Impacts of NPK consortia biofertilizer and mineral fertilizer on growth and yield of two maize (*Zea mays* L.) hybrids in Rajasthan-India

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Abstract

Inoculation of important microbial strains in a modern intensive crop production is a critical step for the improvement of hybrid crop production. This study evaluated the impact of NPK consortia biofertilizer (NPK CB) and mineral fertilizer on growth and yield of two maize (*Zea mays* L.) hybrids at Mewar University research farm, India. The research was conducted during 2020/2021 Kharif cultivation season. The split-plot design was adopted in three replications, each consisting of six treatments combinations; (T1 = control, T2 = 50% Recommended Dose of Fertilizers (RDF), T3 = 100% RDF, T4 = NPK CB, T5 = 50% RDF + NPK CB and T6 = 100% RDF + NPK CB) and two maize hybrids (i.e., N.K-30 and N.K-30 plus). The result obtained revealed that the growth attributes, and yield attributes increased due to the combined application of NPK CB and mineral fertilizers. But there is no significant difference ($p>0.05$) observed between the studied hybrids, except for the 1000 kernels weight. Although the highest grain yield (1987.39 kg ha^{-1}) obtained from the application of T6 (100%RDF + NPK CB) was comparable with the grain yield (1957.64 kg ha^{-1}) obtained from the application of T3 (100% RDF). However, inoculation with NPK CB had superior effects on growth and yield attributes over the sole application of mineral fertilizers below the RDF. Hence, NPK CB could be a potent fertilizer input for hybrids maize production while reducing the level of chemical fertilizers below the RDF.

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Introduction

Maize (*Zea mays* L.) is among the foremost cereal crops grown worldwide, it ranks third after wheat and rice in total grain production. Maize is grown throughout the world under a large range of agro-climatic conditions. Globally, the total productivity across 165 producing countries is estimated at 1,016 Million Metric Tons (MMT), and an average yield of 5.52 Tons per hectare (T ha^{-1}) from a total land area of 184 million hectares (M ha) (FAOSTAT, 2014). Despite these production potentials, an increase in the demand for agricultural commodities is expected to reach 60% by 2030 as reported by Food and Agriculture Organisation FAO (2010). More interestingly, 85% additional demand of this projected yield will be emanated from developing countries dependent on agriculture as their major economic growth

(Mia and Shamsuddin, 2010). In India, maize is the third most vital grain crop after rice and wheat, grown in both rainy (Kharif), winter, and spring season, with major production in the Kharif season (Yadav *et al.*, 2016). It is cultivated in an area of 9.09 M ha, with an annual production of 24.26 MMT and an average yield of 2.56 Metric Tons per hectare (MT ha^{-1}) (Yadav et al., 2015). A serious shift in Indian maize grain demand is underway and by 2022 and 2025, it is anticipated to reach 26 MMT and 50 MMT from the current demand, with a targeted productivity level without a significant increase in acreage to 5-6 (MT ha^{-1}) from the current obtainable yield of 2.43 MT ha^{-1} (Sharma *et al.*, 2018). Moreover, the hybrid crop cultivation method is extensive and requires the employment of mineral fertilizer which is expensive. In addition, High cereal production due to the unnecessary use of chemical fertilizers brings-forth greater cost of production besides the risks of pollution to the soil environment (Mia and Shamsuddin, 2010).

At this critical juncture, the adverse effects of prolonged use of chemical fertilizers have resulted in the emergence of the novel Integrated Nutrients Management (INM), of which bio-fertilizer could be a component. It serves as an effective alternative area concerning the increasing demand for healthy food supply, sustainability in production, and fears of environmental pollution (Reddy, 2013). Bio-fertilizer is a microbial inoculant often incorporated with seeds, plants, or soil, colonizes the rhizosphere or the internal plants' parts, and stimulates the growth of the plant by increasing the availability of accessible nutrients to the host plant (Mahmud *et al.*, 2021; Malusa and Vassilev, 2014; Yahaya *et al.*, 2019). Bio-fertilizers are extensively accustomed to hasten the microbial processes that enhanced the provision of nutrients in the form that will be easily absorbed by the plants, while reducing the level of chemical fertilizers application (Khandare *et al.*, 2020; Cisse *et al.*, 2019). They potentially improve soil fertility through atmospheric nitrogen fixation, solubilizing insoluble phosphates, and release of growth-promoting substances in the plant's rhizosphere (Mahmud *et al.*, 2021; Mazid and Khan, 2015). Liquid microbial consortium contains a group of microbes in a mutual relationship that helps enhanced crop growth (Odoh *et al.*, 2020; Madigan et al., 2009). This liquid formulation is an advanced technology over the conventional carrier-based biofertilizer that contains microbial consortium in a suitable medium and assured their viability for long period (up to 2 years) to aids boost their biological interaction of the target spot (Pindi and Satyanarayana, 2012). The success rate with biofertilizers with great impact on yield ranges between 35-64%. To exploit this potential benefit, the consistency of their performance must be improved. These require research in a diverse area as these biological systems involve a complex interaction among the host, other rhizosphere microflora and fauna as well as the environment (Nandwani, 2016).

