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Research Article

Impact of Grow NPK Consortia and Grow Zinc Biofertilizers on *Zea mays* L. Growth and Yield

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Abstract

This study aimed to evaluate the impact of Grow Zinc and Grow NPK Consortia sachet-based biofertilizers on the growth and yield of maize (*Zea mays* L.), with the objective of identifying the most effective treatment for enhancing productivity while promoting sustainable agricultural practices. A field experiment was conducted during the 2019-2020 Kharif season in Khanpur, Gujarat, using a split-plot design with three replications. Six treatments were tested, including individual and combined applications of Grow NPK Consortia sachets, Grow Zinc sachets, and mineral fertilizers. Growth and yield parameters such as plant height, ear length, kernel number, and grain yield were recorded. The combination of 50% Grow NPK Consortia sachet with 50% mineral fertilizers (T5) resulted in the highest grain yield (1913.5 kg/ha), longest ear length (20.83 cm), and the greatest number of kernels per row (42.37). T5 also produced the tallest plants (298 cm) and highest root dry weight (24.9 g), outperforming all other treatments. Integrating Grow NPK Consortia sachets with mineral fertilizers significantly enhanced maize growth and yield. This approach offers a practical and sustainable nutrient management strategy for improving maize productivity and reducing dependence on chemical fertilizers..

Keywords: Biofertilizers; Environmentally Friendly; Grow NPK Consortia; *Zea mays*; Sachet; Microbial Inoculants; Sustainable Agriculture; Zinc Solubilizers

Introduction

Maize (*Zea mays L.*) is a crucial staple food crop as well as industrial crop which considerably impacts food security and sustainable farming across the globe [1]. Economically, maize is one of the most important crops because of its adaption to a number of agro climatic zones and its significant role on human and livestock diets [2]. Maize is also industrially used to produce feedstuff like high fructose corn syrup [3]. Because of its high starch and moderate protein composition, maize is an essential food and feed stuff [4]. The various uses of maize underscore its contribution to the global food security and industrial activities. With increasing level of development of the population, the efficiency of maize production increases as well [5]. Today's farming practices highly rely on chemical fertilizers to produce higher yields. However, these practices have serious environmental issues like water contamination, soil degradation, and pest resistance magnification [6]. There has been a growing interest in organic farming because of biofertilizers used as a substitute for conventional farming techniques [7].

The natural ability of some microorganisms to fix atmospheric nitrogen, mobilize potassium, and solubilize phosphorus can enhance the productivity of crops greatly with infrequent use of Biofertilizers [8]. Nitrogen-Fixing Bacteria (NFB), Phosphate Solubilizing Bacteria (PSB), and Potassium Solubilizing Bacteria (KSB) render multiple services to the soil as regards its fertility and for nutrition of plants [9]. Azotobacter spp colonize plant roots and fix nitrogen (NFB), which can lead to less reliance on agrochemicals [10]. PSB, mainly *Bacillus megaterium*, increases the soluble forms of phosphorus by decomposing the insoluble particles of phosphorus and makes phosphorus available to crops [11]. Likewise, KSB enhances the proportion of potassium in soil which is essential for the plants and crops to withstand stress [12].

Inadequate zinc intake, as noted by [13], poses challenges to the growth of maize and human nutrition. Various physiological activities require zinc, such as protein synthesis, enzyme activation, and the production of chlorophyll [14]. Certain biofertilizers like *Pseudomonas sp.* and *Bacillus sp.* are important in the biogeochemical cycle of zinc as they aid in its solubilization [15]. The idea that maize plants treated with zinc biofertilizers outperformed those treated with chemicals in terms of growth parameters including leaf area index, chlorophyll content, and grain zinc concentration [16]. Maize growth has been significantly improved with the combination of zinc biofertilizer and NPK consortia sachet. The combination of these biofertilizers resulted in higher nutrient uptake, improved structure of roots, enhanced microbial activity in the soil, and higher crop production [17]. This effect occurs because of the nutrients being solubilized with the help of several microbial species working together to increase soil fertility which forms more favourable conditions for maize crops to growing [18].

The use of bio-fertilizers, Grow zinc sachet and Grow NPK consortia sachet, showcase an inclusive example of sustainable agriculture practice. These bio-fertilizers not only supply the primary macronutrients, nitrogen, phosphorus, and potassium, but also alleviate micronutrient deficiencies like zinc, which is fundamental for maize's growth and development [19]. In addition, they enhance crops tolerance to environmental stresses by increasing poor nutrient supply, promoting beneficial microbial activities in the soils, reducing chemical fertilizers usage, and improving both the quantity and quality of maize.

