PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 11(2): 575–588
https://doi.org/10.14719/pst.2989

HORIZON
e-Publishing Group
HePG

RESEARCH ARTICLE

The influence of foliar macronutrient on growth and yield of sweet corn grown in Rengam and Rasau soil series under greenhouse conditions

Bilal Adil Mohammed[1], Mohammad Moneruzzaman Khandaker[1]*, Adzemi Mat Arshad[2], Mohammed Saifuddin[3] & Nur Fatihah Hasan Nudin[1]

[1]School of Agriculture Science & Biotechnology, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia.
[2]Laboratory of Soil Science, School of Food Science and Technology Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.
[3]Computer and Communication Engineering (CCE), Faculty of Science and Engineering, International Islamic University Chittagong, Kumira, Chittagong -4318, Bangladesh .

*Email: moneruzzaman@unisza.edu.my

OPEN ACCESS

ARTICLE HISTORY

Received: 02 October 2023
Accepted: 01 February 2024

Available online
Version 1.0 : 09 May 2024
Version 2.0 : 20 May 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Mohammed BA, Khandaker MM, Arshad AM, Saifuddin M, Nudin NFH. The influence of foliar macronutrient on growth and yield of sweet corn grown in Rengam and Rasau soil series under greenhouse conditions . Plant Science Today. 2024; 11(2): 575–588. https://doi.org/10.14719/pst.2989

Abstract

The purpose of this study was to determine the effects of different rates of macronutrients as a foliar applications on growth and yield performance of sweet corn cultivated in Rengam and Rasau soil series of Malaysia under greenhouse condition. The study comprised five treatments of macronutrient fertilization as a foliar application (0, 25, 50, 75 and 100 % NPK). The plant height, stem width, leaf number, leaf area and cob height of sweet corn grown in Rengam soil series were significantly influenced by foliar macronutrient application. Notably, a rise in cob weight of sweet corns cultivated in Rasau soil series was observed at the 75 % rate, reaching 75 g, compared to 68 g for sweet corn grown in Rengam soil series. The foliar application of 100 % NPK resulted in the highest total leaf area at 252.92 cm^2 compared to all other treatments. Regarding the cob fresh weight and dry matter content of sweet corn cultivated in the Rasau soil series, significant improvement noted with the 75 % NPK treatment, however plants grown in the Rengam soil series and treated with 75 % NPK as a foliar application did not exhibit significant effects. The concentrations of Fe and Mn in the corn stem from both soil series significantly increased with macronutrients foliar application. In the corn leaves grown in Rengam soil series, the concentration of nutrients was significantly influenced by the rate of NPK used as a foliar application in this study. Notably, the increased of Ca content in the treated leaves was significantly higher compared to control plants. Additionally, the contents of P, K, Cu and Zn in the corn flower of the plants in the Rengam soil series were significantly elevated in treated plants compared to untreated ones. Conclusively, based on this greenhouse study, it can be inferred that two foliar sprays of macronutrient solution at rates of 75 % and 100 % NPK greatly enhanced the growth, yield and nutrient contents of sweet corn cultivated in the Rengam and Rasau soil series.

Keywords

foliar spray; nutrient; growth; yield; corn; greenhouse; Rengam; Rasau

Introduction

Various concerning problem faced by the world to obtain sufficient food in a sustainable manner in order to meet the demands of an expanding global population due to declining food supplies (1). Plant-based nutrients deficiency problems are faced by about 2 billion people across the world, impacting the development of infants and childs (2). Several factors including water availability temperature, availability of nutrients and light in the soil influence growth of plants. Macro and micronutrients are vital for the growth and development of plants (3). Both macro and micro nutrient elements essential for flowering, fruit and seed formation. Foliar feeding is the practise of feeding plants by delivering fertiliser in the form of liquid directly to their leaves because plants may absorb nutrients through their leaves. Foliar feeding is also referred to as foliar spraying. Both their stomata and their epidermis are used for the absorption (4). Recently, micro and macronutrients, humic materials, plant growth regulators and growth promoting chemical like hydrogen peroxide have been applied through foliar spray. Numerous beneficial effects are observed at morphological, physiological and yield properties of agronomic crops due to foliar fertilization (5). Like as nitrogen and potassium, phosphorus is also a mobile macronutrient in the plants and foliar phosphorus may help the root and seed formation of the plants.

The effect of a single nutrient in the growth and development of plant has been studied in most plant nutrition research, on the other hand, study showed the influence of more than one nutrient in the similar experiment is limited. Due to the fact that it is generated in quantities significantly greater than those required for human nourishment the most significant. The readily available maize as affordable sources of protein and energy has greatly contributed to the swift expansion and development of the livestock and poultry industries. Corn became the main component as knowledge of the nutritional requirements of farm animals and the desire for well -balanced diets grew (6).

Rasau series was primarily composed of sandy loam and had a low organic matter content. The Rasau series was typically described as having a sandy soil texture with more than 54 % sand, 30 %-32 % silt and an average of 13 % clay. In this experiment, the physical characteristics of the soil, including bulk density, soil porosity, soil compaction, hydraulic properties, soil losses and yield, were observed. Rengam series are described as well-drained soils produced on granite, with 10-20 cm of dark greyish brown topsoil above yellowish subsoil above yellowish subsoil (7). Based on the Entisols system of USDA soil classification. It was utilised to monitor how treated POME sludge affected particular soil physical qualities and hydraulic characteristics after treatments were applied. This classification of the Rengam Series follows the Second Approximation of the Malaysian Soil Taxonomy (8). Soil porosity, soil compaction, hydraulic properties, soil losses and yield, were observed above yellowish subsoil (9).

Macronutrients are subsequently lost to surface and groundwaters by leaching and erosion if applied to soil. However, due to their low solubility and relative immobilization these minerals are relatively inaccessible to plants. On the other hand, types of soil, pH and environmental factors can also limit nutrient solubility, uptake and accumulation in the plants. Interestingly, a 25-year trial on an inceptisol in some nations found that continual NPK fertilisation did not change the availability of micronutrients in the topsoil, while the micronutrient availability was higher in the non-fertilized control group (10). The introduction of high-yielding cultivars and studies on how soybeans react to delayed N applications have cast doubt on the use of nitrogen fertilisers for soybeans. On the other hand, because urea top-dressing can result in up to 44 % loss of N-NH3 due to ammonia volatilization, nitrogen fertilisation is one of the most crucial aspects of maize management (11).

Sweet corn is a heavy feeder, proper soil fertility and nutrient supply are critical for plant growth, high yield and quality of corn cob. Poor soil is unable to satisfy the nutrient demand of sweet corn and affects the yield and production of corn. Effect of macronutrient as a foliar application on growth and yield of sweet corn (Thai super sweet) cultivated in Rengam and Rasau soil series studied in this research. There are very few studies about the growth and yield manipulation of sweet corn by foliar macronutrients, although corn is very important and popular grain crop. Although, there is no study reported on the foliar macronutrient's effects on growth and yield of sweet corn at green house conditions. The regulatory effects of foliar macronutrients on growth and yield of sweet corn under greenhouse conditions has not been studied. In order to enhance growth and yield of sweet corn grown in two Malaysian soil series foliar macronutrients were applied as alternative to basal fertilization to reduce loss of nutrients. It is proposed that the application of macronutrients as foliar spray can increase the growth, development and yield of sweet corn under greenhouse conditions.

Materials and Methods

This study was carried out at the greenhouse of the Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Terengganu (UniSZA), Besut Campus, Besut, Terengganu, from February 2022 to January 2023 located at latitude 5° 41' North and longitude 103° 1; East, with altitude of about 32 m above sea level (asl) and tropical rainforest being its climate. It has a men annual rainfall of 2911 mm (114.6 in) and average temperature of 26.7 °C (min 22 °C and max 32 °C), 77.7 % as the relative humidity which ranges from 68 % in May/ Jun in December 2022.

Sweet corn var. Thai Super sweet (*Zee mays* var. *saccharata*) sourced from Bumi Maju Agro enterprise, Kuala Terengganu, Terengganu were used as an indicator plant in this experiment. Two types of soil series Rengam and Rasau were used and were collected from different areas depend on the type of soil, for instants Rasau soil series was collected from Bukit Kor, Marang, Terengganu, Malaysia while Rengam soil series was collected from Bukit Wan Kuala Nerus, Terengganu, Malaysia. The soils were collected within 0-15 cm deep from soil surface, each polybag was filled with 25 kg of the soil series using weighing scale, after removing all weeds then the seeds of sweet corn were planted in the polybag at 75 cm X 25 cm. The plants were watered manually twice a day respectively.

The treatments comprised of 5 different levels of NPK as foliar application, the source of NPK nutrients were inorganic, urea as a source of nitrogen then triple superphosphate (TSP) as a source of phosphorus, while muriate of potash as a source of potassium. the macronutrients were spry individually to the plants for instant 150 kgNha-1 as a source of N, 100 kg P2O5 ha-1 as a sources of P and 150 kg K20 ha-1 as a source of K, the treatments consist of (0, 25, 50, 75 and 100 %) which were spray manually twice at different growth stage, first treatment was applied at 20 days after planting while the second treatment was applied at 40 days after planting. The macronutrients were spry individually to the plants as foliar spray that cultivated in the soil series whereas no addition macronutrient added to the soil. The macronutrients were applied to the plants to reduce the loss of nutrients by leaching and soil erosion.

Experimental Layout

The design used to conduct this study was RCBD with 4 replicates which serves as a block, the factors constitute a total of 10 treatment combinations replicated4 times as block which gave a total of 40 experimental units. The corn seedlings were treated with 0% (control), 25 %, 50 %, 75 % and 100 % of NPK as a foliar application for both Rengam and Rasau soil series. A total of 10 treatment combinations was used in this study for 2 soil series of Malaysia under greenhouse conditions. The plants were monitored for data on growth performance of the crop at 10 days interval until harvest. Then the plants were harvested at 75 days after planting. Data on several aspects of plant growth were gathered. Every 10 days following planting, the maize plants were observed to gauge their growth. Plant height from the base to the top of the plant, stem diameter, leaf area and the number of leaves were all measured.