Several researches revealed the impacts of combining bio-fertilizers and chemical fertilizers on growth and yield of maize hybrids. Gao et al. (2020) figured out that, the integrationof bio-organic fertilizers with 50% RDF could efficiently reduce the consumption of chemical fertilizers while meeting the crop nutrients demands on sustainable agricultural practice. Idris and Mohammed (2012) reported that substantial variations in yield and its components among the maize genotypes were detected. Similarly, more ears per plant, improved ear characteristics, the heavierweight of grain per plant, and higher grain yield per hectare are obtained in hybrids as compared with open-pollinated varieties (El-Kalla *et al.*, 2001). Significant interactions between maize hybrids and nutrients application were also detected (Bender *et al.*, 2013). However, this is the first attempt to study the effects of consortia biofertilizers on maize hybrids in the experimental sites. Despite the significance of the study to the policy makers and farmers. Therefore, the present investigation was carried out to envisage the impacts of NPK CB and various levels of mineral fertilizers on growth and yield of maize hybrids.

Materials and Methods

The field experiment was conducted at Mewar University research farm (Latitude 25^0.030N and Longitude 74^0.637E, at an altitude of 40m AMSL; Fig. 1) during the 2020 Kharif crop cultivation season to work out the impact of NPK consortia biofertilizer (NPK CB) and varying levels of mineral fertilizer on growth and yield of two maize (*Zea mays* L.) hybrids (N.K 30 and N.K 30 plus). According to the department of agriculture (DOA) classification, the site falls under Chittorgarh districts agro-climatic zone IV (Sub-humid Southern Plain), characterised by high vagaries of weather variables especially in terms of the temperature. During summers, temperature may rise up to 41.8^{o}C or more and it may fall as low as 8.1^{o}C during the winter season. The annual average rainfall ranges between 500-900 mm.

The soil samples were collected from the experimental locations for the physical and chemical analysis before the onset of the experiment. Three soil samples were taken randomly from each plot and bulked together to obtain a representative composite sample. The soil samples were taken to the laboratory, spread, air-dried and sieve. The prepared samples were subsequently used for the analysis following the standard procedures of laboratory soil analysis, the obtained results are presented in Table 1.

The research was carried out using a split-plot design on a randomized complete block design (RCBD) in three replicates; the maize hybrids are considered the main plot and the treatments combination as a sub-plot representing T1, T2, T3, T4, T5 and T6 (where T1: control, T2: 100% RDF, T3: 50% RDF, T4: NPK CB, T5: NPK CB + 50% RDF, and T6: NPK CB + 100% RDF). Both the maize hybrids (N.K 30 and N.K 30 Plus) were sown on 7th July, 2021 and harvested on 29th Sept., 2021. The total crop growing period was 85 days. Three (3) seeds were sown per hole and later thinned to 1-stand per hole at 2 WAS; the weeding operation was done manually and whenever required. The recommended dose of fertilizer (RDF) was applied using single nutrients fertilizer sources [i.e., Urea (46% N), Single Super Phosphate (SSP) (16% P_2O_5), and, Muriate of Potash (MoP) (60% K_20)]. Blank recommended fertilizer applications of the region (i.e., 120:60:40 kg ha^{-1} NPK) were adopted. The Full dose of P and K along with half of total N were dibbled at the time of sowing, the remaining parts of N were applied as a splits application at 3- and 5- weeks after sowing (WAS), respectively.

The NPK microbial consortia (>8.5 x 10^8 CFU ml^{-1}) was prepared in the Rajasthan College of Agriculture (RCA), MPUAT, Udaipur, which composed the microbial strains of '*Azotobacter* (MPUAT strain AZO15; Acession no. MT312863), phosphorus solubilizing bacteria (PSB) (MPUAT strain PSB16 *Entrobacter cloacae*; Acession no. MW405830) and potassium solubilizing bacteria (KMB) (MPUAT strain KSB 41 *Enterobacter hormaechei*; Accession no. MW405827)' (Jain et al., 2021). The consortia biofertilizer were applied at the rate of 5 mls kg^{-1} and 250 mls acre^{-1} as seeds treatment and field application at 3- and 5-weeks after sowing (WAS) respectively. The plots sizes were 2.4 m x 4 m = 9.6 m^2, with the intra-row spacing of 20 cm. At 15, 30, 45, and 60 days after sowing during the growth phase, as well as at the harvesting period, the following parameters were measured; plant height (cm), stem girth (cm), leaf area (cm^2), root length (cm), root dry weight (g), shoot dry weight (g), root-shoot dry weight ratio, cob length (cm), number of rows cob^{-1}, number of grains cob^{-1}, 1000-grains weight (g) and grain yield kg ha^{-1}).

The growth and yield attributes were measured following the procedures in the previous studies (Ngoune Tandzi and Mutengwa, 2019). For each parameter, the sampling was conducted randomly by selecting three stands of plants per treatment. The plant height was recorded using a plastic hundred-meter rule from the soil surface to the top of the plant. The stem girth was measured using a vernier calliper just above the soil surface. The leaf area was determined by computing the multiple of the length and breadth of the widest portion of the leaf, and multiply with a constant of 0.7 (i.e., LL = LL * LW * 0.7) (Li *et al.,* 2007). The root- and shoot- dry weight and root-shoot dry weight ratio was measured after oven-drying the samples at 60 ^{o}C to a constant weight using an electric weighing balance. Whereas, the grain yield was computed using the formula proposed by Sapkota et al., (2016);

Yield (kg/ha) = [(number of kernels rows per ear * number of ear per m2/100) *(weight of 1000-kernels (g)/1000) * 10,000].

