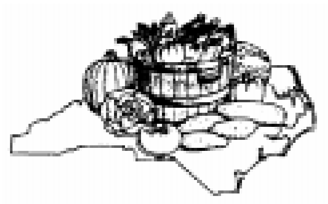

SUMMER COVER CROPS

N.G. Creamer, Assistant Professor and Extension Specialist
K. R. Baldwin, Extension Associate

Introduction

There is growing interest in the use of short-season summer annual legumes or grasses as cover crops and green manures in vegetable production systems. Cover crops can provide a significant source of nitrogen (N) for subsequent crops; reduce erosion, runoff, and potential pollution of surface waters; capture soil N that might otherwise be lost to leaching; add organic matter to the soil; improve soil physical properties; impact insect and disease life cycles; and suppress nematode populations and weed growth. There can be potential drawbacks, such as cooler soils in the spring, and the additional cost of seeding the cover crop. These factors must be considered depending on the particular cash crops and cover crops being grown.

Land does not have to be taken out of production in order to incorporate cover crops into cropping systems. Cover crops are usually grown in the off-season to provide benefits to the subsequent cash crop. In North Carolina, summer cover crops can be planted in the production window immediately following spring harvest and prior to fall planting of vegetable crops. The best use of cover crops maximizes the benefits described above without reducing the yield or quality of commercial cash crops.

Why Use Cover Crops?

Cover crops add organic matter to the soil - Organic matter provides benefits to the soil and the subsequent crop in many different ways. Organic matter improves the physical condition of the soil by improving soil tilth, stability of soil aggregates, water infiltration, air diffusion, and by reducing soil crusting. The addition of organic matter can also increase the populations of soil microbes and earthworms, which in turn, contribute to efficient nutrient cycling and improvements in soil structure. Finally, organic matter additions can also increase nutrient retention in the root zone.

Cover crops reduce soil erosion - Scientists have estimated that the United States has lost 30% of its topsoil in the past 200 years due to agricultural practices that do not return organic matter to the soil and that leave bare fallow soils for a significant portion of the year. Erosion has long-term costs such as loss of agricultural productivity and aquatic habitat as well as sedimentation of rivers, reservoirs, and estuaries. There are also short-term costs to farmers. The USDA estimates that farmers are losing approximately $40.00 worth of fertilizer per acre per year in runoff from farm fields. Cover crops can help reduce soil erosion by keeping the soil covered during high rainfall periods when it would normally be bare.

Farmers also report improved soil structure, stability and permeability, decreased crusting, and increased water infiltration.

Cover crops can enhance nitrogen cycling within the plant-soil system - Grass or non-leguminous cover crops can help keep N in the plant-soil system by utilizing residual N that would otherwise be lost to leaching. The nitrogen is assimilated into the tissue (biomass) of the cover crop and then, as the cover crop decomposes, it is released to subsequent crops. Leguminous cover crops, such as cowpea, soybean, and velvetbean, can also "fix" significant amounts of nitrogen for use by subsequent crops. Through a symbiotic association with the legume, *Rhizobium* bacteria convert atmospheric nitrogen into a form that the legume can use for its own growth. When grass or legume cover crops are killed or incorporated, soil microorganisms decompose their residue. In a process called mineralization, the N in the plant tissue is converted by soil microbes into a form (nitrate) that subsequent plants can use. Nitrogen in the aboveground biomass of the cover crops varies considerably within species, but legumes generally contribute anywhere from 60-200 lbs of N per acre. This nitrogen is mineralized over an extended period of time, with an average of 50% of the total N contained in the cover crop available to subsequent crops.

The ratio of carbon to nitrogen (C:N) in the cover crop biomass affects how much and when the nitrogen contained in the cover crop will be available for subsequent crop uptake. The microbial population that decomposes the cover crops are made up of 10 parts carbon to 1 part nitrogen. When a cover crop is incorporated, the population of soil microorganisms increases in response to the added food source. As the population of these microbes increase, this 10:1 carbon to nitrogen ratio must be maintained. Consequently, as the microbial populations increase, N contained in the cover crop and the soil may be immobilized or "tied up" as part of the physical structure of the microbes. As a result, the cover crop N may not be available for uptake by the following crop. When the microbes die, the N is "mineralized" and becomes available for subsequent crop use.

