INTERCROPPING PRINCIPLES AND PRODUCTION PRACTICES

AGRONOMY SYSTEMS GUIDE

Abstract: *Intercropping offers farmers the opportunity to engage nature's principle of diversity on their farms. Spatial arrangements of plants, planting rates, and maturity dates must be considered when planning intercrops. Intercrops can be more productive than growing pure stands. Many different intercrop systems are discussed, including mixed intercropping, strip cropping, and traditional intercropping arrangements. Pest management benefits can also be realized from intercropping due to increased diversity. Harvesting options for intercrops include hand harvest, machine harvest for on-farm feed, and animal harvest of the standing crop.*

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Updated August 2003

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PRINCIPLES

Sustainable agriculture seeks, at least in principle, to use nature as the model for designing agricultural systems. Since nature consistently integrates her plants and animals into a diverse landscape, a major tenet of sustainable agriculture is to create and maintain diversity. Nature is also efficient. There are no waste products in nature. Outputs from one organism become inputs for another. One organism dies and becomes food for other organisms. Since we are modeling nature, let us first look at some of the principles by which nature functions. By understanding these principles we can use them to reduce costs and increase profitability, while at the same time sustaining our land resource base.

· DIVERSITY IS NATURE'S DESIGN

When early humans replaced hunting and gathering of food with domestication of crops and animals, the landscape changed accordingly. By producing a limited selection of crop plants and animals, humankind has greatly reduced the level of biological diversity over much of the earth. Annual crop monocultures represent a

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classic example. In response to this biological simplification, nature has struggled to restore diversity to these landscapes—that is her tendency. Our "war" with nature over the tendency to diversity is what we call "weed control" and "pest management." Of course we could hardly produce any crops if we simply allowed our fields to return to natural vegetation, but we can realize some of the benefits of diversity by planting mixtures of different crops.

· COOPERATION IS MORE APPARENT THAN COMPETITION

There is far more cooperation in nature than competition. Cooperation is typified by mutually beneficial relationships that occur between species within communities. In *The Redesigned Forest*, ecologist Chris Maser offers a glimpse of the cooperation inherent in a northern temperate forest when he describes a relationship that exists among squirrels, fungi, and trees (1). The squirrels feed on the fungus, then assist in its reproduction by dropping fecal pellets containing viable fungal spores onto the forest floor. There new fungal colonies establish. Tree feeder roots search out the fungi and form a symbiotic association that enables the tree roots to increase their nutrient uptake. The fungi, in turn, derive food from the tree roots. Each benefits from the other's presence or actions.

If we view competition as the driving force in nature, we fail to see the complex relationships and feel compelled to take actions that may have unforeseen impacts. The rancher who views coyotes as competitors (for calves and lambs) and kills them out may later find the predator helped keep rodent populations in check. With the predator gone, rodent numbers explode and cause more problems than ever before. The same is true with many insect pests of crops. When the only food for insects is crops, that is what they will eat. With no predator or parasite habitat present in a pure stand of crop, the pest insect could not possibly have it better. If we can shift our view of nature from a theme of competition to one of collaboration, we can act in ways that yield fewer negative consequences (2).

· STABILITY TENDS TO INCREASE WITH INCREASING DIVERSITY

If left undisturbed and unplanted, an abandoned crop field will first be colonized by just a few species of plants, insects, bacteria, and fungi. After several years, a complex community made up of many wild species develops. Once a wild plant and animal community has reached a high level of diversity, it remains stable for many years.

When wild communities are in the early stages of development, or when they have lost diversity due to natural catastrophe or human actions, they are prone to major fluctuations, both in types of species present and in their numbers. Disease outbreaks in plants and animals occur more frequently—as do outbreaks of weed, insect, bird, or rodent pests. One good example is the grasshopper plagues that follow regional weather shifts. Another is the shift in weed species dominance following a soil disturbance.

The more complex and diverse communities become, the fewer the fluctuations in numbers of a given species, and the more stable communities tend to be. As the number of species increases, so does the web of interdependencies. In both higher and lower rainfall years, there are fewer increases in any one species and fewer fluctuations in the community as a whole (2).

PURSUING DIVERSITY ON THE FARM

So, then, how can we begin to model our agricultural pursuits after some of these natural principles? Can we look for patterns in nature and imitate them? Some pioneering farmers have been able to utilize nature's principle of diversity to their advantage. Results of their efforts include lower cost of production and higher profits. Among the practices that promote diversity and stability are:

Enterprise diversification—Risk reduction through stability of income and yield are two of the reasons people diversify their crop and livestock systems. Increasing diversity on-farm also reduces costs of pest control and fertilizer, because these costs can be spread out over several crop or animal enterprises.

Crop Rotation — Moving from simple monoculture to a higher level of diversity begins with viable crop rotations, which break weed and pest life cycles and provide complementary fertilization to crops in sequence with each other.

Farmscaping—Diversity can be increased by providing more habitat for beneficial organisms, habitats such as borders, windbreaks, and special plantings for natural enemies of pests. Request the ATTRA publication *Farmscaping to En-*

hance Biological Control for more information on special plantings for beneficial insects.