The data were statistically analysed separately in line with the analysis of variance (ANOVA) using SAS (Inc, 2015) statistical software package. Mean separation was figured out using the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

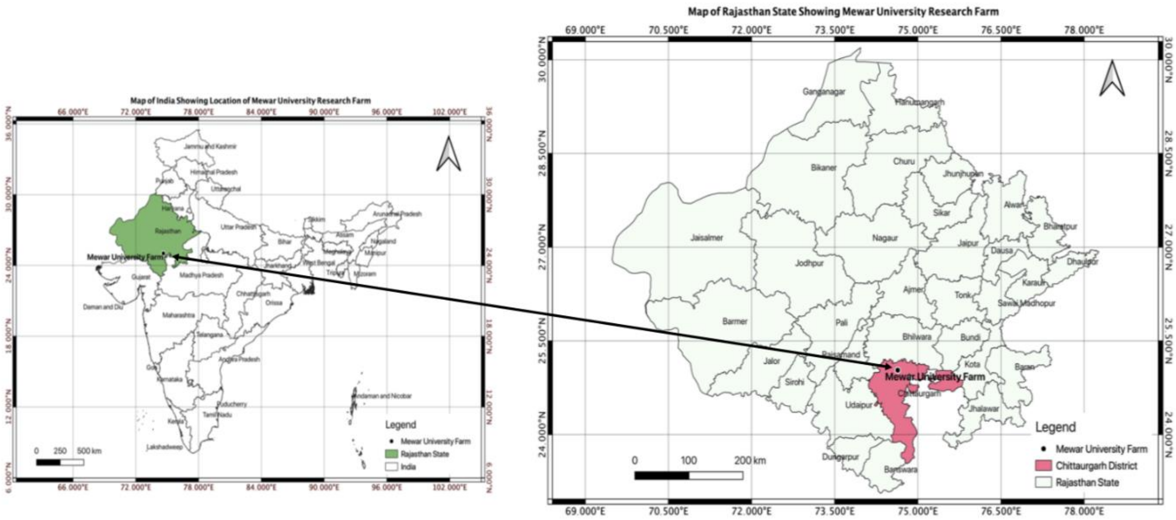

Figure 1. Map of India and Rajasthan state showing the study location

Results and Discussion

The results of the soil analysis showed that the experimental sites were characterized as loamy texture, with organic carbon content 0.51% (medium) and bulk density 1.413 g cm^{-3} (moderate). The soil pH (1:2) value (7.87) showed that the soil was slightly basic, and the electric conductivity of the saturation extract was 0.2 dS m^{-1} (Table 1). The exchangeable bases and available phosphorus of the soil were moderately high. The available nitrogen (391.64 kg ha^{-1}), available phosphorus (18.22 kg ha^{-1}), and available potassium (382.87 kg ha^{-1}) were within the medium range. This proves the true nature of soils in Chittorgarh districts for the suitability of most tropical and sub-tropical crops production (Vyas *et al.,* 2017).

Table 1. Physical and chemical properties of soil of the experimental field

Property/unit	Value obtained	Reference
Mechanical analysis		
Fine sand (2-0.05mm) (%)	42.535	Piper, 1966
Silt (0.05-0.002mm) (%)	35.88	"
Clay (<0.002mm) (%)	21.585	"
Textural class	Loamy	Soil Survey Staff, 1975
Physical analysis		
Bulk density (g cm^{-3})	1.413	Richards, 1968
Chemical composition		
OC (%)	0.51	Walkley and Black, 1934
AN (kg ha^{-1})	391.64	Subbiah and Asija, 1956
AP (kg P_2O_5 ha^{-1})	18.22	Olsen *et al.*, 1954
AK (kg K_2O ha^{-1})	382.87	Jackson, 1973
EC of saturation extract at 25^0C (dS m^{-1})	0.2	Richards, 1968
pH (1:2 soil water suspension)	7.87	"

OC = organic carbon, AN = available nitrogen, AP = available phosphorus, AK = available potash, EC = electrical conductivity.

Growth parameters

Plant height

Based on the results obtained, application of T3 (100% RDF), T5 (50% RDF + NPK CB), and T6 (100% RDF + NPK CB) revealed the highest plant height at 15 Days after sowing (DAS), which are comparably higher than the values obtained in T4 (NPK CB), and T2 (50% RDF). The lowest value was recorded in control T1 (0% RDF). The percentage increased over the control were 5.04%, 14.5%, 3.7%, 9.7% and 14.42%, for T2, T3, T4, T5 and T6 (Figure 2) respectively. At 30 DAS, there was no statistical difference among the treatments. Whereas at 45 DAS, only the control (T1) differed significantly from the other treatments' combinations. The percentage increases were 12.5%, 17.0%, 13.01%, 17.04% and 14.43% for T2, T3, T4, T5 and T6 respectively.

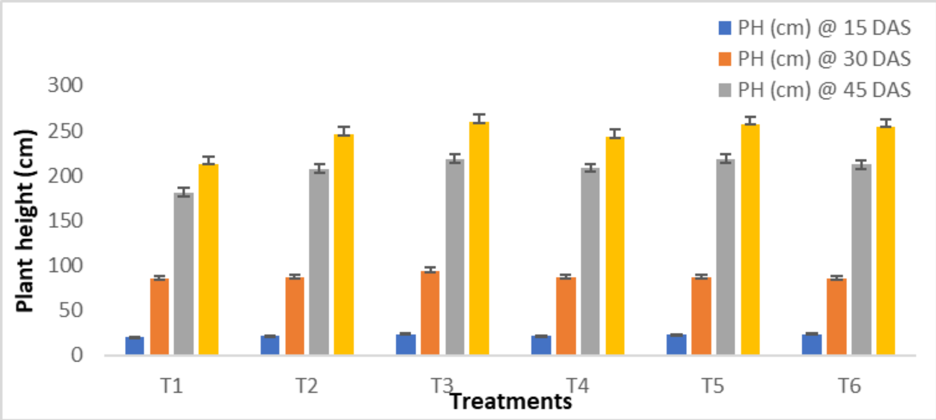

Figure 2. Effects of NPK consortia biofertilizer and chemical fertilizers on mean of plant height at different growth stages; PH = Plant height, DAS = Days after Sowing

