Effect of conservation tillage and precision nitrogen management on wheat: A review

ABSTRACT

The most significant source of protein in the world is wheat, which accounts for roughly 21% of daily dietary protein requirements on average. With more than 60% of the population living in rural regions, the wheat crop system in Indian agriculture represents the backbone and the future of the country's economy. By speeding the oxidation and disintegration of organic matter, which results in the deterioration of soil characteristics, intensive ploughing causes a decrease in soil organic matter. To conserve resources, slow down soil degradation, adjust cropping systems to climate extremes, and increase agricultural sustainability over the long term, conservation agriculture (CA), which involves minimising soil disturbances, is widely supported. One of the greatest restrictions for CA is the immobilisation of N, which is mostly related to the presence of a continuous residue cover on the soil surface. The employment of some technologies, such as the SPAD metre, NDVI sensor, site-specific nutrient management through soil test crop response, nutrient expert LCC, etc., during the growing season for precision N management aids in meeting the crop's nitrogen needs with the least amount of environmental impact. This study aims to examine the research studies where precision nitrogen management technologies were applied in conservation agriculture and discuss the effects of these tools and techniques on wheat growth, productivity, and nutrient usage efficiency (NUE).

Keywords- Conservation tillage, Leaf color chart, nutrient use efficiency, precision nitrogen management, SPAD meter,

1. Introduction

The most significant staple food for around 36% of the world's population is wheat (*Triticum aestivum* L.), sometimes known as the king of cereals. It is the most significant and strategically important cereal crop. Wheat provides around 18% of the daily calorie needs in underdeveloped nations. The most significant source of protein in the world is wheat, which accounts for roughly 21% of daily dietary protein requirements on average **(Shiferaw *et al.,* 2013**). With more than 60% of the population living in rural regions, the wheat crop system in Indian agriculture represents the backbone and the future of the country's economy.

In India, the crop helps support a vast number of people's livelihoods. It is mostly seeded using heavy tillage farming techniques. Traditional/conventional farming practises have a number of drawbacks, including the deterioration and compaction of the soil, the depletion of water supplies, and the loss of biodiversity. Water is becoming increasingly limited in the western Indo-Gangetic Plains (IGP) as a result of increased competition from the urban and industrial sectors **(Toung and Bhuiyan, 1994)**. Overexploitation and poor groundwater management have had detrimental effects on the ecology and the water table in several areas of the region **(Saharawat *et al.,* 2010)**. Other widespread issues in the area include excessive residue burning and degradation of land quality brought on by various types of soil degradation **(Das *et al.,* 2013)**. These variables prompt the idea of conservation agriculture (CA) to be taken into account for long-term productivity, financial success, and soil quality **(Kassam *et al*., 2011)**. Three principles govern CA: I reducing mechanical soil disturbance; (ii) using cover crops and/or crop residues (primarily residue retention); and (iii) diversifying crop types in associations, sequences, and rotations to increase system resilience. According to reports, CA increases input usage effectiveness, soil organic carbon (SOC) content, and has the ability to lower greenhouse gas emissions **(Bhattacharyya *et al*., 2013).**

In 2021, the last year for which we have official production statistics, the world produced an estimated 776.5 million tonnes of wheat with China, India, and Russia accounting for 38% of global production. When India gained independence in 1947, wheat production and productivity were extremely low. In 1950–51, just 6.46 million tonnes of wheat were produced, and the productivity was only 663 kg per hectare, which was insufficient to feed the Indian population. Under PL-480, the nation used to import a lot of wheat to meet the demands of its citizens from various nations, including the USA. The tall plant habit that causes lodging when grown in fertile soils, the poor tillering and low sink capacity of the varieties used, the higher susceptibility to diseases, the higher sensitivity to thermo & photo variations, etc., resulting in poor adaptability, and (e) the longer crop duration that results in a long exposure of plants to the climatic variations and insect pests were the reasons for the low production and productivity of wheat at that time. In 1961, the Indian government established a commission to examine the viability of raising crop output given the country's current ecological circumstances. The wheat situation in our nation has entirely changed as a result of several actions the Indian government has taken. Our nation used to import wheat to meet our needs throughout the post-Independence era, but when the "Green Revolution" of the late 1960s saw a dramatic increase in wheat production and productivity, our nation was able to produce enough wheat to meet its own needs. Currently, the nation produces more wheat than is needed, and godowns are overflowing with it.

