Hello, everyone. I'm Vesh Thapa. I'm a postdoc at Department of Agronomy and Horticulture and I'm based at Panhandle Research, Extension, and Education Center at Scottsbluff. In today's lecture, I'll be talking about cover crop impacts on subsequent main crop yield as a part of this webinar series

The outline of my presentation has been classified into 5 broad categories

I'll be talking about the introduction, adoption trends of cover crops, and then describe the mechanism of how cover crop influence main cash crop yield, and a little bit talk about context of Nebraska, show some of the evidences from the field trials across Nebraska, and share some key take-home points

I'll begin with the introduction of cover crops, what are cover crops? Cover crops are plants that are grown in between main crops, especially at times when main crops are not growing, they are usually not harvested as main crops but terminated before they set seed and decompose in place, cover crops could be any legumes, grasses, brassicas, or combination of all these 3

Cover crops provide multiple ecosystem service benefits. For example, cover crops helps to improve soil properties and processes, they suppress weeds, provide habitat for beneficial predatory insects, facilitate crop pollinators, provide wildlife habitat and forage source for livestock

How does USDA define a cover crop then? In 2014 USDA revised the definition of cover crop for consistency across the agencies. USDA has defined cover crops, as crops including grasses, legumes, and forbs for seasonal cover and other conservation purposes

They are primarily used for erosion control, soil health and water quality improvement, and cover crops should be managed and terminated according to the guidelines that does not consider a crop for insurance purpose, and they could be terminated by natural causes, such as frost, or intentionally terminated through chemical applications, crimping, rolling, tillage, or cutting, they may be grazed or harvested as hay or silage, but cannot be harvested for grain or seed

This is how USDA has defined cover crops to maintain consistency across its agencies

Cover crops are mainly of 3 types, they are fall planted, spring planted, and summer planted

Let me begin with fall planted, Fall planted means they are cool season species that are planted after fall harvest usually in the late September to early October and terminated in the spring of the following year sometime around late April or early May, Some of the examples of fall planted cover crops could be rye, barley, winter pea, hairy vetch, rapeseed, and radish

Spring planted cover crops means they are also cool season species. They are typically short season annual species and generally remain in the ground for about 60 to 90 days before cash crop planting. They are planted during the onset of spring when the soil temperature is just warm enough for germination, which is typically around 40°F, they can be planted in early March and terminated in late May before planting summer cash crops. The examples of spring planted cover crops could be barley, oat, triticale, pea, faba bean, and collard

Another type of cover crop could be planted in summer. Summer planted cover crops are warm season species that are usually planted during late June to early July and terminated in late September to early October. Summer planted species are mostly forage-type cover crops because of their higher production potential, they provide soil health and pollinator benefits, and they also help to increase biodiversity, summer planted cover crops could be Sudan-grasses, forage sorghum, millet, buckwheat, cowpea, and sunn-hemp.

I'm going to talk about the adoption trends of cover crops in the United States and in Nebraska

In recent years, the use of CCs has been spreading across the globe, Recent interest in cover crops has been driven by a variety of factors

These factors could be enthusiasm for soil health and regenerative agriculture, Climate change and water quality problems, Herbicide resistant weeds, and Incentive programs that pay farmers to grow cover crops

The US Census of agriculture has been collecting data on a 5-year cycle. You can see the bar graph on the right. I have a data for 3 census, which is 2012, 2017 and 2022. Cover crop acres increased by 5.1 million or 50% between 2012 and 2017 Census, however area under cover crops increased less between 2017 and 2022 than between 2012 and 2017. There was 18.0 million acres of cover crops in 2022 which was 2.6 million or 17% more than the 2017 Census, In 2022, the latest census, cover crops were planted on 4.7% of total cropland in the United States

This is a study from US Midwest. This study was conducted to quantify cover cropping in corn and soybean fields from 2000 to 2021 in the U.S. Midwest using remote sensing data, this study found that cover crop adoption in most counties was stagnant from 2000 to 2011, but significantly increased from 2011 to 2021

The adoption of 2021 was four times that of 2011. This increment was highly correlated to the funding for conservation programs, However the percentage of cover crop adoption in the U.S. Midwest is still low which is just 7.2%. This study highlights the potential importance of incentive programs to promote wider adoption of cover crops

This bar graph shows cover crops on cropland in States with at least 0.5 million acres in cover crops in 2022, Red color bar represents 2017 census, and red color indicates 2022 census, These 13 states had more than 0.5 million acres in cover crops during 2022