Stem girth

Application of T5 (100% RDF) and T6 (100% RDF + NPK CB) recorded the highest stem girth at 15 DAS, followed by T5 (50% RDF + NPK CB), T2 (50% RDF), and T4 (NPK CB) with the lowest value in control (0% RDF) (Figure 3). The percentage increases were 23.2% and 22.1% for T3 and T6, then 15.9%, 13.8%, and 9.1%, for T5, T2, and T4, respectively. At 30 DAS, the highest values were recorded in T4, T5, and T6. The calculated percentage increment over the control were 24.3%, 22.8% and 21.9% respectively. The same trends were recorded at 45 DAS except for 50% RDF, which revealed similar statistical result with control. However, at 60 DAS, only the control (0% RDF) differs significantly from other treatments' combinations. The percentage increases over the control were 11.52%, 12.17%, 12.14%, 7.94%, 7.15%, and for T6, T4, T5, T3, and T2 respectively.

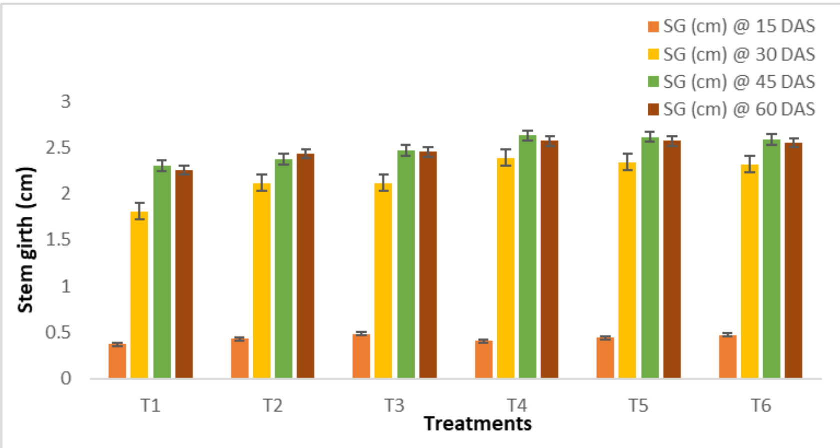

Figure 3. Effects of NPK consortia biofertilizer and chemical fertilizers on mean of stem girth at different growth stages; SG = Stem Girth, DAS = Days after sowing

Total leaf area

The maximum values of leaf area were recorded by the application of T3 (100% RDF) and T6 (100% RDF + NPK CB) at 15 DAS, followed by T5 (50% RDF + NPK CB), T4 (NPK CB), and T2 (50% RDF). The lowest value was recorded in control. The computed percentage increases were compared to control were 48.4% and 28.76% for T3 and T6, then 29.63%, 18.92%, and 13.94% for T5, T4, and T2 respectively. At 30 DAS, the results did not touch level of significance among the treatments. Likewise, at 45 DAS. However, at the peak vegetative growth stage (i.e., at 60 DAS), significance difference was observed, with the highest value in T5. The values obtained from the application of T2, T3, T6, and T4 had similar statistical effects, with the lowest value recorded in control, the computed percentage increased over the control were 23.71% for T5, then 23%, 22.27%, 21.67%, and 14.07% for T6, T3, T2, and T4 respectively.

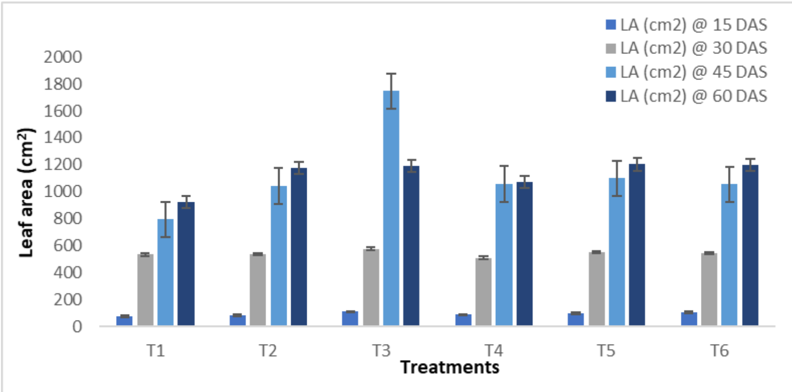

Figure 4. Effects of NPK consortia biofertilizer and chemical fertilizers on mean of total leaf area at different growth stages; LA = Leaf Area, DAS = Days after sowing

Root length

From figure 5, it shows that the highest root length at 15 DAS was recorded from application of T6 (100% RDF + NPK CB), followed by T4 (NPK CB) and T3 (100% RDF). The lowest values were recorded in T5 (50% RDF + NPK CB), 50% RDF, and control (0% RDF). The computed percentage increases over the control were 21.6% for T6, 13% for T3, 13.4% for T4, and 4.67% for T2. However, the values at 30 DAS, 45 DAS, and 60 DAS were not statistically difference.