Intercropping—Intercropping is the growing of two or more crops in proximity to promote interaction between them. Much of this publication focuses on the principles and strategies of intercropping field crops. A related ATTRA publication, *Companion Planting*, provides more information on intercropping of vegetable crops.

Integration—On-farm diversity can be carried to an even higher level by integrating animals with intercropping. With each increase in the level of diversity comes an increase in stability. This publication focuses on intercropping and provides a section on integrating livestock with crops.

INTERCROPPING CONCEPTS

Most grain-crop mixtures with similar ripening times cannot be machine-harvested to produce a marketable commodity since few buyers purchase mixed grains. Because of limited harvest options with that type of intercropping, farmers are left with the options of hand harvesting, grazing crops in the field with animals, or harvesting the mixture for on-farm animal feed. However, some intercropping schemes allow for staggered harvest dates that keep crop species separated. One example would be harvesting wheat that has been interplanted with soybeans, which are harvested later in the season. Another example is planting harvestable strips, also known as strip cropping.

When two or more crops are growing together, each must have adequate space to maximize cooperation and minimize competition between them. To accomplish this, four things need to be considered:

1) spatial arrangement,
2) plant density,
3) maturity dates of the crops being grown, and
4) plant architecture.


strip cropping

Spatial Arrangement

There are at least four basic spatial arrangements used in intercropping. Most practical systems are variations of these (3).

- *Row intercropping*—growing two or more crops at the same time with at least one crop planted in rows.
- *Strip intercropping*—growing two or more crops together in strips wide enough to permit separate crop production using machines but close enough for the crops to interact.
- *Mixed intercropping*—growing two or more crops together in no distinct row arrangement.
- *Relay intercropping*—planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting.

Plant Density

To optimize plant density, the seeding rate of each crop in the mixture is adjusted below its full rate. If full rates of each crop were planted, neither would yield well because of intense overcrowding. By reducing the seeding rates of each, the crops have a chance to yield well within the mixture. The challenge comes in knowing how much to reduce the seeding rates. For example, if you are planning to grow corn and cowpeas and you want mostly peas and only a little corn, it would be easy to achieve this. The corn-seeding rate would be drastically cut (by 80% or more) and the pea rate would be near normal. The field should produce near top yields of peas even from the lower planting rate and offer the advantage of corn plants for the pea vines to run on. If you wanted equal yields from both peas and corn, then the seeding rates would be adjusted to produce those equal yields.

Maturity Dates

Planting intercrops that feature staggered maturity dates or development periods takes advantage of variations in peak resource demands for nutrients, water, and sunlight. Having one crop mature before its companion crop lessens the competition between the two crops. An aggressive climbing bean may pull down corn or sorghum growing with it and lower the grain yield. Timing the planting of the aggressive bean may fix the problem if the corn can be harvested before the bean begins to climb. A common practice in the old southern U.S. cotton culture was to plant velvet beans or cowpeas into standing corn at last corn cultivation. The corn was planted on wide 40-inch rows at a low plant population, allowing enough sunlight to reach the peas or beans. The corn was close enough to maturity that the young legumes did not compete. When the corn was mature, the beans or peas had corn stalks to climb on. The end result was corn and beans that would be hand harvested together in the fall. Following corn and pea harvest, cattle and hogs would be turned into the field to consume the crop fodder.

Selecting crops or varieties with different maturity dates can also assist staggered harvesting and separation of grain commodities. In the traditional sorghum / pigeonpea intercrop, common in India, the sorghum dominates the early stages of growth and matures in about four months. Following harvest of the sorghum, the pigeonpea flowers and ripens. The slow-growing pigeonpea has virtually no effect on the sorghum yield (4).

PLANT ARCHITECTURE

Plant architecture is a commonly used strategy to allow one member of the mix to capture sunlight that would not otherwise be available to the others. Widely spaced corn plants growing above an understory of beans and pumpkins is a classic example.

INTERCROP PRODUCTIVITY

One of the most important reasons to grow two or more crops together is the increase in productivity per unit of land. Researchers have designed a method for assessing intercrop performance as compared to pure stand yields. In research trials, they grow mixtures and pure stands in separate plots. Yields from the pure stands, and from each separate crop from within the mixture, are measured.

From these yields, an assessment of the land requirements per unit of yield can be determined. This information tells them the yield advantage the intercrop has over the pure stand, if any. They then know how much additional yield is required in the pure stand to equal the amount of yield achieved in the intercrop. The calculated figure is called the Land Equivalency Ratio (LER). To calculate an LER, the intercrop yields are divided by the pure stand yields for each component crop in the intercrop. Then, these two figures are added together. Here's the equation for a corn / pea intercrop where the yields from pure corn, pure peas, and the yields from both corn and peas growing together in an intercrop are measured.