Leaf area was calculated by getting the product of the leaf length, leaf width and a leaf correction factor (0.75).

$$LA = LL \times LW \times 0.75$$

Where, LA = Leaf Area, LL = Leaf Length and LW = Leaf Width

Flowering date was calculated manually, starting from the date of the male flower was appeared.

The fresh cob was analysed for its yield potentials, parameters was taken and methods are listed below. Meter ruler was used in measuring the cob length and recorded accordingly.

Fresh Cob Width, Fresh Cob Weight and Relative Yield (%)

Using a digital vernier calliper (Mitutoyo absolute digimatic, Japan), the breadth of the new cob was measured. On an electronic scale (GF-3000 by A&D, Japan), the fresh cob was weighed. Using a method developed, the relative yield of sweet corn was calculated using the weight of the fresh cob (12). A curve at 90 % is plotted on the % yield line graph, which is used to determine the real rate of manure that will produce an optimal yield of 90 %, where the maximum yield is being utilised to find relative percent yield achieved from other treatments.

Calculations; Manure rates (y, x, w and t)

y/y * 100 (if y has the highest yield) ……… 1

x/y * 100…………………………………..… 2

w/y * 100…………………………….….…..3

t/y * 100……………………………….…..… 4

The rate with the highest yield was picked and utilised in getting the % of the yield of other treatments versus the highest and the graph was produced using the result.

Dry Weight and Nutrients Analysis for Corn

At the end of the experiment, plants were harvested to measure dry weights of roots, stems, leaves and flowers. The leaves, stems, flowers and roots were cut out, and then dried in an oven at 80 °C for 72 h. Nutrient in leaves, stem, cob, flower and root such as N, P, K, Ca, Mg, Cu, Zn, Fe and Mn were analysed using dry Ashing method. 2 g of finely ground dried mature leaves samples were taken and replaced in crucible. Then the crucible contains the sample was into the muffle furnace at 500 °C for 5 h. Then the crucible with white and grayish ash was left to be cool, 2 mL of 37 concentrated HCl was added, evaporate to dryness on a hot plate. 10 mL of 20 % HNO3 was added into the water bath for 1 h. The mixture was transferred in to a 100 mL volumetric flask and made up to100 mL distilled water, finally the mixture was shake and filtered using Watman no.2 and the sample analysed for macronutrient by using Inductively Coupled Plasma Mass Spectrophotometer (ICP). Nutrient's uptake of N, P, K, Ca, Mg, Cu, Zn, Fe and Mn of root, stem leaves and flower was calculated using dry weight multiply with nutrient concentration on various parts of corn. Total nutrient uptake of corn plant was calculated by adding the nutrient uptake from various corn plants

Soil Nutrient Analysis

The nutrient content of each soil series was analysed before planting of sweet corn for this current experiment as

Table 1. Methods for soil analyses

Analysis	Method	Reference
N	Semi-micro Kjeldahl	(13)
P	Bray & Kurtz No.2	(14)
K, Ca & Mg	1 N NH4 OAc at pH 7.0	(15)
Cu, Mn& Zn	0.1 NHCL	(16)
Organic Carbon	Walkley & Black	(17)
pH	1:2.5 soil: solution	(18)
Texture	pipette	(19)

shown in Table 1.

Experimental Design and Data Analysis

The experiment was conducted using randomized complete block design (RCBD) with four replications which serves as block. The data were analysed using SAS software (Ver. 9.1) (SAS institute, Inc., Cary, MC, USA). The treatments means were compared by using DMRT at $p<0.05$ level of probability.

Results

Plant height

There was a significant effect of foliar macronutrient (NPK) on plant height of sweet corn cultivated in Rengam soil series under greenhouse condition. The plant height of the sweet corn was measured every 10 days for 6 times in this study. The results showed that foliar macronutrient application produced significant effect on plant height of sweet corn from first to fourth measurements, while, corn plant height is not affected significantly from 50 DAS to 60DAS (Table 2). On the 40 DAS of observation, the highest plant height was recorded in 75 % NPK treatment with a value of 87.50 cm, whereas, the lowest plant height (69.25 cm) was found in control treatment of Rengam soil series (Table 2). On the 60 DAS of measurement, the foliar NPK did not produce any significant on plant height of sweet corn but 75 % NPK treatment showed better effect on plant height increment (Table 2).

Table 2. Effects of different level of foliar NPK on plant height (cm) of sweet corn grown in Rengam and Rasau soil series.

Soil series	Treatment (%)	Growth period (10 DAS)					
		10DAS	20DAS	30DAS	40DAS	50DAS	60DAS
Rengam	0	11.500^{ab}	27.375^{a}	51.000^{a}	69.25^{ab}	102.25^{a}	114.75^{a}
	25	13.000^{a}	25.125^{ab}	50.750^{a}	69.25^{ab}	116.50^{a}	207.00^{a}
	50	11.000^{b}	24.000^{ab}	44.000^{ab}	68.25^{ab}	137.00^{a}	183.75^{a}
	75	12.000^{ab}	26.250^{ab}	51.000^{a}	87.50^{a}	179.00^{a}	214.75^{a}
	100	11.125^{b}	21.750^{a}	37.000^{b}	63.25^{b}	127.00^{a}	196.75^{a}
Rasau	0	11.625^{a}	24.750^{a}	44.500^{a}	68.000^{a}	148.00^{a}	161.50^{a}
	25	10.125^{ab}	19.625^{a}	35.250^{a}	70.750^{a}	145.25^{a}	175.00^{a}
	50	10.625^{ab}	23.000^{a}	44.667^{a}	69.250^{a}	159.25^{a}	190.00^{a}
	75	10.125^{ab}	22.375^{a}	44.250^{a}	73.750^{a}	155.00^{a}	177.50^{a}
	100	09.000^{b}	20.750^{a}	45.000^{a}	70.000^{a}	143.50^{a}	177.50^{a}

Different small case letters in the same column of the table of each soil series indicate significant difference (DMRT, $p < 0.05$).

Using different rates of NPK as a foliar fertilizer has significant effect on plant height of sweet corn grown in Rasau soil series. As it's seen in Table 2, there is a significant effect on plant height at first measurement only. While there was no significant effect on plant height at the rest of the measurement. The lowest height could be seen at first measurement is 9.0 cm for the rate of 100 %, while the highest height can be seen at 11 cm at rate of 0 % compared to rate of 25, 50 and 75 % at 10.125, 10.625 and 10.125 cm respectively. On the last measurement of the height, as it seen there was no significant effect among all the treatments, but using rate of 50 % had the highest height at 190 cm, while the lowest height can be seen at rate of 0 % with height of 161.50 cm.

The 1st, 2nd, 3rd and 4th measurements of plant height all show a substantial difference, as shown in Table 2. The 15th and 16th measurements showed no discernible impact on plant height. The highest height may be observed at 13 cm at a rate of 25 %, while the lowest height can be seen at 11 cm with a rate of 50 % at initial measurement. When using a rate of 100 %, the plant is 11.125 cm tall, whereas when using a rate of 75 %, the plant is 12 cm tall. On the third measurement, there was a significant difference between the rates of 50 % and 100 % at 44.00 and 37.00 cm and rates of 0 %, 25 % and 75 % at 51.00, 50.75 and 51.00 cm.

Stem width

Stem width of the sweet corn was measured every 10 days for 5 times. There was a significant effect using different rates of NPK as a foliar fertilizer on stem width of sweet corn grown in Rengam soil series. As it's seen in Table 3, there is a significant effect on stem width at first and fifth measurements only, while there was no significant effect on stem width at the rest of the measurements. The lowest stem width could be seen at first measurement is 0.8750 mm for the rate of 100 %, while the highest stem width can be seen at 1.15 mm for the rate of 0 followed by 1.10 mm for the rate of 75 %. On the last measurement, thought there was a significant effect among the treatments, the highest stem width was found to be at 2.25 mm followed with 2 mm for the rate of 0 and 100 % respectively.

Table 3 shows the effect of different level of foliar NPK on stem width (mm) of sweet corn cultivated in Rasau soil series, as it is seen in the table, there was no significant effect using different rates NPK as a foliar application on stem width of sweet corn cultivated in Rasau soil series.

Leaf number

As it is seen in Table 4, a significant effect using different rates of NPK as a foliar fertilizer on leaf number of sweet corns grown in rengam soil series. A significant effect on

Table 3. Effects of different level of foliar NPK on stem width (mm) of sweet corn grown in rengam and rasau soil series.

Soil series	Treatment (%)	Growth period (10DAS				
		10DAS	20DAS	30DAS	40DAS	50DAS
Rengam	0	1.150[a]	1.8750[a]	2.0750[a]	2.0000[a]	2.2500[a]
	25	1.025[ab]	1.6250[a]	2.1250[a]	1.7500[a]	1.6250[b]
	50	1.075[ab]	1.6250[a]	2.1250[a]	2.1250[a]	2.2500[a]
	75	1.100[ab]	1.4000[a]	2.2500[a]	1.7500[a]	1.7500[b]
	100	0.875[b]	1.4750[a]	1.8750[a]	1.7500[a]	2.0000[ab]
Rasau	0	0.950[a]	1.4750[a]	1.8750[a]	1.5000[a]	1.7500[a]
	25	0.800[a]	1.5000[a]	1.7500[a]	1.5000[a]	1.6250[a]
	50	1.050[a]	1.4000[a]	1.8250[a]	1.5000[a]	1.625 [a]
	75	0.950[a]	1.8500[a]	1.8750[a]	1.7500[a]	1.8750[a]
	100	0.725[a]	1.5000[a]	1.6250[a]	1.5000[a]	1.8750[a]

Table 4. Effects of different level of foliar NPK on leaf number of sweet corns grown in rengam and rasau soil series.

