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Judicial nutrient management for sustainable production of groundnut: A Review

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Abstract
Groundnut is a leguminous and oilseed crop cultivated throughout the globe due to its excellent nutritional values. Area under groundnut cultivation increased over time though productivity became stagnant and not given the desirable value. Key cause associated with this problem is indiscriminate use of chemical fertilizer which continuously deteriorates soil health and quality. Cultivation through organic inputs is a smatter way to improve soil health but due to population explosion it does not seems a feasible option for developing countries like India. Comprehensive approach should be taken to meet the both end and find a middle way for sustainable production of ground nut over a prolonged period of time. Integrated nutrient management (INM) acts as a bridge between two between two extreme concepts i.e. chemical fertilization and organic farming. INM is getting popular now a days for higher sustainable yield in minimal fertilization. Impact of different fertilizers, organics and integrated approach has been discussed on yield, growth and oil content of ground in this present article through a collective manner.

Keywords: Groundnut, sustainable, chemical fertilizer, organics, integrated nutrient management (INM)

Introduction
Arachis hypogea L., commonly known as groundnut, wonder nut, and poor man's cashew nut is also famous as "The king of all oilseed crops". Groundnut is a dicotyledon leguminous herbaceous plant with an average height of 30-50 cm (Laddha *et al.*, 2020) [68}. Groundnut is a widely accepted oilseed crop, mostly suitable in tropical and subtropical climatic regions of the world (Haerani *et al.*, 2023) [43]. Globally, the total area under groundnut cultivation is around 30 million hectares, and production is around 50.25 million metric tonnes with a productivity of 1.67 metric tonnes ha^{-1} (Gowsalya *et al.*, 2023) [40]. India ranks first in terms of area (6.02 million hectares) and production (6.70 million metric tonnes) of groundnut with a productivity of 1.11 tonnes per hectare during 2020-21 (Gowsalya *et al.*, 2023) [40].

Based on different research results, there are more than 118 elements present in our planet (Jones and Jacobsen, 2005) [56]. Among them there are 17 essential elements which are vital for growth and development of plants that's are Carbon (C), Hydrogen (H), Oxygen(O), Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo), Chlorine (Cl), Nickel (Ni) (Toor *et al.*, 2021) [126]. The world's population is growing daily, yet resources per person are steadily declining (Bodirsky *et al.*, 2020) [20]. Consequently, there is a growing need for us to adopt effective agriculture practises in order to decrease poverty and hunger as prediction shows globally population will reach 9.6 billion by 2050 (Zhang *et al.*, 2015) [146].

Chemical fertilizers are inorganic substance, synthesized in industries in specific combination to supply optimum amount of nutrients for proper growth and yield of crops (Toksha *et al.*, 2021) [125]. The nutrients, present in the fertilizer are easily releasable and accessible to plant (Vejan *et al.*, 2023) [131]. The consumption rate of chemical fertilizer in India was drastically elevated from 2.26 Mt in 1970-71 to 28.97 million tonnes in 2019-20 (Shukla *et al.*, 2022) [109]. India use 19.48 million ton of nitrogenous fertilizer, 7.83 million ton of phosphorus fertilizer and 3.154 million ton of potassic fertilizer.

Organic farming also names as ecological farming which have great principles based on health, fairness, ecology, and care. (Veisi *et al.*, 2021) [130]. Organic farming is a very much well-known traditional approach but due to low production and high cost of cultivation farmers are unwilling to adopt it. Government and NGOs are making different policies, awareness campaigns to more popularize organic farming among farmers (Singh *et al.*, 2023) [112]. Sustainable agriculture is the best possible way out to restrict food crisis problem efficiently without hampering the environment (Earls and Williams, 2005) [36]. The objectives of sustainable agriculture are; to provide food security together with adequate quality and quantity; to maintain the environmental quality and natural resources; to efficiently utilise non-renewable and on-farm resources to sustain the economic viability of farmer (Earls and Williams, 2005) [36]. The concept of integrated nutrient management was developed to derive optimum productivity by maintaining the optimum level of nutrient supply through different sources, *viz*., organic, inorganic, and biological, which helps to maintain the ecological diversity as well (Verma *et al.*, 2022) [132]. Integrated nutrient management helps to maintain soil fertility, productivity as well as soil ecology (Nikoukar and Rashed, 2022) [82].

Precision agriculture aims to control temporal and spatial variability by promoting ideas and technology that maximise agricultural productivity (Higgins *et al.*, 2019) [45]. Site specific nutrient management (SSNM) emphasize on four basic concepts i.e., right source of nutrient, proper quantity of nutrient, proper time to apply, and proper location to place the nutrient (Singh, 2019) [111]. SSNM is a way of supplying nutrients optimally as per need or deficit through using different tools *viz*., Sensors, Global positioning system (GPS), Geographic information system (GIS), Volume rendering technique (VRT), Yield monitoring (Verma *et al.*, 2020) [133].

Classification of plant nutrient

In 1840 Justus von Liebig was the first one to explained that plant growth, size and overall health depend upon some amount of the essential nutrient (Ma *et al.*, 2021) [72]. According to Brown *et al.*, (2022) [23] Boussingalt first tried the nutrient solution culture around 1840 to precisely control nutrients under experimental conditions, later on, Sachs around 1850-60 and Knop (1860) improved the technique. Sachs in the year of 1865 proposed two criteria for distinguishing the essential and non-essential elements *viz*., firstly structural criteria those elements should be integral components of a plant without those cells cannot exist (Ex. C, H, N, O, S) and secondly physiological criteria; without uptake of these elements good growth are not possible (Ex- K, Mg, Ca, Fe and P) also consider as essential, whereas Na and Cl appear to be non-essential (Brown *et al.*, 2022) [23]. After a long time Arnon and Stout in 1939 [12] proposed the criteria of essentiality which is modified by Arnon in 1954 (Jayara *et al.*, 2023) [51]. The criteria are *viz*., first, plant cannot complete their life cycle without this element, second, the element should not be replaced by another element, and third the element directly involved in plant metabolism systems (Arnon and Stout, 1939) [12]. According to these criteria there are 17 elements which can be called as essential for the plants. There are three non-mineral basic elements like H, O and C, because they are opted from water (H_2O) and air (Abas *et al.*, 2020) [1]. Plant nutrients that are needed more than 1 g kg^{-1} of plant dry matter production called macronutrients while micronutrients require 0.1-100 mg kg^{-1} of plant dry matter production (Pandey, 2018) [86]. Rest fourteen elements are further divided into macro and micro by Loomis and shull in 1937 which are enlisted in the table 1 with all others details (Kosiorek and Wyszkowski, 2021) [64]. Macronutrients can be further divided into two types, primary macronutrient and secondary macronutrients (Iqbal *et al.*, 2021) [62]. Some beneficiary elements help to provide resistance to plants *viz*., Sodium (Na), Silicon (Si), Cobalt (Co), Iodine (I), Selenium (Se), And Aluminium (Al) (Pradhan *et al.*, 2023) [90]. Nicholas in 1961 propose the concept of functional nutrient, according to him the element must have some role in plant metabolism but they are not considered as essential element (Dwivedi *et al.*, 2020) [35].