(intercrop corn / pure corn) +
(intercrop pea / pure pea) = LER

When an LER measures 1.0, it tells us that the amount of land required for peas and corn grown together is the same as that for peas and corn grown in pure stand (i.e., there was no advantage to intercropping over pure stands). LERs above 1.0 show an advantage to intercropping, while numbers below 1.0 show a disadvantage to intercropping. For example, an LER of 1.25 tells us that the yield produced in the total intercrop would have required 25% more land if planted in pure stands. If the LER was 0.75, we know the intercrop yield was only 75% of that of the same amount of land that grew pure stands.

In a South Carolina study, researchers planted intercrops of southern peas and sweet corn at three different corn plant densities (5). The plantings were on raised beds with flat and wide crowns on six-foot centers. In the center of each bed was a corn row, with two rows of peas planted 18 inches to either side of the corn row (see Figure 1). The low corn-seeding rate was 6,700 plants per acre, medium corn was 9,500 per acre, and high was 11,900 plants per acre. Peas were established at a rate of 31,800 plants per acre in all intercrop plots. In the pure pea stand, each bed had two rows of peas spaced 24 inches apart. Yields of the intercrops and pure stands are shown in Table 1.

In this trial there was a yield advantage from intercropping over growing the two crops in pure stands. Pea yields suffered from the increased competition in the higher densities of corn. Some practical on-farm guidelines can be drawn to guide seeding-rate choices for a two-crop intercrop. To test seeding rates, experiment with three small plantings of two crops at the following percentages of their full seeding rates: 1/3 + 2/3,

Table 1. Yields of sweet corn and southern peas from intercrops (5)

Seed Rates	Corn (pounds/ acre)	Peas (pounds/ acre)	LER
Full corn	5600	***	***
Full peas	***	1200	***
Low corn	4200	800	1.41
Medium corn	4600	800	1.48
High corn	5000	500	1.30

1/2 + 1/2, and 2/3 + 1/3. From there, make adjustments for future plantings based on the results and your expectations.

MANAGING INTERCROPS

Many combinations of crops have been grown or experimented with as mixed or relay intercrops. Some of these include sunflowers grown with black lentils, wheat with flax, and canola with flax. Other combinations include cucumbers, beans, celery, and chives in China; upland rice, corn, and cassava in Indonesia; and in various parts of the tropics corn and cassava, corn and peanuts, sorghum and millet, and sorghum and pigeonpeas.

Frequently these cropping combinations involve a short and a tall crop both planted at the same time. In many cases the tall crop is harvested first. For example, corn grown with a shorter plant would be harvested first, then peanut or sweet potato would be harvested later. Another pattern would be planting two tall crops with different growth rates. In relay intercrops, different planting dates are used so that one crop might mature sooner. Corn or sorghum, requiring three months to mature, can be grown with pigeon pea, requiring 10 months to maturation.

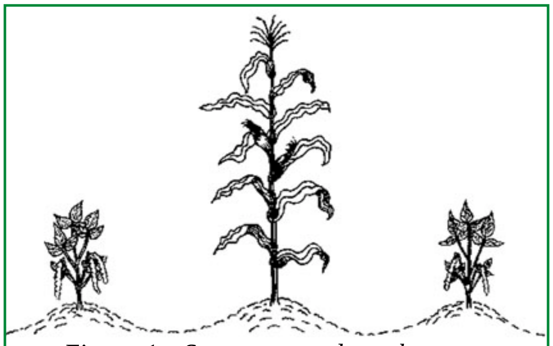

Figure 1. Sweetcorn and southern pea planting pattern

John Bowen and Bernard Kratky, researchers and instructors at the University of Hawaii, tell us that there are five distinct aspects to successful multiple cropping. These are:

1) detailed planning,
2) timely planting of each crop,
3) adequate fertilization at the optimal times,
4) effective weed and pest control, and
5) efficient harvesting (6).

Before any fieldwork is begun, adequate planning should be done. Planning covers selection of crop species and appropriate cultivars, water availability, plant populations and spacing, labor requirements throughout the season, tillage requirements, and predicted profitability of the intercrop. These and other parameters need to be evaluated before spending money on inputs.

With any crop, seed germination and seedling establishment are the most critical phases of the entire season. A good seedbed is needed to get a good stand. Delayed planting may reduce yield, since crop development may not coincide with the optimal growth periods.

Planning fertilization for intercrops can be challenging, as the full needs of both crops must be met. Generally, there is little information available on how to go about this. One possibility would be to ask for soil test results for each crop separately, then formulate a recommendation that will cover the needs of both crops to be grown. Such recommendations are generally 10% to 30% higher than rates for individual crops.

As with any crop, also accounting for residual or carryover fertility from past crops saves money. Carryover fertility from intercrops may well be lower than that of pure stands because of the two crops having different root types and feeding habits.

Weed and pest controls in intercrops will likely be different from those in pure stands. Some disease incidence, such as soybean or mung bean rusts, may increase when aggravated with high corn populations and overfertilization. Any disease or pest that prospers in shady conditions could increase under a taller crop such as corn or sunflowers. In many cases, insect pest populations are lower when two or more crops are grown together. More on pest management will be found later in this publication.