Soil series	Treatment (%)	Growth period (10DAS)					
		10DAS	20DAS	30DAS	40DAS	50DAS	60DAS
Rengam	0	5.00[a]	7.2500[a]	8.5000[ab]	8.2500[b]	9.250[a]	10.750[a]
	25	5.00[a]	6.7500[a]	10.2500[a]	8.2500[b]	9.000[a]	11.250[a]
	50	5.00[a]	7.2500[a]	9.2500[ab]	8.2500[ab]	10.750[a]	11.000[a]
	75	5.00[a]	7.2500[a]	9.0000[ab]	9.7500[a]	10.500[a]	10.500[a]
	100	5.00[a]	7.0000[a]	7.7500[b]	8.0000[a]	9.500[a]	9.750[a]
Rasau	0	5.00[a]	6.7500[a]	7.5000[ab]	8.2500[a]	9.7500[a]	8.7500[b]
	25	4.50[a]	6.5000[a]	6.2250[b]	9.5000[a]	10.2500[a]	9.5000[ab]
	50	4.75[a]	7.0000[a]	7.6667[ab]	8.0000[a]	10.2500[a]	9.5000[ab]
	75	4.50[a]	6.7500[a]	8.7500[a]	9.5000[a]	10.7500[a]	10.5000[a]
	100	4.50[a]	6.7500[a]	8.5000[a]	9.7500[a]	9.5000[a]	9.7500[ab]

leaf number at third and fourth measurements was recorded. The lowest leaf number could be seen at third measurement is 7.75 for the rate of 100 % compared to the highest leaf number at 10.25 for the rate of 25. Fourth measurement, a significant effect was found among the treatments, the highest leaf number was found to be at 9.75 for the rate of 75 % followed by the lowest leaf number at 8 for the rate of 100 %.

As it's seen in Table 4 for Rasau soil series, there is no significant effect of leaf number on every measurement except on third and sixth measurements. The lowest leaf number in the third measurement was 6.22 for the rate of 25 %, while the highest leaf number 8.75 was recorded at rate of 75 %. On the last measurement, as it seen there is a significant effect on leaf number among all the treatments but using rate of 75 % had the highest leaf number at 10.50, while the lowest leaf number can be seen at rate of 0 % with leaf number of 8.75. Different levels of NPK as a foliar fertilizer show a significant effect on leaf number of sweet corns grown in Rasau soil series. As stated in the Table 4, a significant effect was found on leaf number which can be seen at fifth measurement, the lowest leaf number was seen at the rate of 0 % at 7.25, while the highest leaf number by using the rate of 75 and 100 % at 9.

Leaf area

Different rates of NPK as a foliar fertilizer show a significant effect on leaf area of sweet corn as it is seen in Table 5. There is a significant effect between 0 and 100 % at 121.0 and 252.92 respectively. Using rate of 100 % had the highest total leaf area at 252.92 compared to all other

Table 5. Effects of different level of foliar NPK on leaf characteristics and flowering day of sweet corn grown in two types of soil s eries.

Treat (%)	Rengam soil series				Rasau soil series			
	L	W	T	Flowering day	L	W	T	Flowering day
0	95.25[a]	7.25[a]	521.44[a]	53.75[a]	81.00[a]	7.00[a]	415.4[a]	49.25[a]
25	87.00[a]	7.25[a]	476.34[a]	54.25[a]	88.75[a]	6.87[a]	456.94[a]	50.00[a]
50	90.75[a]	7.25[a]	495.75[a]	52.75[a]	90.50[a]	6.62[a]	441.28[a]	50.25[a]
75	92.00[a]	7.37[a]	507.66[a]	48.25[a]	91.75[a]	7.25[a]	503.16[a]	50.25[a]
100	89.25[a]	6.87[a]	463.50[a]	52.50[a]	93.25[a]	6.12[a]	435.47[a]	47.00[a]

L= Leaf length, W= Leaf width, T = Total leaf area treatments. Even though using different rates of NPK as a foliar fertilizer show no significant effect on leaf area of sweet corn cultivated in Rengam soil series but rate of 0 and 75 % showed the highest number at 521.44 and 507.66 respectively. Using different rates of NPK as a foliar fertilizer show no significant effect on leaf area of sweet corn cultivated in Rasau soil series while highest leaf area was found using rate of 75 % at 503.47.

Flowering date

Different rate of NPK as a foliar application did not produce significant effect on sweet corn flowering in 2 different type of soil series. Sweet corn cultivated in Rengam soil series with the treatment of 75 % has given flowers at minimum days at 48.25 while maximum days required of flowering at treatment of 25 % with 54.25 days after planting. Rasau soil series showed minimum days of sweet corn flowering date treated with 100 % of NPK as foliar application at 47 days while maximum days required of flowering at treatment of 50 and 75 % at 50.25 respectively.

Cobs Fresh weight

Different rates of NPK as a foliar fertilizer showed no significant effect on cob fresh weight and cob height of sweet corn grown in 2 different types of soil series (Fig. 1). Although the highest cob weight (67.25 g) was found in the plant treated with rate of 75 and 100 % NPK in Rengam soil series. The highest cob height was found at the plant treated with rate of 50 % at 19.50 cm. The highest cob diameter was also seen at plant treated with the rate of 50 % with a diameter of 41.75 mm.

Different rates of NPK as a foliar fertilizer showed no significant effect on cob fresh weight of sweet corn cultivated in Rasau series (Fig. 1). The highest cob weight and cob height were found in plant treated with rate of 25 and 75 % with a value of 72.25 and 70.25 g respectively. The highest Cob was found to be at sweet corn treated with 25 and 745 % at 18 cm. The 25 and 75 % NPK treatment was also produced highest cob diameter with a value of 44.98 and 42.08 mm respectively (Fig. 2). It was also reported that the plant treated with 75 % NPK as a foliar fertilizer increased the yield characteristics of sweet corn under greenhouse condition cultivated in Rengam and Rasau soil series (Fig. 1 & 2).

Relative yield (%)

It can be seen in the that the relative yield (%) cob weight of Rengam and Rasau soil series was significantly affected by different treatments of NPK fertilizer as foliar spray (Fig. 3). The highest relative yield of sweet corn grown in Rengam soil series was recorded in 75 and 100 % NPK foliar treatment. In case of Rasau soil series highest relative yield of sweet corn found in plants treated with 25 and 75 % NPK treatment. The control treatment produced the lowest relative yield for the both soil series.

Dry weight

Dry weight of the plant was measured at the end of the experiment soon as the plant was harvested and it was affected significantly with the foliar NPK application in 2 soil series (Fig. 4). Root dry weight of the sweet corn was the highest 10.55 g at the 50 % NPK treatment, while the lowest value recorded in control plants. Sweet corn seedlings of Rengam soil series treated with 50 % NPK produced the highest stem, leaf and flower dry weight with a value of 32.23 g, 24.28 g and 3.23 g respectively. On the other hand, the lowest reading of root, stem and leaf were shown in the control treatment (Fig. 5). The sweet corn flower dry weight was not significantly affected by the different rate of NPK in both soil series (Fig. 5).

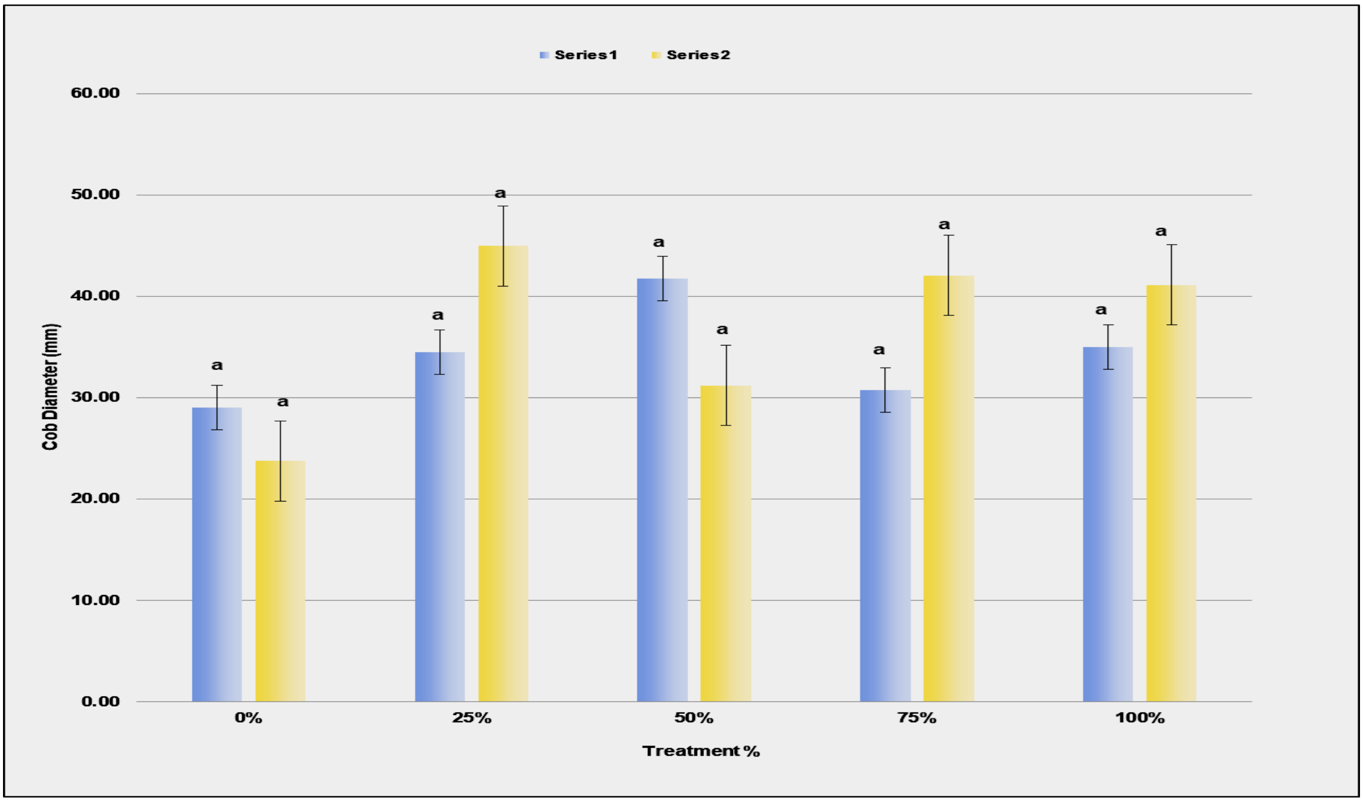

Fig. 1. Effects of different level of foliar NPK on fresh cob weight and cob height of sweet corn grown in rengam and rasau soil series.

