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Growth and yield of groundnut (*Arachis hypogaea*) under varying levels of gypsum and zinc application in Iran

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ABSTRACT

A field study was carried out during spring season of 2021 and 2022 at Astaneh-ye Ashrafiyeh, Guilan, (Islamic Azad University, Lahijan, Iran) northern Iran to study the effect of natural gypsum (NG) and zinc (Zn) foliar application on peanut (*Arachis hypogaea* L.) yield and quality. NG was applied at 4 levels [0 (NG_0); 10 (NG_{10}); 20 (NG_{20}); and 30 (NG_{30}) g/m^2] and Zn nano-chelates were applied at 3 levels [0 (Zn_0); 1 (Zn_1); and 2 (Zn_2) g/L)] as foliar application. The results showed that the interaction of NG × Zn was significant for leaf chlorophyll, kernel and pod number per plant, kernel protein, oil content and and kernel yield during both the years. The interaction of NG × Zn was also significant on the P, S and Fe of kernels. Leaf K and Fe contents were significantly influenced only by NG. The comparison between mean revealed that the highest kernel yield (5839 kg/ha), kernel number (93.5 kernels/plant), pod number (66.3 pods/plant) and kernel S (0.384%) were recorded from the plots applied with NG_{20} + Zn_2. The highest leaf chlorophyll (3.83 mg/kg FW) and oil content (46.09%) were related to the treatment NG_{20} + Zn_1. The plots applied with NG_{10} + Zn_2 exhibited the highest kernel protein (17.92%). Based on the results, it can be stated that the NG and Zn as soil application and foliar spray respectively, improved peanut yield and qualitative traits hence can be recommended for similar climatic conditions.

Keywords: Kernel yield, Natural gypsum, Oil, Sulphur, Zinc

Peanut (*Arachis hypogaea* L.) belongs to the Leguminosae family is also known as the king of oilseed. It contains 46% oil, 22% proteins, 11% carbohydrates and 3% minerals (Asik and Asik 2023). The peanut grows in light textured, well-drained fertile soils with *p*H 6.0–7.5. It needs plenty of calcium (Ca) and sulphur (S) (Yang *et al.* 2022). Unlike other leguminous species, peanut pods grow under the soil. So, little Ca is mobilized from the roots to the growing pods and the plant absorbs much of its Ca requirement directly by the growing pods from the soil (Vaishnav *et al.* 2023). Thus, there must be adequate Ca in the root and pod zone for grain growth and quality (Yang *et al.* 2022). Ca deficiency causes empty pods, called pops and discolours the embryo's plumules. Sulphur (S) is also essential due to its direct involvement in oil biosynthesis and the formation of S-containing amino acids. In addition, it strengthens rhizobium nodulation, retards early leaf shedding and increases pod and oil yield. Natural gypsum (NG) is the common source of Ca and S. Most NGs used in farms are derived from natural gypsum deposits. NG is a hydrated calcium sulfate ($CaSO_4.2H_2O$) that is typically used as an amendment for alkaline soils and as a source of Ca and S in oilseed production (Reddy and Debbarma 2023).

However, microelement cations, which are metallic ions, help adjust cell metabolism and activate many enzymes. Zn is a micro-element cation that is involved in many vital activities of plants including the activation of enzymes and the biosynthesis of growth stimulators such as auxin (Malka *et al.* 2022, Singh *et al.* 2023). In plant cells, Zn catalyzes the oxidation process, controls sugar consumption and conversion, and expands the energy source used for chlorophyll synthesis (Singh and Singh 2017, Jayasree *et al.* 2023). The peanut production areas in Iran are located in the north by the Caspian Sea where soils mostly suffer from S and Zn deficiencies, but farmers use NG to a lesser extent and mostly rely on chemical fertilizers and it results in higher soil EC. Information is, however, limited on the effect of NG and Zn application on peanut production in Astaneh-ye Ashrafiyeh area, northern Iran. The present study aimed to investigate the effect of different levels of NG and Zn on peanut yield and quality and find the best fertilizer combinat for the climatic conditions of northern Iran.