Harvesting of mixed intercrops has been a major limitation to their adoption in mechanized farming. As mentioned earlier, if the crops cannot be harvested by animals, or all together as feed, you're left with hand harvesting. Some crops such as flax and wheat have been harvested together and mechanically separated. Any other mechanized harvest efforts must get one crop without damaging the other. One example would be harvesting wheat over the top of a young stand of soybeans growing beneath the grain heads. All intercropping strategies— especially mixed intercropping—require advanced planning and keen management. Success will likely be the reward for such efforts.

EXAMPLES OF INTERCROP SYSTEMS

Traditional Corn-Bean-Squash Mixed Intercrops

Farmers throughout Central America traditionally grow an intercrop of corn, beans, and squash. Grown together, these three crops optimize available resources. The corn towers high over the other two crops, and the beans climb up the corn stalks. The squash plants sprawl along the ground, capturing light that filters down through the canopy and shading the ground. The shading discourages weeds from growing.

This mixture was compared to the individual crops grown separately in a study near Tabasco, Mexico (7). In the study, corn yields were considerably higher in the mixture than in a pure stand planted at optimum densities. Bean and squash yields suffered considerable yield reductions when grown in mixture. In this example if corn were the most important crop, it was beneficial to grow it in a mixture with squash and beans. The beans and squash were just a bonus. The LER for the whole mixture was considerably higher (1.6) than any of the pure stands. See Table 2 for details.

Table 2. Yields of corn, beans and squash grown alone or in a mixture (7)

Crop	Pure Stand (pounds/ acre)	Intercrop (pounds/ acre)
Corn	1096	1533
Beans	544	98
Squash	383	71

Corn and Soybean Mixed Intercrops

Canadian researchers (8) have worked with several corn-soybean intercrop seeding rates to determine their economic advantages as silage. Pure stands of corn and soybeans were grown for comparison at 24,000 corn seed per acre and 200,000 soybean seed per acre. Results showed that intercrops were more cost effective than pure stands over both years the study was conducted. The study featured five experimental intercrop seeding rates with two planting arrangements (alternate and within the row). The researchers concluded that a planting rate of 16,000 corn seed per acre (67% of the full corn rate) with 135,000 soybean seed per acre (67% of the full bean rate) planted within the same rows along with 53 lbs. of N / acre gave the highest economic returns. (Note: the planter was set to drop 151,000 seeds per acre.) This mixture gave an LER of 1.14 over pure stand yields. The crude protein level of the intercrop silage was considerably higher than that of pure corn silage. A slightly higher yield was achieved from full stands of both corn and beans in alternate rows (LER=1.23), but the cost of production was higher, thus offsetting the improved yields.

Corn and Sorghum Mixed Intercrops

Frank Cawrse, Jr., of Lebanon, Oregon, intercrops forage sorghum into his silage corn. He first plants the corn at 28,000 seed per acre, then goes back over the field with a drill with enough drop tubes closed off to plant 8 pounds of sorghum on 32-inch rows in between the corn. He also plants two different maturities of corn, a 95-day and a 75-day, to even out the silage moisture content. He harvests a mix of corn in hard dent and soft dent, and sorghum in the milk stage (8).

Strip Cropping Corn/Soybeans/ Small Grains

South Dakota farmer Tod Intermill plants alternating strips of corn, soybeans, and spring wheat on his farm (9). The strips are six rows wide in a ridge-till system. All the crop plantings are adapted to existing equipment widths. Regular herbicide treatments can be applied using a ground sprayer of strip width. Even the wheat is drilled on ridges, using a drill with individual depth gauges on each opener. Intermill orients his rows east and west to minimize the shading effects of taller crops like corn. The crops are planted in a wheat–corn–soybean pattern, with soybeans on the north side of the corn (Figure 2). This arrangement reduces the effect of corn shading often associated with a straight corn-soybean pattern, since the wheat is mature before the corn has a chance to shade it. Corn gains the greatest benefit from the additional sunlight interception on the outside rows of the corn strip.

Figure 2. Corn, soybeans, and wheat strip-cropped

Iowa farmer Tom Frantzen strip-crops oats, corn, and soybeans on ridge-till rows. He views his strips as a crop rotation in one field. His rows are oriented generally east and west on the contour. His 1989 strip-crop corn yields were 166 bushels per acre, compared to 130 for his farm average. Stripped soybean yields were two bushels lower than farm average. His oat yields were 109 bushels stripped and 100-bushel farm average. Tom was not surprised at the increase in corn yields. The outer strip rows captured more sunlight. His average corn border row yielded 198 bushels per acre next to the soybeans and 177 bushels next to oats. The soybean yields were 37 bushels, even with the increased shading on the border rows. This loss was made up in the middle rows with yields of 44 bushels per acre. Oats showed a 107-bushel yield on the soybean side, a 103-bushel yield on the corn side, and 99 bushels in the middle. Tom says the strip intercropping is no more labor intensive than monocrop fields. His profits were $76 per acre for the stripped fields and $55 for the same crops grown in monoculture. (11).

