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Review Article

Management of plant nutrients for enhancing oil content in oilseed crops - A review

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Abstract

Nutrient management is an important activity in crop production. Most of the cases, organic and inorganic sources of plant nutrients are advocated for enhancing the nutrient concentration in soil and uptake by plant roots. However, soil physico-chemical properties greatly influenced by the availability of plant nutrients in soil solution. Addition of organic matter through FYM, crop residues, green manuring enhanced the fertilizer use efficiency in most of the soils. In most of the oilseed crops, nutrient management is an important task for improving the soil health parameters and sustainable crop yield. Oilseed crops majorly require nitrogen, phosphorus, potassium, sulfur, calcium, zinc and boron based on the soil test values. Other advance agronomic practices also carried out to enhance the fertilizer use efficiency in oilseed over a period of time. Integrated use of chemical fertilizers with organic sources improved the soil physico-chemical, biological properties in soil in a long run. Soil test based management of plant nutrients are advocating for sustainable oilseed production without compromising the soil and environmental health. In this review, the major plant nutrients role in oilseed production and their efficient management through the best management practices are discussed. It also indicated that the climatic factors also influence the efficiency of plant nutrients during the crop growth. Increasing awareness about the balance application of plant nutrients in oilseed crops is a key activity in nutrient management.

Keywords *: Nutrient availability, microbial properties, oilseed seed crops, plant nutrient dynamics, soil health, soil testing*

Introduction

India is a large country, and people living in many of its regions have developed particular taste for different oils, mostly because of the oils that are accessible there. For instances, people in the East and North use mustard-rapeseed oil; whereas, individuals in the South and West prefer groundnut oil. Sesame and coconut oils are also preferred in some areas of the South (DFPD, 2023). About 56% of the edible oil demand in the country is met by imports, of which 54% is made up of palm oil or palmolein. Knowing and unknowing refined palm oil (RBD palmolein) is used in hotels, restaurants, and the manufacturing of a wide range of food products. Its use and its blending with other oils have grown significantly over time. The increasing usage of vegetable oils in a variety of industries, changing dietary patterns, and population growth have all contributed to a large increase in the demand for vegetable oils globally throughout time. India had a surge of 17.39% (164.7 lakh tonnes) in the amount of edible oil imported during the oil year 2022-23 (November to October) compared to 140.3 lakh tonnes during the oil year 2021-22 (Agricultural Statistics, 2022). Global oilseed production has witnessed a remarkable expansion over the past six decades. According to FAOSTAT (2022), global output for the nine major oilseeds (*i.e*., groundnut, linseed, mustard, rapeseed, safflower, sunflower, sesame, soybean, and castor) reached nearly 559 million tonnes in financial year 2022-23 (GOI, 2021-22).

The government's economic policy of liberalization, which permits more freedom to the open market and promotes healthy competition and self-regulation rather than protection and control, is another prominent feature that has a significant impact on the current state of the edible oilseeds and oil industry. India, the country that imports the most refined oil, reduced the import tariff on refined soybean and sunflower oils to 12.5%. However, it is anticipated that the government's move will raise local oil prices. Prior to that, in 2021, the government reduced the import duty from 32.5% to 17.5% (Agricultural Statistics, 2022). The majorities of oilseeds are grown on marginal ground and are reliant on several weather factors, including rainfall and fertility. A rising need exists to increase the oil content of crops in order to meet this demand in a sustainable manner. In order to increase crop oil yields, efficient management of plant nutrients is essential. Oilseed crop's nutritional needs might change based on the particular crop, the state of the soil, and external variables.

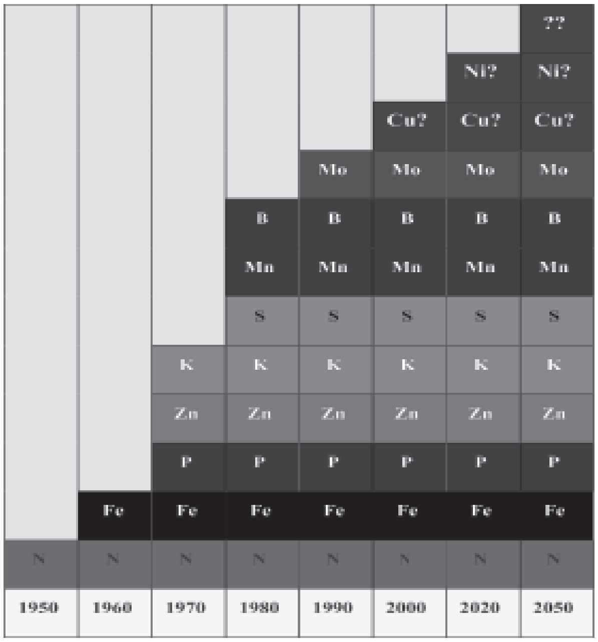

Fig. 1: Plant nutrient deficiency scenario in Indian soils

In the year 1950, deficiency of nitrogen (N) was first reported and the need of the production and application in crop production was emphasized by the policy makers. However, over the year's macro and micronutrients deficiency was occurred in most of the Indian soils (Morton *et al.,* 2023). In present situation major and 2-3 micronutrients are required in most of the cropping systems (Fig. 1).