They accounted for 65% of US cover crop acres in 2022 and 92% of the increase from 2017, Texas had the largest cover crop acres in 2017, with 1.01 million as well as in 2022 with 1.55 million, eventually resulting the largest increase in cover crop acres between 2017 and 2022, which was 0.54 million

Iowa had second largest acres with 1.28 million, and Nebraska ranked fourth in cover crop use with 0.93 million acres during 2022

Coming back to specific Nebraska. In Nebraska, less than 1% of the total cropland which is 22 million is currently sown to cover crops, 0.7 million acres was under cover crops in 2012 which was increased by 7.2% reaching 0.75 million acres in 2017, There was 24% increase in cover crop acres between 2017 and 2022 reaching 0.93 million acres in 2022

Approximately 45,000 producers have adopted cover crops across the State, More cover crop practices are being adopted in eastern part where annual rainfall is in between 28 to 35 inches than central and western part that receives rainfall in between 13 and 18 inches, the statistics say that about 4.3% of the cropland area are under cover crops in Northeast, central, and east part of the state while only 2.4% of the cropland area are under cover crops in Northwest, southwest and northern part of the state

Now I'm going to talk about how cover crop influence crop yield. I'll be talking about the mechanism

Cover crop influence several ecosystem service benefits, these ecosystem service benefits are interconnected, or they are interrelated to each other, and these all together influence main crop yield, for example, cover crops influence soil health improvement by increasing organic matter, enhancing microbial activity and improving nutrient cycling

For nutrient availability, legume cover crops can fix atmospheric nitrogen and grass cover crops can reduce nitrate leaching, and they can all release the nutrients upon decomposition. I'm just providing a few examples here. These all-ecosystem service benefits provided by cover crops together influence the main crop yield

In the next slides, I'll be talking in detail about these ecosystem service, how they influence main cash crop yield

This figure shows the mechanistic pathways of cover crop to affect cash crop yield, cover crops strongly influence the ecosystem carbon, nitrogen, and water cycle processes

In today's lecture, for carbon cycle, I will be focusing on describing the plants carbon fixation, plants and soil respiration

For nitrogen cycle, I will focus on plants nitrogen uptake, legume nitrogen fixation, and soil mineralization, and for water cycle, I will describe plants water uptake, and soil water flow

Let me begin with the carbon cycle. For carbon cycle, I'll begin with carbon fixation

Through photosynthesis, cover crops absorb atmospheric carbon dioxide and convert it into organic carbon compounds. This carbon is stored in the plant tissues, such as leaves, stems, and roots during the cover crop's life cycle. Cover crops use this energy to grow, and when they die, this energy is transferred to the soil ecosystem through the breakdown of plant material

In the soils, microorganisms such as bacteria and fungi break down plant material. During the degradation process, the chemical energy stored in the plant matter is released and utilized by soil organisms, which help break down nutrients and make them available to the subsequent cash crop

Not only one way fixation occurs, but respiration also occurs. It's a loss pathway. During respiration what happens? There is a breakdown of carbohydrates in the presence of oxygen, resulting water and carbon dioxide

Photosynthesis and respiration are opposite to each other, accumulating dry matter or yield is the tradeoff between photosynthesis and respiration

Moving ahead to water cycle. It's just the transfer of water through soil-to-root-to-canopy, and canopy-to-atmosphere pathway. How do cover crop influence this cycle? Let me explain

Cover crops root channels in the soil, allows water to infiltrate more easily, the roots of cover crops break up compacted soil allowing water to penetrate deeper into the soil profile, this reduces surface runoff and helps store water in the soil profile, making it available for the subsequent crop

Soil water potential is almost always negative because of capillary and adhesion forces acting on soil particles, the water moves from areas of higher potential which is soil to lower potential into the root system via root hairs

Transpiration at the leaf level creates a negative pressure in the xylem, a plant tissue that pulls water from the roots to the leaves, plants regulate transpiration by opening and closing their stomata in the leaf. And it is dependent on environmental conditions like temperature, humidity, wind, and light, as well as the plant's water status

In addition to transpiration, water can evaporate directly from the soil and plant surfaces. The combined process of water loss from both evaporation and transpiration is called evapotranspiration. How do cover crop influence this cycle then?