Bray and his coworkers given the concept of nutrient mobility in 1954 (Dhanoa *et al.*, 2021) [32]. Based on mobility, essential nutrients can be divided into two types based on mobility in plants and mobility in soil (Jadeja *et al.*, 2021) [49]. Essential plant nutrient within plants nutrients can be further divided into four forms *viz*; mobile, moderately mobile, less mobile and immobile. In plants, highly mobile nutrients are *viz*., N, P, K and Mg (Jadeja *et al.*, 2021) [49]. Moderately mobile in the plant is Zn (Štofejová *et al.*, 2022) [118]. There are some less mobile nutrients *viz*., S, Fe, Mn, Cu, and Mo (Zenda *et al.*, 2021) [142]. Nutrients which are very much immobile in plants i.e. Ca and B (Karthika *et al.*, 2020) [59]. Accordingly, in soil nutrients which are present in anionic condition are mostly mobile like NO_3^-, SO_4^{2-}, BO_3^{3-}, Cl^- along with a exception of Mn^{2+} (Samreen *et al.*, 2021) [102]. In soil Less mobile plant nutrients are NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Cu^{2+} (Klimczyk *et al.*, 2021) [62]. In soil immobile plant nutrients are HPO_4^{2-}, Zn^{2+}, and $H_2\ PO_4^-$ (Ortas, 2019) [83]. Nutrients have specific role in crops, limmiting or excessive amount also can cause effect in the crops Table 3 and 4 shows more details about the nutrients roles and plants symptoms at different senario.

Table 1: Essentiality of nutrients and plant uptake able forms

Criteria	List of nutrients	Essentiality discover by	Year	Plant Available form	Reference
Basic/structural elements	(C)	Priestley *et al.*,	1800	CO_2	(Wu and Rao, 2023) [141]
	(H)	Since ancient time	Since ancient time	H_2O	(Abas *et al.*, 2020) [1]
	(O)	Since ancient time	Since ancient time	H_2O and O_2	(Abas *et al.*, 2020) [1]
Primary macro nutrient	(N)	Theodore de Saussure	1804	(NH_4^+, NO_3^-)	(Bhardwaj *et al.*, 2022) [18]
	(P)	C. Sprengel	1839	(HPO_4^2, $H_2PO_4^-$)	(Ranjha *et al.*, 2022) [95]
	(K)	C. Sprengel	1839	(K^+)	(Brown *et al.*, 2022) [23]
Secondary Macro nutrient	(Ca)	C. Sprengel	1839	(Ca^{2+})	(Brown *et al.*, 2022) [23]
	(Mg)	C. Sprengel	1839	(Mg^{2+})	(Brown *et al.*, 2022) [23]
	(S)	Sachs and knop	1860	(SO_4^{2-})	(Rajaseger *et al.*, 2023) [94]
Micro nutrients	(Fe)	E. Gris	1943	(Fe^{2+})	(Sharma *et al.*, 2022) [107]
	(Mn)	J.S. McHargue	1922	(Mn^{2+})	(De Oliveira, and de Andrade, 2021) [30]
	(Zn)	A.L. Sommer and C.P. Lipman	1926	(Zn^{2+})	(Monika *et al.*, 2022) [78]
	(Cu)	A.L. Sommer, C.P. Lipman and G. McKinney.	1931	Cu^{2+}	(Linder, 2013) [69]
	(B)	K. Warrington	1923	(H_3BO_3, $H_2BO_3^-$, HBO_3^{2-} , $BO_3^{3-)}$	(Wimmer *et al.*, 2019) [140]
	(Mo)	D.I Arnon and P.R. Stout	1939	(MoO_4^{2-})	(Mondal and Bose, 2019) [77]
	(Cl)	T.C. Broyer, A.B. Carit, C.M. Johnson and P.R. Stout	1954	(Cl^-)	(Willoughby, 2019) [138]
	(Ni)	P.H. Brown, R.M. Welch and E.E. Cary	1987	Ni^{2+}	(Kumar *et al.*, 2021) [66]

Table 2: Essential plant macro nutrients, their functions and deficiency symptoms

Nutrient	Function	Deficiency Symptom	Toxicity Symptom	Reference
(N)	Proper nodule formation and root growth	Lower leave turns yellow	Poor root growth	(Zhang *et al.*, 2023) [143]
	Constituent of chlorophyll	Stunted growth	Black tips around older leaf	(De Bang *et al.*, 2021) [145]
	Increase vegetative growth, protein content	Leaf sheading	Enhance lodging	(Sun *et al.*, 2023) [119]
(P)	Stimulate pod setting, decrease unfilled pods	Small size leaf	Necrosis and tip dieback	(Sunilkumar *et al.*, 2020) [120]
	Improve root growth and formation	Maturity delayed	Interveinal chlorosis in newly formed leaves	(Sameer *et al.*, 2021) [101]
	Energy storage and transfer	Leaves became purple	Marginal scorching of older leaves	(Ahmed *et al.*, 2021) [5]
(K)	Improve stress tolerance	Lodging of crops	Plants does not have so much toxicity hence it shows luxury consumption	(Hasanuzzaman *et al.*, 2018) [44]
	Reduce lodging	Leaf margins dries		(Zörb *et al.*, 2014) [147]
	Helps in stomatal opening	Older leaf became brown		(Johnson *et al.*, 2022) [55]
(Ca)	Maintain cell membrane permeability	Terminal bud dies	Nutrient availability and uptake Disrupts metabolic process	(Rui and Dinneny, 2020) [98]
	Improve soil quality	Wrinkled leaf		(Gao *et al.*, 2021)
	Seed development, seedcoat formation, seed filling, seed viability, seed germination	New leaves are affected	Reduce root growth	(Nautiyal *et al.*, 2023) [80]
(Mg)	Constituent of chlorophyll	Older leaves affected	Leaf become coppery colour	(De Bang *et al.*, 2021) [29]
	helps to capture light	Interveinal chlorosis		(Selvaraj and Sankar, 2010) [104]
	Activate necessary enzyme metabolic processes	Veins remain green	Defoliation of leaf	(Jin *et al.*, 2023) [54]
(S)	Increase pungency in oil	Leaf colour became light	Premature leaf senescence	(Saleem *et al.*, 2019) [100]
	Stimulate seed and nodule formation	Symptom in new leaf		(Walia *et al.*, 2021) [136]
	Protein synthesis	Slow growth rate maturity period high	Reduce leaf size	(Tiwari *et al.*, 2022) [124]

Table 3: Essential plant micro nutrients, their functions and deficiency symptoms