In order to supply oilseed crops with these vital nutrients, farmers usually apply fertilizers. Variable growth phases may have variable nutrient requirements, with times of rapid growth and development resulting in larger demands. It is best to speak with regional agricultural extension agencies, research organizations, or agricultural specialists to find out the precise nutrient needs for an oilseed crop in a certain area. In order to maximize nutrient management strategies and raise crop yields, they can offer recommendations based on soil tests and regional agronomic circumstances (Acharya *et al.,* 2003).

Plant nutrient management is a foremost activity in sustainable crop management. Most of the developed and developing countries are focused on enhancing nutrient use efficiency by modifying the rhizosphere environment (Dotaniya and Meena, 2013; Coumar *et al.,* 2022). In this regards, many organic and inorganic plant nutrient or soil amendments are using over a period. However, India oilseed area enhanced to 29.17 million hectre (mha) from 10.73 mha, showing 171.86 percent increment; whereas production enhanced 5.16 to 37.70 millon tonne (630.62%) and productivity 481 to 1292 (168.61%) by comparing years 1950-51 to 2021-22 (Agricultural Statistics, 2022). It is clearly indicating that by involving the agricultural technology, enhanced more production on limited land. So, we have to focus on the factor affecting the oilseed production potential mainly, quality seed, soil properties, fertilizers, crop cultivation practices, management of insect-pest etc. However, the minimum supporting prices (MSP) and government policies are also affecting the enhancement in area and production in a region.

Scope of oilseed crops

Plants grown mainly for the purpose of oil, produced from their seeds are known as oilseed crops. These oils are used for a variety of purposes, including as industrial uses, human consumption, and as feedstock for biofuels. An important portion of the world's agricultural production, oilseed crops supply vital vegetable oils for food processing, cooking, and other non-food uses. In India, major ones are soybean, groundnut, rapeseed-mustard, sesame, sunflower, castor, safflower, linseed and niger.

i. Soybean (*Glycine max*): It is most extensively grown oilseed crops in the world and important crop for the food and feed industries since it is high in oil and protein. Although soybean oil is frequently used in cooking, the leftover grain from oil extraction is a key ingredient in animal feed.

ii. Groundnut/Peanut (*Arachis hypogaea*): It is both an oilseed and a legume is groundnut. Peanuts are eaten as snacks or utilized in food preparation, and peanut oil is frequently used in cooking.

iii. Rapeseed-mustard: Mustard oil is extracted by pressing mustard seeds and finds usage in the food sector as well as in cooking. Mustard plants categorized into different species like brown, yellow, or black seeds.

iv. Sesame (*Sesamum indicum*): Sesame oil, which is frequently used in cooking, particularly in Asian cuisines, comes from sesame seeds. Additionally, baked items can be topped with sesame seeds.

v. Sunflower (*Helianthus annuus*): Sunflower oil is frequently used for frying and cooking since sunflower seeds are high in oil. The crop is cultivated in numerous nations across the world and is well-known for its capacity to adapt to different conditions.

vi. Castor (*Ricinus communis*): Castor oil is extracted from castor beans and is used in the manufacturing of soaps, biofuels, and lubricants, among other industrial uses.

vii. Linseed (*Linum usitatissimum*): Flax is also grown for its fiber (linen), and flaxseed oil is prized for its high concentration of omega-3 fatty acid, alpha-linolenic acid. Flax seeds are also rich in oil.

viii. Safflower (*Carthamus tinctorius*): It is a flowering plant that produces seeds for oil extraction. This oil is rich in linoleic acid, an essential fatty acid that may help reduce the risk of heart disease.

ix. Niger (*Guizotia abyssinica*): Niger seed oil is an important source of nutrition and health benefits due to its fatty acid profile and high concentration of fat-soluble bioactive compounds. The oil has a pale yellow color and a nutty flavor. Rich in linoleic acid, it closely resembles sunflower and safflower oils.

Other oil containing crops

√ Palm (*Elaeis guineensis*): The oil palm tree is a significant producer of palm oil, which is one of the vegetable oils used most frequently in the world. Palm oil is utilized in food items, cosmetics, and biofuels even though it has encountered issues with social and environmental sustainability.