The current study finds to assess the impacts of bio-fertilizers, Grow zinc sachet and Grow NPK consortia sachet, on maize growth parameters and yield. The research intends to investigate the possible synergistic benefits of integrating biofertilizers with conventional fertilization, by providing information about sustainable agriculture practices that increase crop output and soil health. In addition, the study aims to mitigate the adverse effects of farming practices on the environment in an offer to promote sustainable maize production.

Materials and Methods

Field experiment location for the study and crop details

The field experiment was conducted in the experimental farm in Khanpur, Dahegam, Gujarat, during the 2019-2020 Kharif season. Among the field crops, maize (*Zea mays L.*) was selected as a model crop for the implementation of the study. The entire plot area of 0.00225 hectares way sown with a total of 220 seeds of hybrid maize. The experiment ran for a period of 4 to 6 months and included all the growth stages of the maize crop from planting to the end of the life cycle. The experimental site had a net plot size of 7.5 m by 3 m.

Soil preparation and fertilizer application

The investigational field was prepared by ploughing and levelling to obtain a fine tilt before growing. The field was divided into plots using the split-plot design, and nutrients were provided according to the experimental treatments. The experiment used two biofertilizers: Grow NPK consortia sachet and Grow zinc sachet each containing 10g product quantity. Both products were produced at a concentration of $1x10^{12}$ colony-forming units (CFU) per gram and applied every two weeks during the experiment. A commercial grade standard FCO grade water soluble Mineral NPK 19:19:19 was incorporated.

The physico-chemical properties of the soil at the experimental site are presented in the Table 1.

Table 1: Physico-Chemical Properties of Soil.

Soil Property	Value
Soil texture	Sandy loam
pH	7.2 - 7.8
Electrical conductivity (EC)	0.3 - 0.6 dS/m
Organic carbon	0.45 - 0.65 %
Available nitrogen (N)	180 - 210 kg/ha
Available phosphorus (P_2O_5)	12 - 18 kg/ha
Available potassium (K_2O)	150 - 180 kg/ha
Available zinc (Zn)	0.8 - 1.2 mg/kg

Experimental treatments and design

The trial utilized a split-plot design with three replications to examine six different treatment combinations effects on maize growth and yield qualities. The primary plot portion was applied fertilizer treatment, whereas the secondary plot component was the mixer of biofertilizer and mineral fertilizer application. Treatments were organized as follows:

- Control (0%): No biofertilizers or mineral fertilizers.
- Grow NPK consortia sachet containing (100%)
- Grow zinc sachet (100%)
- Grow NPK consortia sachet (50%) + Grow zinc sachet (50%): Combined application of Grow NPK consortia sachet and Grow zinc sachet, each at 50% of their respective recommended dosages.
- Grow NPK consortia sachet (50%) + Mineral Fertilizer (50%): Application of Grow NPK consortia sachet at 50% of the recommended dosage, supplemented with mineral fertilizer (NPK) at 50% of the standard dose.
- Grow zinc sachet (50%) + Mineral Fertilizer (50%): Application of Grow zinc sachet at 50% of the recommended dose, combined with mineral fertilizer (NPK) at 50% of the standard dose.

Where, NPK sachet contained *Azotobacter chroococcum, Pseudomonas Putida* and *Frateuria aurantia.* Whereas Zinc sachet contained *Pseudomonas fluorescens.*

Biofertilizer preparation and application

Grow zinc sachet and Grow NPK consortia sachet were prepared in liquid form to ensure even distribution of microbial inoculants across the plots. The germination of maize seeds on a one-acre field started with the application of a Grow hybrid maize seed, which raised germination rates to up to 95% and protected against bacterial and fungal diseases. A single sachet of the hybrid Grow Seed was dissolved in 3-5 liters of water, and the seeds soaked in the prepared solution before drying and planting. The soil was treated with a single sachet of Grow NPK Consortia after 8 to 10 days of germination. This application particularly decreased the use of chemical urea and fertilizers by up to 40% while also promoting root development. Additionally, another sachet of the Grow NPK Consortia is sprayed 25-30 days post germination in order to vegetative shoot grow, which in turn enhances the vegetative growth of the maize plant, as well as to help the plant recover from the external stressors. In between 40 and 45 days after germination, one sachet of Grow Zinc and one sachet of Grow NPK Consortia were used to serve the purpose of increasing the growth of leaves, cobs, shoots, as well as stems, which consequently improved the maize crop. To be able to intact the growth together with sustaining the health of the plants, an extra Grow NPK Consortia was used somewhere between 60 and 65 days after germination. Finally, around 80-90 days after germination, a sachet of Grow NPK Consortia was given to stimulate physiological maturation and prepare the crop for harvesting.