Rick Cruse, an Iowa State University agronomist, has observed several characteristics that narrow strips (12 to 30 feet wide) offer. The strips accommodate the pest management and soil building advantages of rotations and the yield boost of border rows. With proper management the border effect can pay off; managed improperly, it can cost yield. With oat and corn strips, the early-maturing oats are nearly mature before corn can pose much of a shade and competition problem. The corn can also provide wind protection for the oats. When the oats are harvested, more sunlight is available to the corn. In times of low moisture, oats may rob the corn border rows of water. In his field trials, Cruse found a 5% increase in oat yields on their borders, while corn realized a 12 to 15% increase.

Soybean yields dropped by 10% on their border rows, but the yields in the soybean middle rows were higher than they would be in a solid field, possibly representing a windbreak effect (10).

Some have experimented with a shorter corn variety in the border row to minimize shading. One farmer tried planting six rows of corn and doubling his soybean strips to 12 rows to eliminate the impact of corn shading on the beans. This same farmer found that corn strips wider than eight rows did not provide adequate results. Using a 12-row planter, it's easy to establish the 6-row strips by filling the middle six hoppers with corn and the outer three hoppers with beans. Some farmers plant higher corn populations and add higher nitrogen rates in the border rows to take advantage of the extra sunlight exposure. Most farmers agree that strip cropping corn, soybeans, and oats works best with ridge-till or no-till. When the field is tilled, it's difficult to gauge where the rows should go in order to get the strips even.

ESCALATING DIVERSITY AND STABILITY TO A HIGHER LEVEL

Ecologists tell us that stable natural systems are typically diverse, containing many different types of plants, arthropods, mammals, birds, and microorganisms. In stable systems, serious pest outbreaks are rare, because natural controls exist to automatically bring populations back into balance. Planting crop mixtures, which increase farmscape biodiversity, can make crop ecosystems more stable, and thereby reduce pest problems.

There is overwhelming evidence that plant mixtures support lower numbers of pests than do pure stands (11), and there are two schools of thought on why this occurs. One suggests that higher natural enemy populations persist in diverse mixtures due to more continuous food sources (nectar, pollen, and prey) and favorable habitat.

The other thought is that pest insects that feed on only one type of plant have greater opportunity to feed, move around in, and breed in pure crop stands because their resources are more concentrated than they would be in a crop mixture (12). Regardless of which reason you accept, the crops growing together in the mixture complement one another, resulting in lower pest levels.

Intercropping also aids pest control efforts by reducing the ability of the pest insects to recognize their host plants. For example, thrips and white flies are attracted to green plants with a brown (soil) background, ignoring areas where vegetation cover is complete—including mulched soil (13). Some intercrops have a spatial arrangement that produces the complete vegetation cover that would be recognized as unfavorable to thrips and whiteflies. Other insects recognize their host plants by smell. Onions planted with carrots mask the smell of carrots from carrot flies. For more information on companion planting for insect management, request the ATTRA publications *Farmscaping to Enhance Biological Control* and *Companion Planting*.

Innovative farmers are paving the way with intercrops and realizing pest management benefits as a result. Georgia cotton farmers Wayne Parramore and sons reduced their insecticide and fertilizer use by growing a lupine cover crop ahead of their spring-planted cotton (14). They started experimenting with lupines on 100 acres in 1993, and by 1995 were growing 1,100 acres of lupines. Ground preparation for cotton planting is begun about 10 days prior to planting by tilling 14-inch wide strips into the lupines. Herbicides are applied to the strips at that time, and row middles remain untouched. The remaining lupines provide a beneficial insect habitat and also serve as a smother crop to curtail weeds and grasses. The lupines in the row middles can be tilled in with the cultivator later in the season to release more legume nitrogen.


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lupine

In the Parramores' system, all the nitrogen needs of the cotton crop are met with cover crops except for 10 units per acre of starter nitrogen and another 15 units applied while spraying herbicides. Petiole samples taken every week to monitor plant nitrogen show that cotton grown with lupines maintains a normal range of tissue nitrogen throughout the growing season. The nitrogen level in cotton grown solely with fertilizer is very high initially, then subsequently falls back to a lower level. In one comparative year, the cotton grown following lupine produced 96 more pounds of lint, with only 25 units of commercial nitrogen, compared to a field with 125 units of nitrogen and no lupines. Additionally, the lupine field required less spraying for insects—only twice compared to five sprays for the commercial nitrogen field. This reduction saved 60% on insecticides, amounting to $35 per acre. The reduction in need for pesticides is attributed to the large population of beneficial insects generated and sustained in this system. The lupines provide food for aphids and thrips, which attract ladybugs, big-eyed bugs, and fire ants as predators. When the cotton gets big enough to shade out the lupines, the beneficial insects move to the cotton rather than migrating from the field. The Parramores estimate that improved yields, combined with cost reductions, are netting them an additional $184 per acre with the strip tillage lupine system when compared to the conventional management system.