Today National wheat production is 109.52 Mt with an acreage of 31.6 million hectare and productivity of 3.46 t ha^{-1}. The top 3 producing states are Uttar Pradesh.>Madhya Pradesh.>Punjab. U.P. is a top producing state in India with 35.5 Mt of production and contributing 32% of total national production.

1.1 Conservation Agriculture

Three crop management principles, namely crop rotation, surface residue retention, and minimal or no-tillage (less soil disturbance), make up the majority of conservation agriculture (CA). The impact of CA on agricultural production components and its use from diverse farming vantage points are hotly contested topics worldwide. The current crop production methods, which involve repetitive tillage and the removal of straw, cause soil compaction and surface crusting, which decrease water infiltration and increase soil erosion, ultimately leading to a general decline in the physical health of the soil. For sustainable crop production, effective use of natural resources, and improved response to additional inputs, it is necessary to maintain soil physical health at its optimum level. Numerous advantages have been linked to conservation agriculture and its components, such as increased soil water storage **(Verhulst *et al.*, 2011; Lampurlanés *et al.*, 2016; Page *et al.*, 2019)**, improved soil quality **(Jat *et al.*, 2019; Somasundaram *et al.*, 2019)**, reduced erosion **(Montgomery, 2007)**, and in some cases, higher yield and net farm income **(Thierfelder *et al.*, 2018; Pradhan *et al*., 2018; Page *et al*., 2019).**

Initially developed as a response to the US Dust Bowl, conservation agriculture (**Baveye *et al*., 2011)**. Since then, CA has gained popularity quickly, especially in North America, South America, and Australia **(Derpsch, 2001)**. It is mostly used on large, automated farms and calls for heavy doses of pesticides to combat weeds that are typically managed by tillage. In South Asia and Sub-Saharan Africa, there are currently coordinated efforts to promote CA in smallholder systems **(Hobbs *et al*., 2008). (Valbuena *et al.*, 2012)**. Based on the available evidence, it is uncertain whether CA, which was developed for high-input systems in more temperate locations, can function and produce profits in smallholder systems in the tropics and subtropics. This issue requires additional research.

1.2 Constraints for the adoption of conservation agriculture

To change the attitudes of farmers, it is vital for farmers, technicians, extensionists, and researchers to shift their thinking away from soil-degrading tillage practises and toward sustainable production techniques like no-tillage **(Derpsch, 2001)**. **Hobbs and Govaerts (2010)** pointed out that overcoming the bias or mindset about tillage is likely the most crucial element in the implementation of CA. It is argued that one of the biggest obstacles to adopting CA widely is persuading farmers that effective cultivation is still achievable with reduced-tillage or without tillage. In many situations, it might be challenging to persuade the farmers of the potential advantages of CA outside of its potential to lower production costs, primarily by reducing tillage. CA is currently regarded as a path toward sustainable agriculture. The spread of conservation agriculture, therefore, will call for scientific research linked with development efforts.

The following are a few important constraints that impede the broad-scale adoption of CA.

- • A lack of suitable seeders, particularly for small and medium-sized farmers: Although significant efforts have been made to develop and promote machinery for seeding wheat in no-till systems, successful adoption will require accelerated effort to develop, standardise, and promote quality machinery aimed at a variety of crops and cropping sequences. These would involve managing crop wastes during harvest and creating permanent bed and furrow planting techniques.
- • The extensive utilisation of agricultural wastes for animal feed and fuel: Farmers, particularly in rainfed environments, experience a shortage of crop residues due to lower biomass production of various crops. For agricultural residue, there is rivalry between CA practise and livestock feeding. This poses a significant obstacle to the promotion of CA in rainfed environments.

