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Seed priming SEAGRO liquid fertilizer most efficacious mode eliciting growth and accumulation of nutrients in shoots and rhizosphere soil of three-week-old cowpea (*Vigna unguiculata* L. Walp) cultivars planted in a potted experiment.

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Abstract

SEAGRO is a liquid fertilizer sold across South Africa and is not recommended for co-addition with other fertilizers. It is recommended for addition through drenching or foliar application on fruit trees and vegetables, among other plants. Cowpea is a leafy vegetable that is native to southern Africa and is cultivated for use as food, feed, medicine, and soil improver. So far, there exist no published information on whether adding SEAGRO liquid fertilizer to food crops that are widely cultivated in South Africa improve the growth, yield, and quality. This study assessed effects of adding SEAGRO liquid fertilizer through different modes on the growth, mineral nutrient accumulation in shoots as well as rhizosphere of cowpea cultivars. The experiment used topsoil collected from the Bon Accord Farm, air-dried, sieved, and 7 kg added into experimental plastic pots. Factors of the experiment involved: mode of SEAGRO application (control: no addition of SEAGRO), seed priming, drenching, seed priming plus drenching, foliar application, drenching plus foliar application, seed priming plus drenching plus foliar application); and cultivar (IT-18 and Accession 791). Each treatment was replicated three times. A solution of SEAGRO was prepared through mixing 5 ml of concentrated SEAGRO with 1 L tap water. Results of this research revealed that three-week-old cowpea plants of the IT-18 cultivar had significantly greater fresh and dry root weights. Also, priming seeds was the most efficacious of the modes of adding SEAGRO to the three-week-old cowpea cultivars. Accession 791 had greater shoot P, Mg, and Fe. Drenching and/or seed priming using SEAGRO improved shoot P and Mg while drenching plus foliar application increased shoot K. The concentration of Fe, Zn, and B was increased by the priming and/or drenching modes. The concentration of K and Fe was increased in the rhizosphere of the cowpea cultivars.

Keywords: Liquid fertilizer, drenching, foliar application, Plant growth,Biostimulant

1.Introduction

Currently, the label of SEAGRO liquid fertilizer is written that it is registered by the Act 36 of 1947 as a Fertilizer Group 2 product that can be used topically or on soil and contains macro-and-micronutrients, and amino acids. Clearly, the category under which the product is registered is incorrect because it contains amino acids. The correct category is Fertilizer Group 3. By definition, a Fertilizer Group 3 product is a fertilizer containing natural or synthetic substance(s) or organism(s) that improve(s) or maintain(s) the growth or yield of plants or the physical, chemical or biological condition (fertility) of the soil [1]. The incorrect registration of SEAGRO is not the only concern as some fertilizer group 3 registered under the Act 36 of 1947 and sold in South Africa are misleading. For example, studies show that when applied alone, some of the products do not increase the growth and yield of food crops, as claimed, rather, through co-application with NPK fertilizers [2,3]. Also, studies reveal that some biofertilizers contain undeclared constituents and potentially contaminated microbes [4]. Therefore, there is reason to question efficacy and safety of fertilizers registered under the Act 36 of 1947 and sold and utilized in by farmers, including SEAGRO.

Across the African continent, countries priorities preservation of indigenous knowledge as well as food plants and food crops. In his speech at the UN Food Systems Summit +4 Stocktake (UNFSS+4) held in Ethiopia in July 2025, Minister of Agriculture in South Africa posited that “We are promoting localized food production, with a clear focus on leveraging indigenous crops and livestock, which have both nutritional and climate resilience advantages” [5]. Among indigenous food crops with traits to tolerate drought conditions is cowpea [6]. In Africa, cowpea is largely cultivated in the small-scale crop sector and its foliage harvested for use as food, feed, and medicine. Asiwe [7]) revealed that among agronomic practices used by cowpea growers in the KwaZulu Natal, Mpumalanga, and Limpopo provinces of South Africa include intercropping with cereals; cultivation without proper row arrangement; poor management of weeds.

When cultivating cowpea, most farmers rarely add enough or recommended rates of fertilizers, leading to a decline in the fertility status of croplands. While the government in South Africa initiated a fertilizer subsidy programme aimed at supporting especially small-scale maize growers to enhance food crop production, the fertilizers are rarely received by all farmers in need of it [8] . In recent years, South Africa has seen an increase in companies selling smaller packages of inorganic fertilizers, liquid fertilizers, and biostimulants [3]. Among liquid fertilizers sold commercially in most parts of South Africa is SEAGRO. SEAGRO liquid fertilizer was chosen for use in this research because it is the only liquid fertilizer that is sold and popular across South Africa and is applied by crop farmers in South Africa. Despite the availability and wide usage of SEAGRO liquid fertilizer, there is no published information on whether it

improves the growth, yield, and quality of food crops and soils. This study's emphasis on assessing the efficacy of the locally produced fish-based liquid organic fertilizer on performance of cowpea is an attempt to assess previously unreported properties. Therefore, there is a need for research that focuses on assessing, among other factors, whether adding SEAGRO through different modes of application to cowpea improves the growth, yield, and concentration of essential nutrient elements in shoots and rhizosphere soil.

Information on the label of SEAGRO shows that it is an organic fertilizer that is produced from fish emulsion. Normally, about 30% of fish is used as food while more than 50% is discarded as waste. The large waste that is produced especially in cities and urban areas require to be discarded in spaces such as disposed offsites. The scarcity of land for disposal of such waste, amongst others, is what has led to initiatives to recycle waste. However, given the high concentration of toxic elements in fish waste [9]. There is a need to regulate the use of fish waste-based products as fertilizers. Indeed, fish waste is recycled into biostimulants and Fertilizer Group 3 products in South Africa. South Africa has seen an increase in the number of Fertilizer Group 3 products produced through fish waste. Fish waste-derived liquid fertilizers or biostimulants are referred to as fish protein hydrolysates and are generally derived from various products of fish including skins, heads, muscle, viscera, bone, frames, as well as roe [10] .

While there is dearth of published studies on effects of the fish waste-based SEAGRO liquid fertilizer, there exist studies on other fish waste-based liquid fertilizers conducted in other parts of the world. For example, adding fish hydrolysate to cowpea increased the fresh and dry weights, shoot length, number of leaves and pods per plant, and root nodules; free proteins, amino acids, total phenolics, flavonoid and chlorophyll content; as well as concentration of micronutrients and macronutrients in the soil [11]). Priming seeds of rice (*Oryza sativa* L. cv. Barak Cenana) in an organic fertilizer made of fish waste at different concentrations resulted in enhanced germination percentage, plant height, and root length [12] . Adding fish waste-based liquid fertilizer increased the height, branches, leaves, as well as fruits of chilli [13] . Adding a fish-based liquid organic fertilizer markedly enhanced the growth and yield of maize in India [11] . Foliar application of a fish waste-based liquid fertilizer was the most efficacious mode as it increased the growth of selected leafy vegetables compared to adding it through the drenching mode [14] . Application of compost derived from fish waste improved contents of leaf N, P, K, Na, Ca, and Mg in lettuce (*Lactuca sativa*) [15]. So far, there is scanty published literature on effects of fish waste-based biostimulants on the quality characters of plant tissue and soils. This gap in knowledge necessitates this research because it is crucial to understand the efficacy of these products on especially edible plant organs and soil health. The application of fish waste based liquid fertilizer through drenching improved the pH of soil, supporting the

growth of onions compared to that treated through the foliar application mode [16]). Unfortunately, so far, there is no published literature showing a relationship between the addition of fish waste-based products on soil pH.

Most liquid fertilizers and biostimulants are recommended for application to the soil (drenching), foliar application, and seed priming. Previous research found that organic liquid fertilizer can regulate cotton plant type, promote cotton boll maturity, and increase cotton yield (Liang et al. [17]. Ngoroyemoto et al. [18] showed that drenching a solution of Kelpak increased the number of leaves while drenching plus foliar spray markedly enhanced number and area of leaves; plant height and dry weight of roots; as well as fresh and dry weights of shoot and stem thickness of cowpea. Arthur et al. [19] revealed that drenching 20% of a Kelpak solution markedly increased number of roots in mung bean plants. Wang et al. [20] reported that exogenous foliar spraying with fulvic acid improved lettuce growth and increased plants' tolerance to environmental stress. In addition, Suhŏ et al. [21] reported that tomato plants exposed to fulvic acid foliar spraying experienced a promotion of their growth and marketable value. Seed priming with different bio-stimulants led to an improvement in the growth, seed yield, and nutritional value of pea plants Arafa et al. [22]). Seed priming with seaweed sap, followed by two foliar sprays at 21 and 42 days after sowing along with (twice) along with RDF_{NPK}, significantly improved growth parameters, yield components, and yield of summer mung bean [23].