√ Cotton seed (*Gossypium spp*.): Cottonseed oil is used in food goods and cooking, and cotton plants yield oil-containing seeds. Livestock feed is made from the byproduct of oil extraction, cottonseed meal.

Why need strategies for enhancing oilseed production

Indian population is increasing with the pace of the time; and attention paying the scientist and policy experts to increase the oilseed production in sustainable manner. In the initial stage of the agriculture development after independence, use of high yield varieties (HYV) were the key for increasing production potential. However, integrated approaches of irrigation, fertilizers, mechanization were played the important role (Table 1). Now a days, indigenous and exotic germplasm collection are exchanging and paying more attention to develop a varieties. Most of the oilseed crops are having narrow genetic base and the varietal development process is slow. However, some of the experts suggesting to enhance the area, but we can enhance the vertical extension of the land. Conversion of forest land to arable land already exhausted. During the green revolution period, farmers were applied excessive amount of fertilizers or straight fertilizers. The ideal ratio of NPK application is 4:2:1, whereas, some of the states are using distorted ratio and imbalance the plant nutrient supply chain. Partial factor productivity of the soils are also declining. More attention was putted by the agriculture research institutes through the ICAR crown by mediating the soil properties. In these areas, application of soil amendments, balance nutrient, addition of organic matter, management of irrigation and tillage operations are key to enhance oilseed production.

Table 1**:** Production enhancement strategies and limitation

Strategies	Limitation
Expansion of arable land from forest land	Not possible
Use of improved varieties	Yes, but it has limited genetic potential
Higher application of crop inputs	Soil has limited nutrient supplying potential; decline partial factor productivity
Use of degraded land for cultivation	Yes, it is having scope

1. Essential plant nutrients-A brief

An essential component of sustainable agricultural production is plant nutrition. The characteristics of the soil, the amount of moisture, and the genetic potential of the cultivars all have a significant impact on its availability to plant roots. The life cycle of a plant's biochemical process is completed by these sources, which also comprise vital plant nutrients including structural (C, H, O), primary (N, P, K), secondary (Ca, Mg, S), and micronutrients (Zn, Cu, Fe, Mn, Ni, B, Mo, Cl). Arnon and Stout (1939) coined the term necessary mineral element, often known as mineral nutrition.

They concluded three criteria must be met for an element to be considered essential. These criteria were:

i. A plant must be unable to complete its life cycle in the absence of the mineral element.

ii. The function of the element must not be replaceable by another mineral element.

iii. The element must be directly involved in plant metabolism.

Table 2: Role of plant nutrients in plant growth (Tisdale *et al.,* 1997)

Nutrient	Plant uptake form	Concentration in dry tissue	Major role in plant
Structural nutrient			
Carbon (C)	CO_2	45 %	Formation of plant structure
Hydrogen (H)	H_2O	6 %	
Oxygen (O)	H_2O, O_2	45 %	
Macronutrient			
Nitrogen (N)	NO_3^-, NH_4^+	1.5 %	Growth, protein production
Phosphorus (P)	$H_2PO_4^-$, HPO_4^{2-}	0.2 %	Root elongation, Energy currency
Potassium (K)	K^+	1.0 %	Metabolic process and stress management, drought tolerance, protein synthesis
Calcium (Ca)	Ca^{2+}	0.5 %	Plant roots, activates enzymes, helps in disease resistance
Magnesium (Mg)	Mg^{2+}	0.2 %	Component of chlorophyll, essential for photosynthesis, respiration
Sulphur (S)	SO_4^{2-}	0.1 %	synthesis of proteins and amino acids
Micronutrients			
Zinc (Zn)	Zn^{2+}	20 mg/kg	Enzyme activity, protein synthesis
Copper (Cu)	Cu^{2+}	6 mg/kg	Enzyme activity, chlorophyll formation
Iron (Fe)	Fe^{2+}	100 mg/kg	Respiration, chlorophyll formation
Manganese (Mn)	Mn^{2+}	20 mg/kg	Enzyme activation, photosynthesis
Molybdenum (Mo)	MoO_4^-	0.1 mg/kg	Nitrate reduction, N-fixation
Chlorine (Cl)	Cl^-	100 mg/kg	Tissue hydration, photosynthesis
Boron (B)	H_3BO_3, $H_2BO_3^-$, HBO_3^{2-}, BO_3^{3-}	20 mg/kg	Cell wall formation, pollen germination, stomatal opening
Nickel (Ni)	Ni^{2+}	0.1 mg/kg	Urease activity, biological N fixation

Although these standards are crucial guides for plant nutrition, they do not include essential mineral elements. Beneficial elements are those that have the ability to counteract the harmful effects of other elements or substitute mineral nutrients in a less specialized role, like maintaining osmotic pressure. It is possible that plants are only being produced at a subsistence level rather than being developed to their full genetic potential when essential nutrients are left out of commercial agriculture. While not considered necessary for all plants, the beneficial elements silicon, vanadium, sodium, and cobalt may be necessary for particular crops. Essential plant nutrients may be supplied through the chemical fertilizers or may be through the recycling of waste materials (Rattan and Goswami 2002). These plant nutrients are having specific role in plant growth and yield (Table 2).