MATERIALS AND METHODS

A field experiment was conducted during spring season of 2020 and 2021 at the research farm of Astaneh-Ashrafieh

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region, Gilan province (7°29' E; 44°90' N, and elevation of 15 m amsl), Islamic Azad University, Lahijan, Iran. The experimental treatments included natural gypsum (NG) at 4 levels of 0, 10, 20, and 30 g/m^2 (NG_0; NG_{10}; NG_{20} and NG_{30}, respectively) and the foliar application of zinc (Zn) at 3 levels, viz. 0 (Zn_0); 1 (Zn_1) and 2 (Zn_2) g/L as zinc oxide nanoparticles. The trial was laid on a factorial experiment based on a randomized complete block design (RCBD) with 3 replications. Each experimental plot consisted of four, 5 m long sowing rows with an inter-row spacing of 0.5 m. After the plots were prepared, sowing was conducted on May 15th during both the years.The peanut kernels used in the research were of the NC2 cultivar. The NC2 cultivar is a standing type of Virginia cultivars with large seeds. Also, due to having a large bush and easy harvesting, it is cultivated in more than 70% of groundnut farms in Iran.

The gypsum used in the research was $CaSO_4.2H_2O$ (18% S and 22% Ca) procured from AgroGyps. It was distributed at the sowing time as strips next to the plants at a depth of 5 cm. Furher, Zn was sprayed at two stages in 4 leaves and 50 days after sowing (DAS), 0.25 litre of water was consumed per 1 m^2 of plot.

At the seed-filling phase [(55 days after emergence (DAE)], leaf chlorophyll content was estimated by Arnon's (1949) method. In both years, the peanut crop was harvested manually at the physiological maturity phase. The plants were randomly harvested from the middle rows of each plot from an area of 1 m^2. Then, the pods, kernels in each pod, and kernels from each plant were counted and their 100-kernel weight apart from root weight were determined with a digital balance. Finally, the kernel yield per unit area was estimated based on 14% moisture. To determine the biological yield (total dry weight), the whole plants were oven-dried at 75°C for 48 h and then weighed.

Leaf and kernel Potassium (K), sulphur (S) and Iron (Fe) contents and kernel Phosphorus (P), protein and oil content were estimated. The N content was estimated by the Kjeldahl method, P content by the vanado-molybdo colorimetric method, K, S and Fe contents by atomic absorption (Perkins Elmer, ZL4100, USA) and the oil content by a Soxhlet apparatus (Buchi, B-811, Switzerland) (Jones 1990). The protein content of the samples was determined by multiplying their N content by 6.25 (Baethgen and Alley 1989).

Data were analyzed using the $SAS_{9.1}$ software package and the means were compared by the least significant difference (LSD) test at the $P<0.05$ level.

RESULTS AND DISCUSSION

There was a significant difference between year (Y) and NG, as well Y and Zn on chlorophyll a and b, respectively (Table 1). The content of chlorophyll a was increased through the use of NG during both of the first and the second years. The highest chlorophyll content was recorded under treatment of NG_{20} in the first year and NG_{30} in the second year (Fig. 1). Gypsum is a valuable nutritional supplement enriched in Fe, Si, Ca and S. So, application of gypsum

Table 1 Effect of NG and Zn levels on K, S, Fe, chlorophyll a and b of leaves and pods and kernels number, root weight, 100-seed weight , biological yield and kernel yield and content of protein, oil, P, K, S and Fe in kernels