Seed soaking and drenching Kelpak markedly enhanced the shoot and root length of cowpea watered once-a-week; its supply for 2 days a week increased shoot length, number of leaves, stem diameter, fresh weight, dry weight and number of flowers; and its application to cowpea three days a week resulted in thicker stems and greater fresh and dry weights [24].

There is limited information on the effects of the widely sold liquid organic fertilizer, SEAGRO, on whether it alters the growth and concentration of essential nutrient elements in the rhizosphere and shoots of cowpea. The productivity of cowpea is limited by the availability of nutrients in the soil, particularly in areas with sandy or degraded soils. In addition, inorganic fertilizers are costly and their untimely application is associated with negative environmental impacts. Therefore, it is important to identify alternative fertilizers that are readily accessible and affordable and assess whether they can improve the productivity of widely grown native food crops. SEAGRO is a natural fertilizer made from animal (fish) products; however, we are yet to see its effects on the fertility of soils as well as productivity of annual food crops. The main problem that this research aimed to address was the dearth of information on whether the widely sold and utilised fish by-product namely SEAGRO, does indeed improve the growth of plants, nutrient accumulation in shoots and rhizosphere soil of three-week-old plants, as

well as growth, yield-related parameters, and grain quality of cowpea. Also, this research intended to address the lack of information on the potential benefits of using SEAGRO as a fertilizer in cowpea production, particularly in clay soils. Among claims on the label of SEAGRO is that it can improve the growth of plants, however, there is limited information on whether it can increase the growth and yield-related parameters of cowpea as well as grain quality. This research was intended to contribute to this knowledge gap and help crop farmers to make informed decisions about their farming practices.

The aim of this study was to assess whether the mode of adding SEAGRO, as seed priming, drenching, foliar application or a combination of these alter the biomass, leaf and grain quality, as well as pH and concentration of nutrient elements in the rhizosphere of improved and a farmer-preferred variety of cowpea.

2. Materials and Methods

2.1 Description of experimental sites, collection, and processing of soil

The soils used for planting in the study were sourced from the Tshwane University of Technology's experimental farm in Gauteng, South Africa. The soil was classified as Hutton form. The soil was collected at coordinates 25˚36'01.0" S, 28˚13.497" E. Only topsoil (0 – 20 cm) was sampled, processed by breaking clods and removing debris, and each soil type was air-dried for three days before being pooled into bulk samples. These were then sent to Elsenberg Laboratories for analysis of pH, P, K, Mg, Zn, Fe, and B.

2.2 Experimental design and planting

The experiment was conducted at Building 66 of the Tshwane University of Technology, Pretoria campus: 43' 53.55" S, 28° 09' 40.38" E, and an elevation of 1230 m.a.s.l. About 7 kg of soil was weighed into experimental plastic pots and placed on benches in an open space where the plants would be exposed to direct sunlight and receive rainfall. The experimental pots were laid out in a completely randomized design, and each treatment was replicated thrice. On the benches, pots were spaced at 30 cm to avoid shading between plants and the position of the pots was changed and rotated once a month to minimize the chances of effects of sunlight, rainfall, and air. The experiment was factorial with Factor I as mode of SEAGRO application (control, prime, drench, prime plus drench, foliar-spray, drench plus foliar-spray, prime plus drench plus foliar-spray). Factor II was cultivar (IT-18 (denoted as 'genotype') and Accession 791 (denoted as 'Accession')). Seeds for the Accession 791 were sourced from the Malkerns Research Station in eSwatini while that for IT-18 were sourced from the IITA-Nampula, Mozambique. Factor III included the types of soil. Treatments were replicated six

times. Three seeds of each cowpea cultivar were sown in each experimental plastic pot and thinned to one after emergence of seedlings. For the seed priming treatment, concentrated SEAGRO was diluted with tap water at a ratio of 1:200 ml, while for the drench as well as the foliar-spray treatments, concentrated SEAGRO was diluted with tap water at a ratio of 1:1000 ml. The experimental plants or the soil did not receive any application of fertilizers, and the seeds were not inoculated. The experimental plants depended on rainfall.

2.3 Measurement of plant height

Soon after plants formed the second trifoliate leaf, the height of each plant stand was measured using a 30 cm ruler.

2.4 Harvesting, processing and determination of growth-related parameters

Soon after the second trifoliate leaf had fully formed, cowpea plants in three of the six replicates were harvested for determination of growth-related parameters and essential mineral nutrients. From each experimental pot, the aboveground part of each plant was cut off at the crown level and the number of leaves counted on per plant basis. The belowground plant part of each plant was carefully dug out and soil attached to roots carefully washed using tap water. Both roots and shoots samples were put in separate sample paper bags and oven-dried at 65°C until constant dry weight was achieved. The dry shoot samples were then ground to fine powder for the mineral analysis. The rhizosphere soil of each plant, defined as the soil attached to the roots, was carefully shaken off from the roots and air-dried for three consecutive days, sieved for the soil mineral analysis. The root-to-shoot ratio was determined by dividing the root dry weight by the shoot dry weight.

2.5 Measurement of shoot mineral content

Foliar and grain P, K, Mg, Fe, Zn, and B were determined using an ICP-mass spectrometry [3]. About 1.0 g of finely ground sample was ashed in a porcelain crucible at 500 °C overnight. The ash was dissolved in 5 mL of 6 M HCl and placed in an oven set at 50 °C for 30 min, followed by adding of 35 mL deionised water. The mixture was filtered through a Whatman #1 filter paper. The quality of data collected was checked using standard solutions with certificate of analysis. In place of analyte isotopes to monitor each element, a known standard was used after every 10 samples.

2.6 Determination of pH and nutrients in rhizosphere soil

The pH of soil was determined by the KCl method while extractable P, K, and Mg were determined by citric acid method as developed by Dyer [25] and modified by the Division of Chemical Services [26] and Du Plessis and Burger [27]. A 20 g air-dried soil sample was extracted in 200 mL of 1% (w/v) citric acid, heated to 80 QC, shaken for 2 min at 10 min intervals over a total period of 1h and filtered. A 50 mL aliquot was heated to dryness on water bath, digested with 5 mL of concentrated HCl and HNO_3, evaporated to dryness on a water bath, and 5 mL of concentrated HNO_3 and 20 mL of deionised water added. The mixture was heated to dissolve the dry residue, and the sample filtered. Measurements of P, K and Mg were then done directly by direct aspiration on the calibrated simultaneous ICP. The trace elements Zn and Fe were extracted from using di-ammonium ethylenediaminetetaacetic (EDTA) acid solution [Trierweiler and Lindsay [28], as modified by Beyers and Coetzer (1971). The extractants were analysed for Zn and Fe using the calibrated simultaneous ICP spectrophotometer. B was determined following the method described by FSSA [29].

2.7 Statistical analysis

The growth and yield-related parameters, shoot nutrients, and rhizospheric nutrients were compared between cultivars and fertilizer treatments using STATISTICA software version 10.0. Where treatment means show significant difference, the Fisher's Least Significant Difference was used to separate the means at $p \leq 0.05$, and Microsoft excel was used to construct the graphs or figures.

3. Results

3.1 Effect of SEAGRO on growth and yield-related parameters of cowpea

In a study on cowpea growth, plants exhibited greater root lengths (Table 1). Cultivar IT-18 recorded much higher root weight compared to Accession 791. The application of SEAGRO fertilizer through foliar methods resulted in longer roots than non-treated plants. The best growth in root and shoot weights occurred with seed priming and drenching methods. Foliar application significantly boosted shoot dry weight, while seed priming combined with drenching and foliar application yielded the least. The root-to-shoot ratio improved with seed priming and drenching, with the highest ratios under foliar application and the lowest from the combined seed priming, drenching, and foliar methods. Plant height was greatest with seed

priming and drenching, followed by foliar application, while the shortest height resulted from the combined treatment (Table 1).

3.2 Nutrient concentration in shoots: response to addition of SEAGRO liquid fertilizer

The study assessed macro- and micronutrient concentrations in cowpea shoots collected after the second trifoliate stage. Among the cowpea cultivars, Accession 791 showed significantly increased in the levels of P, Mg, and Fe. Application methods for SEAGRO liquid fertilizer showed that seed priming overnight combined with drenching resulted in the highest shoot P levels. The combination of seed priming, drenching, and foliar application yielded the greatest K levels, and similar effects were observed for Mg and Fe. In contrast, plants without SEAGRO exhibited the lowest nutrient concentrations (Table 2).

