by holding the sensor immediately above the corn canopy, parallel to row orientation (Fig. 3, Position I). PPF measurements from within the canopy were obtained by holding the light sensor below the corn canopy but directly above the southernpea canopy and parallel to row orientation on each side of the bed (Fig. 3, Positions C_L and C_R). The amount of light penetrating both canopies was measured by placing the sensor between the southernpea and sweet corn rows on each side of the bed, parallel to row orientation (Fig. 1, Positions B_L and B_R). Light irradiance measurements in sweet corn were recorded at three different physiological stages (presilking, silking, and postsilking). Sampling dates were chosen to be representative of the growing season. Presilking and postsilking light irradiance measurements were recorded ≈ 14 days prior to and after 50% silking. All readings were integrated over a 1-m length and averaged over three 5-s intervals. On each recording date, light irradiance was measured at ≈ 1000 HR, 1300 HR, and 1500 HR, and daily averages over the three time periods were determined. PPF measurements were collected from monocropped southernpea plots, and

monocropped and intercropped sweet corn plots fertilized at 125 lb N/acre (140 kg·ha⁻¹). The following equations were used to determine total cropping system light interception and interception by component crops:

I = radiation entering the system

C = the average amount of radiation penetrating the sweet corn canopy immediately above the southernpea canopy = $(C_L + C_R)/2$

B = the average amount of radiation penetrating both the southernpea and sweet corn canopies = $(B_L + B_R)/2$

Total cropping system light interception = $(I - B)/I \times 100$

Sweet corn component light interception = $(I - C)/I \times 100$

Southernpea component light interception = $(C - B)/I$

Patterns of light interception were different for monocropped southernpea and monocropped sweet corn (Fig. 4A), with monocropped sweet corn intercepting more light than monocropped southernpea 38 DAP, and monocropped southernpea intercepting more light than monocropped

sweet corn 52 and 66 DAP. The intercrop system intercepted more light than monocropped southernpea and sweet corn 38 DAP. There were no differences in light interception between the intercrop systems and monocropped southernpea by 52 DAP. The intercrop systems intercepted more light than monocropped sweet corn throughout the growing season. This suggests that the foliage of southernpea is more effective in intercepting light in a canopy than the foliage of sweet corn, regardless of the cropping system.

There were significant differences in component crop light interception between intercropped southernpea and sweet corn (Fig. 4 B and C). The southernpea component contributed an average of 27% more light interception to the overall system light interception than that contributed by the sweet corn component. Sweet corn population density in the intercrop system had the greatest effect on component crop light interception during the middle of the growing season, with southernpea in the low-density treatment contributing more light interception to the intercrop system than the southernpea light interception in the more-dense population treatments (Fig. 4B). Correspondingly, sweet corn in the low-density treatment contributed less to the light interception than it did in the other density treatments (Fig. 4C). While intercropped sweet corn intercepted less total light than the amount intercepted by monocropped sweet corn 38 and 52 DAP, plant growth was similar in these systems during this time period. Intercropping may have affected leaf orientation of sweet corn so that less light was intercepted, but sufficient light was nevertheless intercepted for acceptable plant development. Kasperbauer (1987) showed that plants in crowded conditions perceived light reflected off neighboring plants and modified plant growth and development, including leaf orientation.

The reduction in component crop light intercepted by southernpea and sweet corn in the intercrop as compared to light interception by the monocrop system of these crops probably contributed to the reduction in their respective yields. Intercropped southernpea was more affected by the reduction in light interception than intercropped sweet corn. Intercropped

Fig. 4. The effect of cropping system on total cropping system light interception (A) and on component crop light interception of southernpea (B) and sweet corn (C).

southernpea intercepted $\approx 61\%$ of light intercepted by monocropped southernpea 66 DAP and produced 57% of the yield of monocropped southernpea, while intercropped sweet corn intercepted $\approx 44\%$ of light intercepted by monocropped sweet corn 66 DAP and produced 71% of the yield of monocropped sweet corn. Increased competition or other factors not investigated in the present study (e.g., soil moisture, CO_2) also may have contributed to the reduced individual crop yields in the intercrop systems.

