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Effect of zinc on growth, yield, nutrient uptake and quality of groundnut: A review

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Abstract
Among the nine oilseed crops, groundnut is an important edible oilseed crop of our country and edible oil economy primarily depends upon groundnut production. Zn deficiency in Indian soils is likely to increase from 49 to 63% by 2025. India is leading in groundnut acreage but behind the China in production due to less productivity. Apart from rain dependent cultivation and mineral nutrition play a vital role in groundnut productivity. Among the nutrients, Zn deficiency cause yield loss to the maximum of 40% in groundnut. The average response of groundnut to zinc fertilization ranged from 210 to 470 kg ha^{-1}. Hence, it is ideal to follow suitable crop improvement and agronomic management strategies to enhance the uptake and availability of Zn in peanut. Keeping in view the above facts, the present review reveals the effect of zinc on growth, yield, nutrient uptake and quality of groundnut.

Keywords: Groundnut, zinc, zinc content, uptake, yield

Introduction
Groundnut (*Arachis hypogaea* L.) is an important oilseed and supplementary food crop of the world. It is fourth most important source of edible oil and third most important source of vegetable protein. It belongs to family Leguminaceae. It is premier oilseed crop of India popularly known as peanut, monkey nut, manila nut. India ranks first in respect of area and second in production after China. Globally, the crop is raised on 26.4 million hectares with a total production of 37.1 million MT. In India, it is cultivated over an area of 4596.33 in hectares with production of 6733.33 MT. The average productivity is 1400 kg/ha (Anon, 2017). India accounts for about 27 per cent of global area and contributes 19 per cent to world groundnut production (Rai *et al*., 2016) [24]. Tamil Nadu ranks fourth in terms of groundnut area (4.419 lakh ha) and third in production (9.737 lakh tonnes) (Singh, 2014) [25, 32, 35]. Globally, 50% of groundnut is used for oil extraction, 37% confectionary and 12% for seed purpose (Nurezannat *et al*., 2019).

Zinc known to be the constituent of enzyme and also involved in synthesis of pyruvic decarboxylase and indole acetic acid. Zinc is required in various metabolic processes as catalysts. Zinc also increases the content of protein, calorific value, amino acid and fat in oilseed crop. Zinc catalyses the process of oxidation in plant cells and is vital for transformation of carbohydrates, regulates the consumption of sugar, increases source of energy for the production of chlorophyll, aids in the formation of auxin and promotes absorption of water.

Zinc deficiency start yellowing of leaves from lamina to base, mid-rib and veins remain green. Later on necrotic brown spots are developed and dorsal leaf veins become brown. The deficiency of zinc affects IAA synthesis and delay dehydrogenase enzyme activity leading to poor plant metabolic activity. Balanced fertilization helps to improve the quality of the produce. Thus, use of fertilizer for a particular crop should be considered from quality point of view. Zinc is an important micronutrient reported deficient in Indian soils. As a part of balance nutrition an adequate supply of micronutrient especially of Zn is of paramount importance. Zinc deficiency in crop plants is a widespread nutritional disorder in a variety of soils. Soils being low in zinc status (0.5 ppm), it is assumed that application of micronutrient may increase the productivity of groundnut due to its multifarious role in plant metabolism. Thus, proper plan nutrition is an important factor for improving yield and quality of crop. As balanced fertilization support the demands of plant by regulating the metabolic processes in yield formation towards quality. Ultimately, it is not only the consumer who will benefit; it is also the farmer through higher income and the nation with export opportunity. As its aim is for achieving maximum returns and maintenance of soil fertility.

Now days, country is facing edible oil crisis as well as increasing population demand for edible oil. Thus to overcome this challenges suitable and improved techniques for groundnut production should be adopted by farmer. This paper reviews the effect of zinc on growth, yield, nutrient uptake and quality of groundnut.