Data collection and analysis

Data collection was systematically carried out at maturity stages of maize, including the vegetative, flowering, and maturity phase. This is at early growth (15 DAS), mid-growth (30 and 45 DAS), and late growth (60 DAS). The following growth factors were measured included plant height, stem girth; leaf area, root length, and biomass accumulation (root dry weight and shoot dry weight). Yield parameters were recorded at harvest, ear length, and the number of rows per ear, the number of kernels per row, total kernels per ear, 1000-kernel weight, and grain yield.

Statistical analysis

The statistical analyses were showed using standard software to compare treatment effects on maize growth and yield. ANOVA was performed to determine significant differences between treatments, and the means were separated using the least significant difference (LSD) test at a 5% probability level ($p < 0.05$). This method provided an adequate basis for evaluating the efficacy of various bio fertilizer and fertilizer combinations in enhancing maize growth and productivity.

Results

Yield parameters

Ear length

The study examined the effect of various treatments from T1 to T6 on maize ear length (Table 2), and the results indicated variation across the treatments. Treatment T5 resulted in the largest ear length, 20.83 ±1.5 cm, showing considerable ear growth. Subsequently, ear lengths of T6 and T4 were 19.23 ±1.4 cm and 19.01 ±0.9 cm respectively. An ear length of 16.32 ± 1.1 cm resulted from treatment T2; whereas treatment T3 produced an ear length of 15.24 ± 1.7 cm. T1 had the shortest ear length, 13.04 ± 0.8 cm.

Table 2: Effect of Different Fertilizer Treatments on Ear Length (cm) in Maize (*Zea mays L.*).

Treatments(T)	Ear length (cm)
T1- Control (no fertilizer): 0%	13.04 ± 0.8
T2- Grow NPK consortia sachet 100%	16.32 ± 1.1
T3- Grow zinc sachet 100%	15.24 ± 1.7
T4- Grow NPK consortia sachet 50%+ Grow zinc sachet 50%	19.01 ± 0.9
T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%	20.83 ± 1.5
T6- Grow zinc sachet 50%+ mineral fertilizer 50%	1.23 ± 1.4

Number of rows per ear

Table 3 illustrate the effect of several treatments on the number of rows per unit area (ear^{-1}). The control T1 had an average of 12.72 ± 1.2 rows per ear. Grow NPK consortia sachet at 100% (T2) enhanced this to 14.75 ± 0.7 rows per ear, while Grow zinc sachet

Table 3: Effect of Different Fertilizer Treatments on Number of Rows per Ear in Maize (*Zea mays L.*).

Treatments (T)	Number of rows/ear
T1- Control (no fertilizer): 0%	12.72 ± 1.2
T2- Grow NPK consortia sachet 100%	14.75 ± 0.7
T3- Grow zinc sachet 100%	13.10 ± 0.9
T4- Grow NPK consortia sachet 50%+ Grow zinc sachet 50%	15.50 ± 1.1
T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%	14.91 ± 1.3
T6- Grow zinc sachet 50%+ mineral fertilizer 50%	14.0 ± 1.1

at 100% (T3) resulted in 13.10 ± 0.9 rows ear-1. Grow NPK consortia sachet and Grow zinc sachet at 50% each (T4) resulted in the highest average of 15.50 ± 1.1 rows per ear. T5 yielded 14.91 ± 1.3 rows per ear, while Grow zinc sachet (50%) with mineral fertilizer (50%) (T6) produced 14.00 ± 1.1 rows per ear.

Number of kernels per row

The number of kernels per row in maize was altered by the various fertilizer treatments as shown in Table 3. T5 had the largest average kernel number, 42.37 ± 2.5. T4 and T6 treatments resulted in higher kernel numbers (42.18 ± 1.9 and 42.02 ± 2.3, respectively). T2 (40.17 ± 1.7) and T3 (38.21 ± 2.1) produced lower kernel counts. The control treatment (no fertilizer) had the lowest kernel number (31.24 ± 2.7) (Table 4).

Table 4: Effect of Different Fertilizer Treatments on Number of Kernels per Row in Maize (*Zea mays L.*).

Treatments (T)	Number of Kernels row
T1- Control (no fertilizer): 0%	31.24 ± 2.7
T2- Grow NPK consortia sachet 100%	40.17 ± 1.7
T3- Grow zinc sachet 100%	38.21 ± 2.1
T4- Grow NPK consortia sachet 50%+ Grow zinc sachet 50%	42.18 ± 1.9
T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%	42.37 ± 2.5
T6- Grow zinc sachet 50%+ mineral fertilizer 50%	1.02 ± 2.3

Number of kernels per ear

Each fertilizer treatment had a major impact on the number of kernels per ear in maize as summarized in Table 5. T5 produced the highest kernel count (604.89 ± 46.23). T6 and T4 also had wide kernel numbers of 597.45 ± 32.1 and 579.46 ± 18.5, respectively. T2 and T3 have lower kernel counts (549.63 ± 12.1 and 535.35 ± 24.5). The control group T1 had the lowest kernel count (412.67 ± 23.4).