S.O.V	Leaves					Pod number	Kernel number	RW	100-SW	BY	Kernel yield (kg/ha)	Kernel					
	K	S	Fe	Chl a	Chl b							Protein	Oil	P	K	S	Fe
	(%)		(mg/kg)	(mg/g FW)				(g/plant)				(%)					(mg/kg)
Y	1.16^{**}	1.58^{**}	0.06^{ns}	513^{**}	0.05^{ns}	982^{**}	10670^{**}	518^{**}	1990^{**}	509^{**}	6140^{**}	475^{**}	252^{**}	0.29^{ns}	2.1^{**}	1.4^{ns}	176^{**}
NG	0.84^{**}	1.098^{**}	5.68^{**}	11.4^{**}	1.08^{ns}	618^{ns}	1424^{**}	28.5^{**}	70.8^{ns}	13.6^{ns}	521^{ns}	127^{**}	123^{*}	8.5^{**}	0.96^{*}	9.8^{**}	6.4^{ns}
Zn	0.36^{ns}	0.015^{ns}	0.51^{ns}	0.34^{ns}	0.49^{ns}	72.7^{ns}	114^{ns}	23.1^{**}	581^{ns}	12.3^{ns}	18.2^{ns}	117^{**}	265^{*}	0.62^{ns}	0.12^{ns}	76^{**}	22^{ns}
Y × NG	0.15^{ns}	0.048^{ns}	1.63^{*}	17.2^{**}	1.35^{ns}	431^{**}	289^{ns}	81.2^{**}	165^{ns}	16.8^{ns}	979^{**}	23^{**}	129^{**}	0.42^{ns}	4.5^{**}	0.29^{ns}	21^{ns}
NG × Zn	0.23^{ns}	0.446^{*}	0.56^{ns}	0.71^{ns}	0.15^{ns}	470^{*}	1031^{**}	53.9^{**}	47.8^{ns}	454^{**}	737^{*}	44^{**}	86^{**}	1.4^{*}	1.1^{**}	5.4^{**}	18^{ns}
Y × Zn	0.28^{ns}	0.002^{ns}	0.43^{ns}	0.53^{ns}	13.1^{**}	370^{**}	1269^{**}	22.9^{**}	342.3^{**}	25.6^{ns}	355^{ns}	8.4^{ns}	9.8^{ns}	0.37^{ns}	0.13^{ns}	22^{**}	81^{*}
Y × NG × Zn	0.03^{ns}	0.007^{ns}	0.17^{ns}	0.13^{ns}	0.44^{ns}	97.1^{*}	67.7^{ns}	268^{**}	79.0^{ns}	361^{**}	180^{ns}	10.7^{*}	19^{ns}	0.25^{ns}	3.1^{**}	10.1^{*}	216^{**}

Ns, * and ** are non-significant, significant at 5% and 1% probability level, respectively.
Y, Year; NG, Gypsum; Zn, Zinc; Chl a, Chlorophyll a; Chl b, Chlorophyll b; RW, Root weight; SW, Seed weight and BY, Biological yield.