Cover crops can reduce water loss from the soil by limiting evaporation. The canopy of the cover crop reduces the amount of sunlight that reaches the soil, keeping it cooler and reducing the rate of evaporation. Some cover crops may also act as a windbreak, reduce wind speed and limit the water loss from soil surfaces

As a part of management practices fertilizers applied provide inorganic ammonium and nitrates to uptake by plants, and some parts are lost into the atmosphere via ammonia volatilization, nitrous oxide emissions, leaching, etc.

Legume cover crops fix atmospheric nitrogen in their root nodules and store it as organic nitrogen, called immobilization. Now microbes need to act to release nitrogen and make them available in the soil for subsequent crops

During microbial growth and decay, they seek to maintain their biomass carbon and nitrogen ratio. They get food source from the dissolved decomposition products of diverse litter, particulate organic matter, and humus substrates

This figure is a kind of summary of a mechanistic pathways that I explained earlier, cover crops may cause yield loss by reducing soil water content under dry conditions. Non-legume cover crops may reduce soil nitrogen concentration after termination, due to immobilization, thereby limiting crop nitrogen uptake during early growing stages, leading to yield reduction

However, yields may increase with legume cover crops because they can fix atmospheric nitrogen to overcome limited soil nitrogen availability. Also, residue of legume cover crops can release a large amount of inorganic nitrogen through mineralization

Less oxygen at early growing stage can harm crop growth, and this oxygen stress can result from the increased oxygen consumption by microbes during the decomposition of cover crop residue, especially in fields with wetter springs the seasonal saturation could worsen oxygen demands

Let me talk a little bit about carbon and nitrogen ratio, because this is one of the very important aspects that influence nutrient release from cover crop residue

C:N ratio refers to the ratio of carbon to nitrogen in a substance, and determines the rate of residue decomposition, and release of nutrients from plant residues

A C:N ratio that is high, which means too much carbon relative to nitrogen, can result in slow decomposition of organic residues, while a ratio that is low meaning too much nitrogen relative to carbon can result in fast decomposition of organic residues

The optimum C:N ratio for residue decomposition is 24:1. Soil microbes have a CN ratio 8:1. For optimum health, microbes require 16 parts of carbon for energy and then 8 parts for maintenance

When CN ratio is greater than 25:1 nitrogen immobilization occurs. During this process, soil microorganisms, such as bacteria and fungi, use nitrogen from the soil for their own growth and metabolism. Microorganisms take up nitrogen in the form of ammonium or nitrate and convert it into organic forms of nitrogen, such as amino acids, proteins, and nucleic acids. These organic nitrogen are then incorporated into microbial biomass, making it unavailable to plants until microorganisms die and release nitrogen back into the soil

On the other hand, when CN ratio is less than 25:1, nitrogen mineralization occurs. It is opposite to immobilization. During this process, organic nitrogen is converted back into inorganic forms. During mineralization, soil microorganisms break down organic residues, and release nitrogen in the form of ammonium or nitrate. These inorganic nitrogen are then available for plants to use for their growth and development

The balance between nitrogen immobilization and mineralization can have important implications for soil fertility and plant growth. If nitrogen immobilization exceeds mineralization, soils may become temporarily deficit of nitrogen, which can limit plant growth. Conversely, if mineralization exceeds nitrogen immobilization, excess nitrogen can be released into the soil, which can lead to environmental problems such as groundwater pollution or the eutrophication of surface waters, understanding C:N ratio can help manage soil fertility

I would like to talk CN ratio and its relation to plants age

When plants are young and actively growing, they require a large amounts of nitrogen to support the production of proteins, enzymes, and other nitrogen-containing compounds that are necessary for growth and development. As a result, nitrogen content of young plant tissue is relatively high, and the C:N ratio is low

However, as plant's age increase, carbon-based compounds such as cellulose and lignin in plant tissue increase. These carbon-based compounds provide structural stability to plant, are relatively stable, and thus CN ratio increase

As C:N ratio increase, organic residues becomes more difficult for microorganisms to break down and decompose

Cover crops influence multiple organic matter pools in the soil. Among them soil organic carbon is the most important one because carbon is the heart of soil health

It is estimated that plants provide 50-75% of their fixed carbon to soil via roots in the form of liquid carbon, and when there is high organic soil matter, it makes soils healthy, healthy soils have high water holding capacity

As per USDA estimation, every 1% increase in organic matter can result in up to 20,000 gallons of available soil water per acre

And another important aspects of cover crop is that it helps to maximize soil cover