- Burning agricultural residues: Farmers prefer to seed the crop in a timely manner by burning the residue rather than using technology for sowing under CA systems. The rice-wheat system in north India now frequently includes something like this. For the area, this causes environmental issues.
- Lack of awareness among agricultural leaders, extension agents, and farmers of the potential of CA: This suggests that the full spectrum of conservation agriculture practises, such as planting and harvesting, managing water and nutrients, controlling diseases and pests, etc., must be developed, assessed, and matched in the context of new systems.
- Skilled and scientific labour: Managing conservation agricultural systems would necessitate improved scientific capacity to approach issues from a systems viewpoint and be able to collaborate closely with farmers and other stakeholders. Mechanisms for sharing knowledge and information must be strengthened.

1.3 Precision Nutrient Management

According to specific field circumstances throughout a given cropping season, precise nutrient management is a science-based method for supplying nutrients to crops as and when they are required. Precision nutrient management is the science of managing spatial and temporal variability in the inherent nutrient supply from soil to increase productivity, efficiency, and profitability of agricultural production systems. It involves the use of cutting-edge, innovative, and site-specific technologies. Understanding the geographic variability of soils is necessary **(Jin and Jiang, 2002)**.

The 4 R's of precise nutrient management are

- **Right Source**
- **Right Rate**
- **Right Time**
- **Right Place**

Nitrogen is the nutrient that is most frequently and carelessly used in crop cultivation. Precision nitrogen management techniques can be developed using the spectral characteristics of plant leaves as an index since the dynamics of nitrogen supply to plants control the concentration of chlorophyll in plants. In order to make precise decisions about nutrient management while taking into account spatial and temporal variability in nutrient supply from the inherent sources, other techniques are being used as the plant demand for nutrients other than nitrogen cannot be easily accessed from the spectral properties of the leaves. Recent developments suggest that geospatial technologies like the global positioning system (GPS), geographical information system (GIS), remote sensing, real-time and/or variable rate applications (VRA) can assure need-based nutrient management in crop fields **(Gebbers and Adamchuk, 2010; Robert, 2002; Singh *et al.*, 2010).** By addressing the issue of over- and underfertilization, the need-based variable-rate fertiliser delivery method offers a significant chance of increasing the efficiency of fertiliser use **(Schirrmann and Domsch, 2011)**.

1.4 Precision Nitrogen Management

Tools and Techniques

1.4.1 Optical Sensors:

There are many optical sensors that fall under the multispectral and hyperspectral categories. In contrast to hyperspectral sensors like ASD FieldSpec (350-2500 nm), which have a fine spectral resolution (1-2 nm) and continuous wavebands (2150) across the electromagnetic spectrum, multispectral sensors like Crop Circle (450-880 nm) and CropScan (440^{-1}750 nm) have a wide spectral resolution (10 to 20 nm) and a limited number of wavebands (3 to 16) used to describe nitrogen, biomass variation, Utilizing spectral indices computed using univariate and multivariate regression techniques, the spectral reflectance data can be interpreted.

1.4.2 Chlorophyll Meters:

As trustworthy substitutes for conventional tissue analysis as plant N nutritional diagnosis techniques, chlorophyll metres are available. The handheld Minolta SPAD-502 chlorophyll metre is the most popular model. A rapid, non-destructive hand-held instrument called the SPAD 502 chlorophyll metre (Soil-Plant Analysis Development) was created by Minolta in Osaka, Japan. By utilising two LEDs (light-emitting diodes) that emit red (=650 nm) and infrared (= 940 nm) light, the unplucked leafy tissue is clamped in the metre, instantly providing an estimate of leaf N status as chlorophyll concentration **(Boggs et al., 2003)**. The leaf is constructed to allow the red and infrared radiations to flow through. A silicon photodiode detector transforms the light's transmission through the leaf and partial absorption into an electrical signal.

1.4.3 Leaf Colour Chart (LCC):

A high-quality plastic strip with several shades of green, from light yellowish green to dark green, is called a leaf colour chart. LCC technology was reportedly used in Japan, according to **Furuya (1987)**. The International Rice Research Institute (IRRI) collaborated with the agricultural research systems of various Asian nations to develop an upgraded version of the six-panel LCC (IRRI-LCC, six-panel).