Effect of zinc on growth characters
Root characteristics
Malewar *et al.,* (1993) [14] reported that zinc fertilization to groundnut up to 20 *kg ha^{-1}* showed significantly enhanced root characters like root growth, root volume and root density Bagal *et al.,* (2006) [4] reported that root growth of groundnut crop was significantly influenced with the application of ZnSC>4 @ 20 kg ha^{-1}. Maharnor *et al.,* (2018) [12, 13] studied that application @ 30 kg ha^{-1} + RDF recorded maximum root length and develops rapidly during early vegetative growth stage and younger roots are found most active for absorption and transport of nutrient as zinc application could be attribute to unhindered auxin synthesis in plant.

Nodulation activity
Tripathy *et al.,* (1999) [37] reported that application of zinc to groundnut cultivar JL-24 and TGS-1 significantly increased nodulation. Bagal (2006) [4] reported that application of ZnSC>4 at die rate of 20 kg ha^{-1} Recorded maximum nodulation in groundnut at most active growth stage of crop i.e. (45DAS). Sharma *et al.,* (2013) [34] reported that number of nodules significantly increased with the application of zinc up to 5 kg ha^{-1}. Mondal *et al.,* (2006) [18] studied the application of micronutrient: Zn, Fe, B, Mo, and mixed @ 2 ppm/pot and @1 kg/ha in field as their salt along with basal doses of NPK (30: 60:40) significantly increasing nodulation, and N- fixation in soybean. These might be due to role of Zn and Mo in enzymes activities as they are essential constituent of N2 fixing enzymes complex “nitrogenase” which are responsible for increase in leghemagloubin which ultimately increase nodulation and N- fixation in soybean. Maharnor *et al.,* (2018) [12, 13] observed that the Cultivar JL-24 with $ZnSO_4$ application @ 30 kg ha^{-1}+ RDF recorded maximum nodule number of groundnut at most active growth stage of crop i.e. (45 DAS).The increase in nodulation could be due to enzymatic activity and auxin synthesis.

Effect of zinc on nutrient availability of soil nutrients
Vyas *et al.,* (2003) [39] observed that application of Zn @ 5 kg ha^{-1} and 10 t FYM ha-1 increased NPK contents by soybean seed over control. The content of NPK in soybean seed was higher due to synergistic effect of applied nutrient. As zinc play important role enzymatic activities which help in root development and FYM increases the availability of nutrient thus increases uptake cause increase content of nutrient of seed. Nadaf and Chidanandappa (2015) [16, 20, 21] recorded that the application of zinc sulphate @ 20 kg ha^{-1} + borax @ 5kg ha^{-1}increses N, P, K, S and Zn content in haulm and kernel of groundnut. This might be due to the enhanced root development, uptake and translocation of nutrient in plant in presence of zinc and boron.
Maharnor *et al.,* 2018 [12, 13] studied the application of $ZnSO_4$ @ 30 kg ha^{-1}+ RDF increases concentration of NPK and Zn in kernel and haulm at harvest in cultivar JL-24 because of maximum growth of root and root nodules which ultimately increases absorption of nutrient. Sharma *et al.,* (2011) [34] observed that application of 100 per cent NPK and zinc increased the availability of nitrogen, phosphorus, potassium and zinc content of soil. Shanna *et al.,* (2011) observed that application of 100 per cent NPK and zinc to groundnut increased the availability of phosphorus in soil. Laharia *et al.,* (2015) [11] recorded that the application of 150% RDP + 5kg Zn ha^{-1} to soybean increased phosphorus availability in soil. Laharia *et al.,* (2015) [11] recorded that the application of 150% RDP + 5kg Zn ha^{-1} to soybean increased nitrogen availability in soil. Elayaraja *et al.,* (2014) [30] reported that application of $ZnSO_4$ at 30 kgha^{-1} + 150 per cent RDF to groundnut increased nitrogen availability in soil.

Potassium availability
Shanna *et al.,* (2011) observed that application of 100 per cent NPK and zinc to groundnut increased the availability of potassium in soil. Laharia *et al.,* (2015) [11] recorded that the application of 150% RDP + 5kg Zn ha^{-1} in soybean increased potassium availability in soil. Elayaraja *et al.,* (2014) [30] reported that application of Z11SO4 at 30kgha^{-1} + 150 per cent RDF to groundnut increased potassium availability in soil.