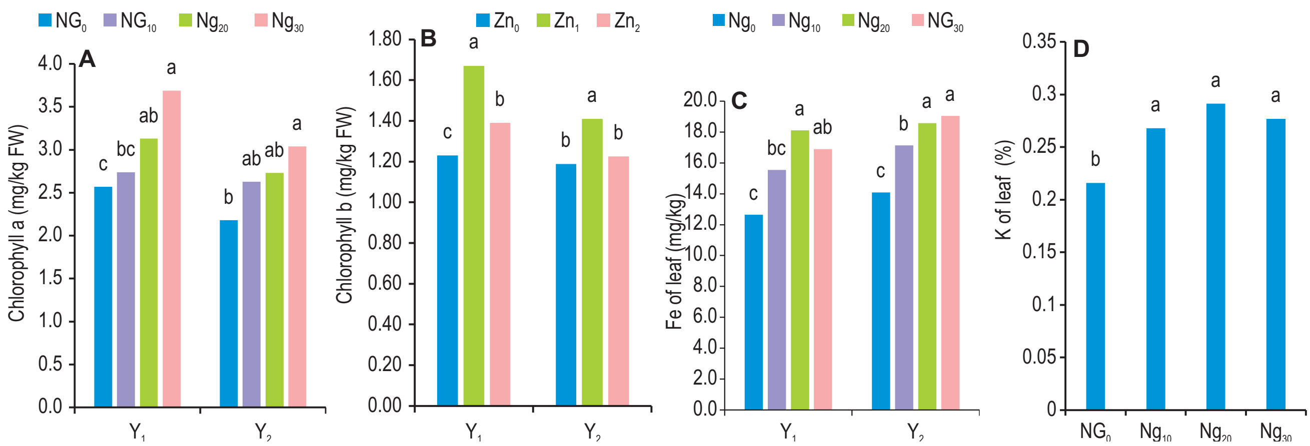

Fig. 1 The comparison of means for the NG × Y on chlorophyll a (A); Zn × Y on chlorophyll b (B); NG × Y on Fe content (C) and NG on K content in leaves (D).

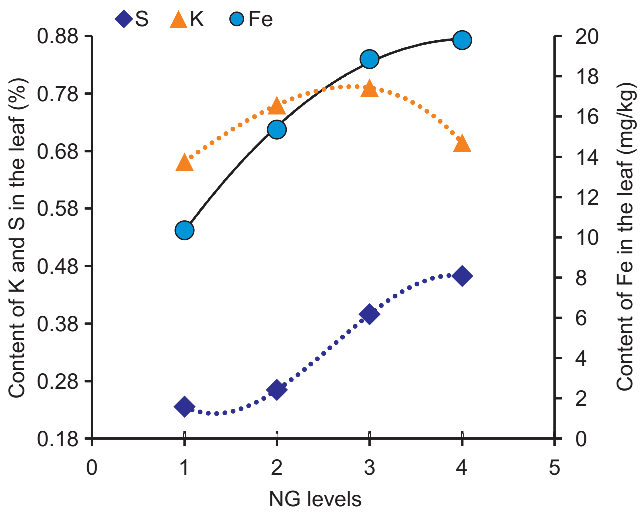

Fig. 2 Comparison of changes in the leaf K, S and Fe content compared to changes in main effect NG levels.

as basal at the time of sowing peanut can improve nutrient uptake. Increased uptake of these nutrients enhances the formation of sulphur-containing amino acids and synthesis of chlorophyll content (Abbas *et al.* 2023). The highest chlorophyll b content was obtained during both years from the plots applied with Zn_1 (Fig. 2), which is consistent with some other studies (Malka *et al.* 2022). Zn has a role in chlorophyll formation by influencing enzymes and accelerates the formation of phytohormones like tryptophan (auxin precursor). Auxin, in turn, stimulates cell elongation. In addition, the content of leaf S and Fe content were significantly influenced by the interaction of Zn × NG and Y × NG, but leaf K content was only influenced by NG (Table 1). Zn_2 had better effect on S content than Zn_0 in all four levels of gypsum. The highest S content was observed in in crop applied with NG_{20} + Zn_2 (Table 2). The content of leaf Fe was also increased by gypsum application in both years. The treatments NG_{20} and NG_{30} exhibited significantly