1.4.5 Nutrient Management Models:

In general, computer-based decision support systems for precise nutrient management in crop production use the Nutrient Expert (NE) and QUEFTS models. The models are developed to ensure need-based nutrient treatments while taking into account regional and temporal variability in nutrient supply. The nutrient expert (NE) creates farmers' unique fertiliser recommendations based on information about the growing environment, residue content, organic and inorganic fertilisers used, achievable yield, and historical yield data going back three to five years. It considers resource availability when estimating their yield target. Site-specific nutrient management (SSNM) standards were used to construct the algorithm for determining fertiliser requirements in Nutrient Expert. It is a highly interactive computer-based instrument that provides quick information on a field's fertiliser needs.

1.5.6 Omission Plot Technique (OPT):

The omission plot approach is used to calculate the amount of fertiliser needed to get a target yield. With the exception of the nutrient of interest, which is the missing nutrient, all the major nutrients are used in this procedure. The method gives an approximation of the soil's natural supply of nutrients. The yield will be constrained by the local supply of P, for instance, if all the nutrients are applied to the P-omission plot except for P. The amount of fertiliser needed is then determined by comparing the yield gap between the maximum yield possible and the yield obtained using the omission plot technique.

2 Effect on growth

When it comes to precision N-management techniques and tillage crop establishment procedures, furrow irrigated raise bed (FIRB) and N 80-LCC measured wheat plant height at harvest significantly higher than conventional tillage and farmer fertilisation approaches. Similar to how conventional tillage and farmer fertilisation approaches recorded the lowest dry-matter accumulation at 90 DAS of wheat crop, FIRB and

N-80 LCC recorded significantly the highest. When wheat was fertilised with N-80 LCC and elevated beds that were irrigated by furrows, the number of tillers increased dramatically at 90 DAS. Wheat plants gradually grew taller till they were fully mature **(Gawdiya, 2020)**. Similar results were also reported by **Biradar, 2012**, and **Sulochna *et al.*, 2018**, where, precision nutrient management treatments recorded maximum plant height of wheat than farmers fertilizer practice as balanced application of nutrients as per crop need under N 80- LCC enhances the nutrient use efficiency.

Table I: Effect of tillage crop establishment methods and precision nitrogen management on plant height, dry-matter accumulation and tillers m^{-2} of wheat crop

Treatments	Plant height at harvest (cm.)	Dry matter accumulation at 90 DAS (g m^{-2})	Tiller m^{-2} at 90 DAS
Tillage crop establishment methods (TCEM)			
T_1 – Zero tillage	**97.1**	**846.9**	**352.7**
T_2 – Roto Tillage	**93.3**	**840.9**	**333.3**
T_3 – Raised bed	**104.7**	**871.5**	**368.3**
T_4 – Conventional tillage	**89.1**	**822.9**	**339.9**
C.D. (P=0.05)	**1.7**	**14.5**	**9.8**
Precision nitrogen management			
F_1 - N 80:20	**95.6**	**821.1**	**339.2**
F_2 – Nutrient expert 33:33:33	**98.1**	**864.5**	**360.1**
F_3 - N 80-LCC	**100.1**	**916.9**	**373.0**
F_4 - Recommended dose of N	**93.9**	**819.9**	**343.1**
F_5 - FFP	**92.5**	**805.5**	**327.5**
C.D. (P=0.05)	***1.2***	***8.5***	***6.9***

Source: Gawdiya, 2020

Budhar (2005) stated that a consistent supply of N supplied at the seedling stage served to generate a favourable influence on growth features, which may be the cause of the higher plant height and greater number of tillers at LCC 4 and 5. With higher LCC values of N application ranging from 3 to 5, there has been a progressive and noticeable rise in tiller output at 80 DAS. When it came to producing tillers per hill among the LCC values used for N application, LCC 5 stood out as being superior, especially at the last stages of growth at 60 and 80 DAS when the tiller count at LCC 5 was the greatest and much greater than LCC 3 and 4. According to **Mohanty *et al.* (2015)**, the maximum NAR was produced by STCR and absolute control at 0-30 and 60-90 DAS, respectively, for precision N-management strategies in wheat. However, at 30–60 DAS, various precision N–management techniques had little to no impact on NAR. It was abundantly obvious that the direct and indirect effects of enhanced nutrition gave the crop an initial boost, increasing RGR and NAR under conservation agriculture.