Zinc availability
Sharma *et al.,* (2011) [34] observed that application of 100 percent NPK and zinc increased the availability of nitrogen, phosphorus, potassium and zinc content of soil. Arunachalam *et al.,* (2013) [1] studied and reported that basal application of Zn and Fe enhance the soil available Zn and Fe content application of micronutrient increased the kernel Zn content to an average of 28.7% and pod yield of 12.6% in groundnut cultivars. Kumbhar *et al.,* (2017) [10] reveled that application of RDF+20 kg ha-1 $ZnSO_4$+20 kg ha^{-1} EDTA FeSO4+2 kg ha^{-1} Borax showed significant effect on nutrient availability. The availability of Zn was maximum with application of micronutrient at different growth stages of sunflower over control. As it was ranged from 1.85 to 0.87 ppm. The periodical availability of zinc in soil from 35 days to harvest showed decreasing trend with advancement of time. This decrease in available zinc in soil may be associated with the utilization of available zinc by crop. Maharnor *et al.,* (2018) [12, 13] reported that the nutrient availability was significantly influenced with application of treatment. The availability of NPK and Zn was maximum in cultivar JL-24 with $ZnSO_4$ @ 30 kg ha^{-1} + RDF (3 stages). The nutrient availability of all the four nutrients was initially higher and gradually decreased from flowering to pod formation stage of groundnut.

Effect of zinc on nutrient uptake *viz.* N, P, K and Zn
Babhulkar *et al.,* (2000) [3] reported that application of zinc up to 15 kg ha $^{-1}$ increase zinc concentration both in kernel and haulm. Vyas *et al.,* (2003) [39] observed that application of Zn @ 5 kg ha^{-1} increased NPK contents and uptake by soybean seed. Nutrient uptake i.e. NPK of control was 75.75, 26.06 and 61.20 kg ha^{-1}, respectively and NPK uptake of plot receiving Zn @ 5 kg ha $^{-1}$ was 84.35, 29.02 and 68.16 kg ha^{-1}, respectively. Singh *et al.,* (2006) [25, 32, 35] reported that zinc uptake by pod of groundnut increased significantly with increasing level of zinc compared to control. Among die zinc levels 5.0 kg ha^{-1} recorded the highest uptake of zinc (96.7 gm. ha^{-1}). Singaravel *et al.,* (2006) [6, 30] reported that application of micronutrient with the recommended NPK and 25 kg zinc sulfate ha^{-1} gave the highest values for N, P, K and Zn uptake in groundnut.
Elayaraja and Singaravel (2012) [6, 30] reported that 150 per

cent NPK + $ZnSO_4$ @ 30 kg ha^{-1} + borax @ 15 kg ha^{-1} recorded the highest N (85.05 and 68.85 kg ha^{-1}), P (11.89 and 14.23 kg ha^{-1}) and K (36.83 and 73.65 ha^{-1}) uptake in pod and haulm, respectively. The increased uptake of major nutrients was mainly due to the fact that the micronutrients like zinc and boron are involved in nitrogen fixation and translocation into plant parts, which might have led to higher dry matter production. The higher nitrogen absorption may also be due to stimulatory effect of zinc and boron on nitrogen uptake. The higher P uptake may be due to the solubilization of native phosphorus by the organic acids in addition to applied fertilizers which ultimately resulted in better root growth and increased physiological activity of roots to absorb more phosphorus. Increased K uptake might be due to better plant growth leading to higher uptake of nutrients and further on the stimulatory effect of B and Zn in absorption of potassium.