Nutrient	Function	Deficiency Symptom	Toxicity Symptom	Reference
Zn	Enzyme activation and cell membrane integrity	Small and thickened leaves	Leaves become yellow	(Zhang *et al.*, 2021) [145]
(Fe)	Synthesise of ferredoxins	Interveinal yellowish of leaves	Bronzing	(Agustinus *et al.*, 2023) [23]
	Chlorophyll synthesis	Small and thickened leaves		(Schmidt *et al.*, 2020) [103]
(Mn)	Essential for photosynthesis and substitute Mg	Interveinal chlorosis in younger leaves	Crinkle leaf of cotton	(Alejandro *et al.*, 2020) [8]
	Enzyme activator for respiration and N metabolism			(Khoshru *et al.*, 2023) [61]
(Cu)	Lignin formation in cell wall	Chlorosis of younger leaves	Reduced shoot vigour	(Zhang *et al.*, 2020) [144]
	Electron transfer in photosynthesis and respiration	Stunted growth	Undeveloped discovered root	(Wang *et al.*, 2021) [137]
(B)	Pollen tube growth and root nodule development in legumes	Terminal bud growth stopped	leaf margins and tips become yellow colour	(Mehboob *et al.*, 2023) [75]
	Translocation of sugar starch and N, P	Death of shoot tips		(Ewais *et al.*, 2020) [38]
	Need for flowering, seed and fruit setting	Sterility occurs		(Day and Aasim, 2020) [28]
(Mo)	Essential component of NO_3 reductase and nitrogenase enzyme	Interveinal chlorosis	Stunted growth and bone deformation of cattle like sheep and goat	(Imran *et al.*, 2019) [47]
(Cl)	Maintain electrical balance in tonoplast	Chlorosis of younger leaves and leaf bronzing	Increases osmotic pressure of soil water	(Liu *et al.*, 2023) [70]
(Ni)	N metabolism in legume	Chlorosis of younger leaves	Necrosis and wilting of plants	(Parwez *et al.*, 2023) [87]

Effect of nutrient on growth of groundnut

Role of nutrients are not replaceable in-case of proper growth in groundnut. Adequate amount of nutrient is necessary as every nutrient has some specific role in case of growth of groundnut.

Nitrogen (N): N is a component of proteins, enzymes, and chlorophyll, all of which are necessary for photosynthesis development of healthy plant (Ahanger *et al.*, 2019) [4]. In groundnuts, N is a crucial component for promoting vegetative growth and leaf development (Anas *et al.*, 2020) [11]. N raises the amount of chlorophyll in plant, which raises photosynthetic area and, eventually, total biomass output, which encourages overall plant growth (Sherin *et al.*, 2022) [108]. Bekele *et al.*, (2019) [15] reported that combined application of N, P and Vermicompost at the rate of 46:46 and 2.5 ton of vermicompost resulted 25.5% more plant height and 34.67% more number of branches per groundnut plant over control. The result may be obtaining because of synergetic effect of N, P fertilizer and vermicompost. Devi *et al.*, (2022) [31} found that among doses of (30,40,50) N ha^{-1}, 50 kg N ha^{-1} helps to opt maximum plant height (52.28cm), nodules $plants^{-1}$ (40.07), dry weight $plant^{-1}$(35.86gm). The result obtains because of optimum level of N stimulates photosynthesis by increasing source area and size (Palsande *et al.*, 2019) [85}.

Phosphorus(P): P helps in the synthesis of energy in groundnut plants, which is necessary for metabolic functions and hence encourages plant development (Basavegowda and Baek, 2021) [14]. P is necessary for the production of nucleic acids, adenosine triphosphate, energy transmission, and root growth (Singh and Dahal, 2022) [109]. Phosphorus aids in healthy root formation, which enables plants to absorb more nutrients (Chen *et al.*, 2022) [27]. Applying adequate amounts of P may promote the uptake of other nutrients (Sharma *et al.*, 2019) [105]. Sharma *et al.*, (2020) [106] observed that 40kg P ha^{-1}as 50% from inorganic source and 50% through vermicompost helps to obtain 3.87% more plant height, 42.61% more dry matter accumulation, 48.55% more number of nodules, 39% more chlorophyl content, and 42.66% more nodule weight over control.

Potassium: Through the opening and closing of stomata, K helps to keeps the plant's osmotic balance in control (Johnson *et al.*, 2022) [55]. Osmotic management allows for the absorption of nutrients and water (Rawat *et al.*, 2022) [97]. In addition, K increases resilience to drought, lodging, and infections, all of which support the growth and development of plants (Singhal *et al.*, 2023) [113]. Bhadiyatar *et al.*, (2022) [16] found that to obtain maximum growth and plant population in groundnut crop 50 kg K_2O $ha^{-1}$is optimum along with 25 kg N $ha^{-1}$and 50 kg P_2O_5 ha^{-1}as RDF. This experiment also shows that the dose 50 kg K_2O ha^{-1}helps to obtain that around 7% more plant population, 3% more height, 14% more number of pods. Sireesha and Dawson., (2022) [115] observed that among doses of 40, 50, 60 kg K ha^{-1}, 60 kg K ha^{-1} helps to obtains 5% more plant height, 11.3% more number of nodules $plants^{-1}$, 9.2% more amount of dry weight and 4.5% more crop growth rate over lower dose. This increment of growth may be occurring because of optimum doses of K enhanced metabolic activity, carbohydrate metabolism, protein metabolism (Jiaying *et al.*, 2022) [53]. Other reason may be more nutrients uptake, proper cell division or osmo-regulation through stomatal opening (Hasanuzzaman *et al.*, 2018) [44].

Calcium (Ca): For peanut crops, Ca is a more crucial ingredient (Kadir Mangalam *et al.*, 2022) [58]. Ca promotes the growth of roots and shoots (Jahanzaib *et al.*, 2021) [50]. Ca helps to increase fresh weight (Nautiyal *et al.*, 2023) [80]. Additionally, Ca helps to increase plant height, root length, vigour, and pegging in groundnut (Kadirimangalam *et al.*, 2022) [58]. Rajanarasimha *et al.*, (2021) [93] found that among doses of (20,40, 60) kg Ca ha^{-1}, maximum plant hight (79.89 cm) obtains in 40 kg Ca ha^{-1}along with 45 kg S ha^{-1} while the greatest number of nodule $plant^{-1}$ (9.50), dry weight (17.46 gm) obtains with 60 kg Ca ha^{-1}along with 45 kg S ha^{-1}. Vu *et al.*, (2022) [135] observed that eggshell as calcium source is very prominent, application of different doses of calcium sources as lime 500kg ha^{-1}, and eggshell powder (200, 300,400, 500) kg ha^{-1}, 300 kg ha^{-1} eggshell powder resulted maximum growth and growth attributing character like, 5.75% more plant height, 9.19% more branch length, 19.24% more shoot weight, 18.26% more root weight, 8.54% more leaf area, 6.27% more nodule number, and 67.14% more nodule dry weight compared to lime application.

Magnesium (Mg): Since Mg is a key component of chlorophyll, photosynthesis depends significantly on it (De Bang *et al.*, 2021) [29]. Mg activates enzymes which affect plant growth and vigour (Chakraborty and Bose, 2020). Sireesha and Dawson., (2022) [115] observed in their experiment that among (10, 15, 20) kg Mg ha^{-1}, Mg 20 kg ha^{-1}resulted maximum growth and growth attributing characters, that is 5% more plant height, 11.3% more nodules $plant^{-1}$, 9.2% more dry weight (g $plant^{-1}$) 4.5% more crop growth rate. This result obtains may be because of adequate amount of magnesium increases photosynthetic efficiency and promote healthy growth (Al-Juthery *et al.*, 2021) [9].