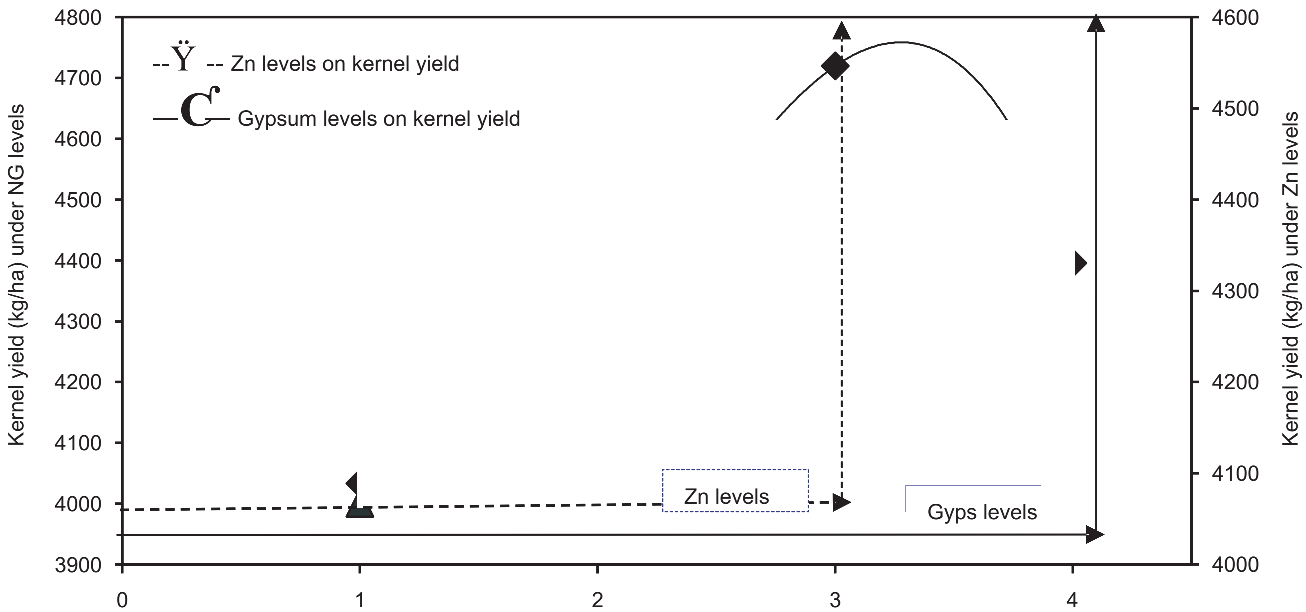

Fig. 3 The main effect of Zn and NG levels on kernel yield.

Table 2 Comparision of means for the interactive effect Y × NG × Zn and NG × Zn on measured traits in two years