All plant nutrients are essential for oil seed crop production. However, some of crucial plant nutrients (N, P, K, Ca, S, B and Zn) are described in detail:

1.1. Nitrogen: One important biogeochemical mechanism that is essential to maintain life on the Earth is the nitrogen cycle (Fig. 2). Nitrogen is a constantly changing element that is present in the soil, atmosphere, and living things. It is necessary for the synthesis of proteins and nucleic acids. Nitrogen fixation, nitrification, assimilation, ammonification, and denitrification are some of the major processes that are involved in this cycle. Nitrogen fixation is the first step in the nitrogen cycle; it involves converting atmospheric nitrogen (N_2) into ammonia (NH_3) or other nitrogen compounds that plants can use (Lin *et al.,* 2023). This process can be carried out by both biological and abiotic means. In the case of

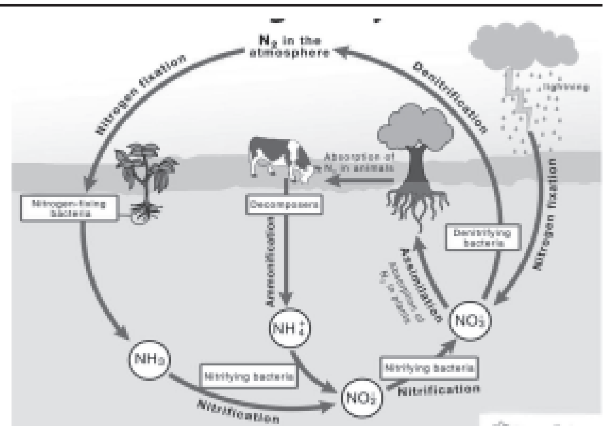

Fig. 2: Nitrogen cycle soil-plant- atmospheric continuum (modified from Brady and Weil, 2008)

biological nitrogen fixation, nitrogen-fixing bacteria, such as *Rhizobium*, work in symbiotic relationships with leguminous plant roots to fix nitrogen (Rao, 2013). Following nitrogen fixation, ammonia is further transformed through nitrification, which is the process of turning ammonia into nitrites (NO_2^-) and then into nitrates (NO_3^-) by particular bacteria, such as nitrosomonas and nitrobacter. Nitrates are vital nutrients for plants and are easily absorbed by their roots to support growth. The nitrogen cycle is essential for sustaining soil fertility, promoting plant development, and safeguarding ecosystem health. The nitrogen cycle has been greatly influenced by human activities, including the usage of fertilizers containing nitrogen and industrial operations. This has resulted in environmental problems such water pollution and greenhouse gas emissions (Bharti *et al.,* 2017).

Nitrogen is comprised 1.5% in plant on dry weight basis, however it's efficiency ranged 30-50 percent in soil application (Table 3). Split application of N fertilizers improved the nitrogen use efficiency (NUE) in most of the crop. Leguminous crops having root nodules fix atmospheric elemental N into crop roots and after degradation of root nodules, it will be taken by crop roots (Dotaniya *et al.,* 2023). The N_2 fixation potential of oilseed crops are varying cropwise and also depends on bacterial strains. Oilseed crops having root nodulation require less amount of N fertilizer compare to non-leguminous crops. In this line soybean, groundnut crops need 20-25 kg/ha N; whereas, rapeseed-mustard require 80 kg/ha N.

Table 3: Approximate concentration of plant nutrients in mature leaf tissue of agricultural crop plants (Rattan and Goswami, 2002)

Nutrients	Deficient	Sufficient or Normal	Toxic
N (%)		1-5	
P (%)		0.1-0.4	
K (%)		1-5	
Ca (%)		0.2-1	
Mg (%)		0.1-0.4	
S (%)		0.1-0.4	
Fe (mg/kg)	<50	100-500	>500
Mn (mg/kg)	15-25	20-300	300-500
Zn (mg/kg)	10-20	27-150	100-400
Cu (mg/kg)	2-5	5-30	200-100
B (mg/kg)	5-30	10-20	50-200
Mo (mg/kg)	0.03-0.15	0.1-2.0	>100
Cl (mg/kg)	<100	100-500	500-1000
Ni (mg/kg)	<0.1		