3.3 Nutrient concentration in rhizosphere soil in cowpea cultivars

The study found that rhizospheric pH was higher, with significant differences in the concentrations of nutrients. Notably, potassium (K) and iron (Fe) were greater in cultivated soil. The addition of the SEAGRO solution did not significantly affect rhizospheric pH, P, or Fe. However, drenching and foliar application of SEAGRO significantly increased rhizospheric K levels. SEAGRO application by spraying enhanced magnesium (Mg) levels, whereas zinc levels were highest with foliar spray, followed by drenching. Rhizospheric boron (B) was highest in treatments involving seed priming, drenching, and foliar applications compared to the control (Table 3).

3.4 Cultivar x mode of SEAGRO application interaction

In this study, IT-18 exhibited a greater root fresh weight than Accession 791 in soil. For shoot dry weight, IT-18 outperformed Accession 791 in the soil, with SEAGRO treatments affecting growth variably across the treatments. The root-to-shoot ratio was more favorable for Accession 791 in the soil. Moreover, Accession 791 exhibited greater plant height than IT-18 in the soil, with various treatments influencing plant height differently for each genotype. Overall, SEAGRO application demonstrated significant effects on plant growth metrics of both genotypes across different soil types (Table 1).

3.5 Interactions: nutrients in shoot materials

IT-18 exhibited an increased in shoot P with seed priming plus drenching plus foliar application. For Accession 791, shoot P was highest with seed priming plus drenching. In soil, both accessions showed increased shoot K with similar treatment strategies. IT-18 had greater shoot Mg with seed priming plus drenching plus foliar application. Iron (Fe) content in IT-18 increased with seed priming or drenching, while Accession 791 showed higher Fe with untreated controls. IT-18's Zn increased with seed priming plus drenching plus foliar application (Figure 3.9A). Boron (B) in IT-18 was increased through drenching, while Accession 791 benefited most from the same mode (Figure 3.9B). IT-18's B rose with seed priming. Overall, the study indicated that SEAGRO application methods significantly affect mineral content in plants, varying by treatment type.

3.6 Interactions: pH and concentration of rhizospheric nutrients

Foliar application of SEAGRO significantly increased soil pH and nutrient levels (P, K, Mg, Fe, Zn, B) in both IT-18 and Accession 791 (Figure 3. 10A). Accession 791 also exhibited marked improvements with specific application strategies, especially noted in rhizospheric P and K. The data highlights the specific effects of SEAGRO across nutrient categories and soil cultivation states, noting that rhizospheric nutrient levels varied significantly between the two cowpea cultivars under the given conditions.

4. Discussion

The study found significant differences in growth and yield-related parameters between cowpea cultivars in South Africa, suggesting genetic variability shown by [22,29]. IT-18 is an improved cultivar from IITA, outperformed Accession 791, an unimproved landrace, in cultivated soil due to better adaptation to southern African conditions. IT-18 exhibited superior root fresh weight, shoot dry weight, and plant height, along with higher bradyrhizobial populations [30] and grain quality in various agro-ecologies [31]. While unimproved landraces typically produce more biomass [32], in this study, IT-18 showed markedly improved growth parameters compared to its unimproved counterpart. The control plants of Accession 791 in different soil types showed increased root fresh weight. In previous studies, Accession 791 outperformed improved genotype Pan 311 in root biomass, suggesting its superior ability to access water and nutrients [8]. Enhanced fresh weight may be linked to improved root architecture, facilitating better nutrient and water uptake [33]. Additionally, Accession 791 demonstrated higher concentrations of nutrients (P, Mg, Fe) in shoots compared to IT-18. This

trend of superior nutrient accumulation in unimproved landraces, was noted in other studies [33], indicates their effective nutrient uptake mechanisms.

4.1 Effect of mode of adding SEAGRO on growth and yield-related parameters

In this study, the addition of SEAGRO enhanced the belowground and aboveground biomass of cowpea plants, particularly when combining seed priming with drenching. Seed priming involved soaking seeds in a concentrated SEAGRO solution as described by [17] which typically accelerates germination and emergence [34]. This method not only improved the germination rates of cowpea seeds but also contributed to increased tolerance to stresses, better drought resistance, and longer root growth [35]. Although not measured, existing literature indicates a positive correlation between improved germination rates and overall plant growth [17]. The advantages of SEAGRO priming are attributed to its constituent macro- and micronutrients, and amino acids that promote root biomass development [36].

The results indicated that drenching cowpea plants with SEAGRO improved root growth, with this method being the second most effective after seed priming. The enhanced belowground growth is attributed to SEAGRO's presence around seeds during germination. All modes of SEAGRO application (seed priming, drenching, foliar) increased shoot dry weight, especially crucial during the second trifoliate stage. However, its requirement in all methods raises concerns about labor and costs, suggesting SEAGRO’s effectiveness may be limited during this growth stage. Overall, plants treated with SEAGRO were taller, indicating the fertilizer's diminished effectiveness and the need for farmers to invest more resources for improved growth.

4.2 Concentration of nutrient in shoots of an unimproved landrace and improved genotype of cowpea

Accession 791 demonstrated significantly higher shoot phosphorus (P), magnesium (Mg), and iron (Fe) levels than the improved genotype IT-18. This aligns with previous findings from South Africa, where landraces exhibited higher nutrient concentrations compared to improved genotypes. The study showed that Accession 791 also had greater root biomass, which correlates positively with nutrient absorption in aboveground plant parts [37]. The application of SEAGRO, a liquid fertilizer, improved shoot P and Mg through soil drenching and seed priming, marking the first report of its effectiveness on cowpea. It was observed that drenching enhanced nutrient uptake, potentially solubilizing nutrients in the soil. This study highlights SEAGRO's efficiency in increasing micronutrient concentrations (Fe, Zn, B) in cowpea shoots,

particularly through targeted applications in the rhizosphere, leading to improved nutrient availability in the plant.

4.3 Nutrient concentration in rhizosphere of cowpea

Rhizospheric pH in the soil was (6.32) (Table 3). This study highlights a gap in knowledge regarding the impact of liquid fertilizers like SEAGRO on rhizospheric pH, especially for cowpea. It is the first to demonstrate that SEAGRO positively affects pH levels in the rhizosphere of cowpea cultivars. Previous studies noted an increased in mineral nutrient levels in low-nutrient soils [3,38,39], but none addressed SEAGRO or compared its effectiveness in high-nutrient soils, making these findings novel.

4.4 Effect of mode of adding SEAGRO on rhizospheric nutrients

The application of SEAGRO solution through foliar spraying on cowpea cultivars significantly enhanced pH levels and increased concentrations of essential minerals (P, K, Mg, Fe, Zn, and B). SEAGRO, containing amino acids, may improve nutrient uptake by promoting soil nutrient exchange [40] and mineral [41]. Despite limited published research on organic liquid fertilizers in rhizospheric nutrient concentration, existing mechanisms suggest effective foliar applications require specific traits for nutrient penetration [23]. Overall, foliar application of SEAGRO proved more effective than seed priming or drenching in boosting nutrients in cowpea.

Seed priming, drenching, and foliar application significantly enhanced rhizospheric concentrations and shoot dry weight of key nutrients (P, K, Mg, Zn, B) in cowpea. This mode improved nutrient solubilization and uptake, which is crucial for plant growth and photosynthesis [42]. The inclusion of SEAGRO liquid fertilizer, rich in these nutrients, is linked to better root exudation and microbial activity, further mobilizing minerals in low-nutrient soils. Consequently, these interactions led to greater nutrient accumulation in plant shoots and overall increased in dry weight.

5. Conclusions

The study assesses the impact of applying SEAGRO through different methods, priming seeds, drenching, and foliar application on cowpea growth and nutrient composition in the soil. Among the cultivars studied, IT-18 performed best overall, while Accession 791 showed superior root fresh weight. Priming seeds with SEAGRO was found to be the most effective method, followed by drenching. Notably, Accession 791 also had higher shoot P, Mg, and Fe levels than IT-18. The study demonstrates that SEAGRO significantly enhances cowpea growth, particularly when used for overnight seed priming.

Table 1: Growth parameters of three-week-old cowpea grown in potted soils, subjected to addition of SEAGRO through different modes. Means with dissimilar letters in a column show statistically significant different at p≤ 0.05.

