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Zinc application on growth, yield parameters, yield, quality, nutrient uptake and economics of groundnut

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Abstract
Groundnut (*Arachis hypogaea* L.) an important oilseed crop plays a major role in nutritional and economic aspects due to its higher demand in vegetable oil and confectionery items for human consumption. It is grown in dry and semiarid regions with improper nutrient management practices, lack of organic sources of nutrient supplement and no micronutrient application causes zinc deficiency. Zinc deficiency initially causes mottling and chlorosis in upper leaves finally chlorotic condition of entire leaflet at severe conditions. Zinc has various functions *viz.,* activator of enzymes, biosynthesis, enhancement of plant cell development by auxin production. Growth attributes, yield parameters, nutrient uptake were enhanced resulting in higher assimilation, more nodulation and significantly increasing pod yield, productivity with zinc application in groundnut. A panoramic review was made and presented in this paper from research evidences of different eminent research scientist with zinc application in groundnut.

Keywords: Groundnut, zinc deficiency, yield, quality, economics

Introduction

Groundnut (*Arachis hypogaea* L.) referred as king of oilseeds is endowed with various names *viz.*, peanut, earthnut, goober peas, pindas, jacknut, manilanut and monkeynut is an important oilseed and legume in nature. Groundnut is grown in tropical and subtropical conditions covering around 108 countries in world owing to its economic and nutritional aspects consisting of 25-30 percent protein, 50 percent oil, 20 percent carbohydrate and 5 percent fiber and ash. In addition Oil ranks fourth in edible oil and attains third position in vegetable protein source for human consumption. It has significant contribution in value added products, confectionery and culinary preparations. Groundnut has considerable amount of vitamins E, K, B and more niacin as compared to cereals. Productivity is lower in India due to cultivation as rainfed crop in semi-arid and dryland areas with lower fertility status of soil and inappropriate nutrient management leads to zinc deficiency. Zinc deficiency in soils of India is likely to increase from 49 to 63% by the year 2025 as most of the marginal soils brought under cultivation are showing zinc deficiency Singh, (2006) [35]. High analysis chemical fertilizers with no micronutrients, lack of organic supplement of nutrients and high intensive cropping lead to deficiency. Irregular mottling, yellow-ivory interveinal chlorosis in initial stages in upper leaves is the symptom later severe deficiency causes entire leaflets to chlorotic. In addition reddish pigments in petioles, leaf veins and stem occurs in groundnut as a result of zinc deficiency. Zinc plays an effective role in activating several enzymes and biosynthesis of growth promoting substances like auxin which enhances development of higher plant cells and dry matter as a result of high source to sink especially yield. Zinc deficiency impairs physiological functions declining health and productivity of plants thereby declining yield. Photosynthesis, nodulation process, synergism in uptake of nutrients, assimilation of source to sink was enhanced resulting in more yield and productivity by zinc application in groundnut. Positive effect of zinc application through soil or foliar application on growth parameters, yield parameters, nutrient uptake, yield and quality were marked from research findings of eminent research scientists in groundnut have been reviewed critically and cited in this present paper.