3 Effect on yield.

The amount of crop dry matter accumulated, the number of tillers, the number of grains spike^{-1}, and the grain weight, among other factors, all affect grain output. The most crucial factor for assessing the results of applied treatments is grain yield. Crop productivity is the pace at which a crop accumulates biomass and is primarily dependent on photosynthesis, which is the process by which green plants transform light energy into chemical energy.

Mahajan (2018) reported that (FIRB) significantly outperformed all other treatments in terms of maximum grain output as seen in Table II (52.6 q ha^{-1}). Nevertheless, treatment T1 (wheat sown with no tillage) outperformed the other treatments. During the experiment, T5 outperformed reduced (T2) and roto tillage (T3). When compared to T4 (wheat sown on FIRB) and T5 (wheat sown by conventional tillage), the decline in grain production caused by reduced tillage and roto tillage procedures was 24.6 and 9.1 percent, respectively. However, compared to the other tillage practise plots, the yield of wheat planted in raised beds with furrow irrigation increased by 18.4%.

Table II: Effect of tillage crop establishment methods and nitrogen management on yield and test weight of wheat

Treatments	Grain yield (quintal ha^{-1})	Straw yield (quintal ha^{-1})	Test weight (g)	Harvest Index (%)
Tillage Crop establishment methods (TCEM)				
T_1 ZT	**48.7**	**57.5**	**41.2**	**45.8**
T_2 Reduced tillage	**41.9**	**50.9**	**39.6**	**45.2**
T_3 Roto tillage	**37.4**	**44.8**	**37.4**	**45.0**
T_4 Raised bed	**52.6**	**63.8**	**42.3**	**45.2**
T_5 Conventional tillage	**43.6**	**56.6**	**40.3**	**43.5**
SEm±	**0.51**	**0.53**	**0.4**	**0.45**
C D (P=0.05)	***1.68***	***1.75***	***1.31***	***1.45***

Precision N management				
F_1 Control	**33.8**	**45**	**36.5**	**42.9**
F_2 RDF (150:60:40)	**45.4**	**55.3**	**40.3**	**45.1**
F_3 SPAD	**47.1**	**58.2**	**41.4**	**44.7**
F_4 Targeted yield	**51.7**	**59.4**	**41.6**	**46.5**
F_5 LCC	**46.2**	**55.7**	**40.9**	**45.4**
SEm±	**0.78**	**1.01**	**0.65**	**0.74**
C D (P=0.05)	***2.22***	***2.93***	***1.87***	***2.13***

Source: Mahajan (2018)

According to **Biradar *et al.* (2006)**, fertiliser application based on SSNM principles produced noticeably higher grain yields than farmer practise (FP) and the required amount of fertiliser (RDF). Averaging 3.7 t ha^{-1}, or 23 percent greater than the RDF and 39 percent more than the FP, was the average wheat yield in the SSNM practise. According to **Khurana *et al.* (2008)**, a N management schedule that took real-time variation in crop N requirement at critical wheat growth stages into consideration. Average grain production increased from 4.2 to 4.8 tha^{-1} as compared to current farmers' fertiliser practises (FFP), while plant N, P, and K accumulations increased by 12 to 20% when using SSNM.