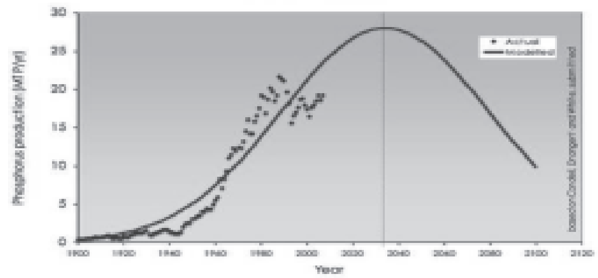

Fig. 3**:** A peak in global production is estimated to occur by 2035 (Cordell *et al.,* 2009)

1.2. Phosphorus: It is also a major plant nutrient in oilseed crop production. While a significantly smaller amount of the P fractions are in available forms that can dissolve in the soil solution and be absorbed by plants, but a larger portion of the P fractions are in very stable, unavailable forms (Busman *et al.,* 1997). These fractions' dynamic and available P, like the P in manure or fertilizer, can swiftly fix into stable, unavailable forms in the soil. Phosphorus fertilizers are among the most crucial types of fertilizers; in India, they are primarily imported. It is produced using rock phosphate (RP), which is mostly found in China, the US, Russia, and African nations (Déry and Anderson, 2007). The amount of P in RP determines how much P fertilizers cost. Most of the Indian deposits are having less concentration of P_2O_5 (35%). As per the projection of Cordell *et al.* (2009) indicated that global deposits of RP will be reached by the year 2035 and after it will go down (Fig. 3). However, if we could not manage the P fertilizer scientifically, than it will create problems for food security in coming years. The P limitations and usefulness compelled users and policymakers to consider P sustainable use in both industrial and agricultural applications. It is a non-renewable resource at most, with limited deposits and high P concentration rock phosphate. The world at large faces a dilemma in determining an economic substitute for P (Dotaniya *et al.,* 2013).

It is P that transfers energy from adenosine triphosphate (ATP) to another molecule, causing an enzyme process or cellular transport. This makes P the key to energy in living things (Dotaniya *et al*., 2014c). Its deficiency symptoms appear on the lower leaves, leaf are smaller in size and more muscular with bronzing symptoms in mustard; need 30-40 P_2O_5/ha application for sunstainable crop yield.

A plant having P deficiency is most prevalent in regions with high rainfall, particularly on acidic, clay- or poorly chalk-based soils. Its deficiency very much affected by the soil pH (maximum availability at 6.5). The availability of P in the soil solution is generally decreased by 30% or more in soils with a pH of less than 5.5 (Tabatabai and

Bremmer, 1969). Just as the C/N ratio controls the preponderance of N mineralization over immobilization, the C/P ratios of the decaying residue control the predominance of P mineralization over immobilization. The recommendations that follow have been made.

C/P ratio	Mineralization/ Immobilization
<200	Net mineralization of organic P
200-300	No gain or loss of inorganic P
>300	Net immobilization of inorganic P

1.3. Potassium: It is largely absorbed by the crop for profuse growth. The plant concentration of K (1-5%) influenced by the availability in soil and climatic factors. In tropical climatic condition it is low due to high rainfall, continuous high temperature as compared to temperate. Potassium absorbed from soil in cationic form (K^+) and largely adsorb on negative sites. It is a key element to metabolic processes; more than 80 plant enzymes require K for their activation. Balance application of K nutrient improves the water relation in oilseed crops and fight against drought. Potassium is a mobile nutrient in plants. Potassium deficiency in mustard plants occur on lower leaves, margins showing yellowing. Most of the oilseed crops require 30-50 kg/ha K for sustainable crop yields. Rate of K application depends on soil properties, plant

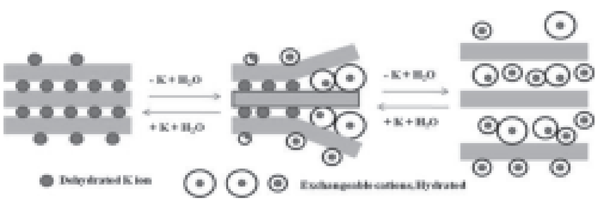

Fig. 4: Mechanism of K release and fixation (Modified from Rao and Brar, 2002)

species, and climatic factors during crop growth period. Muriate of potash or potassium sulphate as a source of K is commonly used in oilseed crops. The availability of potassium in soil is controlled by the silicate clay/mica content of the soil. Higher availability of K in soil solution either uptake by plant or fixed in silicate minerals in most of the soils (Dotaniya *et al.*, 2023). In low concentration, it will be again released from fixed sites to soil solution (Fig. 4). These mechanisms are directly influenced by type and amount of silicate mineral, K concentration, soil properties, climatic factors etc.