Effect of zinc application on growth and growth parameters of groundnut

Jha and Chandel (1987) [13] concluded that foliar application of zinc improves dry matter production in groundnut. Sarkar and Aery (1990) [32] stated that dry matter production was significantly higher with foliar application of zinc in groundnut from his study. Leaf area index, biomass, crop growth rate and net assimilation ratio were significantly higher with application of 4 kg ha^{-1} of zinc than control in groundnut Sarkar *et al.*, (1998) [33]. Sumangala, (2003) [39] reported that zinc 2.5 kg ha^{-1} + boron 2.5 kg ha^{-1} + molybdenum 1 kg ha^{-1} gave maximum increase in height of plant, leaf number $plant^{-1}$, leaf area index, nodules $plant^{-1}$ in groundnut than control. Elayaraja (2014) [10] reported that zinc application at 6 kg ha^{-1} in addition with boron 15 kg ha^{-1} gave maximum plant height at (32.95, 45.88 and 65.15 cm), dry matter production (1884, 2768 and 5296 kg ha^{-1}) compared to control (19.78, 30.25 and 42.74 cm) and (1212, 1819 and 3473 kg ha^{-1}) respectively at flowering stage, peg formation stage and harvest stage of groundnut. Increased top dry weight was noticed at 75 days after sowing and 90 days after sowing with 90 kg ha of phosphorus and foliar spray of zinc 1000 mg $litre^{-1}$ (90.92 g and 159.20 g) compared to 30 kg ha phosphorus and no application of zinc (68.09 g and 118.58 g) respectively in groundnut EL Habbasha *et al.*, (2014) [9]. Sharma *et al.*, (2017) [34] stated that zinc application increased the growth parameters such as plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$ chlorophyll content, crop growth rate (CGR) and net assimilation rate (NAR) against control in groundnut. Palsande *et al.*, (2019) [24] reported that application of zinc at 7.5 kg ha^{-1} gave maximum plant height at peg initiation stage (41.73 and 60.43 cm) and harvest stage (32.78 and 52.48 cm) at both years compared to lower levels in groundnut. Aboyeji *et al.*, (2020) [1] concluded that zinc application at 8 kg ha^{-1} gave significant increase in growth parameters such as plant height, plant spread and biomass compared to lower levels and control in groundnut from his two years study. Nandi *et al.*, (2020) [21] recorded 39% increase in plant height at flowering stage with application of zinc 0.75% spray+ boron 0.45% than control in groundnut

Effect of zinc application on yield parameters of groundnut

Sarkar *et al.*, (1998) [33] noticed an significant increase in yield parameters such as number of pods (18.75), pod weight $plant^{-1}$ (21.1), shelling percentage (73.21) and test weight (412.43 g) with zinc application at 4 kg ha^{-1} against control (9.75, 7.66, 62.52% and 331.03 g) in groundnut. Ali and Mowafy (2003) reported that 2% foliar spray of zinc enhanced the yield attributes and yield of groundnut compared to no application. Mirvat *et al.*, (2006) [18] reported that increasing zinc level from 0.5 to 1.0 g $litre^{-1}$ recorded increased number of pods $plant^{-1}$ (42.38) and seeds per $plant^{-1}$ (71.52), pod weight plant (52.44 g), seed weight plant (36.73 g), and hundred seed weight (81.32 g) in groundnut than control (32.00, 48.07, 45.48g, 27.43g and 63.45g) respectively in groundnut. Shelling percentage and test weight was higher (75.1 and 56.6 g) with zinc application at 2.5 kg ha^{-1} + potassium at 75 kg ha^{-1} over control (71.6% and 50.0 g) respectively in groundnut Polara *et al.*, (2009) [14]. EL Habbasha *et al.*, (2014) [9] recorded significant increase in yield parameters such as number of pods $plant^{-1}$ (36.34), weight of pods $plant^{-1}$ (45,36 g), number of seeds $plant^{-1}$ (74.95), weight of seeds $plant^{-1}$ (44.39 g) and hundred seed weight (83.36 g) with application of 90 kg ha^{-1} of phosphorus and foliar spray of zinc 1000 mg $litre^{-1}$ over 30 kg ha^{-1} phosphorus and no application of zinc (24.01, 31.63 g, 51.04, 30.50 g and 63.81 g) in groundnut. Sharma *et al.*, (2017) [34] stated that zinc application significantly increased the yield parameters *viz.*, pod number $plant^{-1}$, shelling percentage and hundred kernel weight compared to control in groundnut.Yield attributes such as number of pods $plant^{-1}$ (18), pod weight plant (19.88 g), hundred kernel weight (49.17 g) and shelling percentage (73.50) were significantly higher with application of RDF + 1% $ZnSO_4$ spray + $FeSO_4$ spray 1% over control in groundnut from his study Nakum *et al.*, (2019) [20]. Palsande *et al.*, (2019) [24] found that zinc application at 7.5 kg ha^{-1} gave maximum number of branches plant at peg initiation stage (8.49 and 11.48) and harvest stage (8.57 and 10.96) at two consecutive years in groundnut than lower levels. Similarly shelling per cent (79.39 and 81.62) and hundred seed weight (48.03 and 48.77 g) also recorded the same trend. Aboyeji *et al.*, (2020) [1] found that zinc application at 8 kg ha^{-1} recorded significant increase in number of pods $plot^{-1}$, weight of pods $plot^{-1}$, number of seeds $plot^{-1}$ and weight of seeds $plot^{-1}$ than lower levels and control in two year groundnut crop.