Nadaf and chindanandappa (2015) [16, 20, 21] who reported that the application of zinc sulphate at three levels *viz.* 5, 10 and 20 kg ha'1 zinc increased the nitrogen concentration in the haulm. Bagal (2006) [4] reported that application of zinc @ 20 kg ha^{-1} increased zinc concentration both in haulm and kernel. Tathe *et al.*, (2008) [38] studied that zinc application of 40 kg ha1 recorded significantly the highest zinc uptake by groundnut. Elayaraja *et al.*, (2012) [30] reported that application ZnS04 @ 30 kg ha^{-1} significantly increase nutrient uptake by groundnut. Suresh *et al.*, (2013) [36] reported that application of zinc @10 kg ha^{-1} uptake on an average, one ton of oilseed yield leads to 45 to 150g uptake of Zn. Saha *et al.*, (2015) [29] reported that the application of Zn significantly increased their nutrient uptake in kernel. On an average Zn uptake by groundnut ranged from 0.14 to 0.40 kg ha^{-1} respectively. Noman *et al.*, (2015) [19] reported that application of 2.5, 5.0, and 7.5 kg ha $^{-1}$ Zn result in 45.5 Zn- uptakes in kernel over control.

Effect of zinc on kernel and haulm yield of groundnut

Chitdeshwari *et al.*, (2003) [5] reported that soil application of Zn 5 *kg ha*$^{-1}$ significantly increased the pod yield of groundnut the tune of 24.2% for TMV 7 and 14,8% for JL-24 over control. Sing and Mann. (2007) [32] Studied that the application of 5kg Zn ha^{-1} significantly increased the pod yield of groundnut (2251 kgha^{-1}). Saren *et al.*, (2007) [31] recorded that the application of zinc @ 20 kg ha^{-1} significantly higher pod yield (18 q ha^{-1}), kernel yield (13 q ha^{-1}) in groundnut. Bairagi *et al.*, (2007) [2] recorded that the application of zinc @10 kg ha^{-1} and phosphorus @ 75 kg ha^{-1} significant increase in grain and straw yield of soybean. Tathe *et al.*, (2008) [38] studied and reported that zinc application, 40 kg ha^{-1} recorded significantly the highest pod yield, protein content and zinc uptake by groundnut.

Sonawane *et al.*, (2010) [33] studied and was observed that significantly highest pod yield was recorded in 20 kg $ZnSO_4$ soil application with RDF. Thakur *et al.*, (2010) [40] the study revealed that application of 25 kg of $ZnSO_4$ ha^{-1} along with recommended dose of fertilizer 25:50 kg N and P ha-1 has given significantly higher dry pod yield, and haulm yield. Nadaf and Chidanandappa *et al.*, (2011) [16, 20, 21] reported that pod and haulm yield of groundnut was significantly increased over the control due to application of zinc sulphate at three level 5,10 and 20 kg ha^{-1}.

Reddy *et al.*, (2011) [26] reported that the yield attributes of groundnut i.e. pod (2592 kg/ha^{-1} and haulm yield (4426 kg ha^{-1}) were found to be the highest with 60-80-100kg ha^{-1} along with application of four micronutrient application (Zn, B, Fe and Cu). Involvement of boron in catalyzing the metabolism of carbohydrates and Fe and Zn increases enzyme activity and other biological activity ultimately increase yield due absorption of nutrient.

Elayaraja *et al.*, (2012) [30] reported that application of ZnS04 @ 30 kg ha^{-1} application significantly increased pod yield of2466 kg ha4 and haulm yield of 3354 kg ha^{-1}. Which represented 31.31 and 25.95% increase in pod and haulm yield. Elayaraja D and Singaravel R. (2012) [6, 30] observed that the application of 150% NPK+ $ZnSO_4$ @ 30 kg ha^{-1} + borax @ 15 kg ha^{-1} along with 150 per cent NPK recorded the higher pod yield (2466 kg ha^{-1}) and haulm yield (3354 kg ha^{-1}) this might be due to Zn and B through activation of various enzymes and increased basic metabolic rate in plants, facilitated the synthesis of nucleic acids and hormones, which in turn enhanced the pod yield due to greater availability of nutrients and photosynthates. Bhadauria *et al.*, (2012) [4] studied and reported that application of Zn at 10 kg ha^{-1} increase grain and stover yield of mustard.