Singh *et al.* (2014) reported from Meerut that the mean grain yield of wheat was 5.30 t ha^{-1} , 4.47 t ha^{-1} and 3.8 t ha^{-1} under OPT, SR and FFP, respectively. On an average, the OPT out-yielded the SR and FFP by 0.82 t ha^{-1} and1.5 t ha^{-1} or by 18% and 39%, respectively. According to **Hussain *et al.* (2003)**, the crucial SPAD value of 37.5 is suitable for directing Pakistan's need-based N top-dressing of rice. By utilising SPAD value 35 as the threshold SPAD value in Bangladesh, **Kyaw *et al.* (2003)** produced noticeably greater yields with 3 to 12 percent less fertiliser-N use than the general advice. In comparison to a blanket dose of 150 kg N ha^{-1}, **Maiti *et al.* (2004)** discovered that a SPAD value of 37 is adequate for achieving high yields with 27.5 to 45.5 kg N ha^{-1} less fertiliser. When managing N in direct wet-seeded rice, **Huan *et al.* (2002)** used 32 and 29 SPAD threshold values. The grain yield from the SPAD 32 and 29 based N applications was 20 and 40 kg N ha^{-1} less, respectively, than the blanket recommendation for fertiliser N, which is 120 kg N ha^{-1}. For various varietal groups, it can also be necessary to employ different thresholds for SPAD values **(Balasubramanian *et al*., 2000; Huang *et al*., 2008)**. According to **Takebe *et al.* (2006)**, there is a strong correlation between grain protein concentration at harvest and leaf colour at the full heading stage. A grain protein content of more than 120 g kg^{-1} was achieved with the application of 30 kilogramme N ha^{-1} (if SPAD value was 50–52) or 60 kg N ha^{-1} (if SPAD value was 45–50) during the full heading stage.

According to research by **Uppal *et al*. (2000)** on the influence of NPK levels on the development and production of durum wheat, grain yield rose with each increment of N by 40 kg/ha up to 200 kg ha^{-1}. **Tayebeh *et al*. (2010)** conducted research on the impact of organic and inorganic fertilisers on wheat grain production and protein banding pattern, and they found that the plants produced the highest grain yield when fertilised with 160 kg N and 30 t compost per hectare. Spikes/plant, seeds/spike, and 1000 kernels weight among yield components all increased significantly as nitrogen levels rose.

Alam *et al.* (2006) found that LCC-based N management consistently increased grain yield production across two rice seasons compared to farmers' fertiliser practises. Depending on the village and season, the LCC-based N management increased grain output by 0.1 to 0.7 t ha^{-1}. In addition to the prescribed P, K, S, and Zn fertilisation, the use of LCC for regulating N enhanced mean yield by 0.3–0.4 t ha^{-1} **(Alam *et al.*, 2005).**

4 Effect on nutrient use efficiency (NUE)

Ghosh *et al*., 2017, reported that, wheat's Agronomic N use efficiency (AEN), N recovery efficiency (REN), internal N use efficiency (IEN) and partial factor productivity of applied N (PFPN) were significantly impacted by N management practises (Table III). The maximum AEN and REN were obtained with medium rate N application at medium SPAD level (N25S40), which was higher than those obtained with high (N35) and low (N15) rate N topdressing at high (S42) and low SPAD (S38) levels, as well as FTNM and FFP. In comparison to low rate of N topdressing at low SPAD level (N15S38), high rate of N topdressing at high SPAD level (N35S42), and FTNM, N25S40 increased AEN and REN by 29.2 and 50.9 percent, 50 and 8.8 percent, and 58.5 and 15.1 percent, respectively. Regardless of SPAD levels, increasing the rate of N topdressing in wheat caused the IEN and PFPN to gradually drop. As a result, moderate (N25) and low (N15) rates of N topdressing at medium (S40) and low (S38) SPAD levels respectively resulted in significantly higher IEN and PFPN than high rate of N topdressing at high SPAD level (N35S42). FTNM also considerably reduced IEN and PFPN as compared to low to moderate (N15-25) rates of N topdressing at low to medium SPAD levels (S38-40). Moderate rate of N topdressing at medium SPAD level (N25S40) caused higher IEN (+19.1%) and PFPN (+41.5%) than FTNM.