For example, a mature sorghum-sudangrass cover crop may have a relatively high C:N ratio of 50:1. This ratio only supplies about 20% of the N needed by the microorganisms when they utilize this carbon source. As the soil microbial population increases in response to the incorporation of the grass cover crop into the soil, maintenance of a microbial C:N ratio of 10:1 requires the immobilization of all the N contained in the sorghum-sudangrass biomass as well as additional available soil N. If a vegetable crop follows the sorghum-sudangrass, additional N would be required to insure adequate crop growth.

On the other hand, legumes have relatively low C:N ratios and therefore little or no immobilization can be expected from their incorporation into soil. In fact, legume N can be quickly mineralized, perhaps even before the subsequent crop has a high demand for it. Approximately 65 to 70% of the carbon in cowpea and sunnhemp residue (C:N = 32 and 24, respectively) is mineralized in the first two weeks after soil incorporation. If the N is mineralized quickly and available N exceeds the crop need, this N can be subject to leaching losses.

Achieving synchrony of N release from decomposing legume residue and crop N demand is expected to increase the overall efficiency of use. Timing of cover crop kill can affect this synchrony. Generally, the more mature the cover crop, the higher the C:N ratio and the slower the decomposition. Better utilization of N is important to prevent N pollution of surface and groundwater through runoff and leaching.

Cover crops have the potential to enhance nitrogen cycling by reducing nitrate leaching losses - Nitrogen is the most difficult nutrient to manage in agricultural systems. It is necessary in large quantities for adequate crop growth and yield, but it is also extremely mobile in soil. Planting a non-leguminous cover crop after a spring vegetable harvest can "trap" leftover, residual soil nitrogen through cover crop uptake and reduce the potential for leaching losses through the summer months. Additionally, the cover crop utilizes excess water in the soil which also helps limit leaching losses.

Leaving cover crop residues on the soil surface, rather than incorporating them, has advantages and disadvantages with regard to efficiency of utilization of cover crop N. Maintenance of surface residues can result in increased losses of cover crop N to the atmosphere via a process called denitrification. On the other hand, immobilization and slower residue decomposition can result in reduced leaching losses. Also, a higher concentration of crop residues and organic matter near the soil surface can increase the diversity of microorganisms and fauna at the surface, which can result in greater recycling of N in the soil ecosystem.

Cover crops can reduce weeds in subsequent cash crops - While the cover crop is growing, it will suppress the germination and growth of early spring weeds through competition and shading. When killed and left on the surface as a mulch, cover crops continue to suppress weeds, primarily by blocking out light. Cover crops can also suppress weeds chemically - Some plants release chemicals, either while they are growing or while they are decomposing, which prevent the germination or growth of other plants (allelopathy). Researchers have effectively used cover crops of wheat, barley, oats, rye, sorghum, and sudangrass to suppress weeds. Weed suppression has also been reported from residues and leachates of crimson clover, hairy vetch, and other legumes.

Cover crops can impact plant diseases - Pathogens can either be enhanced or inhibited by cover cropping systems. The impact of the cover crop on the pathogen will depend upon the nature and life cycle requirements of the pathogen. For example, if the pathogen survives best on surface residue and the cover crop is left on the surface as a mulch, then the level of disease may increase. On the other hand, increases in soil organic matter content can enhance biological control of soil-borne plant pathogens through direct antagonism and by competition for available energy, water and nutrients. In experiments in Georgia, *Sclerotium rolfsii* was reduced in cover cropped, no-till systems.

Organisms that cause disease can by affected by decreases in temperature, increases in moisture, reductions in soil compaction and bulk density, and changes in nutrient dynamics. Whether or not the cover crop is taxonomically related to the subsequent crop will also influence whether or not disease cycles are interrupted or prolonged. Some cover crops have also been shown to reduce nematode populations, including velvetbean, sorghum-sudangrass, and sunnhemp.