Sulphur (S): Independently S increases N, P, Ca, and Mn uptake (Pratiwi *et al.*, 2016) [92]. Groundnut yield is also increased by S through improved chlorophyll synthesis resulting in higher growth (Ariraman *et al.*, 2020) [96]. The element sometime helps to withstand cold, root growth, and the photosynthesis process (Al-Khayri *et al.*, 2023) [10]. Dileep *et al.*, (2021) [34] found in their experiment that among (20, 30, 40) kg S ha^{-1}dose ,40 kg ha^{-1} S helps to obtained maximum plant height (59.31 cm), highest dry matter accumulation (56.73 gm), maximum number of nodules plant $^{-1}$ (47.53), while maximum crop growth rate (13.82 g/m^2 /day) and relative growth rate (0.008 g/m^2 /day) obtained @ 30 kg ha^{-1} S. Bhadiyatar *et al.*, (2022) [16] found in their experiment that S did not influences as much on height and plant population in groundnut crop. Aier and Nongmaithem, (2020) [96] found that among five S treatment *viz*, (0, 10, 20, 30 and 40) kg S ha^{-1}along with 20:60:40 kg ha^{-1} N: $P_2 O_5$: $K_2 O$ as RDF, 40 kg S ha^{-1}resulted maximum plant height (55.96 cm) at harvest, maximum crop growth rate 11.71 (g/m^2 /day) at the time of 30-60 days, and higher relative growth rate 0.18 (g /g/ d). Rajanarasimha *et al.*, (2021) [93] found that among doses of (15, 30, 45) kg S ha^{-1}, maximum plant hight (79.89 cm) obtains in 45 kg S ha^{-1}along with 40 kg Ca ha^{-1}while the greatest number of nodule $plant^{-1}$ (9.50), most dry weight (17.46 gm) obtains with 60 kg Ca ha^{-1}along with 45 kg S ha^{-1}.

Micronutrients: Aboyeji *et al.*, (2019) [2] observed that among three Zn treatment combinations (0,4 and 8 kg ha^{-1}), 8 kg ha^{-1}helps to obtain highest number of plant height (28.89 cm) and plant spread (45.22cm). Aboyeji *et al.*, (2019) [2] also observed among four B treatment combinations (0,300,600 and 900) ml ha^{-1}, 600 ml ha^{-1} helps to obtain highest number of plant height (30.70 cm) and 900 ml ha^{-1} resulted most plant spread (47.51cm). Hirpara *et al.*, (2017) [46] observed that among the five B treatment combinations, *viz*., 2, 4, 8, 10, and 0 kg ha^{-1} as control, maximum branches $plant^{-1}$ (3.89) obtained with 10 kg ha^{-1} while maximum plant height (23.30 cm), numbers of pegs $plant^{-1}$ (26.04), number of nodules $plant^{-1}$ (91.57) and nodule dry weight $plant^{-1}$ (0.231 g) were obtained with the application of 8 kg B ha^{-1}.

Effect of nutrient on yield of groundnut

Nutrients play significant role in the case of adequate yield of groundnut. Adequate amount of nutrient is necessary to get optimum yield of groundnut, as every nutrient has some specific role. Fig 1 and Fig 2 shows that due to deficiency groundnut pod yield significantly reduced.

Nitrogen (N): In grain producing crops N helps to improve the quality and quantity of dry matter (Sun *et al.*, 2023) [119]. Bharathi *et al.*, (2021) [17] found that among three doses of N (10, 15, 20) kg $ha^{-1}$with different biofertilizer, maximum number of pod $plant^{-1}$ (28.80), kernels pod^{-1} (2.07), seed index (46.26 gm), seed yield (2655.58 kg ha^{-1}), haulm yield (3587.20 kg ha^{-1}), and harvest index (42.31%) obtained from 20kg N ha^{-1}. Mandeewal *et al.*, (2022) [74] observed that among the different doses of N (0, 20, 40, 60) kg ha^{-}1, maximum kernel yield (1802 kg ha^{-1}), pod yield (2707 kg ha^{-1}), haulm yield (3911 kg ha^{-1}) and biological yield (6618 kg ha^{-1}) obtains from 60 kg N ha^{-1} that is. Devi *et al.*, (2022) [31} found that among three N doses (30,40,50) kg ha^{-1},50 kg N ha^{-1} resulted highest number of pod $plant^{-1}$(14.87), kernels pod^{-1} (1.73), seed index (36.43 gm), pod yield (2.163 t ha^{-1}), haulm yield (3.930 t ha^{-1}), and harvest index (31.76%).

Phosphorus (P): Kabir *et al.*, (2013) [57] found that among three different doses of P (0, 25,50) kg ha^{-1}, 50 kg P ha^{-1} resulted maximum number of total pods $plant^{-1}$ (18.96), 100 pod weight (110.84 gm), shelling percentage (64.22%), pod yield (2.85 t ha^{-1}), biological yield (10.87 t ha^{-1}), straw yield (8.02 t ha^{-1}) and harvest index (26.02%). Sharma *et al.*, (2020) [106] found that 50% inorganic source and 50% organic source as vermicompost for P nutrition out of 40kg P ha^{-1}as RDF helps to obtain 79.8% more pod yield ,73.4% more haulm yield, 76% more biological yield, 79.7% more kernel yield over control. Vidya-Sagar *et al.*, (2020) [134] observed that among three P doses *viz*, (40, 50 ,60) kg ha^{-1}, highest number of pods $plant^{-1}$ (32), kernel yield (2.48t ha^{-1}) and dry weight (56.3 g $plant^{-1}$) obtains through 60 kg P ha^{-1}.

Potassium(K): Sakarvadia *et al.*, (2019) [99] found that split treatment of K dose 50 kg ha^{-1} resulted maximum number of pod yield (1.421t ha^{-1}), haulm yield (3.747 t ha^{-1}). Bhadiyatar *et al.*, (2022) [16] observed that application of 50kg K ha^{-1} helps to obtain significantly higher number of pods $plant^{-1}$ (20.67), pod weight $plant^{-1}$ (12.97 gm), seed index (44.84 gm), pod yield (2.28t ha^{-1}) and haulm yield (3.390 t ha^{-1}). Sireesha and

Dawson., (2022) [115] observed in their experiment that among (40, 50 ,60) kg K ha^{-1}, higher pods plant^{-1} (25.80), kernels pod^{-1} (2.4), seed index (46.27 g), seed yield (2.48 kg ha^{-1}), haulm yield (5.51 t ha^{-1}), harvest index (31.07%) was obtained with the application of 60 kg k ha^{-1}.

Calcium (Ca): Rajanarasimha *et al.*, (2021) [93] found that among doses of (20, 40, 60) kg Ca ha^{-1} maximum number of pods plant^{-1} (21.33), kernels pod^{-1} (2), seed index (42.80g), kernel yield (2.17 t ha^{-1}), haulm yield (5.60 t ha^{-1}), harvest index (36.40%) obtains through 60 kg Ca ha^{-1}.Vu *et al.*, (2022) [135] observed that eggshell as Ca source is very prominent, application of different doses of Ca sources as lime 500kg ha^{-1}, and eggshell powder (200, 300, 400, 500) kg ha^{-1}, 300 kg ha^{-1} eggshell powder resulted maximum pod plant^{-1} (11), 100 Pod weight (146.1g), 100 seed weight (58.7g), Pod yield (3.60 t ha^{-1}).