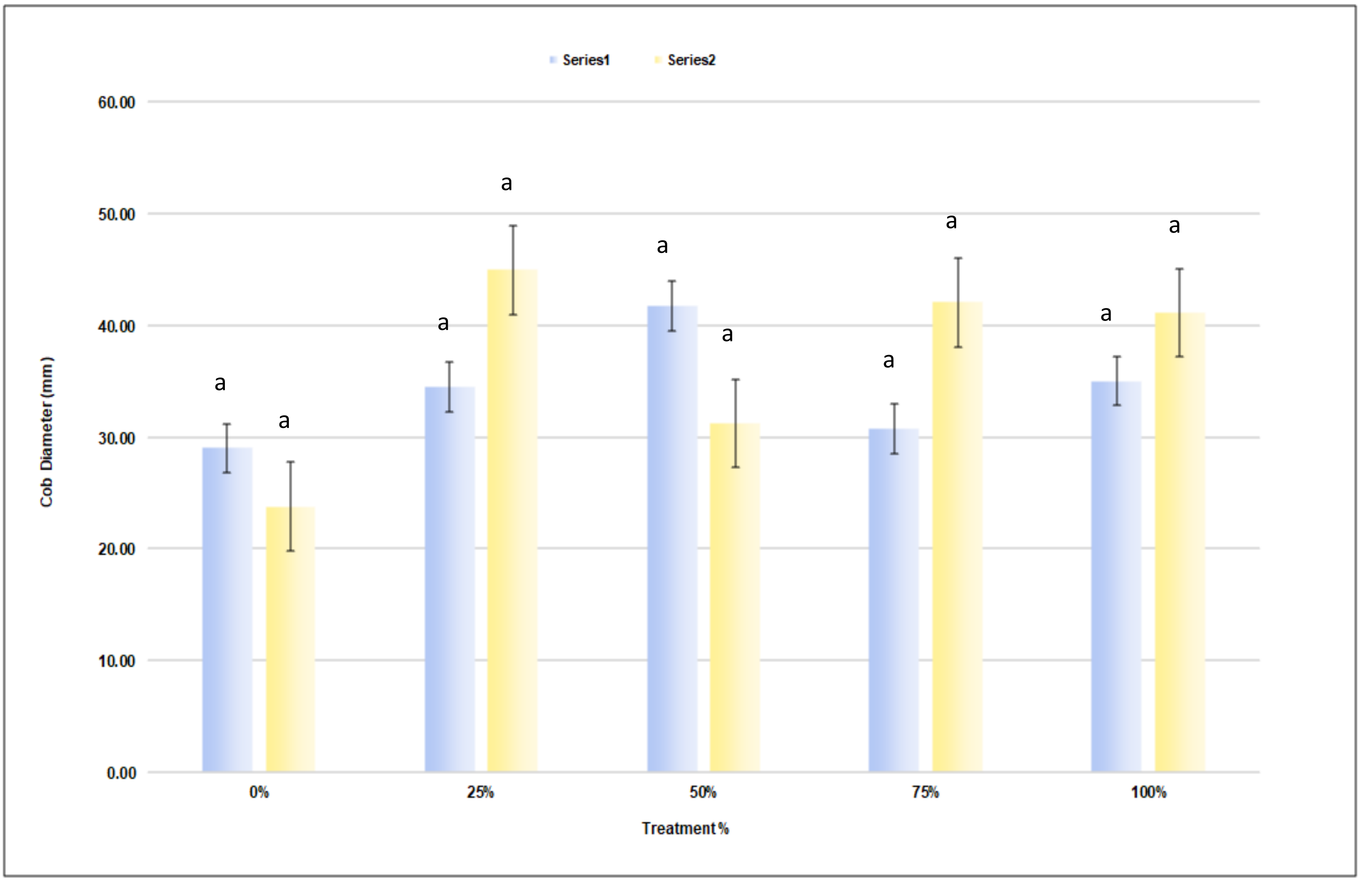

Fig. 2. Effects of different level of foliar NPK on fresh cob diameter of sweet corn grown in Rengam and Rasau soil series.

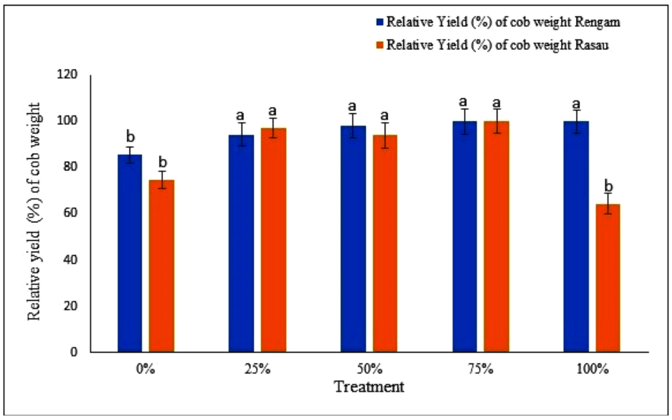

Fig. 3. Effects of different level of foliar NPK on relative yield of sweet corn grown in Rengam and Rasau soil series.

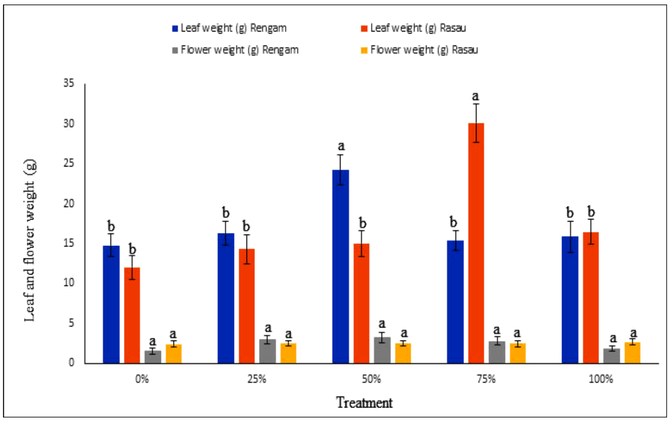

Fig. 5. Effects of different level of foliar NPK on leaves and flower dry weight of sweet corn grown in Rengam and Rasau soil series.

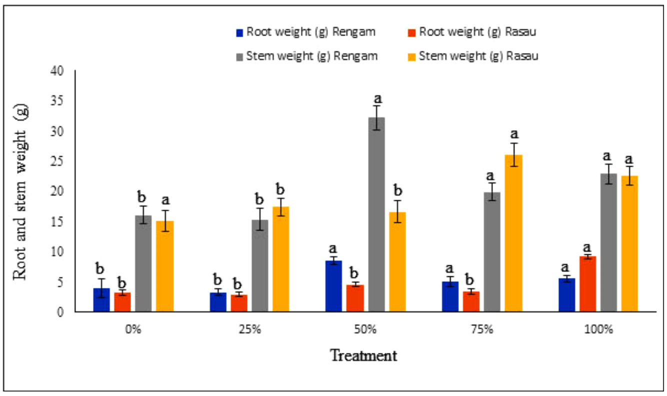

Fig. 4. Effects of different level of foliar NPK on root and stem dry weight of sweet corn grown in Rengam and Rasau soil series.

Sweet corn plant cultivated in Rasau soil series with different rate of NPK as a foliar application has resulted a significant effect on dry weight of the plant. Root dry weight of the sweet corn was the highest (9.26 g) with the 100 % NPK. The treatment 75 % produced highest stem and leaf dry weight with a value of 26.108 g and 30.04 g respectively. Flower dry of sweet corn plant weight was not affected significantly by the different rates of foliar fertilizer at Rasau soil series (Fig. 5).

Root nutrient concentration (%) of plant cultivated in Rengam soil series

The macro and micronutrients concentration of sweet corn root cultivated in Rengam soil series were not affected significantly by using NPK as foliar application (Table 6). An increase in the rate of NPK results to increase in concentration of Mg, Cu, Ca and P in the corn root but decrease the concentration of Mn (Table 6). The treatment 75 % resulted high concentration N and K with a value of 1.0794 and 2.322 % respectively, while 50 % treatment resulted higher Zn concentration around 0.00149 %.

There was no statistically significant effect of using

NPK as a foliar application on nutrient concentration of corn root cultivated in Rasau soil series in all nutrients analysed except for N and Mg (Table 6). The highest concentration of N recorded at 75 % treatment with a value of 1.0364 %. On the other side, the concentration of Mg was reached to the highest at the plant treated with the rate of 100 % at 0.1839 %. Although, sweet corn treated with the rate of 75 % of NPK as a foliar fertilizer resulted to 0.1826 %. The control treatment resulted lowest amount of Mg in the root of sweet corn (Table 6).

Table 6. Effects of different level of foliar NPK on nutrient contents (%) of the root of sweet corn plant grown in rengam and rasau s oil series.