Effect of zinc application on yield of groundnut

Foliar spray of zinc gave maximum seed yield, pod yield, thousand seed weight of groundnut compared to no application Hiri, (1987) [12]. Pod yield, kernel yield and test weight were higher with foliar application of zinc over control in groundnut Sukhija *et al.*, (1987) [38]. Malewar *et al.*, (1993) [16] found that pod yield and haulm yield were higher with 4 kg ha^{-1} of zinc in groundnut cultivars *viz.*, M 13, L 33, K-4-11 and JL 24. Sarkar *et al.*, (1998) [33] revealed that zinc application at 4 kg ha^{-1} recorded higher pod yield (24 q ha^{-1}) over control (14.9 q ha^{-1}) in groundnut. Singh (1999) [37] registered significant increase of pod yield to 41.6% over control with 3 kg ha^{-1} of zinc application in groundnut. Majmudar and Venkatesh (2001) [4] documented higher kernel yield (15.67 q ha^{-1}) with 20 kg ha^{-1} of zinc against control (10.95 q ha^{-1}) in groundnut. Chaube *et al.*, (2002) [6] revealed that zinc application at 5 kg ha^{-1} gave maximum pod yield (3888 kg ha^{-1}), haulm yield (5218 kg ha^{-1}), and seed yield (2512 kg ha^{-1}) in groundnut over control treatment (3366 kg ha^{-1}, 4653 kg ha^{-1} and 2155 kg ha^{-1}, respectively). Chitdeshwari and Poongothai (2003) [7] revealed that soil application of zinc at 5 kg ha^{-1} + 1 kg ha^{-1} boron + 40 kg ha^{-1} sulphur significantly gave maximum pod yield to the tune of 24.2% and 14.8% for TMV 7 and JL 24 compared to control in groundnut. Patil *et al.*, (2003) [26] obtained an significant increase in groundnut yield with soil application of Fe and Zn in addition with RDF in black soils. Gobarah *et al.*, (2006) [11] concluded that foliar spray of zinc improves seed yield significantly compared to control in groundnut. Significant increase in pod yield (1386 kg ha^{-1}) as against (1069 kg ha^{-1}) in control in groundnut Mirvat *et al.*, (2006) [18]. Pod yield was significantly higher with zinc application at 40 kg ha^{-1} against other levels and control in groundnut Tathe *et al.*, (2008) [41]. Nayak *et al.*, (2009) [22] registered an significant increase in pod yield 91.52 and 1.53 t ha^{-1}) with application of Zn 5 kg Zn ha^{-1} + 1 kg ha^{-1}B + 0.5 kg ha^{-1} Mo compared to control (1.10 and 1.23 t ha^{-1}) in two locations. Polara *et al.*, (2009) [14] found that application of 2.5 kg ha^{-1} of zinc + potassium at 75 kg ha^{-1} significantly gave higher pod yield (2874 kg ha^{-1}) as compared to control (2246 kg ha^{-1}) in groundnut. Pour *et al.*, (2010) stated that zinc application by foliar method significantly increased the yield of groundnut. Pendashtek *et* *al.*, (2011) stated that foliar application of zinc improved the groundnut seed yield to 3742 which is found statistically significant compared to no zinc application. Arunachalam *et al.*, (2012) noticed that zinc application at 5kg ha in alfisol basally significantly increased the pod yield plant in groundnut varieties *viz.,* TMV 7 to the range of 19.2 to 21.4 g, TMV (Gn) 13 to the tune of 18.4 to 22.5 g and VRI (Gn) 6 ranging from 35.7 to 38.6 g from his study. Suresh *et al.