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Impact of formulations of microbial consortia on growth maize (*Zea maize* L.) under green house condition

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Abstract
Five formulations of two microbial consortia (MC) were prepared with an objective to study thir effectiveness. Four agriculturally beneficial microorganisms *viz*. *Azospirillum* ACD-15, *Gluconacetobacter* G_1., *Pseudomonas striata* and K-solubilizing bacterium (KSB) were used in consortia preparation. Effectiveness of these formulations of different consortia were studied on maize (*Zea maize* L.) growth under green house. Maximum plant height, number of leaves plant^{-1}, root dry weight and shoot dry weight were recorded significantly the highest in the interaction of Na-alginate and liquid formulations of MC-1. However, the two microbial consortia did not differ significantly except for root dry weight, where MC-2 recorded significantly higher at 45 DAS (7.07 g) and at 90 DAS (16.36 g) compared to MC-1 (6.47 g) at 45 DAS and (15.41 g) at 90 DAS.

Keywords: Microbial consortia, formulations, growth and maize

Introduction
Maize (*Zea mays* L.) is the third most important crop in cereals after wheat and rice in the world. India is the sixth largest producer of maize in the world which contributes two per cent to the global production. It is cultivated in tropical and also temperate regions of the world. In India, maize is grown on an area of 9.03 m ha with 2.77 m tonnes of production and 3.07 tonnes ha^{-1} of productivity. In Karnataka it is being grown on an area of 1.34 m ha with 3.81 m tonnes of production and 2.81 tonnes ha^{-1} of productivity and 190.75 m ha area with 1076 m tonnes production and 5.64 tonnes ha^{-1} globally (Anon, 2018) [2].
Maize for its higher yield potentials, for being processed in industries besides contributing substantially as food additives in India and many parts of the world it is becoming a very popular crop. It is an exhaustive crop requiring more nutrients than other cereal crops to achieve optimum crop yield.
Adding beneficial microbes in the form of biofertilizers to the soil has found to enhance soil health by increasing availability of nutrients and thereby improving plant growth and crop yield (Sneha and Brahmaprakash, 2017) [8]. In this regard, microbial consortia in different formulations such as expanded clays, liquid based and alginate based beads are new and developing bio-inoculant formulations next to lignite or peat based inoculants (Fages, 1992) [3]. They are easy to handle, less costly when compared to multiple applications of many biofertilizers containing single strain and also require less space with extended shelf life as they contain special cell protectants or substances that prevents desiccation of viable cells and possess tolerance to adverse climatic conditions. Hence, microbial consortium containing multiple strains in formulations made using expanded clay (kaolinite and bentonite), lignite based, liquid based and alginate based beads are promising and are recent technologies with many advantages over conventional carrier based microbial consortium formulations.
Hence, this study was conducted with the objective to develop different formulations of microbial consortia and their effectiveness on the growth attributes of maize (*Zea mays* L.) under green house conditions.

Materials and Methods
Preparation of different formulations of microbial consortia: In this study two microbial consortia (MC) containing 1:1:1 ratio of one of the N_2 fixer (*Azospirillum* ACD-15 or *Gluconacetobacter* G_1), *Pseudomonas striata* (PSB) and K-solubilizing bacterium (KSB) collected from the Agricultural Microbiology Laboratory at the Institute of Organic Farming (IOF), University of Agricultural Sciences, Dharwad. These two MC were formulated in five different formulations namely lignite, kaolinite, bentonite, Na-alginate and liquid formulations

were prepared following 1:3 ratio of culture and carrier material for carrier based formulations. For Na-alginate formulation encapsulation technique was followed as proposed by Saxena (2013) [7] and for liquid formulation different additives were used as cell protectants.

A pot experiment was conducted in green house of UAS, Dharwad using five different treatments of consortia formulations along with dual inoculation of recommended biofertilizers (*Azospirillum* ACD-15 and PSB) and uninoculated control to study the performance of the formulations on the growth of maize (hybrid Super 900M Gold).

Plastic pots of 9 kg capacity were filled with 7.5 kg soil of 4mm sieve size and subjected for two cycles of alternate wetting and drying was mixed well after each cycle. Maize seeds of Super 900M Gold were procured from All India Co-ordinated Research Project on Maize, Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, India and pre-germinated seeds were treated with consortia formulated in lignite, kaolinite, bentonite (20 g/kg seeds), Na-alginate encapsulated beads (4 g/kg seeds) and in liquid (4 ml/kg seeds). Simultaneously, control with dual inoculation and N:P:K in the ratio of 1.2:1.5:1.2 g pot^{-1} as RDF and a un-inoculated control were maintained in five replications. Four pre-germinated seeds per pot were sown and seedlings were thinned to two plants in each pot after 15 days after sowing and grown for 90 days.

Plant growth promotion was assessed in terms of differences in the plant height, number of leaves, root length, root and shoot dry weight and plant dry matter accumulation after 45and 90 days of sowing.