Soils in semi-arid High Plains including western Nebraska are inherently low in organic matter, loose, unprotected, coarse-textured and subjected to intense drought and frequent strong winds throughout the year. This has made soil vulnerable to wind and water erosion

There is an estimate that average annual water and wind erosion in Nebraska is about 5 tons per acre, and that erosion cost about $10 per acre per year

Moreover, increasing variability in precipitation and temperature have further accelerated the loss of soil organic matter, and pose additional challenges to sustainable soil management

Now cover crops have the potential to provide soil cover, and soil cover create a vegetative mat that slows down the velocity of wind and water, reduces raindrop impact and helps in reducing soil erosion, reduce water loss by limiting evaporation, block or reduce the amount of sunlight that reaches soil surface, slows down or prevents the transfer of heat and helps maintain a desired soil temperature

Why is desired soil temperature important? If there is higher soil temperature, it means there will be higher evapotranspiration rate that causes greater loss of water from the soil

The optimum soil temperature is about 70°F, during which 100% moisture is used for growth, As we move from 70°F, and in the range of 95-degree Fahrenheit and 113-degree Fahrenheit 15% moisture is used for growth and 85% moisture is lost through evapotranspiration, around 113°F soil temperature some bacteria species starts dying

As we move from 113 to 130°F, 100% moisture is lost through evapotranspiration, and around 140°F soil bacteria and other microorganism starts dying. This is why desired soil temperature is vital

You can see in the photos in the right that bare soil had higher temperature, for example, 133°F, and in the same condition under vegetative cover, temperature is reduced to 100°F. This is an evidence of how soil cover helps to maintain desired soil temperature

Now moving ahead, I would like to talk about the weed suppression mechanism by cover crops

This is a conceptual diagram of a summary of possible interactions during the actively growing phase of the cover crop in the left, and after the cover crop is terminated and left as a surface residue in the right

Let me begin with active growing phase of cover crops. Cover crop interaction that aid in weed suppression mainly include direct competition for resources, allelopathy, facilitation, and indirect interactions. According to competitive production principle, species in a shared niche cause a negative reaction in the other species

Cover crop's biomass and traits, such as plant height, canopy or leaf area or shape affect the outcome of plant competition. Biomass produced by cover crops can reduce moisture availability and soil temperature which in turn can affect the germination of weed seeds

A taller canopy can reduce light availability to the weeds in the understory. Canopy or leaf area can affect competition for light, while root length can affect nutrient competition, cover crops also modifies soil microclimate to suppress weed. Soil bacterial and fungal changes brought by cover crops can also colonize weed seeds

Now let me explain about what happens after cover crop termination, this is an indirect interaction of cover crops

Indirect interaction include cover crop mulch acting as a physical barrier for weed seedling emergence, presence of other biocontrol agents, such as omnivorous predators increase seed predation resulting in weed seed removal, cover crop residues also modifies soil microclimate to suppress weed

While competition is a major mechanism of interaction, the physiological properties of cover crops can also influence weed population dynamics, which is a non-competitive interference

Figure on the right shows the suppression of weeds by the allelochemicals produced from oilseed crops. Oilseed crops act as donor of allelochemicals produced from their shoot and roots in the form of transpiration and root exudates. Allelochemicals are phenolic compounds, terpenes, long chain fatty acids, and simple acids. These allelochemicals are the key factors to suppress weeds and indirectly enhance the crop yield

There are different pathways of releasing such allelochemicals into the environment. Washing of aerial parts such as leaves, flower and stem with rain, dew and fog. Exudation of volatile compounds from aerial parts like volatilization from leaves. Exudation of roots, and decay of plant residues

After decomposition of allelopathic plant residues, both water-soluble and relatively insoluble allelochemical compounds become available in the soil after irrigation

Moving ahead, I would like to summarize the allelopathic effects and how that influence weed dynamics in the soil

Allelopathy is a chemical interaction of plants. This phenomenon has the potential to facilitate environmentally friendly weed management and avoid the concerns associated with the misuse of agrochemicals for pest and weed management

Several practices such as crop residue mulching, cover, cropping, intercropping, and crop rotation release allelochemicals, and release of allelochemical are influenced by plant, soil and environmental factors

Environmental factors include temperature, solar radiation, nutrient availability, and stressors like wounding, invasion of plant pathogen. Plant factor affect in ways like production of root exudates differ on cultivar type, growth stage of plant, etc. (rice vs sorghum). Also, the synthesis of allelochemicals is associated with the activation of some specialized genes inside the plants