*, (2013) [40] reported significant increase in pod yield (4880) with application of 11.2 kg ha^{-1} of zinc against no application (3990) in control in groundnut. Elayaraja (2014) [10] obtained higher pod yield (1463 kg ha^{-1}) and haulm yield (2233 kg ha^{-1}) with application of zinc at 6 kg ha^{-1} and 15 kg ha^{-1} boron while compared to no application (2466 kg ha^{-1} and 3354 kg ha^{-1}) respectively in groundnut. Higher pod yield (5.17 t ha^{-1}), seed yield (5.17 t ha^{-1}) and haulm yield (5.17 t ha^{-1}) were registered with 90 kg ha^{-1} of phosphorus and foliar spray of zinc 1000 mg $litre^{-1}$ than 30 kg ha^{-1} phosphorus and no application of zinc (3.71 t ha^{-1}, 2.33 t ha^{-1} and 8.27 t ha^{-1}) respectively in groundnut EL Habbasha *et al.*, (2014) [9]. Saha *et al.*, (2015) [5] found that application of zinc at 10 kg ha^{-1} gave 28.3% increase in groundnut yield compared to no application in groundnut. Irmak *et al.*, (2016) [31] found significant increase in yield (2708 kg ha^{-1} and 5737 kg ha^{-1}) with soil application of 10 kg ha^{-1} compared to no application (1891 kg ha^{-1} and 4108 kg ha^{-1}) respectively in NC-7 and COM variety in groundnut. Similarly foliar application with 0.5 kg ha^{-1} recorded higher yield (2445 kg ha^{-1} and 5384 kg ha^{-1}) as against control (1907 kg ha^{-1} and 4979) respectively in both the genotypes. Increased pod yield and haulm yield was recorded with zinc application than control Sharma *et al.*, (2017) [34]. Rabari *et al.*, (2018) [30] found that application of zinc at 1.5 kg ha^{-1} gave maximum pod yield (4608 kg ha^{-1}) and haulm yield (8905 kg ha^{-1}) than control (3763 kg ha^{-1} and 6763 kg ha^{-1}) in groundnut. Maharnor *et al.*, (2018) [15] found that zinc application at 6 kg ha^{-1} recorded maximum kernel yield and haulm yield (776 kg ha^{-1} and 2944 kg ha^{-1}) which is significantly higher than control (597 kg ha^{-1} and 2267 kg ha^{-1}) in groundnut. Kadam *et al.*, (2018) reported that zinc application at 6 kg ha^{-1} gave higher pod yield (2140 kg ha^{-1}), kernel yield (853.03kg ha^{-1}), and haulm yield (3443.49 kg ha^{-1}) over 8 kg ha and control in groundnut. Nakum *et al.*, (2019) [20] found an significant increase in pod yield (2527 kg ha^{-1}), haulm yield (5342 kg ha^{-1}) and harvest index (32.11%) with application of RDF + 1% $ZnSO_4$ spray + $FeSO_4$ spray 1% compared to control that recorded least values (1873 kg ha^{-1}, 3912 kg ha^{-1} and 32.11%) respectively in groundnut. Palsande *et al.*, (2019) [24] documented higher pod yield (43.62 and 37.64 q ha^{-1}) and haulm yield (21.69 and 24.98 q ha^{-1}) with 7.5 kg of zinc application in two consecutive years against lower levels in groundnut. Aboyeji *et al.*, (2020) [1] documented higher yield (2066 t ha^{-1}) with zinc application at 8 kg ha^{-1} over control (1798 t ha^{-1}) in two years pooled analysis in groundnut. Meresa and Tsehaye (2020) [17] obtained higher seed yield (2529 kg ha^{-1}) and haulm yield (6992.70 kg ha^{-1}) than control (1908 kg ha^{-1} and 4950.50 kg ha^{-1}) respectively in groundnut.