Soil series	Treat %	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
Rengam	0	0.832^{a}	0.108^{a}	1.467^{a}	0.220^{a}	0.158^{a}	0.0006^{a}	0.0010^{a}	0.615^{a}	0.0078^{a}
	25	0.8575^{a}	0.09^{a}	1.354^{a}	0.199^{a}	0.153^{a}	0.0004^{a}	0.0012^{a}	0.389^{a}	0.0448^{a}
	50	1.227^{a}	0.093^{a}	2.025^{a}	0.276^{a}	0.177^{a}	0.0006^{a}	0.00149^{a}	0.771^{a}	0.0162^{a}
	75	1.079^{a}	0.079^{a}	2.322^{a}	0.301^{a}	0.145^{a}	0.0011^{a}	0.00148^{a}	0.535^{a}	0.0115^{a}
	100	1.059^{a}	0.125^{a}	1.469^{a}	0.310^{a}	0.230^{a}	0.0014^{a}	0.00135^{a}	0.574^{a}	0.0130^{a}
Rasau	0	1.016^{a}	0.182^{a}	1.441^{a}	0.227^{a}	0.120^{ab}	0.0006^{a}	0.0021^{a}	0.308^{a}	0.0554^{a}
	25	0.803^{b}	0.146^{a}	1.424^{a}	0.137^{a}	0.108^{b}	0.0010^{a}	0.0019^{a}	0.203^{a}	0.0346^{a}
	50	1.0156^{a}	0.499^{a}	1.343^{a}	0.219^{a}	0.178^{a}	0.1706^{a}	0.0023^{a}	0.194^{a}	0.0304^{a}
	75	1.036^{a}	0.243^{a}	1.733^{a}	0.183^{a}	0.182^{a}	0.0005^{a}	0.0022^{a}	0.1149^{a}	0.0195^{a}
	100	1.031^{a}	0.179^{a}	1.500^{a}	0.242^{a}	0.183^{a}	0.0007^{a}	0.0016^{a}	0.200^{a}	0.0293^{a}

Stem nutrient concentration (%)

The different treatment of NPK as a foliar spray did not produce significant effects on nutrient concentration except for Fe and Mn in the stem tissue of corn plant cultivated in Rengam soil series under this study (Table 7). As for Fe, an increase in the rate of NPK results to decrease in concentration in the corn stem tissue. The highest amount of Fe and Mn recorded in the treatment 25 % NPK with a value of 0.118 % and 0.0243 %, however, it starts to decrease with the higher concentration of NPK. The lowest concentration of the Mn nutrient element at stem tissue of control sweet corn was found to be at 0.0098 %. The concentration of Fe and Mn nutrients in the corn stem cultivated in Rasau soil series was significantly affected by the rate of NPK as a foliar application in this study (Table 7). Other macro and micro nutrients were not significantly affected by the different rates of NPK as foliar spray. Control treatment followed by rate of 75 % resulted to a high concentration of Fe at 0.1549 and 0.1205 % respectively. The amount of Mn in the stem of sweet corn was also highest in control plants compared to other treatments (Table 7).

Leaf tissue nutrient concentration (%)

The concentration of N, P and Ca nutrients in the corn leaf which is cultivated in Rengam soil series was significantly affected by the rate of NPK as a foliar application (Table 8). The highest amount of N concentration (1.18 %) was recorded in 100 % NPK treatment and control treatment yielded lowest amount of N. Leaf P content was highest in 25 % NPK treatment, whereas, control plants produced the lowest amount (Table 8). The Lowest concentration of the Ca nutrient element at leaf tissue of sweet corn was found for the control plants, whereas, the plant treated with the rate of 100 % produced the highest amount of Ca 0.7178 %.

Result showed no significant effect of NPK rate across all measured nutrients element except for Zn, K and Cu which shows a significant effect table 8 in Rasau soil series. As for Zn, an increase in the rate of NPK at 100 % results to high concentration of Zn at 0.0081 while control treatment resulted the lowest concentration of Zn with a value of 0.021 %. The lowest concentration (1.9144 %) of the K nutrient element of leaf tissue of sweet corn was

Table 7. Effects of different level of foliar NPK on nutrient contents (%) of the stem of sweet corn plant grown in Rengam and Rasau s oil series.

Soil series	Treat %	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
Rengam	0	1.1235^{a}	0.1435^{a}	2.726^{a}	0.1749^{a}	0.1403^{a}	0.00035^{a}	0.00090^{a}	0.047^{b}	0.0098^{b}
	25	1.0551^{a}	0.1541^{a}	3.492^{a}	0.2097^{a}	0.1641^{a}	0.00044^{a}	0.00139^{a}	0.118^{a}	0.0243^{a}
	50	1.0288^{a}	0.1028^{a}	2.346^{a}	0.1534^{a}	0.1188^{a}	0.00075^{a}	0.00071^{a}	0.060^{b}	0.0135^{b}
	75	1.0425^{a}	0.1162^{a}	3.085^{a}	0.1777^{a}	0.1193^{a}	0.00260^{a}	0.00088^{a}	0.065^{b}	0.0128^{b}
	100	1.0186^{a}	0.1446^{a}	3.024^{a}	0.2008^{a}	0.5611^{a}	0.00030^{a}	0.0011^{a}	0.061^{b}	0.0143^{b}
Rasau	0	1.1205^{a}	0.3387^{a}	2.8075^{a}	0.2006^{a}	0.1154^{a}	0.00030^{a}	0.0034^{a}	0.1549^{a}	0.0323^{a}
	25	1.0503^{a}	0.1672^{a}	2.9809^{a}	0.1663^{a}	0.0980^{a}	0.0020^{a}	0.0038^{a}	0.0288^{c}	0.0073^{c}
	50	0.9922^{a}	0.2802^{a}	2.4747^{a}	0.1361^{a}	0.1231^{a}	0.0003^{a}	0.0036^{a}	0.0369^{c}	0.0087^{c}
	75	1.0482^{a}	0.2674^{a}	2.1893^{a}	0.1362^{a}	0.1071^{a}	0.0004^{a}	0.0025^{a}	0.1205^{ab}	0.0253^{ab}
	100	0.9742^{a}	0.2567^{a}	2.5652^{a}	0.1863^{a}	0.1448^{a}	0.0003^{a}	0.0043^{a}	0.0597^{bc}	0.0123^{cb}

Table 8. Effects of different level of foliar NPK on nutrient contents (%) of the leaf of sweet corn plant grown in rengam and rasau s oil series.

Soil series	Treat %	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
Rengam	0	1.0380[b]	0.1752[b]	2.4136[a]	0.4684[b]	0.269[a]	0.00043[a]	0.00216[a]	0.075[a]	0.0203[a]
	25	1.0744[a]	0.3035	2.9516[a]	0.7032[a]	0.300[a]	0.00211[a]	0.00249[a]	0.083[a]	0.0240[a]
	50	1.0465[a]	0.1975	2.6622[a]	0. 4890[b]	0.272[a]	0.00058[a]	0.00171[a]	0.152[a]	0.0231[a]
	75	1.0746[a]	0.1994	2.8203[a]	0.5983[ab]	0.224 [a]	0.00051[a]	0.00239[a]	0.061[a]	0.0184[a]
	100	1.1775[a]	0.1827	2.8719[a]	0.7178[a]	0.270 [a]	0.00068[a]	0.00215[a]	0.079[a]	0.0234[a]
Rasau	0	1.0448[a]	0.1427	1.9144[b]	0.6157[a]	0.2149[a]	0.0004[b]	0.0021[b]	0.0716[a]	0.0251[a]
	25	0.9236[a]	0.1908	2.2420[ab]	0.5784[a]	0.2209[a]	0.0005[b]	0.0031[b]	0.0547[a]	0.0230[a]
	50	0.9998[a]	0.2383	2.0363[ab]	0.5951[a]	0.3148[a]	0.0004[b]	0.0041[b]	0.084[a]	0.0279[a]
	75	0.9686[a]	0.2510	2.5787[a]	0.5155[a]	0.2278[a]	0.0004[b]	0.0040[b]	0.0840[a]	0.0253[a]
	100	1.0863[a]	0.3599[a]	2.2535[ab]	0.6855[a]	0.3245[a]	0.0007[a]	0.0081[a]	0.0718[a]	0.0244[a]

found in control plants, on the other hands plants treated with the rate of 75 % and 25 % resulted to the highest concentration of the K with a value of 2.5787 and 2.2420 respectively. There was also a significant effect on concentration of Cu, where the plant treated with the high rate of NPK 100 % resulted to the high concentration of Cu at 0.0007 (Table 8).

Flower nutrient concentration (%)

There was statistically significant effect of using NPK as a foliar application on nutrient concentration of corn flower cultivated in Rengam soil series in all nutrients analysed except for N, Fe, Mg, Mn and Ca (Table 9). Using rates of 25, 50 and 100 % have the highest concentration of Zn at 0.00592, 0.00532 and 0.00571 respectively. The rate of 25 % NPK produced the highest concentration of K and Cu with a concentration of 0.913 and at 0.0008 %. The sweet corn seedlings treated with 75 % of NPK as a foliar fertilizer resulted to highest amount of P with a value of 0.1428.

The nutrients concentration of corn flower cultivated in Rasau soil series were not affected significantly by the different doses of NPK as a foliar application (Table 9). The amount of macro nutrients (N, P & K) was increased with the lower dose of NPK (25 % NPK) but decrease with high doses of NPK. The plants treated with 75 % NPK resulted higher amount of Mg, Zn, Fe and Mn in the flower of sweet corn (Table 9).

Discussion

To evaluate the effects of foliar macronutrients on the growth, yield and internal nutrient content of sweet corn cultivated on Rengam and Rasau soil series under greenhouse conditions, different percentages of NPK fertilisers were applied as a foliar spray. The results showed that foliar application of macronutrients (NPK) at 75 % and 100 % NKP significantly improved the plant growth and development of the sweet corn grown in Rengam and Rasau soil series. This study confirmed that foliar application of NPK nutrients increased the growth, yield and nutrient levels in sweet corn plants under greenhouse condition. The plant height of the sweet corn increased significantly with the foliar NPK. Foliar nutrient can increase the crop yield by improving the availability of the nutrients compared to the soil applied nutrients which sometimes are not readily available in the soil (20). They also reported that foliar application of nutrient improves the quality of cereals, vegetables, and fruit trees in alkaline and calcareous soil. This current study showed that foliar spray of NPK increased growth, yield and nutrient accumulation in the sweet corn plants. In this study, the positive effect of different rates of NPK as a foliar fertilizer were recorded on stem width and plant height of the sweet corn cultivated in Rengam soil series. Starting from the 10DAS to the 50 DAS this effect was significant between the treatments and the control.