Cover crops can also impact insect populations either negatively or positively - Cover crops attract beneficial and pest insects into cropping systems. Both can disperse to cash crops when the cover crop matures or dies. Prior to the arrival of important insect pests, beneficial insects attracted into an area by a cover crop may reach sufficient population densities to maintain pest populations in adjacent crops below economic threshold levels. Research in Georgia reported high densities of bigeyed bugs, lady bugs, and other beneficial insects in vetches and clovers. It has also been reported that assassin bugs have destroyed Colorado Potato Beetle feeding on eggplant planted into strip-tilled crimson clover.

Cover crops affect the economics of farming operations differently, depending on the cover crop and the cash crop. Growers need to account for cover crop seed and planting costs - Quantifiable savings, on the other hand, can include reduced fertilizer and herbicide applications, and reduced costs of pest and disease control. Growers will have to determine how they want to account for less apparent long-term savings such as, reduced soil erosion, increased organic matter content, improved soil physical properties, reduced nitrate leaching, and enhanced nutrient cycling.

Choosing a Cover Crop

The desired purpose of the cover crop will help determine the most appropriate species. If the purpose of a cover is to provide readily available, biologically-fixed N for subsequent crops, then the grower should choose a legume like cowpea, which fixes nitrogen and has a low C:N ratio. If the cover crop will be managed as a surface mulch for weed suppression, the grower should choose a high C:N, heavy biomass producer with demonstrated weed suppression characteristics, such as sorghum-sudangrass.

Species Suitable for Use as Summer Cover Crops in North Carolina

While additional legumes and grasses are being evaluated for use in North Carolina, the following species are currently the best options.

Non-legumes

Buckwheat *(Fagopyrum esculentum)* - Buckwheat is a very rapidly growing, broadleaf summer annual which can flower in 4 to 6 weeks. It reaches 2 1/2 ft in height and is single-stemmed with many lateral branches. It has a deep tap root and fibrous, superficial roots. It can be grown to maturity between spring and fall vegetable crops, suppressing weed growth and recycling nutrients during that period. Buckwheat flowers are very attractive to insects, and some growers use this cover as a means to attract beneficial insects into cropping systems. Buckwheat is an effective phosphorous scavenger. It is succulent, easy to incorporate, and decomposes rapidly. The main disadvantage to buckwheat is that it sets seed quickly and may, if allowed to go to seed, be a weed problem in subsequent crops.

The optimal time to incorporate buckwheat is a week after flowering, before seed is set. The seeding rate is 30 to 90 lbs/acre; higher rates are used when broadcasting. Seed should be drilled 1/2 inch deep, or broadcast and incorporated with a light disking. Buckwheat can be planted anytime in the spring, summer or fall, but is frost-sensitive.

Sorghum-sudangrass *(Sorghum bicolor X S. sudanense)* - Sorghum-sudangrass is a cross between forage or grain sorghum and sudangrass. It is a warm-season annual grass that grows well in hot, dry conditions and produces a large amount of biomass. Often reaching 6 feet in height, it can be mowed to enhance biomass production. Sorghum-sudangrass is very effective at suppressing weeds and has been shown to have allelopathic properties. The roots of sorghum-sudangrass are good foragers for nutrients (especially nitrogen) and help control erosion. Research on nematode suppression by sorghum-sudangrass is not conclusive. Some studies have shown that nematode populations have been higher in vegetables following sorghum-sudangrass, while other studies have shown that sudangrass suppresses nematode levels.

Sorghum-sudangrass does well when planted in mixtures, providing effective support for viney legumes like velvetbean. It can be planted 1/2 to 1 1/2 inches deep from late spring through midsummer at a rate of 45 lb/acre. If frost-killed, the residue can provide a no-till mulch for early planted spring crops like potatoes.

The main advantages of sorghum-sudangrass include its ability to scavenge nitrogen, grow quickly for erosion control, suppress weeds, and suppress some nematodes. A possible disadvantage is nitrogen tie-up and a resulting limit of available N for subsequent crops.