Treatment	Root fresh weight	Root dry weight	Shoot dry weight	Root:shoot ratio	Plant height
			g/plant		cm
Cultivar					
IT-18	0.48 ± 0.03a	0.23 ± 0.02a	0.53 ± 0.03a	1.96 ± 0.54a	18.57 ± 0.81a
Accession 791	0.21 ± 0.01b	0.16 ± 0.01b	0.51 ± 0.04a	1.25 ± 0.18a	17.56 ± 1.35a
Mode of application					
Control	0.31 ± 0.02b	0.15 ± 0.01b	0.13 ± 0.03c	1.07 ± 0.42ab	17.11 ± 1.47bc
Seed priming	0.28 ± 0.02b	0.14 ± 0.01b	0.55 ± 0.02bc	0.88 ± 0.15ab	17.75 ± 1.95b
Seed priming + Drenching	0.50 ± 0.10a	0.25 ± 0.03a	0.28 ± 0.05c	1.52 ± 0.31ab	21.50 ± 1.33a
Drenching	0.48 ± 0.06a	0.25 ± 0.04a	0.61 ± 0.05ab	2.78 ± 1.01a	15.82 ± 1.92c
Foliar application	0.50 ± 0.10a	0.25 ± 0.04a	0.65 ± 0.02a	2.81 ± 1.23a	19.06 ± 2.03ab
Drenching + Foliar application	0.42 ± 0.04ab	0.09 ± 0.01c	0.51 ± 0.04b	0.35 ± 0.07b	21.27 ± 0.72ab
Seed priming + Drenching + Foliar application	0.53 ± 0.09a	0.12 ± 0.01ab	0.13 ± 0.02d	1.04 ± 0.10ab	10.51 ± 0.98c
F-statistics					
Cultivar (C)	128.09***	11.43**	0.09ns	1.51ns	0.47ns
Mode of application (M)	4.99**	12.63***	28.01***	1.65*	5.15***

Table 2: Concentration of macro-and micronutrients in shoots of three-week-old cowpea grown in potted soils, subjected to addition of SEAGRO through different modes. Means with dissimilar letters in a column show statistically significant different at $p \leq 0.05$.

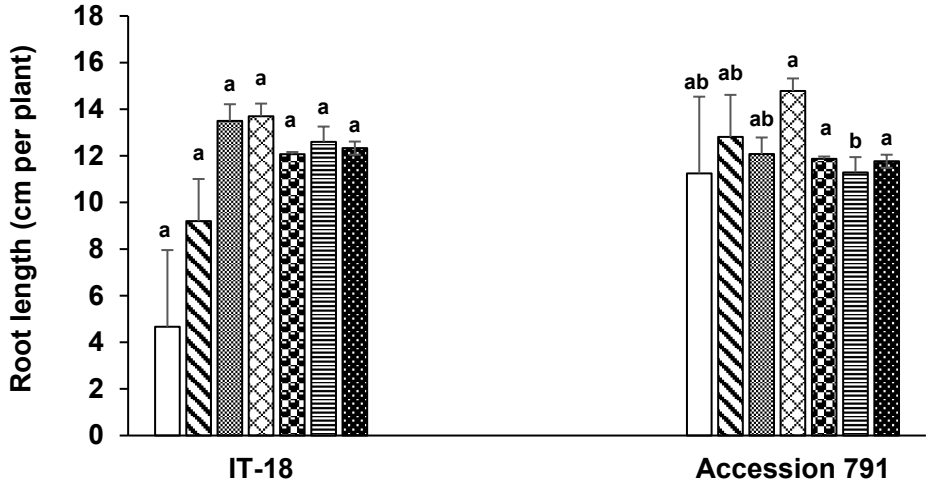
Treatment	P	K	Mg	Fe	Zn	B
	mg/plant					
Cultivar						
IT-18	6.55 ± 0.46b	45.10 ± 3.45a	5.69 ± 0.31b	0.86 ± 0.12b	0.06 ± 0.03a	0.06 ± 0.03a
Accession 791	8.22 ± 0.32a	41.94 ± 1.53a	6.78 ± 0.30a	3.01 ± 0.36a	0.08 ± 0.01a	0.07 ± 0.00a
Mode of application						
Control	6.60 ± 0.56c	32.60 ± 2.10c	5.37 ± 0.53bc	0.55 ± 0.13d	0.07 ± 0.03a	0.04 ± 0.01a
Seed priming	6.78 ± 0.89bc	37.52 ± 1.42bc	5.76 ± 0.25b	1.53 ± 0.37bcd	0.05 ± 0.01a	0.05 ± 0.01a
Seed priming + Drenching	9.62 ± 0.55a	49.08 ± 2.02ab	7.54 ± 0.89a	4.16 ± 0.50a	0.07 ± 0.01a	0.05 ± 0.01a
Drenching	8.01 ± 0.55b	44.04 ± 2.90b	6.33 ± 0.41ab	2.35 ± 0.36b	0.13 ± 0.07 a	0.05 ± 0.01a
Foliar application	6.928 ± 0.55bc	41.70 ± 3.29bc	6.50 ± 0.37a	0.89 ± 0.23cd	0.04 ± 0.01 a	0.04 ± 0.01a
Drenching + Foliar application	8.70 ± 0.54ab	34.53 ± 6.40c	4.45 ± 0.63c	2.05 ± 0.43bc	0.03 ± 0.01 a	0.03 ± 0.01a
Seed priming + Drenching + Foliar application	7.42 ± 0.39bc	51.72 ± 3.29a			0.07 ± 0.00 a	0.06 ± 0.01a
F-statistics						
Cultivar (C)	9.29^{**}	0.51ns	4.96^{*}	27.92^{***}	0.21ns	0.08ns
Mode of application (M)	19.01^{***}	6.01^{***}	3.15^{*}	10.32^{***}	0.74ns	0.74ns

Table 3: Effect of adding SEAGRO liquid fertilizer on the concentration of macro-and micronutrients in rhizosphere soil of cultivars. Mean values with dissimilar letters in a column are significantly different at p≤0.05.

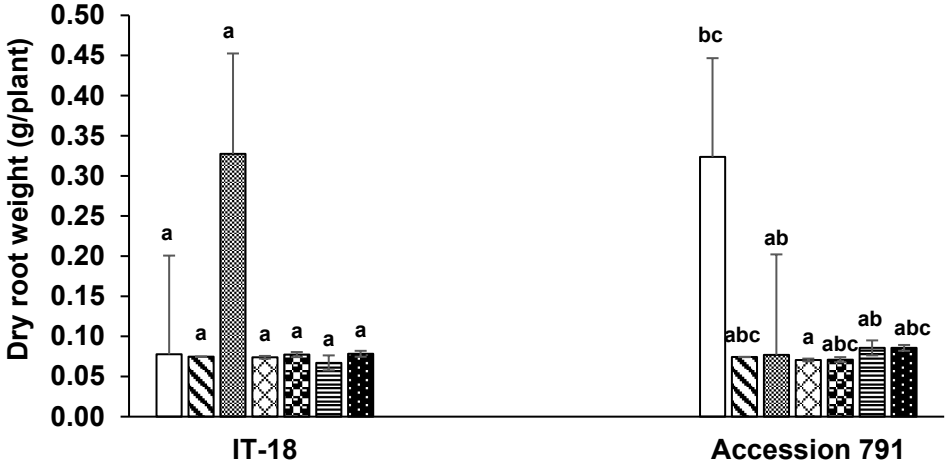
Treatment	pH	P	K	Mg	Fe	Zn	B
		mg/kg					
Cultivar							
IT-18	5.94 ± 0.05a	227 ± 8.56a	388 ± 14.54a	60 ± 0.50a	540 ± 18.87a	22 ± 0.98a	0.56 ± 0.01a
Accession 791	5.99 ± 0.05a	248 ± 8.61a	370 ± 14.18a	60 ± 1.60a	520 ± 20.35a	22 ± 0.72a	0.57 ± 0.01a
Mode of Kelpak application							
Control	5.98 ± 0.10a	229 ± 19.92a	356 ± 23.77b	60 ± 1.15ab	513 ± 28.15ab	20 ± 1.54bc	0.50 ± 0.02b
Seed priming	6.02 ± 0.09a	250 ± 17.37a	403 ± 28.46ab	61 ± 0.79ab	567 ± 39.26ab	22 ± 0.97bc	0.59 ± 0.03a
Seed priming + Drenching	5.97 ± 0.09a	229 ± 16.36a	337 ± 13.30b	59 ± 0.83b	570 ± 40.46ab	25 ± 1.26ab	0.55 ± 0.02ab
Drenching	5.88 ± 0.10a	229 ± 14.01a	393 ± 25.69ab	62 ± 1.47ab	576 ± 43.56a	22 ± 1.01bc	0.56 ± 0.02a
Foliar application	6.00 ± 0.10a	246 ± 14.78a	341 ± 11.55b	62 ± 1.50a	480 ± 13.27b	27 ± 2.68a	0.59 ± 0.02a
Drenching + Foliar application	5.93 ± 0.08a	229 ± 14.29a	449 ± 33.68a	61 ± 0.20ab	547 ± 33.42ab	20 ± 1.10c	0.61 ± 0.02a
Seed priming + Drenching + Foliar application	5.99 ± 0.09a	248 ± 16.17a	400 ± 30.86ab	59 ± 4.95ab	585 ± 55.11ab	23 ± 1.14bc	0.58 ± 0.05ab
F-statistics							
Cultivar (C)	0.66^{ns}	3.06^{ns}	0.73^{ns}	0.01^{ns}	0.56^{ns}	0.03^{ns}	0.57^{ns}
Mode of application (M)	0.27^{ns}	0.40^{ns}	2.58*	1.29*	1.00*	2.73*	2.52*