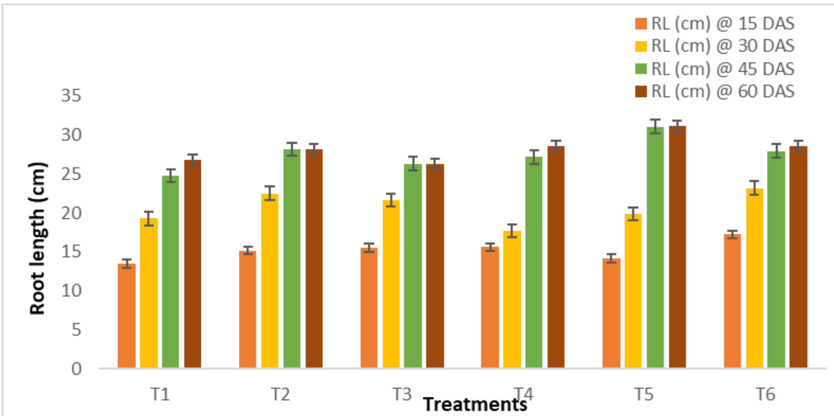

Figure 5. Effects of NPK consortia biofertilizer and chemical fertilizers on mean of root length at different growth stages; RL = Root Length, DAS = Days after Sowing

Root dry weight (RDW)

The root dry weight was not significant at 30 DAS and 45 DAS. Contrarily, at 60 DAS, a significant difference was observed among the treatments, the maximum value was recorded in T6 (100% RDF + NPK CB), with the percentage increase of 48.25% over the control (Figure 6). Followed by T2 (50% RDF), T3 (100% RDF), and T5 (50% RDF + NPK CB). The minimum values were recorded in T4 (NPK CB) and control (0% RDF). The percentage increase over the control were 32.34% for T2, 41.06% for T3, 38.9% for T5, and 28.9% for T4.

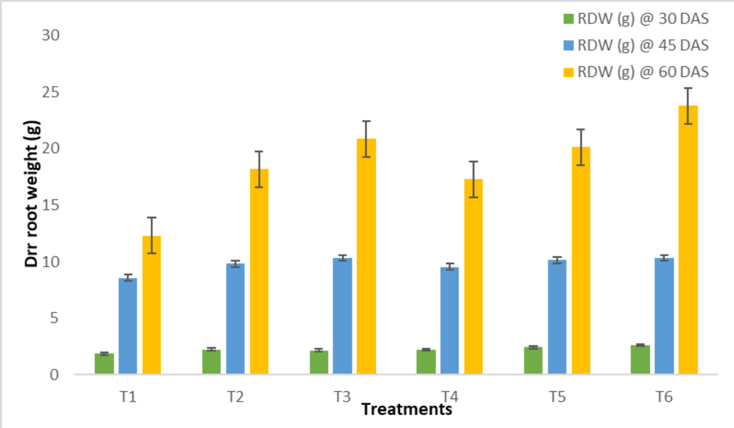

Figure 6. Effects of NPK consortia biofertilizer and chemical fertilizers on mean of root dry weight at different growth stages; RDW = Dry Root Weight, DAS = Days after sowing

Shoot dry weight (SDW)

At 30 DAS, the highest SDW were obtained in T2 (50% RDF), T3 (100% RDF), T5 (50% RDF + NPK CB), and T6 (100% RDF + NPK CB), followed by T4 (NPK CB), the lowest value was obtained in control (0% RDF). The percentage increase over the control were 32.38% for T6, 28.5% for T3, 26.0% for T5, 25.9% for T2, and 20.52% for T4 (figure 7). Similar trends were observed at 45 DAS. Moreover, at 60 DAS, significant difference was observed in response to treatment application, the peak values were recorded in T3 and T6, with the percentage increase 45.9% and 45.8% respectively. Followed by T5, T2, and T4 with the 39.9%, 33.78%, and 30.29% as the percentage increase over the control respectively.

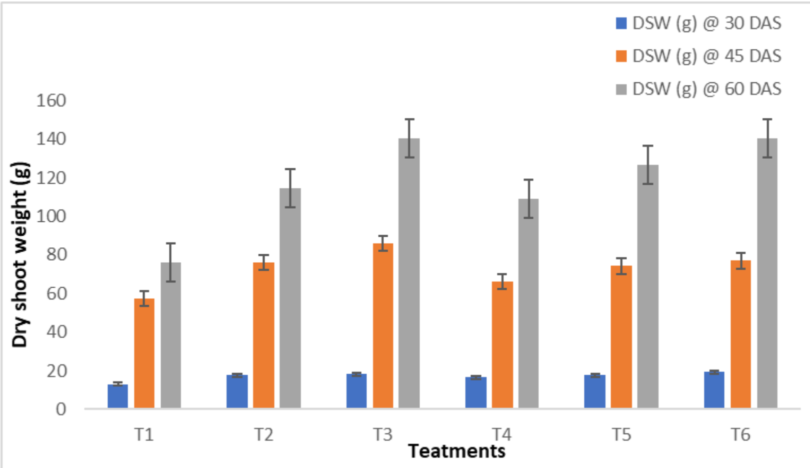

Figure 7. Effects of NPK consortia biofertilizer and chemical fertilizers on mean of shoot dry weight at different growth stages; SDW = Shoot Dry Weight, DAS = Days After Sowing

Root-shoot dry weight ratio

The maximum values for root-shoot dry weight were recorded in control T1 (0% RDF) among the treatment combination, followed by T4 (NPK CB), T5 (50% RDF + NPK CB), and T6 (100% RDF + NPK CB). The least values were recorded in T2 (50% RDF) and T3 (100% RDF) (Figure 8). The percentage decreased over the control were

16.9% for T3, 12% for T2, 7% for T4, 6.3% for T6, and 3.5% for T5. At 30 DAS, similar trends were obtained, with the percentage decrease over the control; 18.7% for T3, 14.7% for T2, 10.0% for T6, 8.0% for T5, and 4.7% for T4.