Table 5: Effect of Different Fertilizer Treatments on Number of Kernels per Ear in Maize (*Zea mays L.*).

Treatments (T)	Number of kernels/ear
T1- Control (no fertilizer): 0%	412.67 ± 23.4
T2- Grow NPK consortia sachet 100%	549.63 ±12.1
T3- Grow zinc sachet 100%	535.35 ± 24.5
T4- Grow NPK consortia sachet 50%+ Grow zinc sachet 50%	579.46 ± 18.5
T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%	604.89 ± 46.23
T6- Grow zinc sachet 50%+ mineral fertilizer 50%	1.45 ± 32.1

Weight of 1000-kernels

As presented in Table 6, the 1000-kernel weight exhibited a variety of responses to the different treatments. T1 had the lowest weight, weighing 121.43 ± 27.4 g, which indicates a noteworthy amount of variation. However, T2 and T3 produced comparable weights of 142.23 ± 15.2 g and 141.05 ± 14.3 g, respectively, with less variation than T1. T4 increased to 156.14 ± 13.5 g. T5 had the highest weight, obtaining 184.24 ± 22.5 g. T6 yielded a weight of 179.13 ± 15.6 g, a lower variability than T5.

Grain yield

There was a noticeable variance in the grain yield between the treatments as shown in Table 7. It was observed that out of 220 maize seeds; 187 seeds were germinated resulting in 85% of germination rate. Utilizing T1 as a baseline with lower input, the control produced 1397.0 ± 117.6 kg/ha. T2 yielded 1732.3 ± 121.5 kg/ha; which was higher than T3, with a slightly reduced production of 1602.7 ± 134.3 kg/ha. T4, which consisted of a combination of treatments, yielded 1852.4 ± 142.6 kg/ha. T5 and T6 produced the highest yields, 1913.5 ± 153.7 kg/ha and 1894.1 ± 110.2 kg/ha, respectively.

Table 6. Effect of Different Fertilizer Treatments on 1000-Kernel Weight in Maize (*Zea mays L.*).

Treatments(T)	1000- kernels weight (g)
T1- Control (no fertilizer): 0%	121.43 ± 27.4
T2- Grow NPK consortia sachet 100%	142.23 ± 15.2
T3- Grow zinc sachet 100%	141.05 ± 14.3
T4- Grow NPK consortia sachet 50%+ Grow zinc sachet 50%	156.14 ± 13.5
T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%	184.24 ± 22.5
T6- Grow zinc sachet 50%+ mineral fertilizer 50%	1.13 ± 15.6

Table 7: Effect of Different Fertilizer Treatments on Grain Yield in Maize (*Zea mays L.*).

Treatments(T)	Grain yield (kg/ha)
T1- Control (no fertilizer): 0%	1397.0 ± 117.6
T2- Grow NPK consortia sachet 100%	1732.3 ± 121.5
T3- Grow zinc sachet 100%	1602.7 ± 134.3
T4- Grow NPK consortia sachet 50%+ Grow zinc sachet 50%	1852.4 ± 142.6
T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%	1913.5 ± 153.7
T6- Grow zinc sachet 50%+ mineral fertilizer 50%	1894.1 ± 110.2

Growth parameters

Plant height

The study assessed the impact of several treatments on plant height during 60 days (Figure 1). The control group (T1) with no fertilizer showed the lowest growth, with heights of 10 ± 1 cm at

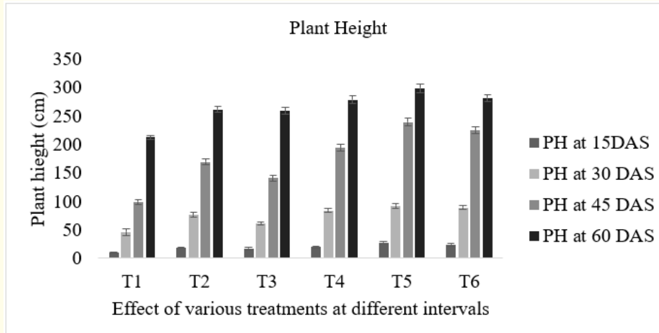

Figure 1: The effects of Grow NPK consortia sachet and Grow zinc sachet biofertilizers sachet on plant height at various stages of growth (PH- Plant Height, DAS- Days after Sowing).