1.4. Calcium: It is secondary plant nutrients responsible for cell wall formation and activation of enzymatic activities. In plant, its concentration ranged 0.2-1%; whereas, in soil it is 0.7-1.5 %. However, Ca levels in calcareous soils vary from less than 1 % to more than 25 %. It is absorbed by plants in divalent form (Ca^{2+}) from soil solution and is supplied by mass flow and root interception. Most of the Indian soils are having sufficient amount of Ca for crop growth except humid or high rainfall regions. Among the oilseed crops, groundnut needs application of Ca fertilizer for higher yield (Adhikari *et al.,* 2003). Deficiency of Ca in groundnut lead pop pod (Kadirimangalam *et al.,* 2022). Application of gypsum @ 300-500 kg/ha is recommended during the groundnut cultivation (Singh *et al.,* 1991).

1.5. Sulfur: This nutrient is playing and controlling the oil synthesis process in most of the oilseed crops. It also required for the production of vitamins, oils, and proteins. The prevalent sulfur-containing amino acids include homocysteine, cysteine, and methionine; however, proteins mostly contain cysteine and methionine (Walker and Booth, 2003). Sulfur application rate greatly influenced by the soil type, plant and microbial population for its utilization during crop growth period. In general, 40 kg/ha sulfur application is recommended in rapeseed-mustard crop. Whereas, 20 -30 kg/ha is required for soybean crop. Sulfur cycle in nature involve in soil-plant-atmosphere continuum, and influenced by related factors (Fig. 5). Enhancement in SOC improves the S level in soil, however N/S ratio 6-8:1 and C/N/S 120:10:1 are ideal for improving the S availability in soil solution. More than 60% of soils in states such as Assam, Bihar, Goa, Gujarat, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Uttar Pradesh, and West Bengal are deficient in available S. This deficiency can impact crop growth and yield, as sulfur is an essential nutrient for plant development, playing a key role in protein synthesis, enzyme activation, and overall plant metabolism (Shukla *et al.,* 2021).

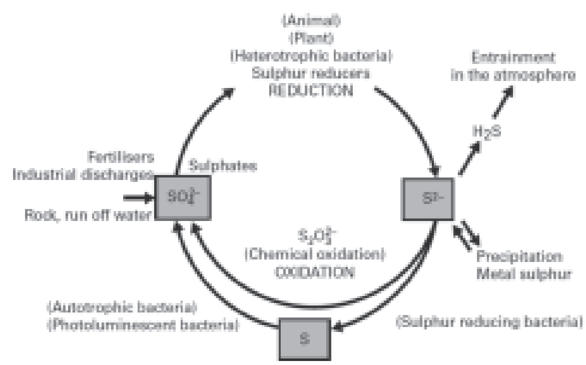

Fig. 5: Sulphur cycle in soil-plant-animal continuum (Anonymous, 2023)

1.6. Boron: It is very important plant nutrient for seed setting, stomata opening, viability of pollen; and also uptake of other nutrients like Ca in groundnut. It is present in boric acid and uptake by crop plants in different forms (H_3BO_3, $H_2BO_3^-$, HBO_3^{2-}, BO_3^{3-}) based on soil pH.

At higher pH it is BO_3^{3-} and in neutral it is H_3BO_3. Application of 1 kg/ha B during the mustard cultivation is recommended. However, deficiency of B plant showing bushy in appearance and lower crop yield. It also observed that oilseed crops showing low content of oil in most of the oilseed crops in B deficient soils (Dinh *et al.,* 2022).

1.7. Zinc: It application in mustard crops is essential for promoting healthy growth and maximizing yield. It is a crucial micronutrient that plays a vital role in enzyme activity, protein synthesis, and chlorophyll production (Kumar *et al.,* 2014). Plants uptake it as a cation (Zn^{2+}) from the soil solution. Deficiency in Zn can lead to stunted growth, poor leaf development, and reduced seed production in mustard plants. To ensure optimal zinc levels, zinc sulfate or other zinc-based fertilizers can be applied to the soil or as a foliar spray. However, the requirement of Zn application rate is based on the soil test value and soil properties. In common, zinc sulphate (20-25 kg/ha) as a solid application; whereas 2.5% zinc sulphate solution with 0.25% lime is fruitful for improving the mustard yield. The timing and method of application depend on soil zinc levels and crop requirements. Proper zinc fertilization helps improve mustard crop productivity, enhances disease resistance, and contributes to better overall plant health.

2. Nutrient management strategies in oilseed crops

For enhancing the oilseed production and quality parameters, the balance application of plant nutrient and their concentration in soil solution should be maintain by application of organic and inorganic substances (Rashmi *et al.,* 2022). Improvement in soil health parameters also the pre-requisition condition for nutrient management in oilseed crops.