Although allelochemicals are produced by the entire plant, leaf and stem, roots are the main point of release. When allelochemicals are released into the environment, it undergoes several interacting processes like retention which means mechanisms that delay or restrict the movement of chemicals from one point to another, due to physical hindrances imparted by various soil constituents, example cation exchange capacity, adsorption in soil colloids

Transformation is a process that change the shape or structure of allelochemicals, microbes transform allelochemicals into less toxic or more toxic compounds, and transportation is a process that control the movement of chemicals in the environment which can be influenced by soil structure. For example, Porous soil easy movement, compact soil restrict movement

This is an evidence how cover crops can suppress weed in the cropping system. This is a result from an experiment in producers' field and in research station in west central Nebraska. Cereal rye cover crop reduced winter annual weed density and biomass by more than 90% in both producers’ field and research station

Moving ahead, I would like to a little bit talk on the context of Nebraska. Nebraska’s annual precipitation varies greatly from west to east, ranging from 13 to 35 inches. Western Nebraska, including panhandle region, receives low precipitation less than 400 mm and have cold dry winters, As we move towards east the precipitation levels keeps increasing

Picture on the right is for Ogallala aquifer. It is the major source of irrigation water for agricultural purposes in Nebraska. However, with high irrigation demand and low recharge rate, the water levels in the aquifer is continuously going down. With the declining ground water levels, many farms are transitioning to drylands. Recent prediction shows that 35% of the currently irrigated acreage will be unable to support irrigation within the next 30 years

Talking about the cropping system in Nebraska. Nebraska contributes 4% of total winter wheat production in the United States. Winter wheat is mostly concentrated in the western part of the state. Winter wheat is typically planted in late-Sep to early Oct. The goal is to acquire 400 growing degree days before Dec 31

Annual wheat cropping system has 3 months of fallow period. Wheat-fallow system produce one crop in 2 years and leave the land fallow for 13 months. The purpose of leaving the land fallow is to conserve soil water and nutrients, and control weeds. However, fallowing limits the amount of plant residues produced and returned to the soil and contributes to soil erosion and soil degradation

Corn and soybean rotation is a commonly adopted practice among Nebraska growers, especially in the eastern part of the state. The summed planted area of corn and soybean in Nebraska is 6.5 million hactre, which represents 30% of the state territory and more than 90% of total cropland

Corn has always been a dominant crop in Nebraska, and it is the third-largest producer and contributes 12% of total corn production in the US, corn are usually planted in April to May when soil temperature reach 50F. Soybean is the second-most grown crop in the state, and it is the fourth-largest producer and contributes 8% of total soybean production in the United States, soybean are usually planted in April or May

The dependence on corn and soybean rotation has reduced crop diversity. As a result, pest outbreaks and nitrogen runoff are some of the issues of Nebraska agriculture. Corn-soybean rotation offers an important opportunity to implement cover crops when these major field crops are not grown during winter

Let me show some of the evidences how cover crops has influenced cash crop yield across Nebraska and beyond

This is a Meta analysis. This meta-analysis summarized 65 peer-reviewed research articles from north America, especially from the United Sates and Canada that were published between 1965 and 2015. Figure on the left compares corn yield for three levels of winter cover crops, and on the right on two levels of tillage management within legume cover crop

Results showed a neutral to positive contribution of winter cover crops to corn yields, On average, grass winter cover crops neither increased nor decreased corn yields, it had neutral effect i.e., corn yields following a grass winter cover crops were not significantly different than no-cover crop

Corn following a mixture winter cover crop treatment showed 13% higher average yields than no-cover crop, corn that followed a legume winter cover crop yielded 21% more than without a cover

Under conventional tillage, corn following legume winter cover crops exhibited 15% higher yields than no-cover crops. However, yield increase was 30% for no-tillage corn following a legume winter cover crops.