Where, T1 - Control (no fertilizer): 0%, T2- Grow NPK consortia sachet 100%, T3- Grow zinc sachet 100%, T4- Grow NPK consortia sachet 50% + Grow zinc sachet 50%, T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%, T6- Grow zinc sachet 50% + mineral fertilizer 50%.

15 days after sowing (DAS) and growing to 212 ± 3 cm by 60 days. Grow NPK consortia sachet 100% (T2) considerably increased growth compared to the control, reaching 261 ± 5 cm by 60 DAS. Grow zinc sachet 100% (T3) also improved growth, but less effectively, with an ultimate height of 258 ± 6 cm. Combining Grow NPK consortia sachet 50% and Grow zinc sachet 50% (T4) resulted in a height of 278 ± 7 cm at 60 DAS, demonstrating an effective synergistic effect. The combination of Grow NPK consortia sachet 50% and mineral fertilizer 50% (T5) resulted in the highest growth rate (298 ± 7 cm), indicating the maximum effectiveness. The combination of Grow zinc sachet 50% and mineral fertilizer 50% (T6) resulted in heights of 281 ± 6 cm, which, while effective, was less optimal compared to T5.

Stem girth

The study (Figure 2) examined several treatments that affected stem girth over 60 days the control group (T1) got no fertilizer and had the lowest stem girth at all stages, measuring 0.2 ± 0.0 cm at 15 days after sowing (DAS) and growing to 2.0 ± 0.2 cm at 60 DAS. Grow NPK consortia sachet (T2) increased stem girth to 0.6 ± 0.0 cm at 15 DAS and 2.2 ± 0.2 cm at 60 DAS, whereas full-strength Grow zinc sachet (T3) resulted in girths of 0.5 ± 0.0 cm and 2.1 ± 0.2 cm. The stem girth measured at 15 DAS was 0.8 ± 0.1 cm when using Grow NPK consortia sachet and 2.7 ± 0.2 cm by 60 DAS when using Grow zinc sachet at 50% each. Grow NPK consortia sachet combined with 50% mineral fertilizer produced the most noticeable growth (T5), with the largest stem girth of 1.0 ± 0.1 cm at 15 DAS and 2.9 ± 0.1 cm at 60 DAS, indicating the ideal nutrient balance. Ultimately, the Grow zinc sachet and mineral fertilizer combination at 50% each (T6) produced stem girth measures that were intermediate at 0.9 ± 0.1 cm at 15 DAS and 2.5 ± 0.2 cm at 60 DAS, indicating efficacy but not reaching the most growth possible with the other combination treatments.

Leaf area

The examination of leaf area growth over 60 days demonstrated different responses to various treatments (Figure 3). The T1 control group saw minimal growth, increasing from 30 ± 1 to 956 ± 11. Leaf area increased with full-strength Grow NPK consortia sachet (T2) from 40 ± 2 to 1162 ± 12, whereas Grow zinc sachet (T3) initially obtained 39 ± 2 and after 60 days, 1098 ± 13. Grow NPK consortia sachet and Grow zinc sachet combined at 50% each (T4) produced leaf areas of 44 ± 4 and 1242 ± 12, respectively, showing a synergistic impact. When Grow NPK consortia sachet and mineral fertilizer were combined at a 50% rate (T5), the largest growth was seen, obtaining 48 ± 3 and 1408 ± 12.

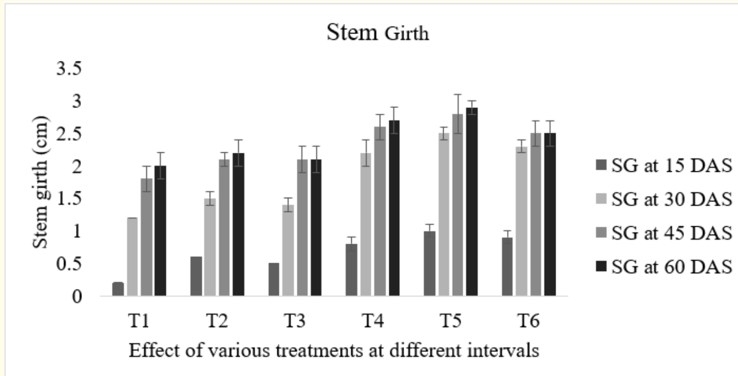

Figure 2: The effects of Grow NPK consortia sachet and Grow zinc sachet biofertilizers on stem girth at various stages of growth (SG- Stem Girth, DAS- Days after Sowing).

Where, T1 - Control (no fertilizer): 0%, T2- Grow NPK consortia sachet 100%, T3- Grow zinc sachet 100%, T4- Grow NPK consortia sachet 50% + Grow zinc sachet 50%, T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%, T6- Grow zinc sachet 50% + mineral fertilizer 50%.