German (foxtail) millet *(Setaria italica)* - German or foxtail millet is an annual warm season grass that matures quickly in the hot summer months. It is one of the oldest of cultivated crops. Although German millet has a fairly low water requirement, it doesn't recover easily after a drought because of its shallow root system. Grain formation requires 75 to 90 days. German millet forms slender, erect, and leafy stems that can vary in height from 2 to 5 ft. The seed can be planted from mid-May through August at a rate of 25 to 30 lbs/acre. A small seeded crop, German millet requires a relatively fine, firm seedbed for adequate germination. In order to avoid early competition from germinating weed seed, German millet should be sown in a stale seed bed or closely drilled in the row. Coarse sands should be avoided.

Pearl Millet *(Pennisetum glaucum)* - Pearl millet is a tall summer annual bunchgrass that grows 4 to 12 ft tall. It is also often referred to as cattail millet because its long dense spike-like inflorescences resemble cattails. The mature panicle is brown. Though it performs best in sandy loam soils, pearl millet is well adapted to sandy and/or infertile soils, Pearl millet can be planted from late April through July at a rate of 5 to 15 lbs/acre. Pearl millet matures in 60 to 70 days. In studies in North Carolina, pearl millet was not as readily killed by mechanical methods (mowing and undercutting) as German or Japanese millet.

Japanese Millet *(Enchinochloa frumentacea)* - Japanese millet is an annual grass that grows 2 to 4 ft tall. It resembles, and may have originated from barnyardgrass. The inflorescence is a brown to purple panicle made up of 5 to 15 sessile erect branches. Japanese millet is commonly grown as a late-season green forage. If weather conditions are favorable, it grows rapidly and will mature seed in as little as 45 days. Japanese millet can be planted from April-July at a rate of 20 to 25 lbs/acre. It performs poorly on sandy soils.

Legumes

Cowpea *(Vigna unguiculata)* - Other common names for this plant include blackeye, crowder, and southern pea. Cowpea is a fast growing, summer cover crop that is adapted to a wide range of soil conditions. Having a taproot that can obtain moisture from deep in the soil profile, it does well in droughty conditions. Vigorous cowpea varieties compete well against weeds. A high nitrogen producer, cowpea yields average 3000 to 4000 lbs/acre of dry biomass containing 3 to 4% nitrogen. Maximum biomass is achieved in 60 to 90 days. Residues are succulent and decompose readily when incorporated into the soil. Cowpea can be planted in the spring after all danger of frost through late summer. Cowpea seed can be drilled in rows 6 to 8 inches apart at 40 lbs/acre or broadcast at 70 to 120 lbs/acre. However, higher seeding rates are necessary in late summer if soil moisture is likely to be limiting. Recommended cultivars include Ironclay and Redripper. Ironclay matures later than Redripper. Plants normally grow up to 2 ft tall, but some cultivars can climb when planted in mixtures with other species. Good mixture options are sorghum-sudangrass and German foxtail millet. When killed mechanically, cowpeas can have considerable regrowth after mowing and undercutting in some years.

Soybean *(Glycine max)* - Soybean is one of the best economic choices for a summer legume cover crop. It is an erect, bushy plant that grows 2 to 4 ft tall, establishes quickly, and competes well with weeds. When grown as a green-manure crop, late maturing varieties usually give the highest biomass yield and fix the most nitrogen. While most of the roots are in the top 8 inches of the soil, some roots can penetrate up to 6 ft deep. Soybean will withstand short periods of drought if they are well-established. Soybean will grow on nearly all types of soils, but are most productive on loam soils. Soybean planted as cover crops should be broadcast or closely drilled at 60 to 100 lbs/acre. Some new viney forage types (e.g. quailhaven soybeans) are available or are being developed that have the potential to produce more biomass than traditional soybean varieties.

Velvetbean *(Mucuna deeringiana)* - Velvetbean is a vigorously growing, warm-season annual legume native to the tropics but well adapted to southern conditions. It performs well in sandy and infertile soils. Most cultivars are viney and some can attain a stem length of 30 ft. The leaves of velvetbean are trifoliate with large ovate leaflets. Pods are hairy, up to 6 inches long, and contain 3 to 6 seeds. Velvetbean is an excellent green manure crop, producing high amounts of biomass that decomposes readily to provide N for subsequent crops. Velvetbean should be seeded into warm soils at 25 to 35 lbs/acre in 40-inch rows. Velvetbean seed should not be drilled because the very large seed can be damaged in conventional drills. When grown for seed, velvetbean should be sown in a mixture with an upright crop like sorghum-sudangrass or corn. Velvetbean vines will climb stems of these grasses and flowers produced will get necessary air circulation.