Alfalfa is one of the best crops for attracting and retaining beneficial insects. This characteristic can be enhanced further. Strip-cutting alfalfa (i.e., cutting only half of the crop at any one time, in alternating strips) maintains two growth stages in the crop; consequently, some beneficial habitat is available at all times. In some cases alfalfa is mixed with another legume and a grass. Auburn University researcher Mike

Gayler is just starting research projects using alfalfa as an attractant crop for beneficials. He speculates that it will work in the Southeast with proper management. Other main-season strip crops that research suggests will benefit cotton crop pest management include cowpeas, sorghum, corn, and crotalaria (15).

Dr. Sharad Phatak of the University of Georgia has been working with cotton growers in Georgia testing a strip-cropping method using annual winter cover crops (16). Planting cotton into strip-killed crimson clover improves soil health, cuts tillage costs, and allows him to grow cotton with no insecticides and only 30 pounds of nitrogen fertilizer. Working with Phatak, farmer Benny Johnson reportedly saved at least $120 / acre on his 16-acre test plot with the clover system. There were no insect problems in the test plot, while beet armyworms and whiteflies were infesting nearby cotton and requiring 8 to 12 sprayings to control. Cotton intercropped with crimson clover yielded more than three bales of lint per acre compared to 1.2 bales of lint per acre in the rest of the field (16). Boll counts were 30 per plant with crimson clover and 11 without it. Phatak identified up to 15 different kinds of beneficial insects in these strip-planted plots.

Phatak finds that planting crimson clover seed at 15 pounds per acre in the fall produces around 60 pounds of nitrogen per acre by spring. By late spring, beneficial insects are active in the clover. At that time, 6- to 12-inch planting strips of clover are killed with Roundup™ herbicide. Fifteen to 20 days later the strips are lightly tilled and cotton is planted. The clover in the row-middles is left growing to maintain beneficial insect habitat. When the clover is past the bloom stage and less desirable for beneficials, they move readily onto the cotton. Even early-season thrips, which can be a problem following cover crops, are limited or prevented by beneficial insects in this system. The timing coincides with a period when cotton is most vulnerable to insect pests. Following cotton defoliation, the beneficials hibernate in adjacent non-crop areas.

Phatak points out that switching to a whole-farm focus while reducing off-farm inputs is not simple. It requires planning, management, and several years to implement on a large scale. It is just as important to increase and maintain organic matter, which stimulates beneficial soil microorganisms. Eventually a “living soil” will keep harmful nematodes and soilborne fungi under control (16). For more information on management of soil-borne diseases, request the ATTRA publication *Sustainable Management of Soilborne Plant Diseases*.

Texas dryland farmer Ron Gobel intercrops 8-row strips of sesame and cotton for insect control benefits. The sesame harbors many beneficial insects, including high populations of lacewings, assassin bugs, and lady beetles. Ron’s 1995 crop was planted late due to prolonged spring rains. He did not use a Bt cotton variety. Early frost terminated the crop two weeks earlier than normal, yet he still produced 0.8 bales per acre under dryland conditions. His sesame produced 800 pounds per acre. The 1996 cotton rows were planted where the sesame rows were the previous year, and sesame planted where cotton was before.

Since Ron sells his cotton for a premium price in the organic market, he cannot spray any synthetic insecticides. Consequently, he must rely on beneficial insects attracted to his fields by cultural practices and a handful of natural insecticides.

Following the fall harvest, Ron plants annual rye at a low rate of 20 to 40 pounds per acre. The rye is tilled in prior to crop planting in the spring. Ron believes the rye helps with soil moisture retention and weed control. During the 1997 crop year his fields suffered only minimal boll weevil damage. Ron noticed lots of adult bollworm moths but no worms. The eggs were eaten or parasitized by the beneficials.

Ron’s fields were scouted as part of a boll weevil eradication program. The scouts were amazed at the lack of worms and the high numbers of beneficial insects. The cotton crop was sprayed one time with diatomaceous earth impregnated with natural pyrethrum, which was acceptable under the organic standards. The insect scouts noticed a 70% reduction in adult boll weevil population three days after the spray. They were so surprised that they placed cages of 20 live weevils in the field to see whether the spray was working. The next day, 45% of those weevils were dead. The entomologists speculated that the weevils were getting enough of the diatomaceous earth on their leg joints to cut their exoskeletons, allowing the pyrethrum to kill them.

In a scientific study, Mississippi researchers interplanted 24 rows of cotton with 4 rows of sesame to study the intercrop’s effects on tobacco budworms and bollworms *(Heliothis* spp.*)*. Throughout the growing season, larvae numbers were much higher in the sesame than on the cotton until late August, indicating the worm's preference for sesame. Following a large summer rain at a time when the sesame was reaching maturity, the *Heliothis* adults became more attracted to the cotton. The researchers noted that sesame's attractiveness to *Heliothis* and sesame's ability to harbor high numbers of beneficial insects made it useful in a cotton pest management program (17).