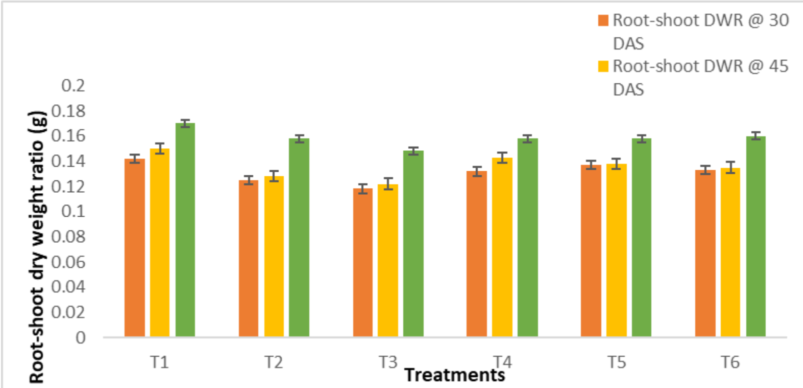

Figure 8. Effects of NPK consortia biofertilizer and chemical fertilizers on mean of root-shoot dry weight ratio at different growth stages; DWR = Dry Weight Ratio, DAS = Days after sowing

Nonetheless, none of the hybrids could exert significant effects on growth parameters *viz;* plant height, stem girth, leaf area, root length, root dry weight, shoot dry weight and root-shoot dry weight ratio, and along the growth stages, i.e., at 15 DAS, 30 DAS, 45 DAS and 60 DAS. Similar results were recorded due to interaction between treatments and hybrids (Figure 2-8).

Yield parameters

Ear length

Analysis of yield parameters revealed that the highest mean values of ear length were recorded in T5 (50% RDF + NPK CB), and T6 (100% RDF + NPK CB), followed by T3 (100% RDF) and T2 (50% RDF), the least value was recorded in T4 (NPK CB) (Table 2). The percentage increased over the control were 25.6% for T6, 23.5% for T5, 21.86% for T3, 18.1% for T2, and 11.72% for T4. Interestingly, none of the treatments could exert significant difference on the number of rows ear^{-1} (Table 2).

Number of kernels row^{-1} and ear^{-1}

The number of kernels row^{-1} revealed the highest values due to application of T3 (100% RDF), T5 (50% RDF + NPK CB), and T6 (100% RDF + NPK CB). Then, T2 (50% RDF) and T4 (NPK CB), with the lowest value in control T1 (0% RDF). However, the percentage increased due to treatment effects were; 23.4%, 23.1%, 21.9%, 14.6%, and 13.1% for T6, T5, T3, T2, and T4 respectively. Similarly, the same trends were recorded for the number of kernels ear^{-1} (Table 2). Nevertheless, the results were not significantly differed on the number of kernels row^{-1} and kernels ear^{-1} in response to hybrids effects. Likewise, the interaction between treatments and hybrids.

Weight of 1000-kernels

The maximum values of 1000-kernels weight were obtained from the application of T3 (100% RDF) and T6 (100% RDF + NPK CB), followed by T5 (50% RDF + NPK CB), and the lowest values from T2 (50% RDF), T4 (NPK CB) and control T1 (0% RDF) (Table 2). The increased percentage due to treatments application were 26.9% for T6, 26.5% for T3, 20.2% for T5, 12.9% for T4, and 10.6% for T2 respectively. Moreover, the hybrids exert significant influence on the weight of 1000-kernels, the higher value (151.07 g) was obtained under the N.K 30 plus hybrid, compared to (144.95 g) under the N.K 30 hybrid, the comparative percentage increase was 4.1%. However, the interaction between treatments and hybrids was not significance on the weight of 1000-kernels.

Grain yield

The application of T3 (100% RDF) and T6 (100% RDF + NPK CB) revealed the highest grain yield. The percentage increases were 29.2% and 28.2% for T6 and T3 respectively, followed by T5 (50% RDF + NPK) with percent increase of 20.1%. The minimum values were recorded in T2 (50% RDF) and T4 (NPK CB) (Table 2). The percentage increases over the control were 14.9% for T4, and 10.7% for T2. However, for the two maize hybrids (i.e., N.K 30 and N.K 30 plus), the results were not significantly differed among the measured yield parameters *viz;* ear length, number of kernels per row, number of kernels per ear, and grain yield, except the weight of 1000-kernels. While for the interaction between treatment and hybrids, none of the yield parameters could touch the level of significant difference.

Table 2. Effects of biofertilizers, chemical fertilizers, and maize hybrids on the mean of yield attributing characters

Treatments (T)	Ear length (cm)	Number of rows ear^{-1}	Number of kernels row^{-1}	Number of kernels ear^{-1}	1000-kernels weight (g)	Grain yield (kg ha^{-1})
T1	14.08^{d}	13.83	32.17^{c}	444.00^{c}	122.50^{d}	1406.10^{d}
T2	17.20^{b}	13.83	37.67^{b}	518.67^{b}	137.00^{c}	1573.79^{c}
T3	18.02^{ab}	14.17	41.17^{a}	581.50^{a}	166.72^{a}	1957.64^{a}
T4	15.95^{c}	14.17	37.00^{b}	521.50^{b}	140.67 c	1652.73^{bc}
T5	18.41^{a}	13.67	41.83^{a}	577.83^{a}	153.50^{b}	1759.57^{b}
T6	18.93^{a}	14.33	42.00^{a}	599.50^{a}	167.67^{a}	1987.39^{a}
SE±	0.41	0.33	1.07	15.91	3.15	47.46
LOS	***	NS	***	***	***	***
Varieties (V)						
NK 30	17.26	14.11	38.56	540.28	144.95	1695.70
NK 30 plus	16.94	13.89	38.72	540.72	151.07	1750.04
SE±	0.24	0.19	0.62	9.18	1.82	27.40
LOS	NS	NS	NS	NS	**	NS
Interactions						
T*V	NS	NS	NS	NS	NS	NS

*Means with same letter are not significantly difference (NS), *** highly significance @ 0.05%, PH = Plant height, DAS = Days after sowing, T1 = control (0%RDF), T2 (50%RDF), T3 (100%RDF), T4 (NPK CB), T5 (50%RDF + NPK CB), T6 (100%RDF + NPK CB).