Magnesium (Mg): Sireesha and Dawson., (2022) [115] observed in their experiment that among (10, 15, 20) kg Mg ha^{-1}, 20 kg Mg ha^{-1}, helps to obtain the greatest number of pods plant^{-1} (25.80), kernels pod^{-1} (2.4), seed index (46.27 g), seed yield (2.48 kg ha^{-1}), haulm yield (5.51 t ha^{-1}), harvest index (31.07%) were obtained with the application of 60 kg Mg ha^{-1}.

Sulphur(S): Rajanarasimha *et al.*, (2021) [93] found that among doses of (15, 30, 45) kg Sulphur ha^{-1}, highest number of pods plan^{t-1} (21.33), kernels pod^{-1} (2), seed index (42.80g), kernel yield (2.17 t ha^{-1}), haulm yield (5.60 t ha^{-1}), harvest index (36.40%) obtains through 45 kg S ha^{-1} dose along with 60 kg Ca ha^{-1}. Dileep *et al.*, (2021) [34] found in their experiment that among (20, 30, 40) kg S ha^{-1} dose, 40 kg S ha^{-1} helps to obtain maximum number of pods plant^{-1} (22.65), kernels pod^{-1} (2.01), shelling (70.83%), seed index (38.57%), seed yield (2.9 t ha^{-1}), haulm yield (4.48 t ha^{-1}), harvest index (39.32%). Bhadiyatar *et al.*, (2022) [16] observed that application of 45kg S ha^{-1} helps to obtain significantly highest number of pods plant^{-1} (20.67), pod weight plant^{-1} (12.75 gm), seed index (44.58 gm), pod yield (2.27 t ha^{-1}) and haulm yield (3.4 t ha^{-1}). Devi *et al.*, (2022) [31] found that among three S doses (0, 20,40) kg ha^{-1}, 40 kg S ha^{-1} combined application with 50 kg N ha^{-1} obtained highest number of pod plant^{-1} (20.6), kernels pod^{-1} (2), seed index (41.17 gm), pod yield (2.74t ha^{-1}), haulm yield (4.37 t ha^{-1}), and harvest index (34.84%).

Micronutrient: Aboyeji *et al.*, (2019) [2] observed that among three Zn treatment combinations (0,4 and 8) kg ha^{-1}, 8 kg ha^{-1} helps to obtain highest number of pods plant-1 (29.40), seeds pod^{-1} (45.46), weight of seeds plot^{-1} (31.16 gm), pod yield (3.59 t ha^{-1}), seed yield (2.67 t ha^{-1}), and seed quality**.** They also observed that among four B treatment combinations (0,300,600 and 900) ml ha^{-1} @ 900 ml ha^{-1} helps to obtain highest number of pods plant^{-1} (32.05), seeds pod^{-1} (48.16), weight of seeds plot^{-1} (35.29 gm), pod yield (3.69 t ha^{-1}), seed yield (2.82 t ha^{-1}) Hirpara *et al.*, (2017) [46] observed that among the five B treatment combinations, *viz*., 2, 4, 8, 10, and 0 kg ha^{-1}, maximum haulm yield (18.56 g plant^{-1}) obtained with 10 kg ha^{-1} while the highest of number of pods plant^{-1} (10.556), mature pods plant^{-1} (7.572), shelling percentage (67.15), pod yield (19.75 g plant^{-1}) were obtained with the application of 8 kg B ha^{-1}.
Porkodi *et al.*, (2022) [88] observed that among different sources and doses of Fe, Fe-enhanced FYM @ 50 kg ha^{-1} along with RDF (25:50:75 NPK kg ha^{-1}) and Bacillus subtilis @ 2 kg ha^{-1} resulted maximum number of pod plant^{-1} (38.67), 100 grain weight (48.69g), pod yield (2.09 t ha^{-1}) and haulm yield (2.89 t ha^{-1}).

Effect of nutrient on oil content of groundnut

Nutrients play significant role in the case of oil content of groundnut. Adequate amount of nutrient is necessary to get optimum quantity. Fig 3 shows that increase in oil content by application of different nutrients.
Chaudhary *et al.*, (2019) [26] Found that among 10th different treatment combination 9th treatment (RDF + NPK consortium) resulted maximum amount of oil (40.28%) which is 1.66% more than control. Sakarvadia *et al.*, (2019) [99] found that among different doses of potassium *viz*, 0, 25, 50, and 75 kg ha^{-1}, as basal and as well as split, 50 kg ha^{-1}potassium in split application helps to opt maximum oil content (50.58%) which is 2.38% more than control (48.2%).
Prakash *et al.*, (2020) [91] observed in their experiment that among different sources *viz*, natural gypsum 500 kg ha^{-1} and Slag Based Gypsum (SBG) with full and split doses (625,500) kg ha^{-1}, split dose of 625 kg ha^{-1} (312.5+312) kg ha^{-1} shows highest amount of oil content (46.88%) and 46.12% as lowest for 500kg ha^{-1} (250+250 kg ha^{-1}) split in the area of Baljigapade. While in Pavagada highest oil percentage obtain (46.73%) and lowest (46.12%) with same treatment.
Sisodiya *et al.*, (2016) [116] found that among different sources of S *viz*, Cosa wet, Gypsum, Bentonite and elemental S as treatment combination, elemental S at the rate of 20 mg kg^{-1} helps to obtain maximum oil content in groundnut crop.
Yadav *et al.*, (2020) [148] observed that among four different S treatment combination *viz*., (0,20,40,60) kg ha^{-1}, 60 kg S ha^{-1} helps to obtain maximum oil content (44.87%) than control (37.12%) in groundnut crop.
Hirpara *et al.*, (2017) [46] observed that among the five B treatment combinations, *viz*., 2, 4, 8, 10, and 0 kg ha^{-1} as control, the maximum oil percentage was 46.25% obtained with 8 kg ha^{-1}, and the minimum (42.12%) obtained at control. Hirpara *et al.*, (2017) [46] observed that among three Mo treatment combinations, *viz*., 1, 2 and 0 kg ha^{-1} as control, the maximum oil percentage (47.44%) obtained with 1 kg ha^{-1}, and minimum (42.69%) obtained at control.