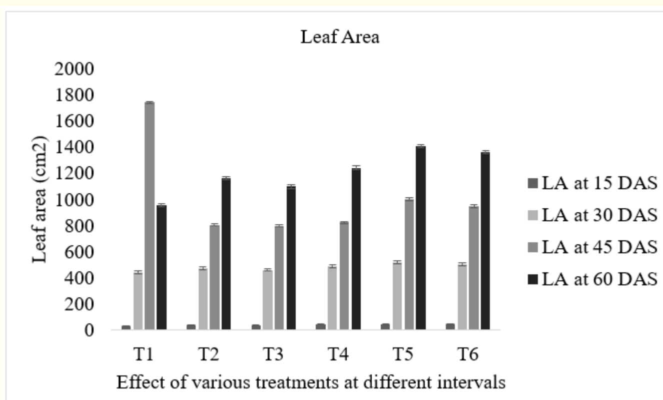

Figure 3: The effects of Grow NPK consortia sachet and Grow zinc sachet biofertilizers on Leaf area at various stages of growth (LA- Leaf Area, DAS- Days after Sowing).

Where, T1 - Control (no fertilizer): 0%, T2- Grow NPK consortia sachet 100%, T3- Grow zinc sachet 100%, T4- Grow NPK consortia sachet 50% + Grow zinc sachet 50%, T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%, T6- Grow zinc sachet 50% + mineral fertilizer 50%.

Root length

Root length analysis conducted over 60 days showed that different treatments obtained varied effects as depicted in Figure 4. Between 13 ± 1 and 28 ± 1, the control group (T1) gradually increased. When compared to full-strength Grow zinc sachet (T3), full-strength Grow NPK consortia sachet (T2) increased root growth from 14 ± 1 to 30 ± 2. The maximum root length, reaching 18 ± 2 to 35 ± 2, was reached by combining Grow NPK consortia sachet and Grow zinc sachet at 50% intensity (T4). The longest roots, measuring from 19 ± 2 to 38 ± 2, were produced by the Grow NPK consortia sachet (T5) combination with 50% mineral fertilizer. Increased root development from 18 ± 1 to 36 ± 2 was also seen when Grow zinc sachet and mineral fertilizer at 50% each combined (T6).

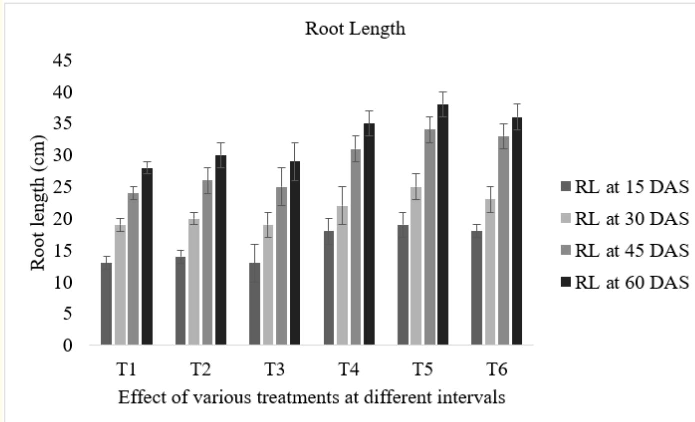

Figure 4: The effects of Grow NPK consortia sachet and Grow zinc sachet biofertilizers on Root length at various stages of growth (RL-Root Length, DAS- Days after Sowing).

Where, T1 - Control (no fertilizer): 0%, T2- Grow NPK consortia sachet 100%, T3- Grow zinc sachet 100%, T4- Grow NPK consortia sachet 50% + Grow zinc sachet 50%, T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%, T6- Grow zinc sachet 50% + mineral fertilizer 50%.

Root dry weight

Over 60 days, the root dry weight analysis under various treatments showed clear differences in growth (Figure 5). Root dry weight of the control group (T1) increased gradually over 30 days after sowing (DAS), rising from 2.1 ± 0.0 g to 12.7 ± 0.4 g at 60 DAS. Higher root dry weights were obtained with the Grow NPK consortia sachet (T2); these weights increased from 2.5 ± 0.2 g to 14.9 ± 0.2 g. Likewise, full-strength Grow zinc sachet (T3) showed an initial root dry weight of 2.4 ± 0.1 g, rising to 13.6 ± 0.2 g by 60 DAS. The maximum root dry weight was reached by the combination of Grow NPK consortia sachet and Grow zinc sachet at 50% each (T4), with values of 2.6 ± 0.2 g at 30 DAS and 15.8 ± 0.3 g at 60 DAS. Based on the results, the Grow NPK consortia sachet + 50% mineral fertilizer combination (T5) gave dry weight the maximum increase, which started at 3.0 ± 0.2 g and increased to 24.9 ± 0.5 g. Besides, the root dry weight was greatly increased by Grow zinc sachet with 50% mineral fertilizer of the total content (T6) from 2.8 ± 0.2 g to 20.8 ± 0.9 g.