Figure 1. Interactive effect of genotype x SEAGRO on **A)** root length, **B)** root fresh weight, **C)** root dry weight, **D)** shoot dry weight, and **E)** root shoot ratio. Bars with dissimilar letters are significantly different at $p \leq 0.05$.

A

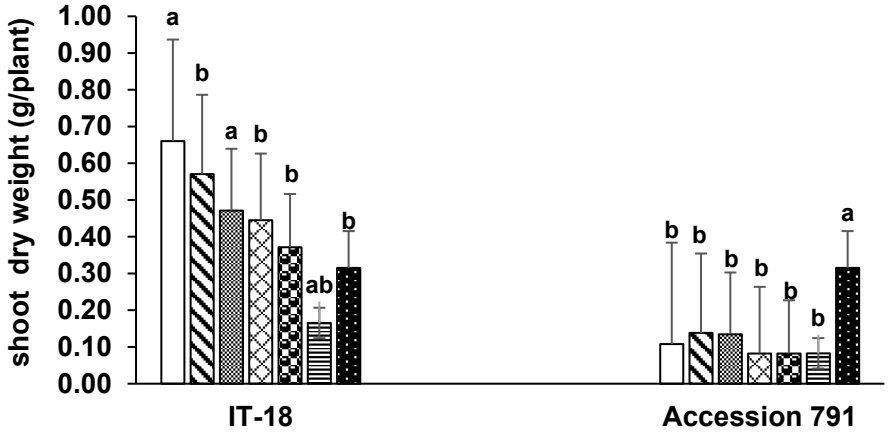


B



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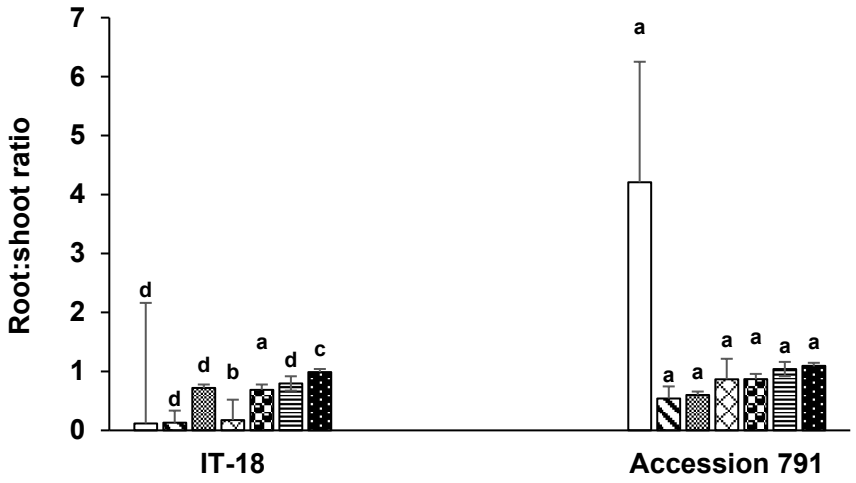
C



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D



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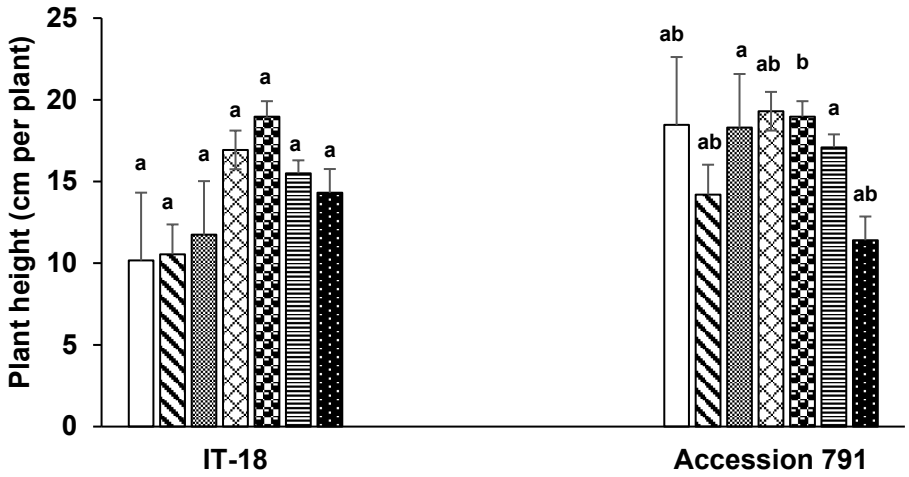
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401 **E**

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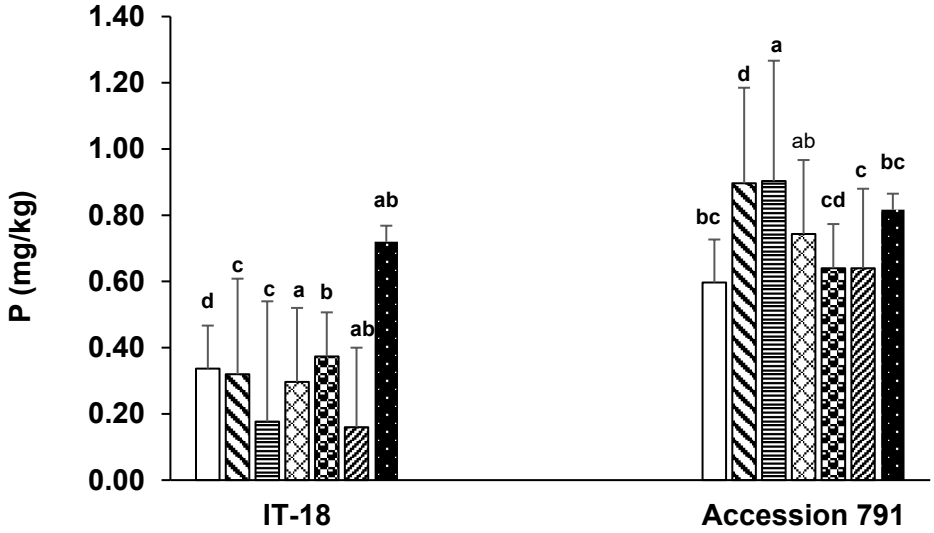


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404 **Figure 2**. Interactive effect of cultivar x mode of application x type of soil on concentration of
405 **A)** P and **B)** K in shoots of cowpea. Vertical bars represent mean values and vertical lines on
406 mean bars represent standard error.