Table III: Effect of nitrogen management practices on nutrient use efficiency

Treatment	**N rate**	**REN**	**AEN**	**PFPN**	**IEN**
	(kg ha–^{1})	**(kg kg^{-1})**	**(kg kg–^{1})**	**(kg kg–^{1})**	**(kgkg–^{1})**
S38N15	**70**	**0.53**	**19.5**	**46.5**	**49.1**
S38N25	**68.3**	**0.70**	**20.5**	**46.5**	**42.4**
S38N35	**95**	**0.69**	**17.6**	**38.5**	**38.6**
S40N15	**90**	**0.59**	**21.4**	**45.1**	**46.7**
S40N25	**101.7**	**0.80**	**25.2**	**46.6**	**40.9**
S40N35	**118.3**	**0.70**	**18.3**	**36.1**	**36.9**
S42N15	**105**	**0.60**	**21.1**	**42.2**	**45.7**
S42N25	**110**	**0.71**	**19.4**	**38.3**	**38.4**
S42N35	**118.3**	**0.74**	**16.8**	**34.9**	**34.7**
FTNM	**120**	**0.70**	**15.9**	**32.9**	**34.3**
FFP	**80**	**0.69**	**20.2**	**45.8**	**42.3**
Control	**0**	**–**	**–**	**–**	**66.7**
SEm (±)		**0.06**	**1.8**	**2.1**	**2.1**
LSD (0.05)		**0.17**	**5.2**	**6.2**	**6.3**

Source: **Ghosh *et al* (2017)**

The harvest index for potassium, phosphorus, and nitrogen was considerably higher in SSNM and significantly lower in absolute control. Absolute control yielded significantly higher harvest indices of nitrogen and phosphorus among the various N precision management techniques, however the harvest index of potassium was not significantly impacted. Regardless of the wheat treatments used, the nutrient harvest index was in the order of P>N>K, indicating that more P was ingested in the grain than K was in the straw **(Mohanty *et al.*, 2016)**.

According to **Mahajan (2018)**, ZTW (T1) treatments had the highest nitrogen, phosphorus, and potassium harvest index, while FIRB (T4) treatments had the lowest. Absolute control (F1) produced a significantly greater nitrogen and phosphorus harvest index across the various precision N management techniques, while the harvest index of potassium was not significantly impacted. The order of P, N, and K in the nutrient harvest index was highest to lowest. The ability of the soil to give nutrients and the plant's innate ability to use nutrients are both demonstrated by the recovery of any added nutrients. It also depends on how it is applied and the environment in which it grows. Different tillage techniques and precise N management techniques dramatically affected apparent nutrient recovery in wheat. Due to a high amount of potassium in the soil and lower potassium fertiliser doses, the crop recovered more than 100% of the potassium that was applied. Different tillage methods had a substantial impact on potassium apparent recovery, but FIRB had the highest potassium apparent recovery, followed by zero tillage plots. This was because FIRB produced significantly higher nitrogen and phosphorus apparent recovery. Since all of these nutrients have a synergistic effect on one another, different tillage techniques increased the availability of nutrients for FIRB, resulting in a much higher apparent recovery (percent of nutrients applied). Targeted yield-based nitrogen management among precision N management techniques produced much higher apparent recovery (N, P & K).

Conclusion

Farm management must employ more environmentally friendly agricultural practises if it is to increase crop output efficiency and lower environmental dangers associated with agriculture. These requirements can be met through precision agriculture. As is commonly agreed, it can assist farmers in applying the proper input in the proper quantity, at the proper location, at the proper time, and in the proper manner. When making decisions on the production of wheat crops, the within-field variability is the main source of uncertainty. At both the geographical and temporal scales, variability must be understood and controlled. In order to produce variable wheat N fertilisation, novel experimental methods, distant and proximal sensing, and crop simulation models will increasingly be used to analyse field variability at a cheap cost.

Looking at the research findings we can conclude that when it comes to growth, productivity and NUE wheat grown in FIRB performs better while economically speaking zero tillage fared better than other tillage methods.Precise nitrogen management involving LCC, SPAD, NE, GS, and targeted yield not only increase growth, yield and NUE but also turned out more profitable than a blanket application of N.

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