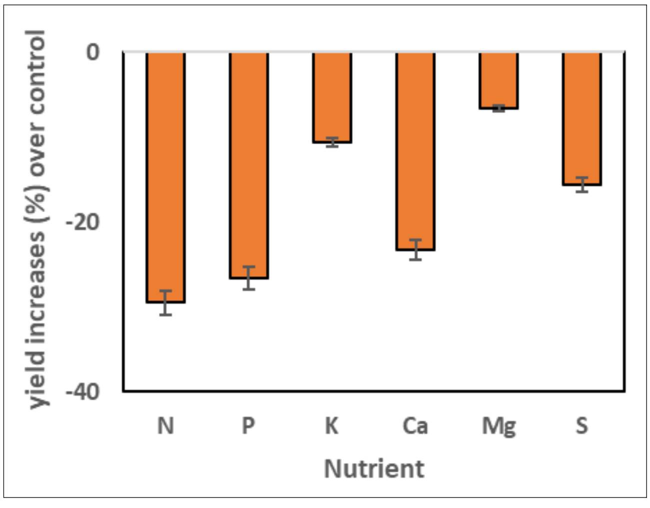

Fig 1: Yield increase due to macro-nutrient deficiency

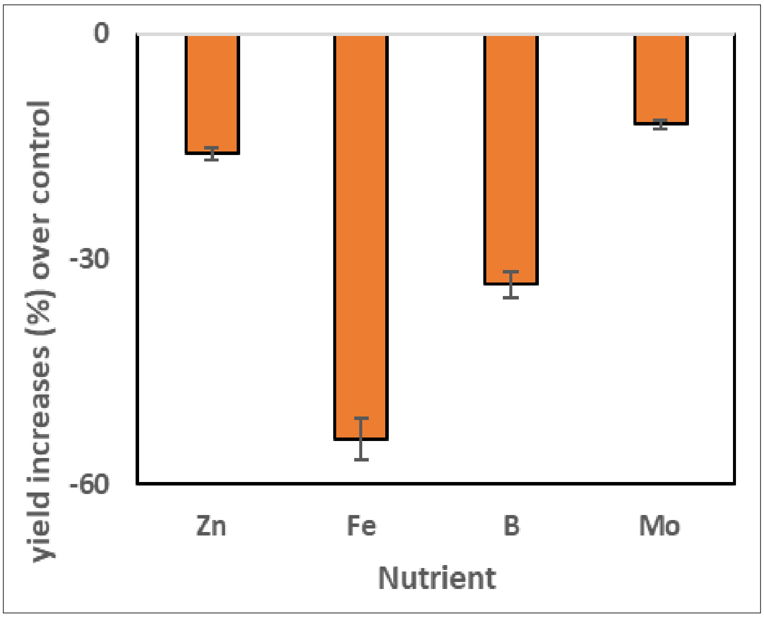

Fig 2: Yield increase due to micro-nutrient deficiency

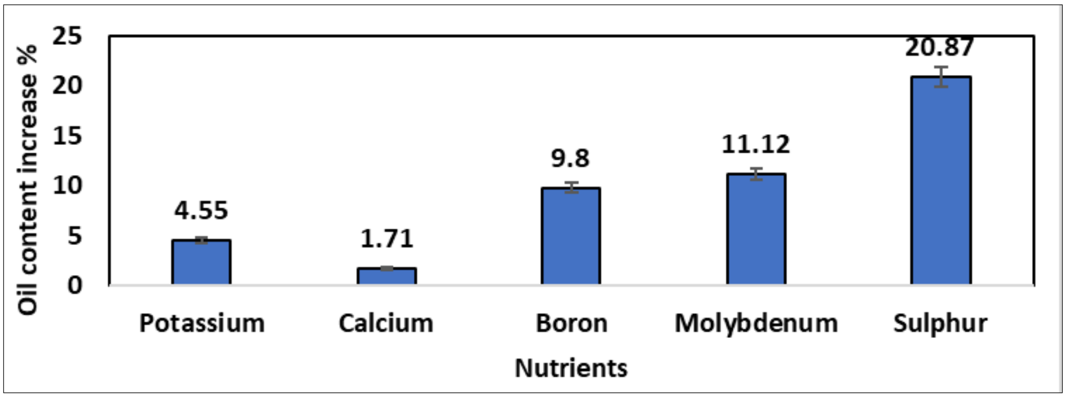

Fig 3: Groundnut oil content increase due to different nutrient

Nutrient management for sustainable production

To get optimum production without endangering future generation resources it become necessity to go with sustainable crop production techniques (Bradu *et al.*, 2022) [22]. For optimum production we have to remember some key points *viz*, optimum resource use efficiency, renewable resources, Biodiversity Conservation, Social Responsibility, Soil testing, Precision agriculture (Kumar *et al.*, 2022) [67]. Major components are optimum use of chemical fertilizer, inclusion of Integrated nutrient management, adaptation of organic farming and sight specific nutrient management (Borase *et al.*, 2022) [21].

Chemical fertilizers

Chemical fertilisers are produced synthetically in factories. NPK fertilisers, that's are mainly made up of three primary nutrients: N, P, and K (Sinha and Tandon, 2020) [114]. N is very much abundant in atmosphere, but plants are unable to use this directly. The most common nitrogenous fertilizers are ammonium nitrate, urea, and ammonium sulphate (Powlson and Dawson, 2022) [89]. Phosphorus is mainly found form of minerals and rocks naturally. The most common phosphate fertilizers are single, double and triple superphosphate (Guelfi *et al.*, 2022) [42]. Potassium is also found from minerals and rocks but its availability is lower comparatively than N and P (Jena, 2021) [52]. Most common potassic fertilizers are potassium chloride and potassium sulphate (Wilmer *et al.*, 2022) [139].

The low nutritional content and sluggish release of organic fertilisers make them unsuitable for meeting the demands of the current generation; instead, artificial fertilisers are required to provide plants with the nutrients they require (Ayilara *et al.*, 2020) [13]. Since various fertilisers are sources of different nutrients, different crops require optimal dosages of different chemical fertilisers (Toksha *et al.*, 2021) [125], As per different research for groundnut crop recommend dose of fertilizers 50 kg K_2O $ha^{-1}$is optimum along with 25 kg N $ha^{-1}$and 50 kg P_2O_5 ha^{-1} as RDF (Bhadiyatar *et al.*, 2022) [16]. Urea used as common N source. Di ammonium phosphate (DAP) for N and P source, Muriate of Potash (MOP) as a source of K. Rock phosphate used for P source. Single super phosphate used for P and S. Gypsum ($CaSO_4$) for S and Ca, lime also a good source of Ca (Liu *et al.*, 2023) [71]. Fig 4 and Fig 5 represented yield increase due to different inorganic fertilizer and amendments.