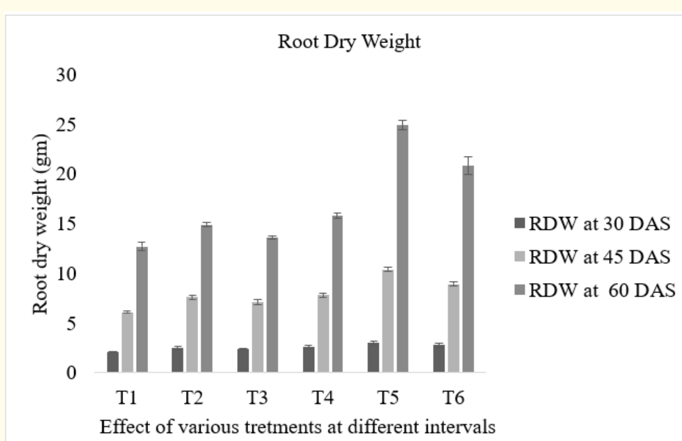

Figure 5: The effects of Grow NPK consortia sachet and Grow zinc sachet biofertilizers on Root dry weight at various stages of growth (RDW- Root Dry Weight, DAS- Days after Sowing).

Where, T1 - Control (no fertilizer): 0%, T2- Grow NPK consortia sachet 100%, T3- Grow zinc sachet 100%, T4- Grow NPK consortia sachet 50% + Grow zinc sachet 50%, T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%, T6- Grow zinc sachet 50% + mineral fertilizer 50%.

Shoot dry weight

The assessment of shoot dry weight over a 60-day period indicated substantial variations in plant biomass increase. The control group (T1) had a rise in shoot dry weight from 7.4 ± 0.4 g at 30 days after sowing (DAS) to 78.4 ± 1.2 g at 60 days as shown in Figure 6. Grow NPK consortia sachet (T2) resulted in larger shoot dry weights, measuring 8.0 ± 0.3 g at 30 DAS and 88.7 ± 1.1 g at 60 DAS. Full-strength Grow zinc sachet (T3) led to substantial shoot growth, beginning at 7.6 ± 0.4 g and reaching 91.4 ± 1.2 g. The highest possible shoot dry weight (values of 8.9 ± 0.2 g at 30 DAS and 113.1 ± 1.1 g by 60 DAS) was obtained by combining Grow NPK consortia sachet and Grow zinc sachet at 50% each (T4). By starting at 10.2 ± 1.0 g and increasing up to 129.4 ± 1.5 g, the Grow NPK consortia sachet and mineral fertilizer at 50% each (T5) combination produced the highest shoot dry weight. Measurements of 9.8 ± 0.5 g at 30 DAS and 129.4 ± 1.5 g at 60 DAS showed improvements in shoot dry weight when Grow zinc sachet and mineral fertilizer at 50% each were combined (T6).

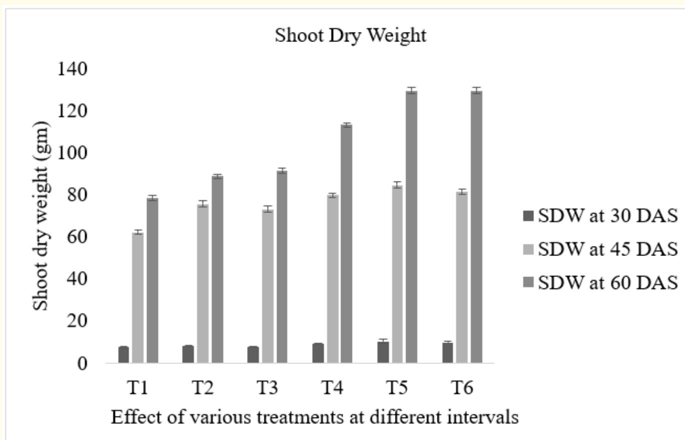

Figure 6: The effects of Grow NPK consortia sachet and Grow zinc sachet biofertilizers on Shoot dry weight at various stages of growth (SDW-Shoot Dry Weight, DAS- Days after Sowing).

Where, T1 - Control (no fertilizer): 0%, T2- Grow NPK consortia sachet 100%, T3- Grow zinc sachet 100%, T4- Grow NPK consortia sachet 50% + Grow zinc sachet 50%, T5- Grow NPK consortia sachet 50% + mineral fertilizer 50%, T6- Grow zinc sachet 50% + mineral fertilizer 50%.