2.1. Management of soil pH

For the balance supply of essential plant nutrients, soil pH should be in ideal condition (6.5 to 7.5). Both acidic and alkaline/sodic soils are needing soil amendment for enhancing the plant nutrient concentration and nutrient use efficiency.

a) **For saline soils -** These soils are containing the higher amount of soluble salts. These soils are having pH less than 8.5 and EC_e greater than 4 dS/m. Saline soils having good soil structure. To combat the salinity, different management practices are to be used, i.e. application of FYM, scrapping of salt, use of salt tolerant varieties, mulching, deep ploughing, leaching of soluble salt from root zone by good quality water (Dotaniya *et al.,* 2025).

i. *Leaching*- Dissolve and translocate the soluble salts in downwards below 45–60 cm. Based on the water availability and soil types the leaching method differentiated into two types continuous leaching and intermittent leaching. Intermittent leaching is done by after drain of previous leaching water another application takes place which is followed in were the scarcity of good quality water.

Leaching requirement (LR)=$(EC_{iw}/EC_{dW})\times 100$ ...Eq.1

Where, EC_{iw} = electrical conductivity of irrigated water, EC_{dw} = electrical conductivity of drainage water.

b) **Alkaline soil -** Soils that have a high pH (more than 8.5), a weak soil structure, and a restricted capacity for infiltrations are referred to as alkaline or alkali soils. The primary cause of the unfavorable physico-chemical properties of alkali soils is the carbonates ($CO_3^{2-} + HCO_3^{-}$) of sodium (Na) that are largely present in these soils (Dotaniya *et al.,* 2020). These soils are sufficiently alkaline and saturated with sodium to negatively impact agricultural productivity and plant growth. The dry and semi-arid regions of Punjab, Haryana, Uttar Pradesh, Bihar, and western Rajasthan are the primary locations of these soils in India. The development of alkalinity in soil involves the alkalinization process. Alkaline soils are defined as having a pH of at least 8.5, an EC of less than 4 dS/m, residual sodium carbonate (RSC) of more than 2.5 meq/L, and exchangeable sodium (ESP) of more than 15 (Dotaniya *et al*. 2020). For its management most of the saline soil management options are viable; in addition gypsum application is needed for counter the higher concentration of sodium (Dotaniya et al., 2023).

Gypsum application- among the chemicals, gypsum (calcium sulfate, $CaSO_4 \cdot 2\ H_2O$) is applied at farmers field as a source of Ca^{2+} ions to replace the sodium at the exchange complex. Gypsum also reacts with sodium carbonate to convert into sodium sulphate which is a neutral salt and does not contribute to high pH.

$2Na\text{-soil} + CaSO_4 \rightarrow Ca\text{-soil} + Na_2SO_4$ (precipitation) ...Eq. 2

c) **Acidic soils -** Problematic soils include acid soils as well. The soil has a pH of less than 6.5 and is mostly composed of H^+ and Al^{3+} ions (Enesi *et al.,* 2023). The availability of plant nutrients, especially phosphorus, calcium, magnesium, molybdenum, iron, manganese, potassium, sulfur, nitrogen, boron, copper, and zinc, is reduced by high soil acidity (pH 5 to 6.5). Additionally, it has a negative impact on crucial microbiological functions such nitrogen fixation by bacteria that reside nodules in leguminous plants (*Rhizobia*), *Clostridium*, and *Azotobacter* (Rao, 2014). It causes an imbalance in the ratio of plant nutrients and makes them immobile (Enesi *et al.,* 2023). Addition of FYM, organic residues, balance application of nutrients, cultivation of acid loving crops, lime application are need of today to reduce the soil acidity.

Liming: It improves the base status, inactivates Fe, Mn, Al ions concentration in soil solution. For this pH enhancing substances are to be used like lime. When lime is added to moist soil, the soil solution becomes charged with cations and the exchangeable hydrogen and aluminum ions on clay-organic colloid complex as well as the H^+ ions in soil solution are displaced by calcium ions.

$\text{Acid-clay} + Ca(OH)_2 \rightarrow \text{Ca-clay} + H_2O$ ...Eq. 3

5.2. Management of soil organic matter

A vital element of soil health, soil organic matter (SOM) affects fertility, structural integrity, and sustainability as a whole. Effective soil organic carbon (SOC) management becomes critical when oilseed crops are involved in order to maximize crop output, reduce environmental impact, and maintain long-term soil health (Raji *et al.,* 2019). The significance of SOC in oilseed crop production, variables affecting SOC levels, and methods for sustainable SOC management are all included (Dotaniya *et al.,* 2022). Importance of soil organic carbon for oilseed crops are:

- Nutrient cycling: SOC serves as a reservoir of essential nutrients, contributing to nutrient cycling and availability for oilseed crops.
- Soil structure: SOC improves soil structure, enhancing water retention, drainage, and root penetration, crucial for oilseed crop growth.
- Microbial activity: SOC supports microbial communities that play a pivotal role in nutrient mineralization, disease suppression, and overall soil health.