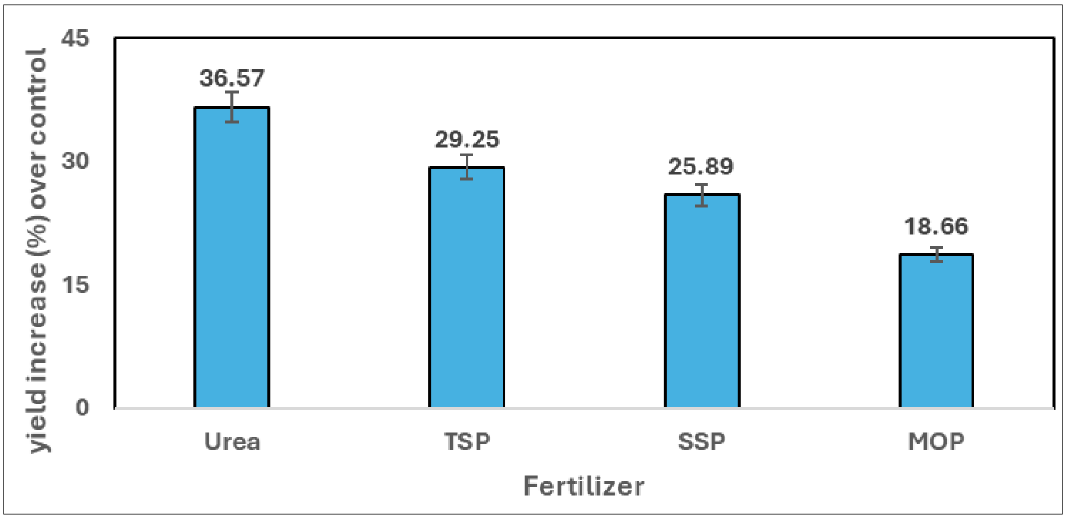

Fig 4: Ground nut pod yield increase due to different inorganic fertilizer

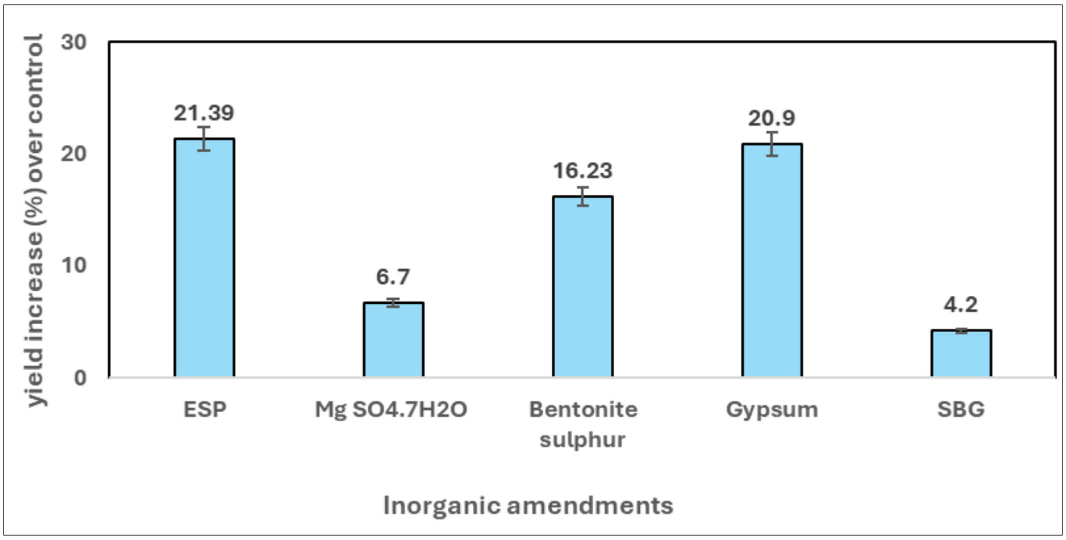

Fig 5: Groundnut pod yield increase due to different inorganic amendments

Organic farming

Organic farming is a holistic and sustainable approach based on the principles of health, fairness, ecology, and care (Dhiman, 2020) [33]. Chemical fertilisers are very much adopted because of the quick supply of nutrients and better management of weeds and pests (Edwards, 2020) [37]. But in the long term, they can cause soil fertility degradation, food quality degradation, and ecological destruction (Pahalvi *et al.*, 2021) [84]. Kulkarni *et al.*, (2018) [65] found that among inorganic treatments that's are only RDF and RDF plus zinc sulphate @ 20kg ha^{-1}and sulphur 40kg ha^{-1}through gypsum and organic sources like vermicompost, FYM, castor cake and bio fertilizer like, Rhizobium and PSB (seed treatment) organic sources showed better yield and yield attributes *viz*, 3% more pod yield and 2.25% more haulm yield than inorganic. Tan *et al.*, (2019) [123] found that application of biochar as organic matter significantly improves soil properties like, soil pH, EC, moisture content, C:N ratio, soil organic carbon as well as improve the peanut yield over control also suggest that for carbon sequestration in soil biochar is a prominent amendment. Madhuri *et al.*, (2019) [73] observed that press mud 10 t ha^{-1}, FYM 10 t ha^{-1}, vermicompost 2.5t ha^{-1}, poultry manures 4 t ha^{-1}as a source of organic manure helps to increase soil nutrient status compared to control and among them press mud shows better result. Kavad *et al.*, (2019) [60] observed that different organic sources *viz*, Bangalore-compost, Vermicompost, NADEP-Compost, FYM and (Wheat straw Mulch) helps to increase the yield of groundnut crop significantly, among them vermicompost resulted maximum yield. Bekele *et al.*, (2019) [15] found that 5 t ha^{-1}vermicompost is optimum for maximum yield production among different doses. Bhutadiya *et al.*, (2019) [19] observed that 5 t ha^{-1}FYM and 1 t ha^{-1} castor cake is optimum for higher yield production among different doses and castor cake is more superior than FYM. Murugan *et al.*, (2020) [79] observed that among different sources and doses of organic manure *viz*, FYM @12.5t ha^{-1}, vermicompost @ 5 t ha^{-1}, fish pond silt @ 5t ha^{-1}, and composted poultry manure@ 5t ha^{-1}, Vermicompost resulted maximum pod (2.64 t ha^{-1}) and haulm yield (4.47 t ha^{-1}). Veeral and Kalaimathi, (2021) [129] found in their experiment that Press mud is more superior than Bagasse ash and Diluted distillery spentwash, Swamy *et al.*, (2021) [122] found in their experiment that full N supply through sheep pinning resulted maximum growth and yield, which is also a promising environment friendly, economically viable and sustainable option. Chandra and Mehera, (2022) [25] observed that Panchagavya and Vermiwash as a liquid organic manure source helps to increase plant height, Plant dry weight, pods plant^{-1}, kernels pod^{-1}, Test weight, Seed yield, Haulm yield and Harvest index. Fig 6 and Fig 7 showing that different organic manure and substances increase yield differently.