Delayed planting of sweet corn evaluation

In previous research, Clark and Francis (1985) reported that plant growth of maize and beans in an intercrop could be increased if the planting dates of the individual crops were staggered. In 1989, the influence of delay-

ing the planting of sweet corn on the southernpea and sweet corn intercrop system was evaluated: southernpea was planted on 19 May in all plots and sweet corn was planted on 19 May (simultaneous planting) or 2 June (delayed planting). In this evaluation, fertilizer rate was not an experimental variable and all plots received 800 lb/acre ($896 \text{ kg} \cdot \text{ha}^{-1}$) of 5N-10P-10K broadcast 3 days prior to planting. The planting density of southernpea and sweet corn was $\approx 31,800$ and 9500 plants/acre (78,600 and 23,500 plants/ha), respectively. A randomized complete block design investigating simultaneous planting vs. delayed planting of sweet corn was used with four replications.

When sweet corn was planted simultaneously with southernpea in the intercrop, southernpea plant growth was reduced at all sampling periods (Fig. 5A). Simultaneous planting of sweet corn and southernpea did not reduce sweet corn plant growth until 60 DAP (Fig. 5B). This suggests that southernpea was effected more negatively by intercropping and that southernpea was affected sooner than sweet corn. This supports the conclusion from the 1988 evaluation that sweet corn is the dominant crop in this intercrop system.

The negative effect of intercropping on southernpea growth was ameliorated by delaying the planting of sweet corn in the intercrop by 2 weeks (Fig. 5A). The 2-week delay in plant-

Fig. 5. The influence of delayed planting of sweet corn in a southernpea and sweet corn intercrop on plant growth (dry mass accumulation) of southernpea (A) and sweet corn (B) components of the intercrop system.

Fig. 6. The influence of delayed planting of sweet corn in a southernpea and sweet corn intercrop on yield and resulting land equivalent ratios (LER) of the southernpea (A) and sweet corn (B) components of the intercrop system.

ing of sweet corn had a deleterious effect on sweet corn growth and resulted in small, nonproductive plants (Fig. 5B).

Southernpea and sweet corn yields in the simultaneously planted intercrop plots were reduced with LER values of 0.49 and 0.71, respectively (Fig. 6), resulting in a total system LER of 1.20. Intercropping also affected southernpea yields when the planting of the sweet corn was delayed for 3 weeks, producing 76% of the yield of monocropped southernpea and a total system LER of 0.76. The earlier-planted southernpea crop became dominant in the planting and delayed the maturity of sweet corn sufficiently so that no marketable yield was produced in the delayed-planting sweet corn plots. Simultaneous planting of southernpea and sweet corn in the intercrop reduced the number of pods and branches per southernpea plant (data not shown). Delayed planting of sweet corn did not affect the number of pods or branches per southernpea plant as compared to monocropped southernpea plants. Future research should determine if a delayed planting of sweet corn of less than 2 weeks would result in an increase in southernpea growth and production (as compared to simultaneous planting of southernpea and sweet corn) with less deleterious effects of delayed planting on sweet corn growth and production observed in the 2-week delayed planting.

Conclusions

Intercropping is a viable an ap-

propriate alternate agricultural technology for growers to maximize land use and increase food production. The diversification of crop species involved in intercropping systems often allow for efficient use of both renewable (e.g., light, water, and atmospheric gases) and nonrenewable (e.g., fertilizer) resources. The intercropping system research on southernpea and sweet corn in the Clemson Univ. intercropping program was directed at understanding better the biological and physical mechanisms that influences crop growth and yield. This type of research on intercropping systems is essential for improving existing practices and designing new sustainable cropping systems that growers can use effectively.

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