Effect of zinc application on quality parameters of groundnut

Sukhija *et al.*, (1987) [38] concluded that oil content was decreased by 11% in mature kernels in zinc deficient groundnut plants from his study. Nayyar (1990) [30] found significant increase in crude protein and total lipid content with application of zinc in groundnut. Hundred seed weight of groundnut was higher with application of 4 kg ha^{-1} of zinc in groundnut varieties *viz.*, M 13, L 33, K-4-11 and JL 24 Malewar *et al.*, (1993) [16]. Majmudar and Venkatesh (2001) [4] reported that application of 20 kg ha^{-1} of zinc gave 27% increased protein yield compared to control in groundnut. Gobarah *et al.*, (2006) [11] recorded higher oil and protein yield with zinc application as foliar spray in groundnut compared to no application. Protein content (26.02%), protein yield (360 kg ha^{-1}) and oil content (44.97%), oil yield (622 kg ha^{-1}) were significantly higher with foliar spray of zinc at 1.5 g $litre^{-1}$ against control (25.56% and 267 kg ha^{-1}) and (44.52% and 475 kg ha^{-1}) respectively in groundnut Mirvat *et al.*, (2006) [18]. Higher protein content and oil content was recorded with application of 40 kg ha^{-1} of zinc in groundnut than control Tathe *et al.*, (2008) [41]. Nayak *et al.*, (2009) [22] found oil content was significant (37.5% and 36.7%) with application of 5 kg Zn ha^{-1} + 1 kg ha^{-1}B + 0.5 kg ha^{-1} Mo as against control (35.9% and 35.5%) from two locations. Suresh *et al.*, (2013) [40] reported significant increase in protein content (22.49%) with application of 11.2 kg ha^{-1} of zinc against no application in control (20.26%) in groundnut. EL Habbasha *et al.*, (2014) [9] found that protein content of seeds (25.28%) were significantly higher with 90 kg ha^{-1} of phosphorus and foliar spray of zinc 1000 mg $litre^{-1}$ than 30 kg ha^{-1} phosphorus and no application of zinc (24.29%) in groundnut.Oil yield was significantly higher with application of 10 kg ha^{-1} of zinc application compared to control in groundnut Saha *et al.*, (2015) [5]. Irmak *et al.*, (2016) [31] recorded higher oil content (46.5% and 46.95%) and protein content (30.25% and 27.55%) in seeds with zinc application at 10 kg ha^{-1} than control (46.1% and 45.8%) and (30.65% and 26.95%) respectively in NC-7 and COM variety in groundnut. Oil content was significantly higher with zinc application over control in groundnut Sharma *et al.*, (2017) [34]. Maharnor *et al.*, (2018) [15] found an significant increase in oil content (45.17%), oil yield (350.47 kg ha^{-1}), protein content (23.74%) and protein yield (183.64 kg ha^{-1}) with zinc application at 6 kg ha^{-1} over control in groundnut. Oil content (45.39%), protein content (21.51%), oil yield (387.56 ha^{-1}) and protein yield(187.87 ha^{-1}) were significantly higher with 6 compare to 8 (44.69%, 21.30%, 343.92 ha^{-1} and 173.97 ha^{-1}) and control in groundnut Kadam *et al.*, (2018). Palsande *et al.*, (2019) [24] registered higher protein content (25.25% and 26.50%), protein yield (439.8 kg $ha^{-1}$and 550 kg ha^{-1}), oil content (45.63% and 47.98%), oil yield (791.2 kg ha^{-1} and 992.3 kg ha^{-1}) and methionine content (0.369% and 0.394%) with application of 7.5 kg ha^{-1} of zinc in two consecutive years over lower levels.