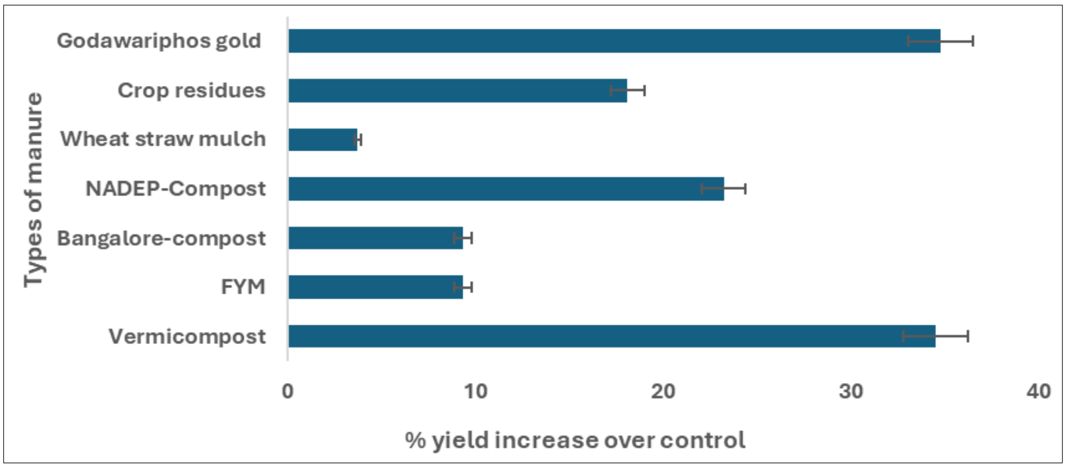

Fig 6: Ground nut pod yield increase due to different organic manure

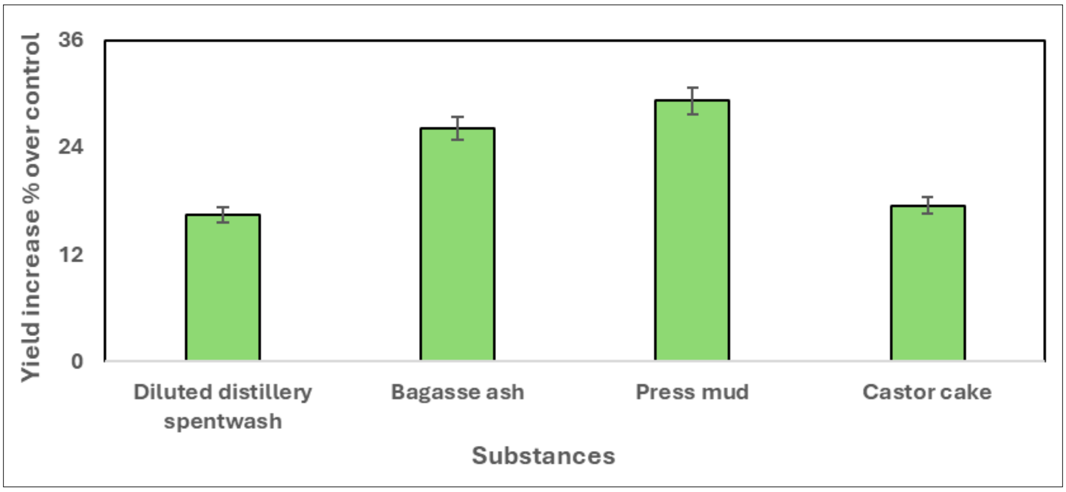

Fig 7: Ground nut pod yield increase due to different organic substances

Integrated nutrient management

Integrated nutrient management is a sustainable strategy for managing soil and plant nutrients and achieving maximum agricultural productivity (Gruhn *et al.*, 2000) [41]. Since a totally organic farming technique cannot fully meet the requirements of the current generation, conventional farming may be able to do so (Smith *et al.*, 2019) [117]. However, prolonged use of inorganic goods will deteriorate soil, the ecosystem, and human health over time. (Pahalvi *et al.*, 2021) [84]. Hence, we must adopt an aggregative agricultural strategy that uses more organic materials and fewer inorganic ones. Fig 8 shows that combined application of different organic and inorganic sources increases groundnut pod yield significantly. Naveen and Senthilkumar, (2021) [81] observed that integrated application of 100% RDF along with Rhizobium and Phosphobacteria @ 2 kg ha^{-1}as basal application resulted highest plant height (82.20 cm), leaf area index (2.76), dry matter production (5776.20 kg ha^{-1}), number of pods plant^{-1} (20.96), 100 kernel weight (49.76 g), shelling percentage (72.83), pod yield (2.58 t ha^{-1}), haulm yield (3.18 t ha^{-1}) and kernel yield (2.05 t ha^{-1}) of groundnut. Veeral and Kalaimathi, (2021) [129] noticed that press-mud @ 12.5t ha^{-1} combined with Rhizobiza @ 2 kg ha^{-1}and 50% RDF resulted 65.54% more pod yield than only RDF. Akshaya *et al.*, (2022) [149] observed that among different amendment *viz*, FYM, goat manure, poultry manure, bio-fertilizer (Rhizobium), Panchagavya, Dasagavya and their combination treatment, FYM @ 10 t ha^{-1}as basal application and 50% RDF along with Rhizobium @2 kg ha^{-1}including foliar spray of 3% Dasagavya at 30 and 45 DAS resulted 63.75% more pod yield than control. Mohanty *et al.*, (2022) [76] noticed that combined application of 125% RDF (N_1: P_2 O_5: K_2O =25:50:50 kg ha^{-1}), 5 t FYM ha^{-1}, Gypsum @250 kg ha^{-1}, along with PSB soil application helps to obtain maximum growth, yield attributes, pod yield and quality factors than control. Sunitha *et al.*, (2023) [121] found in their experiment that 30:40:50 kg N, P_2O_5 and K_2O as RDF along with liquid bio fertilizer @ 3.75 l ha^{-1}(Phosphorus solubilizing bacteria, Potassium solubilizing bacteria, and *Rhizobium* @ 1.25 l ha^{-1} each) through fertigation helps to obtain maximum growth, yield, economics and nutrient uptake compare to 100% RDF + humic acid @ 12.5 l ha^{-1}. Fig 8 describes yield increase over control by application of INM for a long period of time.

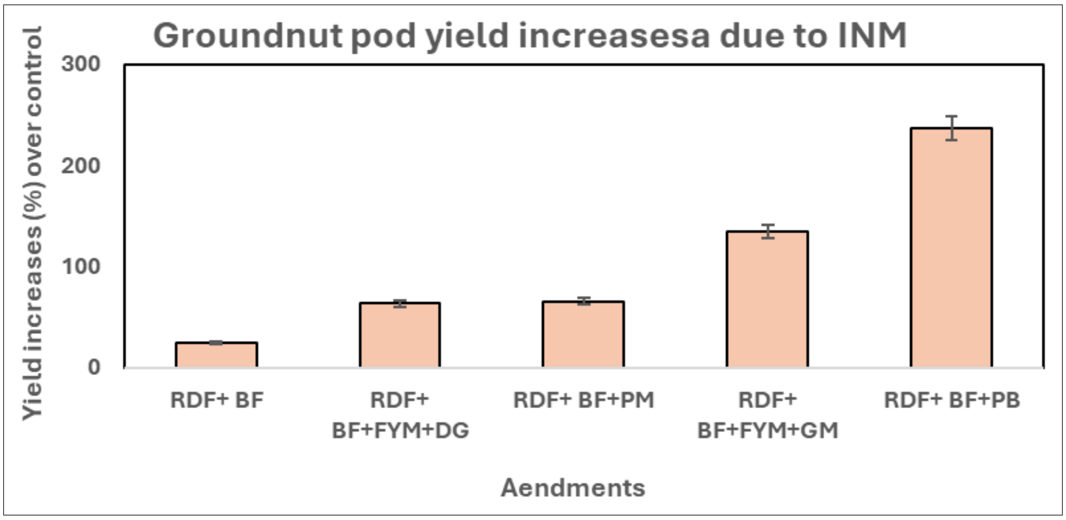

Fig 8: Ground nut pod yield increase due to INM. Recommended dose of fertilizer (RDF), Bio Fertilizers (BF), Dasagavya(DG), Phosphobacteria(PB), Pressmud(PM), Gypsum(GM), Farm yard manure(FYM)

Conclusion

Groundnut is a major oilseed crop which can fulfil the gap between huge oil consumption in India and vegetable oil import from other countries. Though it is not only a source of high-quality oil but also it provides quality protein which contain most of the essential amino acids. Cultivation of ground nut required fertile soil and to maintain the soil fertility farmers are continuously adding synthetic chemical fertilizers year after year. Heavy chemical fertilization in continuous basis reduced soil quality which hamper the sustainable production of it. On a flip side organic manure can improve the soil quality but not feasible in developing countries like India due to low productivity. So, to meet the both ends, scientists have chosen the middle path named Integrated Nutrient Management (INM) mostly focused in the current review. Research studies from different countries proved that INM have given more yield or economic return in a long-term basis over individual application of organics or chemicals.

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