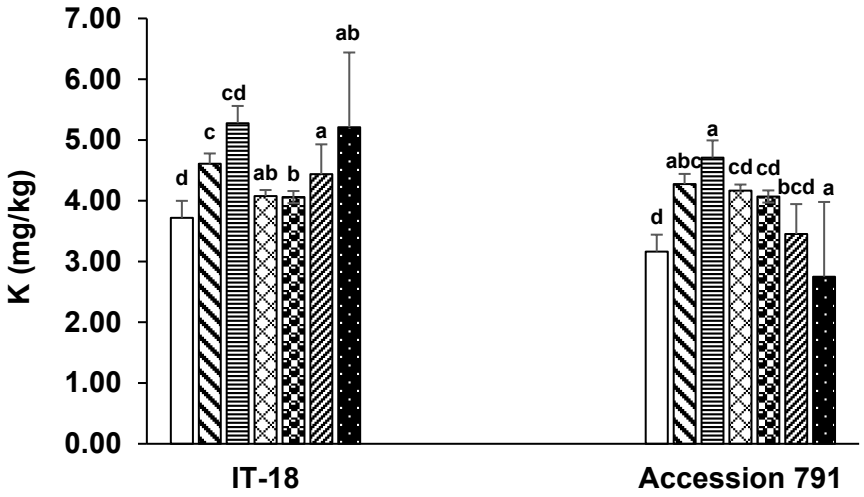
407 **A**

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409

410 **B**



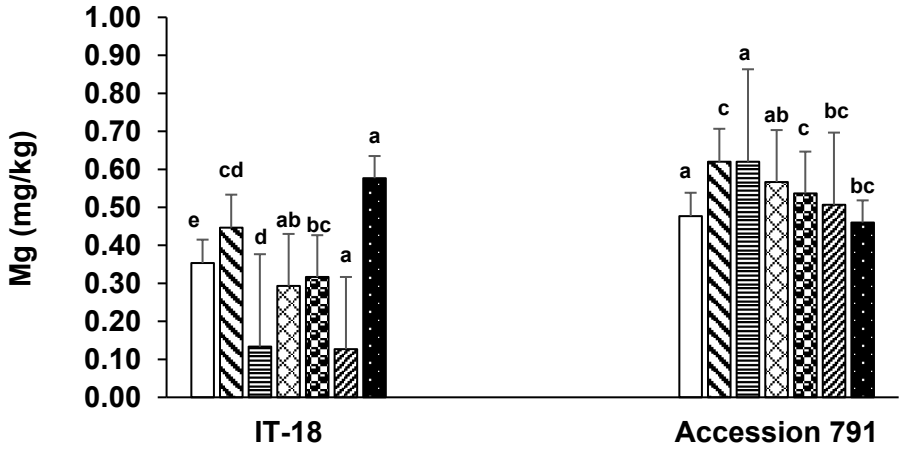
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412

413 **Figure 3.** Interactive effect of cultivar x mode of application x type of soil on concentration of **A)**
414 Mg and **B)** Fe in shoots of cowpea. Vertical bars represent mean values and vertical lines on mean
415 bars represent standard error.

416

417 **A**

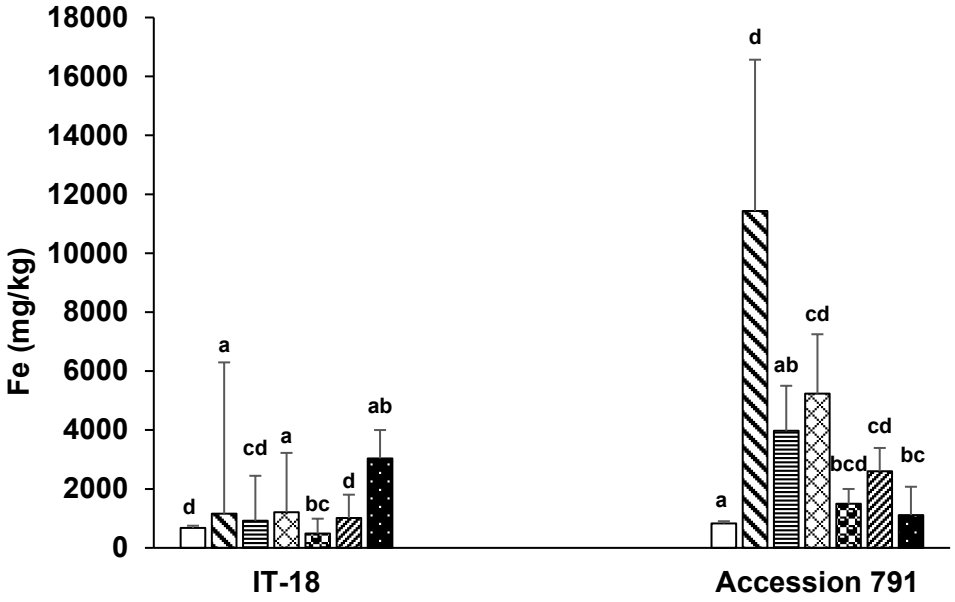


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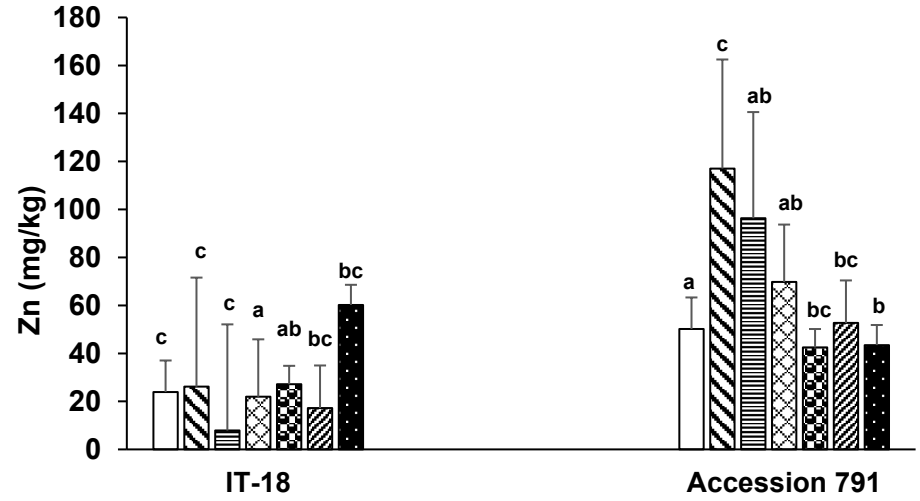
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421 **B**



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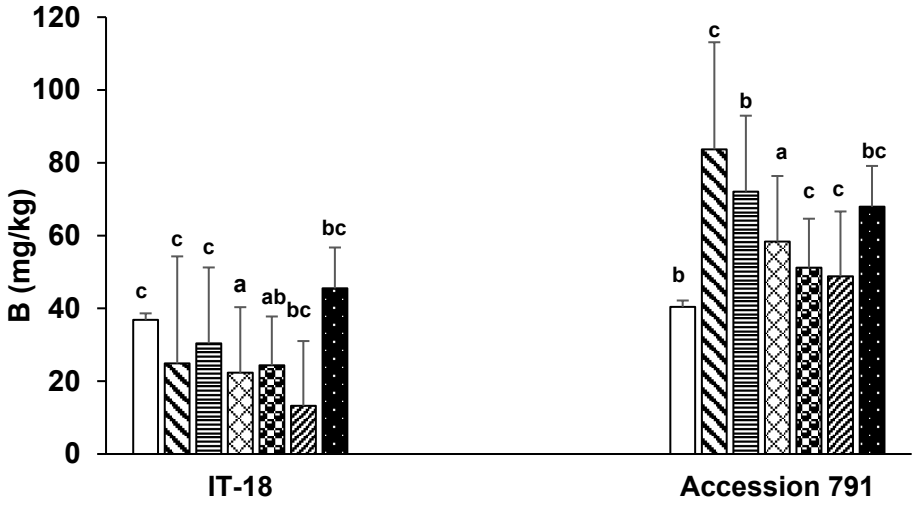
423 **Figure 4.** Interactive effect of cultivar x mode of application x type of soil on concentration of
424 A) Zn and B) B in shoots of cowpea. Vertical bars represent mean values and vertical lines on
425 mean bars represent standard error.
426
427 **A**



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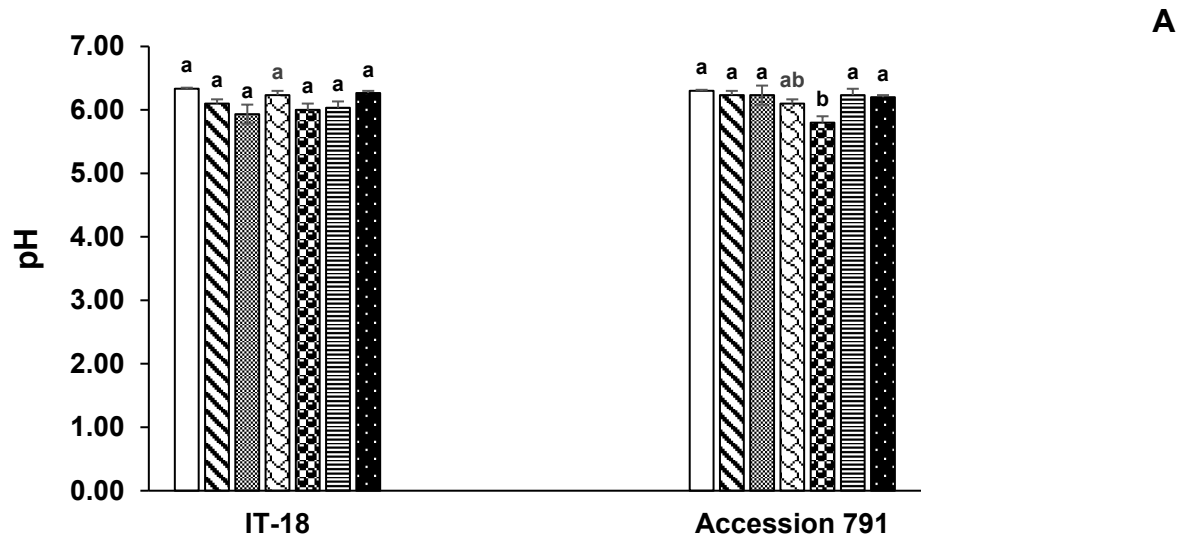
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430 **B**