Leaf number and leaf area of the sweet corn culti-

Table 9. Effects of different level of foliar NPK on nutrient contents (%) of the flower of sweet corn plant grown in rengam soil seri es.

Soil series	Treat %	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
Rengam	0	2.0476[a]	0.0644[b]	0.913[b]	0.1968[a]	0.2580[a]	0.0005[ab]	0.00472[b]	0.089[a]	0.0204[a]
	25	1.5860[a]	0.1184[a]	0.913[a]	0.3468[a]	0.3586[a]	0.0008[a]	0.00592[a]	0.089[a]	0.0220[a]
	50	1.9124[a]	0.1269[a]	1.307[ab]	0.2385[a]	0.2907[a]	0.0006[ab]	0.00532[a]	0.130[a]	0.0323[a]
	75	1.7712[a]	0.1428[a]	1.307[ab]	0.2434[a]	0.3140[a]	0.0004[b]	0.00512[a]	0.190[a]	0.0407[a]
	100	1.7819[a]	0.1174[a]	1.095[ab]	0.2877[a]	0.3003[a]	0.0006[ab]	0.00571[a]	0.305[a]	0.0656[a]
Rasau	0	1.8672[a]	0.1344[a]	1.4904[a]	0.2567[a]	0.1864[a]	0.0003[a]	0.0058[a]	0.1114[a]	0.0304[a]
	25	2.7741[a]	0.2408[a]	1.4904[a]	0.2388[a]	0.1864[a]	0.0005[a]	0.0070[a]	0.1235[a]	0.0359[a]
	50	1.8662[a]	0.1892[a]	1.3751[a]	0.2582[a]	0.2324[a]	0.0006[a]	0.0075[a]	0.2189[a]	0.0555[a]
	75	1.4622[a]	0.2051[a]	1.2045[a]	0.2515[a]	0.2343[a]	0.0004[a]	0.0091[a]	0.1429[a]	0.0381[a]
	100	1.6633[a]	0.8087[a]	1.5454[a]	0.2826[a]	0.2217[a]	0.0006[a]	0.0095[a]	0.1245[a]	0.0327[a]

vated in Rengam soil series show a significant effect as a result of different rates of NPK applied as a foliar fertilizer. On 3rd and 4th measurement the plant treated with 75 % NPK treatment significantly increased the leaf number of the sweet corn seedlings. The leaf area almost double in treated sweet corn of Rengam soil series compared to the control ones in greenhouse condition. Mineral nutrients play a significant role in cell division, cell differentiations, formation of chlorophyll, photosynthesis process, enzyme activity, fixation and reduction of nitrogen. While, the effect of foliar fertiliser on the plant cultivated in Rasau soil series did not show significant increase on leaf area. Sweet corn flowering also affected by foliar fertilization under greenhouse condition. Foliar fertilizer of NPK at the rate of 75 % enhance the flowering of the sweet corn planted in Rengam soil series and it requires only 48 days for flowering while control plants required 54 days to appear the flowers. For the Rasau soil series, 100 % NPK treatment stimulate the flowering and requires less time to complete flowering. An increased crop responses such as higher plant height, leaf number and leaf area were recorded with the application of different macronutrients was reported (21). The foliar application of urea before flag leaf emergence increased the flowering and grain yield when N availability is limited (22). It was also reported that foliar application of fertilizer increase grain and stover yields, number of grains per ear, 1000 seed weight and individual grain weight (23).

Cob or yield characteristics of sweet corn cultivated in Rengam and Rasau soil series affected by different rates of foliar fertilizer at greenhouse condition. Fresh cob weight, cob diameter and cob height were recorded in this study. The results of this study showed that plants treated with 75 % and 100 % NPK as foliar application significantly improved the cob characteristics of the sweet corn. Mineral nutrients are important for the metabolic processes that begin with cell division and continue through differentiation, photosynthesis, respiration, enzyme activity, nitrogen fixation and reduction in plants (24). This study showed that foliar spray of macronutrients increased the fresh cob weight, cob number and dry matter yield of sweet corn. Our results also showed that 75 % to 100 % NPK treatments were better to improve the cob characteristics of the sweet corn cultivated in Rengam and Rasau soil series under greenhouse condition. The yield characteristics of sweet corn improved by foliar macronutrients due to increasing enzyme activities, flower stimulation, pollen viability and grain filling (25). Also stated that foliar application of micronutrients increases the cob weight of corn by improving plant growth, physiological and biochemical processes. Our results showed that the relative yield of cob weight increased with foliar fertilizer treatment in green house conditions. It was earlier reported that foliar application macro and micronutrients increase the growth and grain relative yield of dahlia (21). In this study, the highest relative yield was recorded in 75 % NPK treatment, which is supported by findings of another study (26). Our study ensured maximum utilization of resources and as well give an insight for further research in finding the minimum rate of NPK as a foliar application that will give optimum sweet corn growth performance and yield. In addition, the foliar nutrients to corn plants increase the synthesis and translocation of non-structural carbohydrates from leaf to stems, which stimulates the sucrose phosphate synthase (SPS) activity, and in turn, which increase flowering and filled grain number and grain weight per cob.

Our results showed that foliar application macronutrients increased leaf area and leaf number of sweet corn cultivated in green house under 2 different types of soil. Exogenous macronutrients may be increased the cell division, cell proliferation and maturation of leaf primordia thus increased the leaf number and leaf area of sweet corn seedlings. Leaf area, leaf area index, chlorophyll content and growth rate of the crop regulated by the foliar application of nutrient elements (27). In addition, synthesis and translocation of non-structural carbohydrates from leaf to stems or other sink areas increases by applying the foliar fertilization, which encourage the sucrose phosphate synthase (SPS) activity and in turn increase filled grain number and grain weight per panicle in rice plants (28). The crop growth, development and yield increased when apply foliar fertilization of macro and micronutrients (29). On the other hand, it has been shown that foliar urea sprays at the boot stage, when nitrogen availability is quite low, improve maize grain yield and grain filling percentage (30).

The cob or yield characteristics of sweet corn improved by the foliar macronutrients in this study. Potassium and magnesium participate in the transportation of photosynthates from the source to the sink and exerted a significant effect on the weight of grains in the cob (31). The combination of macro and micronutrients were better than conventional fertilisers which lacked micronutrients, and yield of the sweet corn was higher with the combined foliar fertilizer (32). Foliar fertilization is a better technique to supply the macro and micro nutrients where plants or soil lack of nutrient availability (33).

Mineral nutrients applied topically improved the amount of chlorophyll in leaves and the rate of photosynthesis, which in turn increased crop growth and dry weight (34). Plant growth rate is significantly connected with leaf chlorophyll content, which is the component that controls photosynthesis. According to this study, sweet corn plants' growing dry weight in response to foliar spray may be caused by a faster photosynthetic rate and a transfer of carbohydrates from the leaves to the grains (35). Foliar nitrogen feeding has a considerable impact on dry matter accumulation as well as net photosynthetic rate (36). Optimum concentration of nutrients as a foliar application increased photosynthesis, improved accumulation and translocation of photosynthates in the grain and produced healthy panicle (37), and also increased the yield of grain and dry matter content (38). Plant growth improved by applying foliar spray of Mn, also increased the yield and biomass content in wheat (39). Nitrogen is a primary constituent which regulates plant growth and development by affecting protein synthesis and production of plant growth regulators, neurotransmitters and antioxidant compounds (40).

In this greenhouse study, applying different amounts of NPK as a foliar spray enhanced the internal level of macro and micronutrient content in the corn ear leaf, mature leaves, corn stem, corn cob, corn flower and whole plant. This increased nutritional level may result in improvements in the amount of chlorophyll, the net photosynthetic rate, the activity of sucrose phosphate synthase (SPS) and the accumulation of photosynthates in the plants. In comparison to the control maize plants, the treated maize plants produced more cobs, had higher fresh cob weights, and produced more dry matter. According to studies, foliar applications of nitrogen (N), phosphorous (P) and potassium (K) boost crop growth and output in dry land areas (41). However, the Zn content of wheat seed and flour reduced as a result of foliar application of NPK elements as foliar phosphorus (P). It is common practise in sustainable agriculture to employ macronutrients as a foliar spray to address soil nutrient deficiencies. In addition to absorbing light and CO_2 for photosynthesis, plant leaves may also absorb nutrients because this is already known and used in nutrient management systems (42). It has been reported that when plants treated with NPK as a foliar application at the flowering stage increased N uptake after flowering and protein content in the grain (43). Foliar macronutrient induced root growth of wheat led to enhancing the absorption of nutrient elements from the soil (44). Thus, elevated levels of macro and micronutrient content in the plants indeed play a significant role to improving the yield and quality of crop. It was also reported that wheat production increased significantly when applying foliar application of nutrients (45).

Because the leaf has numerous holes, including stomata, hydathodes and lenticel, the plant may easily absorb nutrients sprayed on it by foliar spray. Despite the fact that the cuticle is present on both surfaces, the leaf can still absorb minerals. Before being metabolised by plants, a nutrient component applied to a leaf surface must pass through a cuticle layer (made of wax or suberin), the cell wall and the cell membrane. Foliar spray is more effective than other strategies at controlling nutrient deficit and unavailable nutritional components in the soil and can thus be used on plant surfaces (46). Foliar fertilisation provides rapid absorption and utilisation of nutrient minerals, this can go into plant metabolism systems directly. Due to unfavourable soil situation, runoff and leaching, sometimes soil applied nutrients are insufficient for crops and plants to meet requirements which can cease their growth and development and affect the yield and quality of the crop produced. Foliar fertilisation is the most cost-effective and efficient technique to produce high-quality products and yields when nitrogen intake from the soil is constrained and sink competition occurs among plant organs (47).