Suresh *et al.*, (2013) [36] reported that application of Z11S04 at 5 kg ha with recommended dose of NPK showed significantly highest pod yield of groundnut. Sharma *et al.*, (2013) [34] studied and reported that varying levels of zinc on growth and yield of groundnut varieties and recorded that the pod per plant, kernel per pod, pod yield, haulm yield, etc. significantly increased with the application of Zn up to 5 *kg ha*$^{-1}$. Sara *et al.*, (2013) [27] Reported that highest yield of groundnut was achieved with applying 60kgha1 nitrogen and 3 g ha^{-1} zinc.

Elayaraja D (2014) [30] recorded the highest pod yield of 2466 kg ha^{-1} and haulm yield of 3354 kg ha^{-1} at 150% NPK along with $ZnSO_4$ @30 kg ha^{-1} and borax @ 15 kg ha^{-1} with composted coirpith as compared 100% recommended NPK alone 1878 and 2663 kg ha^{-1} of pod and haulm yield respectively. Rahevar *et al.*, (2015) [23] reported that the application of FYM@ 5 t ha^{-1} with 5 kg Fe ha^{-1} +4 kg Zn ha^{-1} to groundnut considerably increased yield, yield attributes and quality parameters. Saha *et al.*, (2015) [29] studied on Zn, B and S on the yield and quality of groundnut. Reported that the basal application of Zn @ 5 and 10 kg ha^{-1} caused an increase in nut yield by 3.7% and 28.3% respectively over control.

Gowthami and Ananda (2017) [8] studied the effect of soil application of $ZnSO_4$ @ 25 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5% recorded significantly higher kernel (2051 kg ha^{-1}) and haulm yield (3080 kg ha^{-1}). This was due to favorable effect of higher dry matter production and cumulative effective effect of yield attributes. Rabari *et al.*, (2018) [22] observed that application of $ZnSO_4$ @ 8 kg ha^{-1} + Foliar Spray of FeSO4 @ 1% significantliy increased the haulm and pod yield in groundnut. It might be due to improvement in nutrient uptake particularly iron and zinc that increased transformation of photosynthetic activity towards growing plant parts.

To study the effect of zinc on quality of groundnut kernels

Oil content

Saini *et al.*, (1976) [28] studied the effect of micronutrients (Zn, Mn, Mo, Cu, Fe and B, at rates of 11, 20, 1, 11, 20 and 2 kg ha*1 respectively) on the yield and quality of groundnut cultivar M 145, the application of micronutrients in addition to NPK increased oil content (1.25-2.45%), and total oil yield (7.8- 21.8%) compared with those of control plants (NPK only). Ramlal *et al.*, (1990) [25] reported that increase oil and protein content of groundnut due to the application of zinc sulphate. Malewar *et al.*, (1992) [14] studied on inorganic mineral matter and quality of grains as influenced by zinc levels in peanut cultivars, reported that the Zinc application up to 20 *kg ha*$^{-1}$ improve the content of ash, N, K, Ca, Zn and Fe in grain legume further, significant accumulation of proteins and soluble carbohydrates in peanut cultivars were recorded due to zinc application. Krishnappa *et al.,* (1994) [9] revealed that application of N, P, K and Zn, had significantly increased seed oil content in groundnut

Tathe *et al.,* (2008) [38] studied the effect of zinc on groundnut in vertisol, as regards zinc application, 40 kg ha^{-1} recorded significantly the highest pod yield, protein content and zinc uptake by groundnut.

Nadaf and Chidanandappa (2011) [16, 20, 21] reported that that crude protein content, oil content and oil yield of groundnut was significantly increased over the control due to application of zinc sulphate at three level 5, 10 and 20 kg ha^{-1}. Suresh *et al*., (2013) [36] reported that application of $ZnSO_4$ at 5 kg ha^{-1} + $FeSO_4$ at 10 kg ha^{-1} + boron at 1 kg ha^{-1} with recommended dose of NPK showed significantly highest pod yield, oil content and protein content of groundnut significantly increased. Saha *et al.,* (2015) [29] studied effect of Zn, B and S on the yield and quality of groundnut, and reported that the basal application of Zn, S and B showed a positive interaction as yield increase with their uptake in groundnut and oil content in nuts ranged from 45.3 to 54.4%. Meena *et al.,* (2007) [11, 15] studied effect of secondary and micronutrient for groundnut and reported that the application of $ZnSO_4$ @ 20%/+0.5% foliar spray along with borax @ 25 kg ha^{-1} +0.2 5% foliar spray recorded the highest pod, kernel and oil yield.