Discussion

The present study demonstrated that the integration of biofertilizer consortia with mineral fertilizers significantly enhanced maize growth and yield parameters compared to sole mineral fertilizer application or control. The treatment combining Grow NPK consortia sachet with 50% mineral fertilizer (T5) consistently outperformed other treatments in ear length, kernel number, 1000-kernel weight, and grain yield. This synergistic effect likely results from the complementary nutrient supply and improved nutrient use efficiency offered by biofertilizers, which aligns with findings by El-Shafey and El-Hawary [20], who reported increased ear length with combined organic and mineral fertilizer application. Similarly, the combined use of recommended dose of fertilizers (RDF) with NPK biofertilizer consortia significantly enhanced ear length in maize, supporting the current study's results [21].

The number of rows per ear and kernels per row were also notably increased by biofertilizer treatments, especially when combined with zinc supplementation as in T4 and T5. Biofertilizer consortia combined with full RDF improved ear length and row numbers in wheat. The enhanced kernel number per ear observed here can be attributed to improved nutrient availability, particularly phosphorus and zinc, which are critical during reproductive development, coupled with biofertilizer-mediated phytohormone production (IAA, cytokinins) that enhances floret differentiation and fertilization, and improved root growth and nutrient uptake ensuring efficient assimilate translocation to developing grains [22]. Similarly the RDF supplemented with FYM and zinc sulfate resulted in the highest kernel weight per cob, confirming the importance of micronutrient supplementation [23]. Moreover, increased nitrogen application improved kernel number per row, highlighting nitrogen's role in grain filling. The increase in 1000-kernel weight under combined treatments indicates that biofertilizers may improve photosynthate translocation and grain filling [24]. This observation resonates with Wolna-Maruwka et. al, who found that maize treated with biochar and *Bacillus spp*. showed significant increases in kernel weight, suggesting that microbial inoculants can enhance grain quality parameters through improved nutrient uptake and hormonal stimulation of growth [25].

Grain yield followed a similar trend, with the highest yields recorded under T5 and T6 treatments, confirming the benefits of integrating biofertilizers with mineral fertilizers. Although these yield values are lower than the potential yield of hybrid maize under ideal irrigation and high-fertility conditions, they are appropriate and realistic for the soil and agro-climatic conditions of the experimental site. The study area is characterized by medium-fertility soils and rainfed cultivation, where average maize yields typically fall within the 1500-2200 kg/ha range. Significant yield increases with a consortium of biofertilizers and mineral nutrients in maize [26]. The enhanced cob yield with bacterial consortia inoculation, further validating the positive role of biofertilizers in maize productivity [27].

Growth parameters such as plant height, stem girth, leaf area, root length, and dry weights of root and shoot were consistently improved under treatments integrating biofertilizers and mineral fertilizers. Enhanced plant height under T5 was similar to findings by Bharti., *et al*. who reported increased height in *Brassica juncea* with phosphorus-solubilizing bacteria, *Azotobacter*, potassium, and zinc mobilizing bacteria [28]. The combined nutrient management increased maize plant height, underscoring the importance of balanced fertilization [29].

Stem girth improvements parallel results in which increased girth with combined mineral and biofertilizer application [30,31]. Enhanced leaf area under combined treatments agrees with Babu., *et al*. who showed improved leaf expansion in maize with zinc-solubilizing bacteria [32]. Similarly, increased root length and dry weight observed here are in line with another study demonstrating that biofertilizers promote root development, enhancing nutrient and water uptake [33]. Shoot dry weight also improved under combined treatments, suggesting better overall biomass accumulation and nutrient assimilation. These results are consistent with other study who documented increased shoot biomass with biofertilizer consortia in maize and mustard, respectively [34].

In summary, the integration of biofertilizers such as Grow NPK consortia and zinc sachets with reduced mineral fertilizer rates substantially improved maize growth, yield, and nutrient use efficiency. These results are supported by multiple studies emphasizing the critical role of microbial inoculants and micronutrient supplementation in sustainable crop production systems.

Conclusion

This study evaluated the effects of Grow Zinc and Grow NPK Consortia sachet biofertilizers on maize yield and growth, showing significant improvements in both quality and quantity, particularly when combined with mineral fertilizers. The application enhanced the sweetness and yield of maize, highlighting its potential for large-scale agriculture. By reducing the reliance on chemical fertilizers, these biofertilizers support sustainable farming, improve soil health, and lower input costs, making them a valuable addition to modern agricultural practices.

Conflicts of Interest

The authors declare no conflicts of interest or competing interests related to this study.

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