The amount of amino acids in the plants rose when N was applied topically. Foliar fertilisers, encourage the growth of corn stems, leaves and roots (48). Foliar application of NPK boosts agricultural plants' internal levels of nitrogen (N), phosphorus (P) and potassium (K), maintains leaf nutrition during photosynthesis and controls the C: N ratio (49). Foliar applications of N and P at 25 and 45 days following sowing filled the crop's nitrogen needs (50). Exogenous N and P may speed up photosynthesis, increasing the amount of carbohydrates and yielding more dry matter in the crop (51). This can be attributed to high N concentration as reported by Malvi 2011s possible hindrance to other element availability.

The nitrate reductase (NRase) activity is increased by foliar applications of nitrogen and phosphate, which results in higher chlorophyll content, improved photosynthesis and other physiological processes important for plant growth and development. In our investigation, foliar application of macronutrients boosted corn growth and physiological parameters, which are strongly connected with maize yield features (data not shown). Micronutrients sprayed onto plants' leaves increased growth and yield, which may have been caused by a rise in photosynthetic rate, an accumulation of photosynthates and higher output (52). Plants can quickly absorb foliar urea and that urea can easily hydrolyze in the cytoplasm of cells (53). Foliar application of K is preferable to a soil application in terms of crop growth, development, and economic yield (54). Comparing foliar fertilisation to soil application, it is -6-20 times more effective (55). Early on in a crop's growth cycle, supplemental foliar fertiliser treatment increased the mineral content of the plant, enhancing crop output (56). The foliar application of nutrients raised the amount of micronutrients in wheat grain and this beneficial outcome may be attributed to the improved physiological functions of root cells that promoted the absorption of nutrients from the soil (57).

Iron (Fe) and manganese (Mn) are quickly fixed with the clay particles in alkaline soil pH, making it difficult for plant roots to readily absorb these 2 minerals from the topsoil properly (58). However, because they have fewer mobile elements, calcium (Ca), magnesium (Mg) and manganese (Mn) cannot just go from the roots to other sections of the plant (59). Therefore, applying mineral nutrients exclusively to the root zone may not be providing the plant with what it needs for healthy root development and effective nutrient uptake. In order to provide nutrients to the crops for optimum growth, development and production, foliar spraying is an alternate method. According to the discussion above, it can be concluded that in Rengam series soil, foliar application of macronutrients (NPK) at 25 and 50 days after corn sowing enhanced the fresh weight of cob, the number of cobs and the dry matter yield under greenhouse condition.

Conclusion

This study was conducted to find the suitable concentration of the Macronutrients as foliar fertilization for increasing the growth, development, yield and mineral accumulation in the sweet corn grown in Rengam and Rasau soil series under greenhouse condition. All the traits of maize that were examined in this study were positively impacted by the application of macronutrients to the leaves. A considerable increase in the quantity of the sweet corn cobs was observed when the plants treated with macronutrient as foliar application at the rate of 75 % and 100 %, according to the results obtained. Additionally, plants treated with 75 % and 100 % of NPK as foliar sprays showed a considerable increase in the fresh weight of the cob and dry matter production. The results of this study could be applied to enhance crop growth, increase crop yields and enhance crop quality. Finally, it can be concluded that foliar macronutrient at the rate of 75 % to 100 % increased growth, yield and quality of corn under greenhouse condition grown on Rengam and Rasau soil series.

Acknowledgements

The Authors would like to thank the Center for Research Excellence and Incubation Management (CREIM), Universiti Sultan Zainal Abidin (UniSZA), Terengganu, Malaysia for publication support. We are also grateful to Associate Prof. Dr. Caser G. Abdel for his valuable support during project implementation

Authors' contributions

BAM: Experimentation, data collection, wrote and revised the manuscript. MMK: Wrote and revised the manuscript and supervision. AMA: Suggestion the proposal of the article & supervision: MS: Review the manuscript. NFHN: Reviewed the manuscript and supervision.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

References

1. Kalsoom M, Rehman FU, Shafique TA, Junaid SA, Khalid N, Adnan M *et al*. Biological importance of microbes in agriculture, food and pharmaceutical industry: A review. Innovare J Life Sci. 2020;8(6):1-4. https://doi.org/10.22159/ijls.2020.v8i6.39845
2. Das JK, Salam RA, Saeed M, Kazmi FA, Bhutta ZA. Effectiveness of interventions for managing acute malnutrition in children under five years of age in low-income and middle-income countries: A systematic review and meta-analysis. Nutrients. 2020;12 (1):116. http://dx.doi.org/10.3390/nu12010116
3. Kalsoom MN, Rehman FUTA, Adnan M, Anwar S, Zahra A. Chemistry of plant–Microbe interactions in rhizosphere and rhizoplane. Ind J Pure App Biosci. 2020;8(5): 11-19. http://dx.doi.org/10.18782/2582-2845.8350
4. Kannan S. Foliar fertilization for sustainable crop production. Genetic Engineering, Biofertilisation, Soil Quality and Organic Farming. 2010;371-402. http://dx.doi.org/10.1007/978-90-481-8741-6_13
5. Wahab A, Abdi G, Saleem MH, Ali B, Ullah S, Shah W, Marc RA. Plants' physio-biochemical and phyto-hormonal responses to alleviate the adverse effects of drought stress: A comprehensive review. Plants. 2022;11(13):1620. https://doi.org/10.3390/plants11131620
6. Floros JD, Newsome R, Fisher W, Barbosa-Cánovas GV, Chen H, Dunne CP, Ziegler GR. Feeding the world today and tomorrow: The importance of food science and technology: An IFT scientific review. Comprehensive Rev Food Sci Food Safety. 2010;9 (5):572-99. https://doi.org/10.1111/j.1541-4337.2010.00127.x
7. Gasim MB, Ismail BS, Sujaul-Islam M, Rahim SA, Toriman ME. The physico-chemical properties of four soil series in Tasik Chini, Pahang, Malaysia. Asian J Earth Sci. 2011;4(2):75-84. http://dx.doi.org/10.3923/ajes.2011.75.84
8. Khalid K, Ali MF, Abd Rahman NF. The development and application of Malaysian soil taxonomy in SWAT watershed model. In ISFRAM 2014: Proc Int Sym Flood Res Manage. Springer Singapore. 2015;77-88. http://dx.doi.org/10.1007/978-981-287-365-1_7
9. de Oliveira TS, Fernandes RBA. Physical subsoil constraints of agricultural and forestry land. In: Subsoil Constraints for Crop Production. Cham: Springer International Publishing. 022;125-60. https://doi.org/10.1007/978-3-031-00317-2_6
10. Thilakarathna MS, Raizada MN. A review of nutrient management studies involving finger millet in the semi-arid tropics of Asia and Africa. Agronomy. 2015;5(3):262-90. https://doi.org/10.3390/agronomy5030262
11. Santos C, Pinto SIDC, Guelfi D, Rosa SD, da Fonseca AB, Fernandes TJ, e Silva KP. Corn cropping system and nitrogen fertilizers technologies affect ammonia volatilization in Brazilian tropical soils. Soil Systems. 2023;7(2):54. http://dx.doi.org/10.21203/rs.3.rs-1051385/v1
12. Cate Junior RB. A rapid method for correlation of soil test analyses with plant response data. NC State University Agricultural Experiment Station. 1965;13pp.
13. Coleman DC, Callaham M, Crossley Jr DA. Fundamentals of soil ecology. Academic Press; 2017. https://doi.org/10.1016/C2015-0-04083-7
14. Landon JR. Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Routledge. 2013;530. https://doi.org/10.4324/9781315846842
15. Dilipkumar M, Adzemi MA, Chuah TS. Effects of soil types on phytotoxic activity of pretilachlor in combination with sunflower leaf extracts on barnyardgrass (*Echinochloa crusgalli*). Weed Sci. 2012;60(1):126-32. http://dx.doi.org/10.1614/WS-D-11-00075.1
16. Massey CG, Slaton NA, Norman RJ, Gbur Jr EE, DeLong RE, Golden BR. Bermudagrass forage yield and ammonia volatilization as affected by nitrogen fertilization. Soil Sci Soc Amer J. 2011;75 (2):638-48. https://doi.org/10.2136/sssaj2010.0254
17. Fried M. The soil-plant system: In relation to inorganic nutrition. Elsevier. 2012;258. https://doi.org/10.1016/B978-0-12-395728-3.X5001-5
18. Salama MED, Hoda AA, Marwa HZE. Effect of soil type on the allelotoxic activity of *Medicago sativa* L. residues in *Vicia faba* L. agroecosystems. J Taibah Univ Sci. 2014;8(2):84-89. https://doi.org/10.1016/j.jtusci.2014.01.001
19. Buol SW, Southard RJ, Graham RC, McDaniel PA. Soil genesis and classification. John Wiley & Sons; 2011. http://dx.doi.org/10.1002/9780470960622
20. Fageria NK, Filho MB, Moreira A, Guimarães CM. Foliar fertilization of crop plants. J Plant Nutri. 2009;32(6):1044-64. https://doi.org/10.3390/agriculture13091715
21. Kashif M, Rizwan K, Khan MA, Younis A. Efficacy of macro and micro-nutrients as foliar application on growth and yield of *Dahlia hybrida* L (Fresco). Int J Chem Biochem Sci. 2014;5:6-10. https://www.iscientific.org/wp-content/uploads/2018/02/2-IJCBS-14-05-04.pdf
22. Kumar U, Shahid M, Tripathi R, Mohanty S, Kumar A, Bhattacharyya P, Nayak AK. Variation of functional diversity of

soil microbial community in sub-humid tropical rice-rice cropping system under long-term organic and inorganic fertilization. Ecological Indicators. 2017;73:536-43. https://doi.org/10.1016/j.ecolind.2016.10.014

23. Tolera A, Sundstøl F, Said AN. The effect of stage of maturity on yield and quality of maize grain and stover. Animal Feed Sci Technol. 1998;75(2):157-68. https://doi.org/10.1016/S0377-8401(98)00192-8