ESCALATING DIVERSITY AND STABILITY TO AN EVEN HIGHER LEVEL

The diversity created by intercropping can be enhanced even further by integrating livestock (single or mixed species) into the cropping plan as harvesters. Allowing animals to harvest feed crops in the field puts gain on animals at the cost of crop production—considerably less than the purchase price of the grain. If you think about it, feed grains cost a lot less when they're not run through a $150,000 combine or hauled 1000 miles across the country.

Grazing animals and other livestock can be managed on croplands to reduce costs, increase income, and increase diversity. There are ways of incorporating animals into cropping without the farmer getting into animal husbandry or ownership directly. Collaboration with neighbors who own animals will benefit both croppers and livestock owners. Grazing or hogging-off of corn residue is one example where a cost can be turned into a profit. The animals replace the $6 per acre stalk mowing cost and produce income in animal gains.

Shasta College provides a unique demonstration of integrating livestock with intercrops. Shasta is a two-year community college located in Redding, California, that offers associate degrees in several branches of agriculture. Stan Gorden (18) heads the college's holistic resource laboratory, where students get hands-on experience with ranching and farming (19). Stan and his students have taken intercropping to a high level of efficiency. They run hogs, sheep, cattle, and chickens together over 42 small paddocks of various forages and crops growing on 100 acres of college-owned land. One paddock is a pumpkin patch, another a garlic and carrot patch. Some are planted in alfalfa or mixes of grasses and clover. Not all the pastures have water sources for the animals, so water is moved on a trailer tank when necessary. The animals are moved daily in a planned grazing system during rapid plant growth and much more slowly, up to five days on a paddock, during slow plant growth.

Some of the paddocks are planted with mixtures of either winter or summer forage or grain crops. An intercrop of cereal grain, fava beans, and Canadian field peas is planted for winter grain, each crop at 1/3 normal seeding rate. The grain mixture is combine-harvested to make energy and protein supplement feed as needed. After harvest, the animals are turned into the paddock to glean what's left. For summer feed, a mixture of milo planted on 18-inch rows is intercropped with a row of black-eyed peas planted six inches to either side of each sorghum row, using a drill with partitions in the seedbox. The milo provides a trellis for the pea vines to run on (Figure 3). The milo/black-eyed mixture requires no herbicide. Before peas and milo were grown together, the milo pure stand would be plagued with whiteflies and green bugs. Mixing the two crops together ended the pest problem. Cowpeas have extrafloral nectaries that attract lots of beneficial insects. This could explain the absence of pest insects in the mixture. The milo/pea mixture is harvested by setting the combine to cut at the height of the milo heads. This yields a milo to bean ratio of 2:1—ideal for feed.


Figure 3. Cowpeas and milo growing together

The college animal herd consists of 20 sows that farrow on pasture, 35 head of cattle, 50 sheep, and 30 laying hens that all range together. The hens are with the herd during the day and roost in a nearby eggmobile at night. Gorden selects breeds and genetics to fit this system, as opposed to selecting breeds for maximum production and adapting a system to match the animal. The animals benefit one another. The sheep learn to stay close to the middle of the herd to avoid predators, which are fended off by the hogs. The cattle learn that the hogs know how to break the pumpkins open, so they stick close and get some too. The hogs eat the cow and sheep droppings and benefit from the predigestion. The hens scavenge wasted seeds from the various crops. There are three different kinds of hens, each of which lays eggs of a different color. The eggs are marketed as rainbow eggs, with each dozen containing four white, four blue, and four brown eggs. The chickens also scratch apart cattle dung pats searching for insects, thus destroying cattle parasites.

Gorden says that developing and maintaining this high level of diversity has required creativity, selection criteria, constant monitoring, and re-examining traditional beliefs. By challenging long-held beliefs, Bill and his students discovered that hogs do not need standard farrowing crates and that sheep and cattle are compatible grazers. Animals and crops are selected and culled according to their ability to adapt to this complex system. Shasta College has one of the largest heritage hog herds in the country. The hogs have been fitted with humane nose rings to prevent rooting. Also, hog breeds are selected that don't root up the ground nor eat the baby lambs when they are born. The sows farrow on pasture with only a single bale of hay for bedding. Hogs are not vaccinated, nor are needle teeth removed or other detailing done. Sows generally wean 12 pigs with no supplemental feed. The only purchased input is some nitrogen and phosphorus fertilizer applied to the pastures. The pigs are only touched twice; once to castrate and once to wean. As with the hogs, the cattle and sheep are selected to prosper on grass. Predators are not controlled in any way. Any animal that gets killed by wandering off is naturally selected out of the herd.

The sheep / hog / cow mix provides much better utilization of forage than single species grazing. Since the animals do most of the harvesting, less fossil fuel and labor-hours are expended. There are no pens to wash and no manure to deal with. The herd is controlled using an electric fence charged up to 8,000 volts to hold the sheep.

Before the 100-acre crop / animal integration project began in 1987, the College's agriculture resource laboratory was costing $8,000 per year. That was the first year the resource laboratory started managing holistically. By 1996, the resource lab's income was up $12,000, and expenses were down $10,000—rendering a $14,000 profit over the 1987 figure. During that same time the soil organic matter has increased from 1.7% to 3.2 % (18).