NG	Zn	Mean comparision of Y × NG × Zn								Mean comparision of NG × Zn				
		RW (g)	Pods number	100-SW (g)	BY (g/Plant)	KY (kg/ha)	Kernels K (%)	Kernels S (%)	Fe (mg/kg)	Kernels number	Protein (%)	Oil (%)	P (%)	S (%)
					2021									
	Zn_1	18.6^{fg}	38^{d}	1058^{b-d}	92^{h}	4013^{c}	0.604^{d}	0.219^{ef}	27.2^{a-c}	27.2^{a-c}	10.7^{c}	32.6^{e}	0.107^{e}	21^{d}
NG_0	Zn_2	20.5^{d-f}	43^{cd}	1026^{cd}	126^{f}	4205^{bc}	0.609^{d}	0.271^{d}	30.0^{a}	30.0^{a}	15.1^{ab}	34.5^{de}	0.108^{de}	29^{bc}
	Zn_3	25.9^{b}	41^{cd}	1163^{ab}	132^{ef}	4313^{bc}	0.627^{cd}	0.350^{b}	21.5^{d}	21.5^{d}	15.3^{ab}	38.8^{b-d}	0.110^{c-e}	33^{a-c}
	Zn_1	20.1^{f}	43^{b-d}	1101^{b-d}	108^{g}	4463^{bc}	0.631^{cd}	0.216^{ef}	24.7^{b-d}	24.7^{b-d}	11.1^{c}	41.6^{ab}	0.119^{a-e}	26^{c}
NG_{10}	Zn_2	20.4^{ef}	46^{b-d}	1070^{b-d}	148^{d}	5107^{a-c}	0.673^{bc}	0.285^{d}	29.3^{ab}	29.3^{ab}	14.9^{ab}	33.8^{de}	0.122^{ab}	33^{a-c}
	Zn_3	29.0^{a}	49^{a-c}	1151^{ab}	171^{c}	5228^{a-c}	0.610^{d}	0.354^{b}	23.5^{cd}	23.5^{cd}	17.9^{a}	35.2^{c-e}	0.107^{e}	37^{ab}
	Zn_1	12.2^{h}	49^{a-c}	1047^{b-d}	139de	4613^{a-c}	0.650^{b-d}	0.210^{f}	24.5^{b-d}	24.5^{b-d}	11.3^{c}	46.0^{a}	0.113^{b-e}	25^{d}
NG_{20}	Zn_2	22.0^{c-e}	54^{ab}	1116^{b-d}	145^{d}	5693^{ab}	0.742^{ab}	0.319^{c}	24.3^{b-d}	24.3^{b-d}	10.6^{c}	45.7^{a}	0.110^{c-e}	35^{a-c}
	Zn_3	23.2^{c}	59^{a}	1257^{a}	167^{c}	6083^{a}	0.730^{a-c}	0.382^{a}	23.2^{cd}	23.2^{cd}	10.5^{c}	44.8^{a}	0.121^{a-c}	41^{a}
	Zn_1	13.7^{h}	48^{a-c}	997^{d}	166^{c}	3975^{c}	0.740^{ab}	0.178^{g}	25.5^{a-d}	25.5^{a-d}	9.4^{c}	45.2^{a}	0.128^{a}	31^{a-c}
NG_{30}	Zn_2	16.8^{g}	53^{ab}	1149^{ab}	237^{a}	5738^{ab}	0.766^{a}	0.235^{e}	24.2^{b-d}	24.2^{b-d}	11.7^{bc}	43.9^{ab}	0.117^{a-e}	33^{a-c}
	Zn_3	22.4^{cd}	50^{a-c}	1162^{a-c}	224^{b}	5415^{a-c}	0.625^{cd}	0.273^{d}	25.6^{a-d}	25.6^{a-d}	12.3^{bc}	40.5^{a-c}	0.12^{a-d}	36^{ab}
					2022									
	Zn_1	15.9^{b}	36^{e}	949^{d}	137^{c}	3510^{e}	0.643^{c}	0.195^{e}	25.6^{b-d}					
NG_0	Zn_2	18.0^{ab}	44de	1044^{a-d}	184^{c}	3683de	0.614^{c}	0.226^{c-e}	20.7^{d}					
	Zn_3	17.9^{ab}	51^{c-e}	1089^{a-d}	142^{c}	3840de	0.728^{b}	0.286^{b}	29.^{ab}					
	Zn_1	17.5^{ab}	46de	962^{cd}	160^{bc}	4148^{d}	0.731^{b}	0.202^{de}	29.3^{ab}					
NG_{10}	Zn_2	20.0^{ab}	58^{b-d}	988^{b-d}	191^{c}	4620^{c}	0.703^{b}	0.229^{cd}	23.0^{d}					
	Zn_3	22.8^{a}	58^{b-d}	1039^{a-d}	213^{c}	4928^{bc}	0.725^{b}	0.363^{a}	24.0^{cd}					
	Zn_1	18.3^{ab}	59^{b-d}	1028^{a-d}	207^{c}	4718^{c}	0.740^{ab}	0.217^{de}	23.4^{d}					
NG_{20}	Zn_2	18.2^{ab}	67^{ab}	1073^{a-d}	163^{bc}	4808^{bc}	0.616^{c}	0.338^{a}	24.0^{cd}					
	Zn_3	20.0^{ab}	77^{a}	1126^{a}	209^{c}	5640^{a}	0.728^{b}	0.333^{a}	29.0^{a-c}					
	Zn_1	16.2^{b}	56^{b-d}	1011^{a-d}	163^{bc}	3908^{d}	0.731^{b}	0.250^{c}	33.0^{a}					
NG_{30}	Zn_2	16.7^{b}	67^{ab}	1014^{a-d}	234^{ab}	5595^{a}	0.793^{a}	0.289^{b}	23.0^{d}					
	Zn_3	19.3^{ab}	63^{ab}	1133^{a}	253^{a}	5258^{ab}	0.725^{b}	0.250^{c}	25.4^{b-d}					

Similar letter(s) in each column shows insignificance of the difference based on the LSD test.
RW, Root weight; SW, Seed weight; BY, Biological yield; and KY, Kernel yield. Treatment details are given under Materials and Methods.

higher Fe content than NG_0 and NG_{10} (Fig. 3). Although gypsum significantly increased the leaf K content compared to the control, but there were no statistically significant differences among the gypsum levels (Fig. 3).