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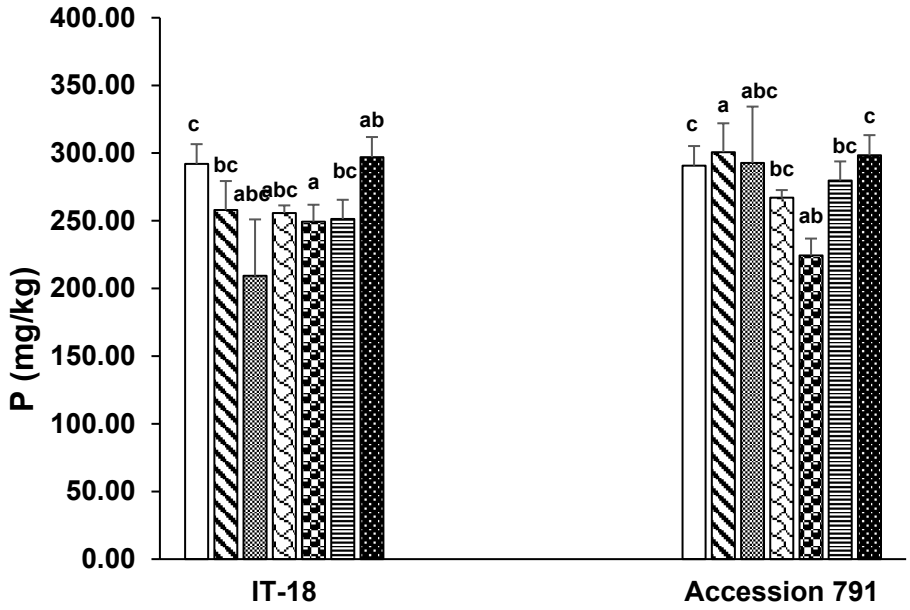
432 **Figure 5.** Interactive effect of genotype x SEAGRO on rhizosphere soil on A) PH, B) P, C) K,
433 D) Mg, E) Fe, and F) Zn concentrations. Bars with dissimilar letters are significantly different
434 at p≤ 0.05.



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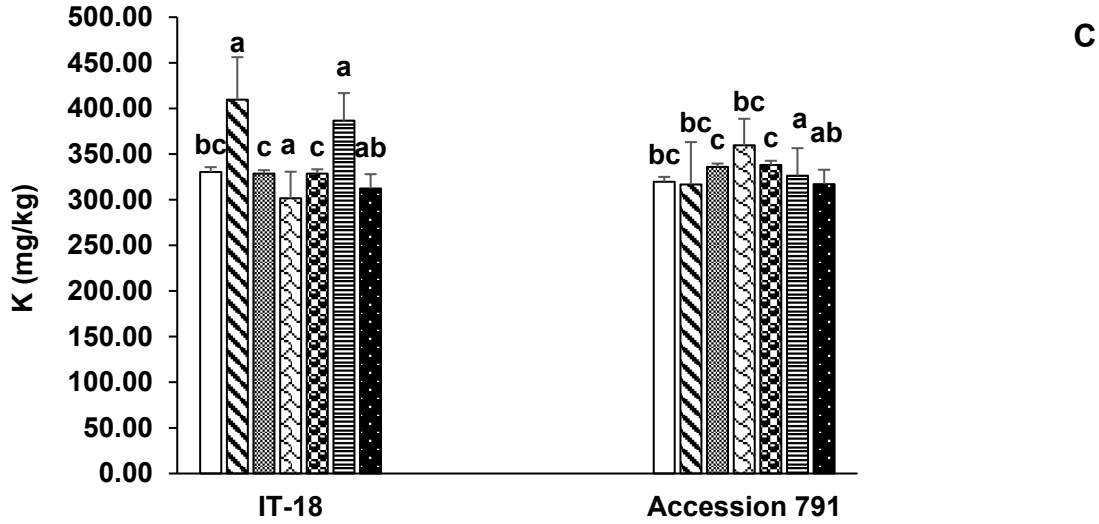
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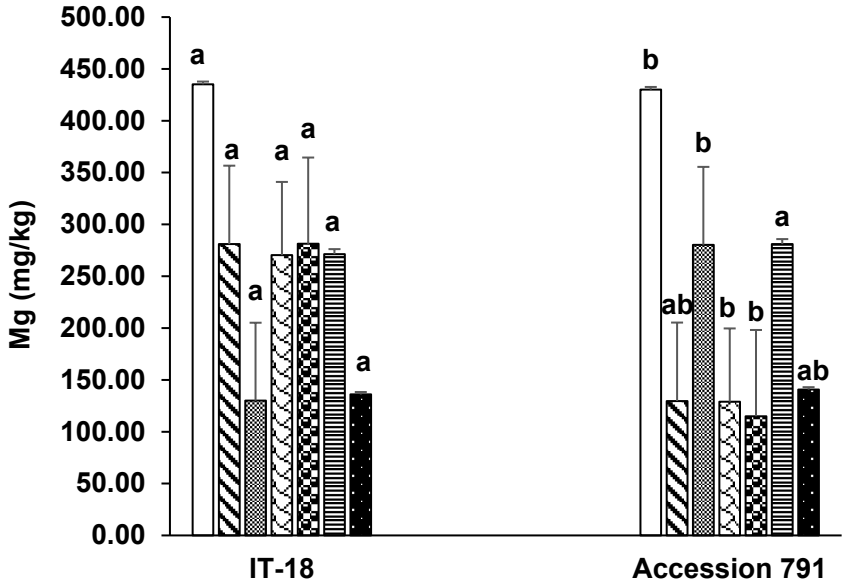
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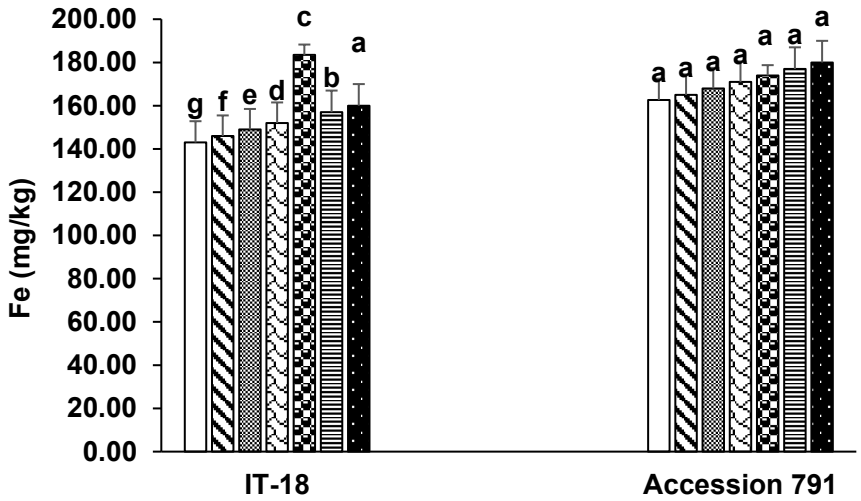
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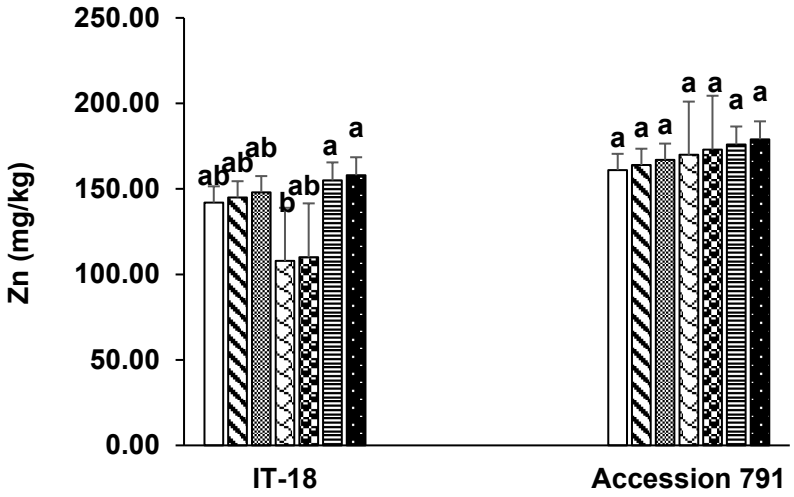