INTERCROPPING FOR DISEASE CONTROL

Under direction of an international team of scientists, farmers in China's Yunnan province made some simple changes in their rice production methods (20). They changed from planting their typical pure stand of a single rice variety to planting a mixture of two different rice varieties. Their primary reason for trying this new technique was to reduce the incidence of rice blast, the main disease of rice. The technique was so successful at reducing blast disease that the farmers were able to abandon chemical fungicides they had been using. The biodiversity effect is apparent here in that if one variety of a crop is susceptible to a disease, the denser the stand, the worse the disease can spread. If susceptible plants are separated by non-host plants that can act as a physical barrier to the disease, the susceptible variety will suffer less disease infection. Rice blast moves from plant to plant via airborne spores. These spores can be blocked by a row of a resistant variety. In this on-farm study, the rice was harvested by hand. Separating the varieties was easily done during harvest, since one variety towered above the other.

ADAPTING INTERCROPPING TO YOUR FARM

Intercropping has been important in the U.S. and other countries and continues to be an important practice in developing nations. In traditional systems, intercropping evolved through many centuries of trial and error. To have persisted, intercropping had to have merit biologically, environmentally, economically, and sociologically. To gain acceptance, any agricultural practice must provide advantages over other available options in the eyes of the practitioner . Many of the impediments to adoption of new strategies or practices of diversification are sociological (Will I look foolish to my neighbors? Will I fail?) and financial (What are the risks? What is the profit potential?) rather than technological.

Farmers have generally regarded intercropping as a technique that reduces risks in crop production; if one member of an intercrop fails, the other survives and compensates in yield to some extent, allowing the farmer an acceptable harvest. Pest levels are often lowered in intercrops, as the diversity of plants hampers movement of certain pest insects and in some cases encourages beneficial insect populations.

REFERENCES

1. Maser, Chris. 1990. The Redesigned Forest. Stoddart, Toronto, Canada. 224 p.
2. Savory, Allan. 1998. Holistic Management—A New Framework for Decision-Making. 2nd edition. Island Press. Covelo, CA. 550 p.
3. Grossman, Joel, and William Quarles. 1993. Strip intercropping for biological control. IPM Practitioner. April. p. 1–11.
4. Willy, R.W., et al. 1983. Intercropping studies with annual crops. In: Better Crops for Food, CIBA Foundation Symposium 97. Pitman, London, UK.
5. Francis, R., and D.R. Decoteau. 1993. Developing an effective southernpea and sweet corn intercrop system. Hort Technology. Vol. 3, No. 2. p. 178–184.
6. Bowen, John F., and Bernard A. Kratky. 1986. Successful multiple cropping requires superior management skills. Agribusiness Worldwide. November/December. p. 22–30.
7. Amador, M.F. 1980. Behavior of three species (corn, beans, squash) in polyculture in Chontalpa, Tabasco, Mexico. CSAT, Cardenas, Tabasco, Mexico.
8. Martin, Ralph, Don Smith, and Harvey Voldeng. 1987. Intercropping corn and soybeans. Sustainable Farming. REAP Canada. McGill University, Macdonald Campus. http://www.eap.mcgill.ca/
9. Anon. 1987. Intercropping bolsters silage yields. Hay and Forage Grower. August. p. 29.
10. Tonneson, Lon, and Jim Houtsma. 1991. Adding new wrinkles to alternate strips. The Farmer. September 7. p. 8–9.
11. Anon. 1990. Strip intercropping offers low-input way to boost yields. Sensible Agriculture. May. p. 7–8.
12. Altieri, M.A., and M. Leibman. 1994. Insect, weed, and plant disease management in multiple cropping systems. In Francis, C.A. (ed.). Multiple Cropping Systems. Macmillan Company, New York. 383 p.
13. Ecological Agriculture Projects. Mixing Crop Species. McGill University, Macdonald Campus. http://www.eap.mcgill.ca/CSI_2.htm
14. Dirnerger, J.M. 1995. The bottom line matters—you can laugh at him on the way to the bank. National Conservation Tillage Digest. October–November. p. 20–23.
15. Rincon-Vitova. No date. Product Information: Biological Control Solutions for Cotton Pests. Rincon-Vitova Insectaries, Inc. Oak View, CA. 6 p.
16. Yancey, Cecil Jr. 1994. Covers challenge cotton chemicals. The New Farm. February. p. 20–23.
17. Laster, M.L., and R.E. Furr. 1972. *Heliothis* populations in cotton-sesame interplantings. Journal of Economic Entomology. Vol. 65, No. 5. p. 1524–1525.
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19. Richardson, Pat. 1997. Polyculture makes the most of biodiversity. HRM of Texas Newsletter. Summer. p. 5, 7.
20. Wolfe, Martin S. 2000. Crop strength through diversity. Nature. August. p. 681–682.

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Edited by Paul Williams
Formatted by Gail Hardy

Updated August 2003

IP135/8

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