Saren *et al.,* (2007) [31] studied the effect of application of zinc @ 20 kg ha^{-1} significant increased the oil yield (620.1 kg/ha) and oil content as compared to 15 and 25 kg ha^{-1} in groundnut. Zn @ 25 kg ha^{-1} lowered the oil yield might be due to toxicity of zinc. The result for increases in oil content and oil yield may be due to Zn play vital role in groundnut production as it is an essential component of enzymes help in synthesis of amino acid. Bairagi *et al.,* (2007) [2] reported the effect of application of zinc @10 kg ha^{-1} and phosphatic fertilizer @ 75 kg ha^{-1} recorded significantly maximum oil content in soybean. Thakur *et al.,* (2010) [40] revealed that the application of 25 kg of $ZnSO_4$ ha^{-1} along with RDF 25: 50 kg N and P ha^{-1} significantly increase oil yield than the combination of RDF + $FeSO_4$ and control. As Zn play special role in oil seed crop to activate the enzymes for biosynthesis of oil.

Protein content

Ramlal *et al.,* (1990) [25] reported that increase in pod yield, oil and protein content of groundnut due to the application of zinc sulphate. Malewar *et al.,* (1992) [14] studied on inorganic mineral matter and quality of grains as influenced by zinc levels in peanut cultivars, reported that the Zinc application up to 20 kg ha'1 improve the content of ash, N, K, Ca, Zn and Fe in grain legume further, significant accumulation of proteins and soluble carbohydrates in peanut cultivars were recorded due to zinc application. Majumdar *et al.,* (2001) reported that the application of Zn 25 kg ha^{-1} to groundnut Cv.ICGS-76 significantly increased protein contents. Mirvat *et al*., (2006) studied the effect of phosphorus fertilizer rates (30 and 60 kg P_2O_5/ ha with foliar spraying with zinc (0, 0.50, 0.75, and 1.00 g/L) on seed quality of groundnut under reclaimed sandy soil. As it gives significantly increased in protein content (26.15). These result may due to the beneficial effect of P and Zn on metabolic processes and growth which in turn reflected positively on chemical content of groundnut seed.

Bairagi *et al.,* (2007) [2] reported that effect of application of zinc @10 kg ha^{-1} and phosphatic fertilizer @ 75 kg ha^{-1} recorded significantly maximum protein content. This may be due to zinc role in oil seed crop to activate the enzymes for the synthesis of biochemical like tryptophan result, increase in protein synthesis. And P being constituent of carbohydrate, protein and nucleic acid responsible for synthesis amino acids, tryptophan ultimately increases in protein content of soybean. Tathe *et al.,* (2008) [38] studied the effect of sulphur and zinc on groundnut in vertisol, as regards zinc application, 40 kg ha1 recorded significantly the highest pod yield, protein content and zinc uptake by groundnut. Nadaf and Chidanandappa (2011) [16, 20, 21] reported that crude protein content oil content and oil yield of groundnut was significantly increased over the control due to application of ZnSC>4 at three levels 5,10 and 20 kg ha^{-1}.

Reddy *et al.,* (2011) [26] reported that the application of macro nutrient NPK 60-80-100 kg ha^{-1} along with four micronutrient (Zn, B, Fe and Cu) improve quality parameter i.e. protein content (36.57%) of groundnut were found to be the highest protein content with higher level of major nutrient as protein content is always directly proportional to nitrogen and forms the principal constituent of protein. Involvement of Zn in synthesis of amino acids, leading to the formation of the protein molecules. Suresh *et al.,* (2013) [36] studied the effect of application of ZnSC>4 at 5 kg ha^{-1} with recommended dose of NPK reported that significantly increase in oil content and protein content of groundnut.

Conclusion

It can be concluded that fertilizer application of zinc shows significant increase in growth parameter, nutrient concentration, uptake, availability, yield and quality of groundnut.

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