Discussion

The enthusiastic growth of the above-ground part at higher fertility levels; T3 (100% RDF) and T6 (100% RDF + NPK CB) at 15 DAS, might have occurred due to rapid metabolic activities, division and elongation of cells in response to balanced and adequate NPK supply (Bhatla and Lal, 2018; Tripathi *et al.,* 2014). The conspicuous increment in plant height due to NPK CB is possibly due to increased auxin production capacity by the microbes in the rhizosphere (Bradáčová et al., 2020; Singh *et al.,* 2013). However, the trivial response at 30 DAS might be the subsequent nutrients applied being under-utilized to revealed significant impacts on plant's height. Moreover, at 45 DAS and 60 DAS, similar trends of results were observed among the treatments with exception to control. These results correspond with findings of Soleimanzadeh and Ghooshchi (2013); El-Lateef and Ahmed (2018); and Preetham *et al.* (2020).

The maximum stem girth values were obtained at highest fertility levels (i.e., T3 and T6) at 15 DAS, which is comparatively greater than the values obtained from the application of fertility levels; T2 (50% NPK), T4 (NPK CB), and T5 (50% NPK + NPK CB), this might be in response to greater nutrients availability at the former fertility levels than the later. Mtaita et al. (2019) reported that increased fertility levels especially in combination with biofertilizers resulted in amplified cell division and enlargement of the cell size, thus, producing relatively larger stem girth. Similar results have been reported by Anuroopa *et al.* (2017). On the other hand, sole application of consortia biofertilizers (T4) had similar statistical effects and revealed the highest stem girth value, over the use of chemical fertilizers alone at 30 DAS and 45 DAS. Thilagar *et al.* (2014) and Zahid (2015) documented that isolation and inoculation into microbial consortia of different microbes increase the availability of macronutrients, probably due to synergistic interaction between the microbes in the consortia, with positive consequences on the above-ground growth. The increased stem girth value due to microbial co-inoculation were reported in other crops like Thilagar *et al.* (2014) in chilly; Chauhan and Bagyaraj (2015) in French bean, and Alori *et al.* (2019) in maize plant. Furthermore, the stem girth had similar statistical effects under different fertility levels at 60 DAS. This result is in conformity with the findings of Mtaita *et al.* (2019) who have reported similar results at 60 DAP.

Decreasing levels of mineral fertilizer along with the incorporation of NPK CB revealed superior impacts on leaf area over the solitary use of chemical fertilizers at 15 DAS (Figure 4). Alternatively, at 30 DAS and 45 DAS, the difference did not touch levels of significance, whereas at the later stage of plant growth (60 DAS), a significant difference was observed among the treatments, with pronounced effects in response to NPK CB. These results are closely confirmed with the findings of El-Shafey and El-Hawary (2016); Kwadzo *et al.* (2016); Gao *et al.* (2020); and Sajjad Haider *et al.* (2020).

At 15 DAS, Application of T6, T4 and T3 revealed the highest value of root length. However, T6 recorded superior over the other fertility levels, this suggested that NPK CB plays a critical role in plant root extension. Bradáčová *et al.* (2019) filed that microbial consortium product enhanced root and shoot growth along with increased absorption of macronutrients primarily due to increased supply of auxin by the transient expression of *AuxIAA5* in the root tissue. Vafadar *et al.* (2014) also reported a significant increase in root length from co-inoculation of microbes compared to control. The general increase in root length could be a result of optimum N fertilization and uptake, as it is reported to have a positive effect on root growth (Su *et al.*, 2019; York *et al.*, 2015). However, the treatment application at 30 DAS, 45 DAS and 60 DAS did not reveal significant effects on root length during the growth period. This might be because of high N contents from the higher fertility levels (Fageria and Moreira, 2011; Feng *et al.*, 2016).

During the initial phase of plant growth (i.e., at 30 DAS and 45 DAS), the increased fertility level had no effects on root dry weight (Figure 6). Interestingly, this contradicts the statement made by Mpanga *et al.* (2019) and Bradáčová *et al.* (2019) who reported that microbial consortia hold beneficial effects during the first four weeks of field-grown maize especially with optimum NH_4 fertilization, then decline at the later stage of growth primarily due to abstention of a nitrification inhibitor. However, a significant response was observed during the peak vegetative growth stage (60 DAS), with the highest value in response to T3 and T6. The data also illustrated that the values from the application of T4 and T5 have similar statistical effects on root dry weight, which are comparatively higher than those in T1 and T2 respectively, which are also better than the control (T1). The result is in proximity with findings of Anuroopa *et al.* (2017); and Sajjad Haider *et al.* (2020).