24. Adhikary S. Vermicompost, the story of organic gold: A review. Agril Sci. 2012;3(7):905-17. http://dx.doi.org/10.4236/as.2012.37110

25. Salem HM, El-Gizawy NK. Importance of micronutrients and its application methods for improving maize (*Zea mays* L.) yield grown in clayey soil. Chem Anal. 2012;19:19. https://doi.org/10.5829/idosi.aejaes.2012.12.07.1759

26. Bansal KN, Pal AR. Evaluation of a soil test method and plant analysis for determining the sulphur status of alluvial soils. Plant Soil. 1987;98:331-36. https://doi.org/10.1007/BF02378354

27. Abdel-Mawgoud AMR, El-Bassiouny AM, Ghoname A, Abou-Hussein SD. Foliar application of amino acids and micronutrients enhance performance of green bean crop under newly reclaimed land conditions. Aus J Basic Appl Sci. 2011;5(6):51-55. http://www.ajbasweb.com/old/ajbas/2011/june-2011/51-55.pdf

28. Silviya RA, Stalin P. Rice crop response to applied copper under varying soil available copper status at Tamil nadu, India. Int J Current Microbiol App Sci. 2017;6(8):1400-08. https://doi.org/10.20546/ijcmas.2017.608.170

29. Ali S, Javed HU, Rehman RNU, Sabir IA, Naeem MS, Siddiqui MZ, Nawaz MA. Foliar application of some macro and micro nutrients improves tomato growth, flowering and yield. Int J Biosci. 2013;3(10):280-87. http://dx.doi.org/10.12692/ijb/3.10.280-287

30. Ordóñez RA, Savin R, Cossani CM, Slafer GA. Yield response to heat stress as affected by nitrogen availability in maize. Field Crops Res. 2015;183:184-203. https://doi.org/10.1016/j.fcr.2015.07.010

31. Barlog P, Frackowiak-Pawlak K. Effect of mineral fertilization on yield of maize cultivars differing in maturity scale. Acta Scientiarum Polonorum. Agril. 2008;7(4):5-17. https://bibliotekanauki.pl/articles/47219

32. Mohammed BA, Khandaker MM, Arshad AM, Nudin NFH, Majrashi A, Mohd KS. Effects of foliar NPK application on growth, yield and nutrient content of sweet corn grown on Rengam Series soil. Basrah J Agril Sci. 2023;36(1):254-70. https://doi.org/10.37077/25200860.2023.36.1.20

33. Kihara J, Bolo P, Kinyua M, Rurinda J, Piikki K. Micronutrient deficiencies in African soils and the human nutritional nexus: Opportunities with staple crops. Environ Geochem Health. 2020;42:3015-33. https://doi.org/10.1007/s10653-019-00499-w

34. Tariq A, Shahbaz M. Glycinebetaine induced modulation in oxidative defense system and mineral nutrients sesame (*Sesamum indicum* L.) under saline regimes. Pak J Bot. 2020;52(3):775-82. http://dx.doi.org/10.30848/PJB2020-3(34)

35. Ziaeyan AH, Rajaei M. Combined effect of zinc and boron on yield and nutrients accumulation in corn. Int J Plant Prod. 2009;3(3):1735-6814. https://api.semanticscholar.org/CorpusID:54534530

36. Paponov IA, Engels C. Effect of nitrogen supply on leaf traits related to photosynthesis during grain filling in two maize genotypes with different N efficiency. J Plant Nutri Soil Sci. 2003;166(6):756-63. https://doi.org/10.1002/jpln.200320339

37. Liu ZY, Shi JJ, Zhang LW, Huang JF. Discrimination of rice panicles by hyperspectral reflectance data based on principal component analysis and support vector classification. J Zhejiang Univ Sci B. 2020;11:71-78. https://doi.org/10.1631%2Fjzus.B0900193

38. Singh S, Prasad SM. Growth, photosynthesis and oxidative responses of *Solanum melongena* L. seedlings to cadmium stress: Mechanism of toxicity amelioration by kinetin. Sci Hort. 2014;176:1-10. https://doi.org/10.1016/j.scienta.2014.06.022

39. Sadana US, Lata K, Claassen N. Manganese efficiency of wheat cultivars as related to root growth and internal manganese requirement. J Plant Nutri. 2002;25(12):2677-88. https://doi.org/10.1081/PLN-120015531

40. Li P, Yin YL, Li D, Kim SW, Wu G. Amino acids and immune function. British J Nutri. 2007;98(2):237-52. https://doi.org/10.1017/S000711450769936X

41. Doni F, Suhaimi NSM, Mispan MS, Fathurrahman F, Marzuki BM, Kusmoro J, Uphoff N. Microbial contributions for rice production: From conventional crop management to the use of 'omics' technologies. International J Mol Sci. 2022;23(2):737. https://doi.org/10.3390/ijms23020737

42. Wang JL, Liu KL, Zhao XQ, Zhang HQ, Li D, Li JJ, Shen RF. Balanced fertilization over four decades has sustained soil microbial communities and improved soil fertility and rice productivity in red paddy soil. Sci Total Enviro. 2021;793:148664. https://doi.org/10.1016/j.scitotenv.2021.148664

43. Mohammad Abdel-Aziz HM, Abdel-Ghany HMN, Omer AM. Foliar application of nano chitosan NPK fertilizer improves the yield of wheat plants grown on two different soils. Egyptian J Exp Biol. 2018;14(1):63-72. https://dx.doi.org/10.5455/egyjebb.20180106032701

44. Saquee FS, Diakite S, Kavhiza NJ, Pakina E, Zargar M. The efficacy of micronutrient fertilizers on the yield formulation and quality of wheat grains. Agronomy. 2023;13(2):566. https://doi.org/10.3390/agronomy13020566

45. Aziz MZ, Yaseen M, Abbas T, Naveed M, Mustafa A, Hamid Y, Xu MG. Foliar application of micronutrients enhances crop stand, yield and the biofortification essential for human health of different wheat cultivars. J Integra Agril. 2019;18(6):1369-78. https://doi.org/10.1016/S2095-3119(18)62095-7

46. Deng X, Zheng X, Jia F, Cao C, Song H, Jiang Y, Wang L. Unspecific peroxygenases immobilized on Pd-loaded three-dimensional ordered macroporous (3DOM) titania photocatalyst for photo-enzyme integrated catalysis. Applied Catalysis B: Environ. 2023;330:122622. https://doi.org/10.1016/j.apcatb.2023.122622

47. Salomi Grace M, Ramana AV, Upendra Rao A, Murthy PG. Effect of foliar nutrition on growth and yield of sweet corn. The Pharma Innovation Journal. 2020;9(3):622-25. https://www.thepharmajournal.com/archives/2020/vol9issue3/PartK/8-7-63-406.pdf

48. Fan X. Gaseous ozone to preserve quality and enhance microbial safety of fresh produce: Recent developments and research needs. Comprehensive Reviews Food Sci Food Safety. 2021;20(5):4993-5014. https://doi.org/10.1111/1541-4337.12796

49. Turner NC, Wright GC, Siddique KHM. Adaptation of grain legumes (pulses) to water-limited environments. Advances Agron. 2001;71(2001):193-231. https://doi.org/10.1016/S0065-2113(01)71015-2

50. Anas M, Liao F, Verma KK, Sarwar MA, Mahmood A, Chen ZL, Li YR. Fate of nitrogen in agriculture and environment: Agronomic, eco-physiological and molecular approaches to improve nitrogen use efficiency. Biol Res. 2020;53(1):1-20. https://doi.org/10.1186/s40659-020-00312-4

51. Thakur V, Pandey GC, Rane J. Stem carbohydrate dynamics during post anthesis period in diverse wheat genotypes under different environments. Plant Sci Today. 2019;6(sp1):556-59. http://dx.doi.org/10.14719/pst.2019.6.sp1.688

52. Witte CP, Tiller SA, Taylor MA, Davies HV. Leaf urea metabolism in potato. Urease activity profile and patterns of recovery and distribution of 15N after foliar urea application in wild-type and

urease-antisense transgenics. Plant Physiol. 2002;128(3):1129-36. https://doi.org/10.1104%2Fpp.010506

53. Qian X, Shen Q, Xu G, Wang J, Zhou M. Nitrogen form effects on yield and nitrogen uptake of rice crop grown in aerobic soil. J Plant Nutr. 2004;27(6):1061-76. https://doi.org/10.1081/PLN-120037536
54. Anees MA, Ali A, Shakoor U, Ahmed F, Hasnain Z, Hussain A. Foliar applied potassium and zinc enhances growth and yield performance of maize under rainfed conditions. Int J Agril Biol. 2016;18(5):1814-9596. http://dx.doi.org/10.17957/IJAB/15.0204
55. Islam MK, Acharzo AK, Saha S, Hossain H, Shilpi JA, Das AK, Biswas NN. Bioactivity studies on *Zanthoxylum budrunga* wall (Rutaceae) root bark. Clinical Phytosci. 2018;4:1-12. http://dx.doi.org/10.1186/s40816-018-0084-9
56. Dehnavard S, Souri MK, Mardanlu S. Tomato growth responses to foliar application of ammonium sulfate in hydroponic culture. J Plant Nutri. 2017;40(3):315-23. https://doi.org/10.1080/01904167.2016.1240191
57. Toor MD, Adnan M, Javed MS, Habibah U, Arshad A, Din MM, Ahmad R. Foliar application of Zn: Best way to mitigate drought stress in plants- A review. Int J App Res. 2020;6(8):16-20. https://www.researchgate.net/publication/344886255
58. Arrobas M, Afonso S, Rodrigues MÂ. Diagnosing the nutritional condition of chestnut groves by soil and leaf analyses. Sci Hort. 2018;228:113-21. https://doi.org/10.1016/j.scienta.2017.10.027
59. Dhaliwal SS, Sharma V, Shukla AK. Impact of micronutrients in mitigation of abiotic stresses in soils and plants- A progressive step toward crop security and nutritional quality. Adv Agron.