D
Mg (mg/kg)
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
a a a a a a
b ab b b a ab
IT-18
Accession 791

443

444


E
Fe (mg/kg)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
g f e d c b a
a a a a a a a
IT-18
Accession 791

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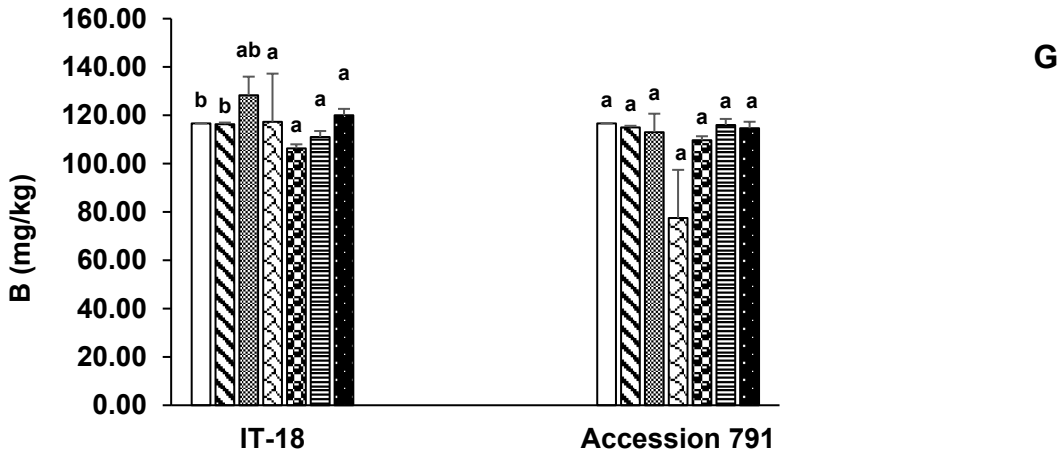
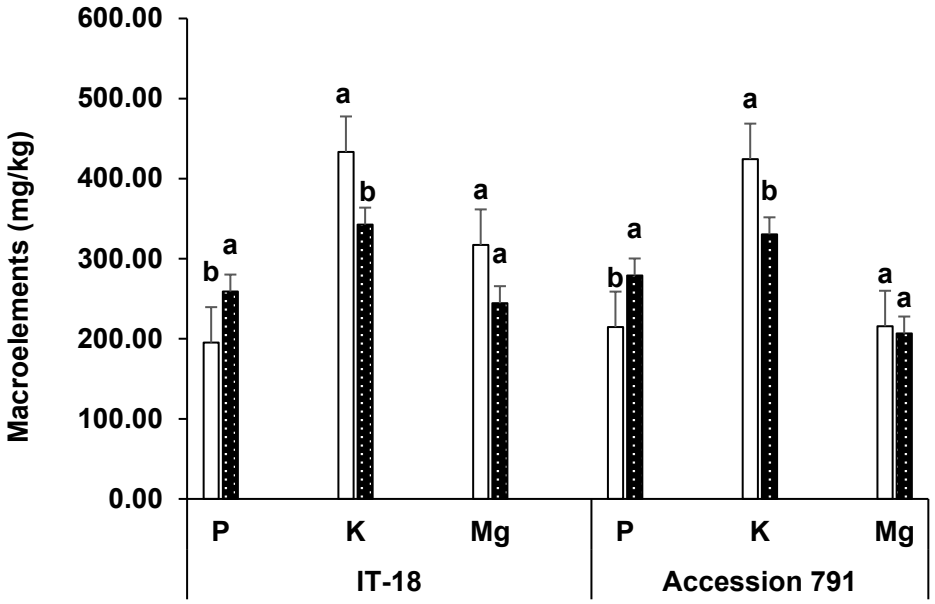


Figure 6. Effects of adding SEAGRO solution on A) P, K, Mg, and B) Fe, Zn, and B concentration in rhizosphere of cowpea genotypes grown in cultivated and uncultivated soil. Vertical bars represent mean values and vertical lines on mean bars represent standard error.

A

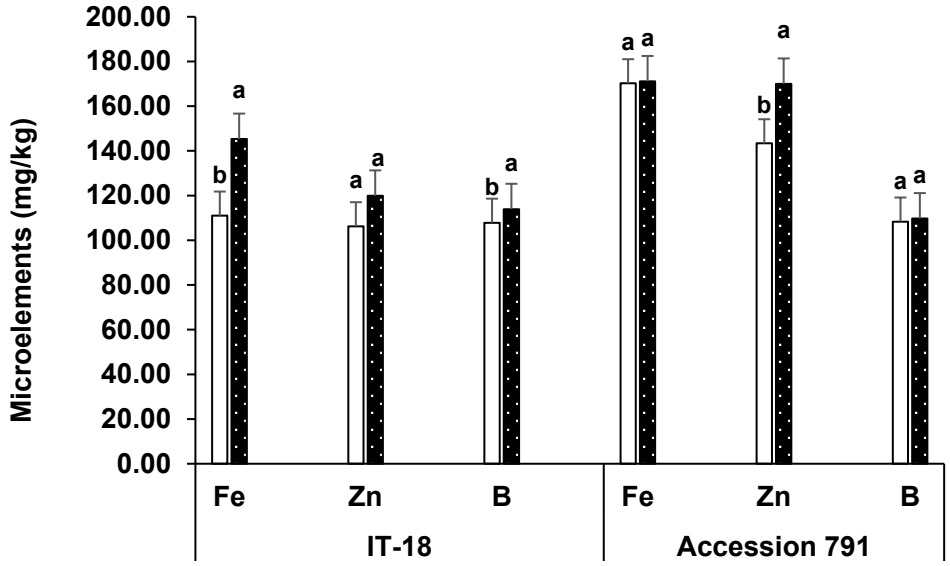


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B



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6.Author Contributions: R.R.: conducted and managed the experiment, collected and analyzed the data, wrote the original manuscript, and revised the manuscript. T.Y.N.: managed the experiment, reviewed and edited the manuscript. S.T.M.: initiated the concept, conceptualized and finalized the research methodology, reviewed and edited the manuscript, and supervision. S.P.: funding acquisition, project administration, reviewed and edited the manuscript.

7. Data Availability Statement: The data that supports the findings of this study are not publicly availabl. However, anonymized data supporting the findings of this study are available from the corresponding author upon reasonable request.

8. Funding: This research received no funding.

9. Plant Ethics declaration

The crop species used in this study were identified and verified by qualified agronomists and researchers from the Malkerns Research station, eSwastini, and the IITA-Nampula, Mozambique, who routinely manage and evaluate these crop species within national agricultural research programs.

9.1Plant accession identified

The crop species used in the experimental trial in this study included two cowpea (*Vigna unguiculata* L.), accessions 791 and IT-18.

9.2 Permission

The soil sample used for the experiments were collected from the Tshwane University of Technology experimental farm, Pretoria, Permission was obtained from the farm manager and the department of crop sciences, Tshwane University of Technology, South Africa. The cowpea accessions used in this study were obtained from the Malkerns Research Station, eSwatini supplied by Mr. Nicolas Manana, IT-18 was obtained from IITA-Nampula, Mozambique, supplied Dr. Steve Boagen.

9.3 Source of plant materials

The study did not involve the collection of wild plants, protected species, endangered species, or herbarium specimens. All seeds used in the experiments were cultivated accessions supplied by Mr. Nicolas Manana (farm manager) at the Malkerns Research Station in eSwatini for Accession 791 and IT-18 from IITA- Nampula- Mozambique supplied by Dr. Steve Boahen (Agronomy specialist).

10. Declaration of Computing.

This manuscript is original unpublished work, read and approved by all authors, and not being considered for publication elsewhere. All those listed as authors have contributed to the development of this paper and have approved of the manuscript and this submission. We have no conflicts of interest to declare.

11. Consent for publication

Not applicable.

12. Consent to Participate:

Not applicable

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