Plants treated with NG_{20} + Zn_2 contained the highest content of S in the first year (Table 2). On the other hand, this content was highest in the plants treated with treatment NG_{20} + Zn_2 in the second year. There is no statistical difference between the treatments NG_{40} + Zn_1 and NG_{40} + Zn_2 (Table 2). The highest and the lowest rate of seed P content were recorded with combined application of NG_{60} + Zn_0 (with an average of 0.128%) and NG_0 + Zn_0, as well NG_{20} + Zn_2 (with an average of 0.107%), respectively (Table 2). The highest rate of seed K was related to the interaction of NG_{40} + Zn_1 (with an average of 0.766% in the first year and 0.793% in the second year). The seed K content was increased in line with increasing the gypsum level in the Zn_1 level but it decreased in the Zn_2 level. Among the Zn levels, Zn_2 recorded a lower seed K content than Zn_0 and Zn_1 (Table 2). In the first year, the highest and lowest seed Fe content (30.05 and 21.53 mg/kg) were measured with NG_{10} + Zn_0 and NG_0 + Zn_2, respectively. On the other hand, in the second year, the highest and lowest seed Fe content (33 and 20.7 mg/kg) were measured with NG_{60} + Zn_0 and NG_0 + Zn_1, respectively (Table 2). The application of gypsum releases important elements like P, Fe, Zn and Mn. These elements play a remarkable role in increasing photosynthesis and consequently, plant growth (Mohanty *et al.* 2022). On the other hand, they are useful for vital functions like enzyme activities, which promote yield components including pod number and yield and seed number (Aruna *et al.* 2022). Researches showed that the foliar application of Zn increases photosynthesis in oilseed plants, which can enhance photosynthesis efficiency and plant growth, also accelerate photosynthate allocation to growing peanut pods (Jat *et al.* 2021, Jayasree *et al.* 2023).

NG × Zn treatment had a significant effect on seed protein and oil content (Table 1). The results of mean comparison showed that seed protein content was influenced by all Zn levels compared to the control. The highest protein content (17.94%) was obtained in plants treated with NG_{10}+Zn_3 (Table 2). The highest content of seed oil (46.09%) was extracted from the plants under treatment of NG_{20} + Zn_2, however there was no significant difference between this treatment and treatments of NG_{20} + Zn_1, NG_{20} + Zn_3 and NG_{30} + Zn_1. On the other hand, the lowest content (32.61%) value was recorded with NG_0 + Zn_3 (Table 2). Concentration of Fe and K in the leaves was increased through application of gypsum up to the NG_{20} level, but these elements were decreased and/or did not change at NG_{30}. However, the leaf Fe content was significantly increased with increasing the Zn level up to 2 g/L.

The interaction of Y × NG × Zn was found to be significant on root weight, pod number, 100-seed weight, biological yield and kernel yield (Table 1). Combination of gypsum and zinc significantly improved the biological yield. The highest biological yield was observed at NG_{30} level in both years. NG_{30} + Zn_2 induced the highest values (237.7 and 213.7 g/plant) in the first and second year, respectively (Table 2). Further, increasing the Zn level in both years increased root weight at gypsum levels. So, the root weight was increased in Zn_2 and Zn_3 than Zn_1 (22.3–30.6% in the first year and 7.7–28.2% in the second year). The increase resulted from the treatment Zn_1 was significant in the first year but not significant in the second year (Table 2). The effect of Zn on biological yield is related to the increase in auxin biosynthesis, N uptake efficiency, chlorophyll content and the activity of ribulose,1,5-bisphosphate carboxylase (Malka *et al.* 2022). Higher biological yield in faba beans was obtained by the foliar application of micronutrients along with gypsum (Kumar *et al.* 2023). This result corroborates with our finding.