Sunnhemp *(Crotalaria juncea)* - Sunnhemp is a tall, herbaceous, warm-season annual legume that has been used extensively for soil improvement and green manuring in the tropics. The erect fibrous stems are competitive with weeds. It grows rapidly and can reach a height of 9 ft in 60 days. It can tolerate poor, sandy, droughty soils but requires good drainage. Sunnhemp tolerates moderate alkalinity and a soil pH below 5 reduces growth. Sunnhemp should be broadcast at 30 lbs/acre or seeded in 3.5 foot rows at 5 to 7 lbs/acre. Higher seeding rates will lead to prolonged succulence of the stems and are recommended if the crop will only be grown for 4 to 5 weeks. Lower rates are recommended if grown for seed production. Sunnhemp becomes fibrous with age, but the plants will remain succulent for about 8 weeks after seeding. It can be integrated into cropping systems by sowing it in late summer after corn. It will produce high biomass yields and N in the months before frost. Residues left on the soil surface over the winter months will facilitate no-till crop production the following spring. Seed is not currently readily available, but if demand were to increase, seed availability would most likely respond. While forage of some *Crotalaria* species is toxic to animals, sunnhemp forage is not. Sunnhemp should also not to be confused with the weed species, and the growing season in North Carolina is not long enough for sunnhemp to produce viable seed.

*It is very important that the legumes are inoculated with the appropriate Rhizobium bacteria. Sources of inoculant are listed at the end of this document.

Single Species vs. Mixtures

Mixtures of cover crop species can be planted to optimize the benefits associated with cover crop use. Mixtures which include species that establish quickly can reduce soil erosion. Above-ground biomass, and consequently N in the above-ground biomass, can be increased by a mixture that can utilize more below-ground and above-ground niches for nutrients, water, and light.

For example, a deep rooted cover crop can be combined with a shallow rooted cover crop to utilize water and resources in more of the soil profile.

Competition for soil N in mixed stands results in increased biological nitrogen fixation by the legume. Cereal crops usually germinate and establish effective root systems more rapidly than legumes and effectively lower soil N concentration. Since nodulation of legume roots and fixation of atmospheric N_2 by legumes is generally greater when soil N concentration is low, nodulation and nitrogen fixation is increased in mixtures.

Nitrogen cycling can also be manipulated with mixed cover crop species. Combining plants with high C:N ratios (mature cereals) with plants that have low C:N ratios (legumes) can influence mineralization of cover crop residues. The release of nitrogen from residues can be more properly timed with subsequent crop uptake; that is, both nitrogen immobilization and large flushes of nitrate can be moderated. This can help to optimize the efficiency with which fixed nitrogen is used by subsequent crops.

Planting mixtures of cover crops can take advantage of the allelopathic potential of the cover crops to suppress weeds. Allelopathic suppression of weeds has been shown to be a species specific phenomenon, therefore a broader spectrum of weed control may be possible by growing a mixture of cover crop species, each contributing allelopathic activity towards specific weed species.

Mixtures can also be planted to influence insect populations. Cover crop species, regardless of biomass or biomass-N production potential, could be included a mixture if they were known to attract important beneficial insects into the cropping system.

Relative Biomass and N production in North Carolina

Above-ground biomass (AGB), and AGB-N production data of various summer cover crops and mixtures planted in Plymouth and Goldsboro are summarized below.

Species	Seeding rate	AGB (lb/ac)[1]	C:N	Nitrogen (lb/ac)
Legumes				
Cowpeas	70	3529	21	75
Sesbania	20	4278	23	86
Soybean	90	3507	20	80
Velvetbean[2]	40	1263	21	28
Lab Lab	40	1994	29	30
Non-legumes				
Sorghum-sudangrass	35	7825	53	78
Sudangrass	35	5018	44	58
Japanese Millet	30	3486	42	35
Pearl Millet	30	5936	50	57
German Foxtail Millet	30	4066	44	43
Buckwheat	60	3157	34	43
Mixtures (percent species)				
J. Millet/Soybean (36/64)	12/54	34/93	28	85
Cowpea/Sudex (25/75)	50/10	7067	33	57
Cowpea/sesbania (77/23)	50/6	3480	28	64

[1]Dry matter

[2] Velvetbean biomass was low in this study as a result of poor germination. In this case, the large-seeded velvetbean seed coat was cracked while attempting to drill the seed. Germination was adequate in subsequent trials where velvetbean was planted with a traditional seeder.