Production of oilseed crops must be managed well to maintain SOC. Farmers can increase soil health, nutrient availability, and long-term agricultural sustainability by implementing measures that raise SOC levels, such as cover crops, conservation tillage, and organic additions (Brady and Weil, 2008). In order to maximize SOC levels for the benefit of oilseed crops and the environment, as agriculture develops further, it will be essential to conduct continuing research and incorporate cutting-edge management techniques. Accumulation of SOM in soil by adopting the different set of management practices are the need of the hours (Lal, 2007). In this connection conservation tillage are practicing to minimize the C loss from the soil (Lakaria *et al.,* 2019). More number of tillage operations exposes the C from lower layer of soil to the top layer and lost as a carbon di-oxide (CO_2) in the atmosphere (Fig. 6). Climate change enhance SOC burning rate from soil by increasing soil temperature (Zhou *et al.,* 2019).

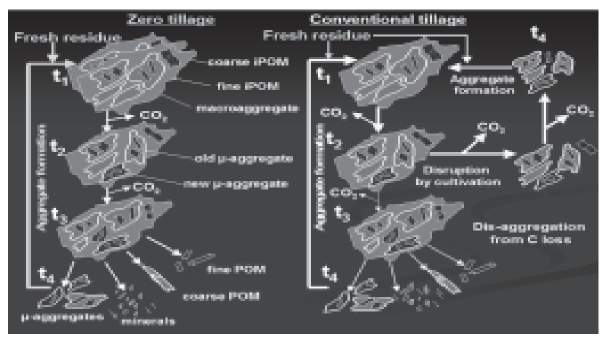

Fig. 6: Effect of zero tillage on soil aggregates stability (Manna and Ghosh, 2021)

Management of plant nutrients

The management of plant nutrient is more crucial for enhancing the nutrient use efficiency during the crop growth. It is observed that the efficiency was highly affected by the source of nutrient, soil properties, crop uptake. The 4R principles were given to improve the soil health parameters, nutrient dynamics, uptake by crops (Johnston and Bruulsema, 2014). It is classified into i) right source- select appropriate source of plant nutrient, for example application of SSP is more advisable than DAP (additional supply of S enhances oil content in oilseed crops), ii) right dose- recommended dose of plant nutrient should be apply based on soil test value. Under and excessive application of fertilizers may reduce the soil health and crop yield. iii) right time- apply fertilizers at right time for example, half dose of N and full dose of P and K should be

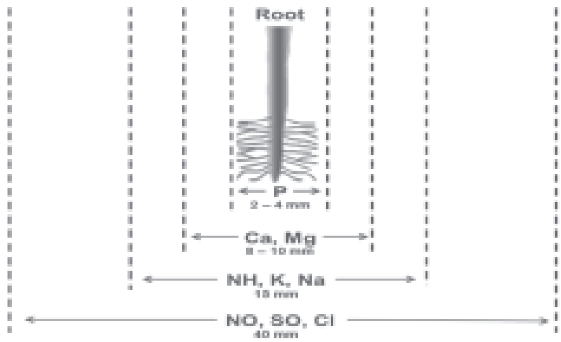

Fig. 7: Nutrient mobility in soils (Dotaniya *et al.,* 2020)

applied at the time of sowing. iv) right place- plant nutrients are having the mobility process in soil, nutrient like N is having higher mobility, whereas phosphorus having lowest. Most of the scientific cultivation practices recommending the sowing by seed cum fertilizer drill for better management of nutrients in oil seed crops (Fig. 7). Apart from this, soil test based application of plant nutrients or STCR based recommendation of plant nutrients will improve the crop yield and oil content in oilseed crops.

3. Epilogue

Plant nutrient management in oilseed crops is necessary to enhance the crop yield and oil content. As we aware that more than 50% vegetable oil is imported from foreign countries. However, scientific management of low fertility area, degraded soils may have huge potential to enhance oilseed production in the country. Other side of the story, India is importing more than 30% fertilizers consumed every year, comprising potassium fertilizers (90-100%), phosphatic (35-40%) and nitrogenous fertilizers (30-35%). Management of soil pH, SOC and plant nutrients are the key to improve the oilseed production in India. Based on the soil and climatic factors, plant nutrients can be managed with respect to crop and soil for better nutrient use efficiency and crop yield. Popularization of soil testing and nutrient application based on the value among the farmers may lead the soil health improvement. Formal and informal training to the farmers and stakeholders will enhance their skills for balanced application of plant nutrients.

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