Increasing levels of fertility levels showed marked increased in shoot dry weight at 30 DAS. The same trends of results revealed at 45 DAS. Moreover, the result differed significantly at 60 DAS, where the fertility levels distinctly influenced the shoot dry weight (Figure 7). This might be attributed due to adequate and balanced fertilization supplied from the two-fertilization source (biofertilizers and mineral fertilizer) that have been fully utilized and converted into tissues. Certainly, maize hybrids as one of the cereal crops cherished with high nutrients demand especially N. Therefore, adequate supply of mineral nutrition especially N on the soil (Table 1), exert marked influences on photosynthesis and dry matter partitioning between roots and shoots of the plant, ultimately producing the higher shoot and root biomass (Costa *et al.,* 2002; Kandil, 2013; Bradáčová *et al.,* 2020). Anuroopa *et al.* (2017) and Tshewang et al. (2020) revealed similar results due to the combined effects of MC and mineral fertilizers in *Withania somnifera* and some selected grass species respectively.

Decreasing levels of fertility from T3 to T2 and T1 resulted in a marked increase in root-shoot dry weight ratio at 30 DAS and 45 DAS. However, a slight increase was observed with the integration of T4 at 30 DAS and 60 DAS (Figure 8). This might be the maximum vegetative growth being favored owing to marked increase in macronutrients (NPK) contents by the microbial inoculants (El-Sawah *et al.*, 2018), along the growth stages as explained in the above paragraph. Thus, resulting in a low root-shoot dry weight ratio. The result is in close proximity with the results of Mohammed (2012), who reported an increase in a root-shoot dry weight ratio with inoculation of biofertilizers at various stages of plant growth.

The application of T5 and T6 revealed similar results on the mean of ear length with superior effects over solitary use of high-level chemical fertilizer of T2 and T3 (Table 2). This suggested that the incorporation of NPK CB markedly increased the ear length of maize hybrids compared to the use of mineral fertilizers alone in recommended dose. The same result has been reported due to increased level of mineral fertilizers and biofertilizers by El-Shafey and El-Hawary (2016); Obid *et al.* (2016); and Preetham et al. (2020). Interestingly, neither the mineral fertility levels (T3, T2, and T1) nor the NPK CB (T4), as well as their interaction, revealed significant impact on the number of rows ear^{-1}, this might be associated with the genetic attribute of the hybrids. Ajami (2016) obtained similar results from the application of varying levels of (Urea and Nitroxin). Likewise, Farnia and Torkaman (2015) reported nearly similar results from the use of two different fertilizers (N and P).

Fertilizer application at varying rates along with the combination of T4 showed marked improvement in the number of kernels row^{-1}. Similar effects were recorded in the number of kernels ear^{-1} as presented in (Table 2). The maximum number of kernels row^{-1} and ear^{-1} at higher fertility levels (T3, T5, and T6) could clearly explain the positive consequences of balanced fertilization from both mineral and biofertilizers source on yield attributes (number of kernels/ear) of maize hybrids. These results are highly agreed with the findings of Ajami (2016); and El-Lateef and Ahmed (2018).

The increased in 1000-kernels weight could be due to comparatively improved yield attributing characters *viz*; ear length, number of kernels row^{-1}, and number of kernels ear^{-1} at higher fertility levels (Table 2). Kalhapure *et al.* (2013); Farnia and Torkaman (2015); and Mahmood *et al.* (2017) revealed similar results.

The grain yield increased significantly in response to increased level of mineral fertilizer up to T3 (100% RDF) with the percentage increase of 28.2%. However, combined application of chemical fertilizer along with biofertilizer T6 (100% RDF + NPK CB) found superior with the 29.2% percentage increase. Decreasing level of mineral fertilizers along with integration of consortia biofertilizer markedly improved grain yield over the sole application of chemical fertilizers, this has been proved in percentage yield increase from 10.7% to 20.1% due to the application of T2 (50% RDF) and T5 (50% RDF + NPK CB) respectively. More fascinatingly, 14.9% percentage increase was obtained from the solitary application of consortia biofertilizer (T4) over the control (0% RDF) (Table 2). This might be attributed to increased growth and yield attributing characters in maize hybrids. Philippot et al. (2013) and Odoh et al. (2020) reported that inoculation of the seeds, plants, or soil surface with NPK CB markedly increased grain yield and above-ground plant parts by a process called biofertilization. A similar result has been reported number of researchers such as Choudhary *et al.* (2015); Kwadzo *et al.* (2016); Preetham *et al.* (2020); and Jain *et al.* (2021).

Conclusion

The experiment was conducted to investigate the effects of NPK consortia biofertilizer (NPK CB) and varying levels of chemical fertilizers on growth and yield parameters of two maize hybrids (N.K 30 and N.K 30 plus) during the 2020 *Kharif* season. Based on our experimental findings, it is clearly shown that the combined fertilization of NPK CB and chemical fertilizers could significantly increase the growth and yield of maize hybrids compared to sole application of either type of fertilizers. Moreover, application of NPK CB had superior effects under reduced level of chemical fertilizers among the treatment combinations. The maximum yield attributes such as ear length (18.93cm), number of kernels row^{-1} (42.00), number of kernels ear^{-1} (599.50), 1000-kernels weight (167.67g), and grain yield (1987.39 Kg ha^{-1}) was recorded with the application of T6 (100%RDF + NPK CB). The percentage yield increased up to 29.2% compared to control. Therefore, it can be inferred that the maize hybrid could be grown with the application of NPK CB along with the reduced level of chemical fertilizers (50% RDF), which is comparable with the (100% RDF) fertility levels under *Kharif* season maize hybrids cultivation. Nonetheless, in future studies, the effects of these fertilizers' levels on soil health and the consequences on the diversity of microbial consortia needs to be investigated in the university research farm.

Conflict of Interest

The authors declare that they have no conflict of interest.

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