This means the effect of cover crops are more pronounced with reduced tillage than intensive tillage management

This is an on-farm study from Iowa. In 2008, 12 farmers across Iowa established replicated strips of winter cereal rye and strips without cereal rye within their corn and soybean rotation. Cover crop was drilled after fall harvest each year. At each site, cover crops were chemically terminated in the following spring in two timings, which were 10 to 14 day before planting, and within 1 or 2 days of planting

Over 8 years, cereal rye added to a corn-soybean rotation have little to no-negative effect on yield and increased soybean yields in seven site-years and corn yield in two-sites years

Cover crop did reduce corn yields in three site-years in the first two years of the study. Farmers who experienced yield loss was due to challenges associated with terminating their cover crop. Cover crops terminated within one or two days of planting nearly tripled cover crop biomass production compared to 14 days earlier termination. The extra cover crop growth came at the expense of reduced corn yields

Because corn is considered a heavy feeder when it comes to nutrients and water, cover crops could have utilized that nutrients and water otherwise become available for corn

Unlike corn, there was improved soybean yield in two site-years in the first two years of the study. In fact, cover crop boosted soybean yields eight times over the course of the study, and that yield increase became more frequent over the years. Soybeans yields did not differ between cover crops terminated 14 days earlier versus within one or two days of planting

Based on these results, it seems soybeans are more flexible than corn when it comes to cover crop termination timing. It appears terminating cereal rye 10 to 14 days before planting is a sound advice for corn following a cereal rye. Waiting longer to kill cereal rye doesn't affect soybean yields and can benefit weed management

This is why management is a key that influence main cash crop yield

This is a review study from Nebraska. This review from Nebraska compared on-farm farmer-led field scale trials to researcher-led trials carried out in small plots on UNL experiment stations

The number of comparisons for farmer-led trials were 89 obtained from Nebraska On-Farm Research Network, and the number of comparisons for the researcher-led trials were 290 obtained from the Web of Science database

Farmer-led trials were carried out on a variety of soils, including sandy soils, whereas sandy soils were absent from researcher-led trials. The bar graph on the left shows the percentage of observations out of the total number of observation that reported information for each variable, variables were crop rotation, cover crop species, irrigation, field slope, soil type, and Nebraska region. The graph on the right show the percentage change in cash crop grain yield following a cover crop vs no-cover crop in farmer-led and researcher-led trials

Three crops for which grain yield was analyzed were corn in gray dots, soybean in green dots, and wheat in orange dots. The solid vertical black line indicates the average of all experiments

Yield differences or variability due to cover crops appeared smaller in farmer-led than in researcher-led trials. This was attributed to lower biomass production which was 600 kg per hectare in farmer-led than researcher-led trials which was 2,000 kg per hectare

Across all cash crops, an average yield decline of 3.4% occurred with standard error 11% in farmer-led experiments, while in researcher-led trials, an average yield decline was 7.0% with standard error 5.6%

However, neither of these differences were statistically different from zero. This means cover crops did not significantly increase or decrease cash crop yields compared to no-cover crop in either farmer-led or researcher-led trials

This is the results from a survey. This survey was carried out in the year 2022 to 2023. Of the cash crops highlighted in the survey, corn and soybean was the most widely grown in the mid-west region. Blue bar indicate yield with covers and red indicate yield without covers

Corn yield increased by 14% with cover than without covers and soybean yield increased by 12% with cover compared to no-cover

In the interest of time. To make sure we have a good amount of time for the discussion groups. I might encourage you to move on to your summary, and we have a few more slides for Vesh that are related to some experimental trials in Nebraska. I think that what I can do is for our water session. This is like what we do in class. We see. This series is like a couple of classes for everyone. But I want to make sure we have some good time for discussion

I see we've lost a few people at the hour which I would have expected. But if you want to move on to your summary slides, I'm going to put in the chat the facilitators I propose, if you're one of the facilitators, I encourage you to grab those discussion questions you can copy them for all, and we'll open the breakout rooms in just a minute

Okay, yeah, I will just quickly move on to the key take home points from this lecture

Cover crop impacts on cash crop yield can vary by species and years, and generally legumes and mixtures led to higher yields, especially under no-till and irrigated systems. Grass species terminated late can slightly reduce yields, particularly in the 1st few years, and in the drier regions

Yield increases become more frequent over years, and termination timing is critical, which means terminating cover crops 10 to 14 days before corn planting or planting green with soybeans optimized results

Spring oats could be an alternative to cereal rye in semi-arid regions

At-last, but not the least, I would like to emphasize that cover crop management is a key that can optimize main crop yield. These are some of the management considerations that I would like to highlight, species selection, optimal termination timing, inter-seeding, water use concerns, and manage water and nutrient competition

Knowing what cover crops to use, when to plant, and how and when to terminate are the key strategies for cover crop management. With this I would like to conclude my talk here, Thank you!