Methods of Mechanical Kill

Cover crops that will be left on the surface as a mulch for no-till production need to be killed, either with chemicals or mechanically. In systems where the goal is to reduce chemical use, mechanically killing the cover crops is desirable. Three methods for mechanically killing cover crops were evaluated in a study in Eastern North Carolina: undercutting, mowing, and rolling. The effectiveness of the various methods of mechanical kill were evaluated 3 weeks after cover crop kill. Mowing was accomplished with a flail mower which leaves the finely chopped residue evenly distributed over the bed. Rolling was accomplished using the same flail mower, but with the mowing tines disengaged. The undercutting was performed with a single blade that severed cover crop roots, approximately 2 inches deep, and an attached roller laid the undercut cover crops flat.

Species	Growth Stage	Percent kill		
		Mow	Undercut	Roll
Legumes				
Cowpeas[1]	Vegetative	98	86	15
Sesbania	Vegetative	100	100	5
Soybean	Early bloom	100	98	10
Velvetbean	Vegetative	100	95	52
Lab Lab	Vegetative	10	93	30
Non-legumes				
Sorghum-sudangrass	Immature seed	0	93	16
Sudangrass	Immature seed	0	78	6
Japanese Millet	Mature seed	95	100	100
Pearl Millet	Pod	0	52	13
German Foxtail Millet	Green seed	100	100	100
Buckwheat	Mature seed	100	100	100

[1]In subsequent studies, when cowpea was killed in mid-August, considerable regrowth was observed when cowpea was mowed and undercut.

Sources of Cover Crop Seed

Species	Avg. price/lb, 1998 (price/acre)	Sources*
Buckwheat	0.50 ($30.00)	All
Sorghum-sudangrass	0.36 ($16.20)	1,2,4,5,7,8,10
Pearl Millet	0.30 ($4.50)	2,4,5,7,8,9,10
German Millet	0.45 ($13.50)	1,2,4,9,10
Japanese Millet	0.58 ($14.50)	1,2,4,7,8,9
Cowpeas	0.52 ($36.00)	1,2,3,4,5,6,7,8,10
Soybean	0.45 ($36.00)	1,4,5,6,7
Velvetbean	2.50 ($75.00)	1
Sunnhemp	1.95 ($58.50)	6

***Sources**

1. Adams-Briscoe Seed Company
PO Box 18
Jackson, GA 30233
770/775-7826

2. Jeffries Seed Co.
PO Box 887
Goldsboro, NC 27533
919/734-2985

3. Wyatt-Quarels Seed Co.
PO Box 739
Garner, NC 27529
919/772-4243

4. Kaufman Seeds, Inc.
PO Box 398
Ashdown, Arkansas 71822
800/892-1082

5. Southern States Cooperatives, Inc.
2600 Durham St.
Richmond, VA 23220
(local outlets throughout NC)

6. Peaceful Valley Farm Supply
PO Box 2209
Grass Valley, CA 95945
530/272-4769

7. Hale Dean
PO Box 771458
Winter Garden, FL 347771458
407/877-3333

8. Pennington Seed
PO Box 290
Madison, GA 30650
800/285-7333

9. Budd Seed Inc.
PO Box 25087
Winston-Salem, NC 27114
910/857-2591

10. Garner Seed Co.
6292 Old NC Hwy 95
Denton, NC 27239
910/857-2591

**** Inoculant Suppliers**

1. Urbana Laboratories
PO Box 1393
310 S. Third St.
St. Joseph, MO 65402

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For Further Reading

Managing Cover Crops Profitably, 2nd Edition. 1998. Sustainable Agriculture Network, Handbook Series 3. Beltsville, MD.