Effect of zinc application on nutrient uptake of groundnut

Pattar *et al.*, (1999) [27] found that macronutrient uptake zinc uptake was higher with application of 5 kg ha^{-1} of zinc in groundnut kernels and haulm from his study. Nitrogen, phosphorus and potassium uptake were higher with foliar application of zinc at 05 to 1.0 g $litre^{-1}$ in groundnut compared to no application Mirvat *et al.*, (2006) [18]. Zinc uptake of kernels and haulm was significantly higher with 5 kg ha^{-1} of zinc compared to control treatment in groundnut Patel *et al.*, (2007) [26]. Singh *et al.*, (2007) [36] found an increase of 16% zinc concentration in groundnut seeds through foliar application than control. Tathe *et al.*, (2008) [41] reported that application of zinc at 20 kg ha^{-1} significantly increased the uptake of N, P, K and S, Zn in vertisol compared to other levels and control in groundnut. Polara *et al.*, (2009) [14] found increased uptake of nutrients in pods with 2.5 kg ha of zinc application in groundnut. Increased uptake of nutrients *viz.*, nitrogen (4.04% and 2.03%), phosphorus (0.92% and 0.24%) and potassium (0.92% and 2.35%) with 90 kg ha^{-1} of phosphorus and foliar spray of zinc 1000 mg $litre^{-1}$ in seeds and straw than 30 kg ha^{-1} phosphorus and no application of zinc (3.88% and 1.95%, 0.86% and 0.23%, 0.76% and 1.93%)) respectively in groundnut EL Habbasha *et al.,* (2014) [9]. Nadaf and Chidanandappa (2015) [19] found that nitogen, phosphorus and potassium contents was higher in haulm and kernel, due to increased uptake with application of zinc at three level 1 5, 2 and 4 kg ha^{-1} either singly or in combination with borax application @ 5 kg ha^{-1} in groundnut. Saha *et al.*, (2015) [5] found 93% increase in zinc uptake with 10 kg ha^{-1} of zinc compared to control and 29% increase with 5 kg ha^{-1} in groundnut. Irmak *et al.,* (2016) [31] documented that application of zinc at 10 kg ha significantly increased the zinc uptake in haulm and seeds of groundnut compared to control in groundnut. Nandi *et al.*, (2020) [21] found that application of zinc 0.75% spray+ boron 0.45% spray increased the nutrient uptake of nutrients significantly *viz.*, nitrogen (1188.8 mg), phosphorus (129.5 mg) and potassium (577.9 mg) $plant^{-1}$ against control (807 mg, 85 mg and 443.9 mg) respectively in groundnut. Similarly increased nutrient uptake was found in pods with 0.75% spray+ boron 0.45% spray *viz.*, nitrogen (1188.8 mg), phosphorus (129.5 mg) and potassium (577.9 mg) $plant^{-1}$ against control (37.1 mg, 6.2 mg and 8.0 mg) respectively.

Effect of zinc application on economics of groundnut
Nayak *et al.*, (2009) [22] recorded highest net return (Rs. 11,010 ha^{-1}) and benefit-cost ratio (1.67) over control (Rs. 6,788 and 1.48 respectively) with soil application of 5 kg Zn ha^{-1} + 1 kg ha^{-1}B + 0.5 kg ha^{-1} Mo in groundnut. Irmak *et al.*, (2016) [31] recorded higher net income (Rs. 9884.50 ha^{-1}) with soil application of 10 kg ha^{-1} against control (Rs. 7798.40 ha^{-1}) in groundnut. Similarly foliar application at 0.5 kg ha^{-1} gave maximum net income (Rs. 10271.20 ha^{-1}) than control (Rs. 8588.60 ha^{-1}) in groundnut. Nakum *et al.*, (2019) [20] registered higher gross returns of (Rs. 1,22,516 ha^{-1}), higher net returns (Rs. 94957 ha^{-1}) and benefit cost ratio (4.45) against control (Rs. 90752 ha^{-1}, Rs. 65020 $ha^{-1}$and 3.53) respectively in groundnut with application of RDF + 1% $ZnSO_4$ spray + $FeSO_4$ spray 1% . Meresa and Tsehaye (2020) [17] found maximum gross returns (Rs. 84203 ha^{-1}), net returns (Rs. 43519 ha^{-1}) and benefit cost ratio (1.07) with application of 1.5 g $litre^{-1}$ compared to control (Rs. 62551.35 ha^{-1}, Rs. 24650.15 ha^{-1} and 0.65) in groundnut.

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