Combined application of Zn and NG increased pods/plant over control by 7.3–34.6% in the first year and 11.2–48.6% in the second year, although some treatments did not differ significantly. The highest number of pods (59.3 and 77.7) were counted in the plots applied with NG_{20} + Zn_3 in the first and second year, respectively (Table 2). Mean comparison for the kernel number per plant revealed that application of different levels of gypsum and Zn increased the number of kernels per plant (16.3–73.5%). Among the treatments, NG_{20} + Zn_3 recorded the highest number of kernels (93.5 per plant) (Table 2). Among all NG levels and in both years, treatment of Zn_3 level exhibited higher 100-kernel weight than Zn_1 and Zn_2. The highest 100-seed weight in both years was obtained at higher levels of NG, including N_{20} + Zn_3 and NG_{30} + Zn_3 (Table 2).

The gypsum used in the research contained Fe, Mn, Zn, Si, Ca and S. Similarly application of gypsum increased the number of branches, pegs and pods (Vaishnav *et al.* 2023). Fe and Zn play a key role in adjusting various biochemical reactions in plants, thereby improves the crop growth parameters and yield. Although Si is not an essential element for plant growth and development, its positive and significant effect on plant growth parameters has been extensively reported in grain and oilseed crops (Saja-Garbarz *et al.* 2022). Improving Si in soil solution by Si fertilization enhanced uptake of other minerals and it had a positive effect on peanut growth and development. Application of Zn promoted the effect of gypsum by improving crop yields and acted as a supplement for gypsum (Latha and Dawson 2023).

The comparison of means for seed yield showed that the plots applied with gypsum and Zn increased kernel yield as compared to control by 6.6–52.4% in the first year and by 8.7–44.6% in the second year. In addition, the highest kernel yield was recorded by the application of NG_{20} + Zn_3 in both years (5640 kg/ha in the first and 6083 kg/ha in the second year) (Table 2). Since peanut pods grow underground and can directly absorb nutrients from the surrounding soil (Singh *et al.* 2023), nutrient availability around the pods and their uptake by the growing pods have a significant influence on the development of pods and finally kernel yield (Dhumgond *et al.* 2022). The absorption of S and other nutrients, especially P and Fe, increased at higher gypsum levels. This increase along with the transfer of more photosynthates from the shoots to the growing pods increased kernel yield in these treatments. Also, the enzymes activated by Zn in plants are involved in carbohydrate metabolism, protein production, preservation of cell membrane integrity, adjustment of auxin production and pollen formation (Halim *et al.* 2023). Dhumgond *et al.* (2022) reported increased number of pods with gypsum application and revealed a positive and significant correlation between the rate of S uptake by the plants and pod number and pod yield. Kumar *et al.* (2023) asserted that the application of gypsum and Zn had a significant impact on increasing pod number and peanut yield.

Given the soil texture and the climate conditions of the growing region, it was found that the simultaneous application of gypsum and Zn foliar application influenced the vegetative and reproductive traits, as well as seed quality. The highest pod number (66.3 pods/plant) and kernel yield (5839 kg/ha) were recorded by the combined application of $NG_{20} + Zn_2$. Therefore, applying gypsum as basal at the rate of 20 g/m^2 along with foliar application of Zn (2 g/litre) may be considered the best strategy to enhance the productivity of groundnuts by improving soil and crop nutritional status. In comparison to control, the combined application of Zn and gypsum additionally supplies higher K, P and S along with Fe and protein. Hence, it could be a cost-effective and potential source for alleviating these nutrient deficiencies in soils and a better alternative for reducing the consumption of chemical fertilizers.

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