Statistical analysis: The data obtained from study was subjected to statistical analysis using Factorial Completely Randomized Design (FCRD). Interpretation of the data was carried out in accordance with Panse and Sukhatme (1985). The level of significance used in the 'F' and 't' test was $p<0.001$. The mean values between treatments were compared using the least significance differences (L. S. D). The treatment means were compared by applying Duncan's Multiple Range Test (DMRT).

Results and Discussion

Plant growth attributes were significantly influenced by the application of different formulations of microbial consortia. Plant height (Fig. 1) of the maize under green house was recorded significantly the highest in the Interaction of MC_1T_4 receiving Na-alginate formulation of MC-1 (62.48 cm) at 45 DAS. Whereas at 90 DAS, the interaction of MC_2T_3 receiving liquid formulation of MC-2 (115.30 cm) was found significantly superior compared to other interactions with respect to plant height. The plant height was the lowest in the interaction of MC_2T_1 receiving lignite formulation of MC-2 (52.87 cm) at 45 DAS and the interaction of MC_1T_5 receiving bentonite formulation of MC-2 (96.52 cm) at 90 DAS. However the two microbial consortia did not differ significantly for number of leaves $plant^{-1}$ at both 45 and 90 DAS.

The two microbial consortia did not differ significantly for number of leaves $plant^{-1}$ at both 45 and 90 DAS (Fig. 2). However, significant increases in the number of leaves $plant^{-1}$ (8.80) were recorded in the interaction of MC_2T_3 receiving liquid formulation of MC-2 at 45 DAS. Whereas, at 90 DAS the interaction treatment MC_2T_3 receiving liquid formulation of MC-2 (13.00) was found significantly superior over other formulations. The lowest number of leaves $plant^{-1}$ was recorded in the interaction of MC_2T_5 receiving bentonite formulation of microbial consortium-2 (6.80) at 45 DAS and the interaction of MC_2T_2 receiving kaolinite formulation of MC-2 (9.20) at 90 DAS.

The inoculation effect of two microbial consortia on root dry weight of maize was recorded significantly the highest in the interaction of MC_2T_3 receiving liquid formulation of MC-2 (8.80 g) at 45 DAS and (19.58 g) at 90 DAS (Fig. 3). The root dry weight recorded was the lowest in the interaction MC_1T_2 receiving kaolinite formulation of MC-1 (5.38 g) at 45 DAS and MC_2T_1 of MC-2 (11.80 g) followed by MC_1T_1 having lignite formulation of MC-1 (12.2 g) at 90 DAS. Both microbial consortia used were found to significantly influence root dry weight. The MC-2 recorded significantly higher root dry weight (7.07 g) at 45 DAS and (16.36 g) at 90 DAS compared to MC-1 (6.47 g) at 45 DAS and (15.41 g) at 90 DAS.

However, the two microbial consortia did not significantly different for shoot dry weight of maize at 45 DAS of plant growth (Fig. 4). Whereas at 90 DAS, MC-1 was recorded significantly higher shoot dry weight (55.50 g) compared to MC-1 (53.87 g). The interaction effect of consortia and formulation was found to vary significantly for shoot dry weight of maize. The interaction of MC_1T_4 receiving Na-alginate formulation of MC-1 (16.48 g) at 45 DAS and (63.23 g) at 90 DAS was recorded significantly higher in shoot dry weight. The lowest shoot dry weight of maize was recorded in the interaction MC_1T_2 receiving kaolinite formulation of MC-1 (11.18 g) at 45 DAS and the interaction MC_2T_1 receiving lignite formulation of MC-2 (49.81 g) at 90 DAS.

Similarly, the two microbial consortia did not differ significantly for plant dry matter of maize at 45 DAS (Fig. 5). Whereas at 90 DAS, MC-1 recorded significantly higher shoot dry weight (70.92 g) compared to MC-1 (70.19 g). But, the interaction effect of consortia and formulation was found to vary significantly for plant dry matter accumulation. Where the plants under the interaction effect of MC_1T_4 receiving Na-alginate formulation of MC-1 (24.98 g) was found significantly higher in dry matter accumulation at 45 DAS. Whereas, at 90 DAS, the interaction MC_1T_4 receiving Na-alginate formulation of MC-1 was recorded significantly superior compared to other treatments. The dry matter of maize plant was the lowest in the interaction MC_1T_2 receiving kaolinite formulation of MC-1 (16.56 g) at 45 DAS and at 90 DAS, it was recorded that interaction MC_2T_1 (61.61 g) receiving lignite formulation of MC-2 showed the lowest plant dry matter accumulation. These results are in accordance with the earlier studies conducted on the use of microbial consortia in different combinations of inoculants (Mariappan *et al*., 2014; Abou and Abdel, 2012; Jayashree and Jagadeesh, 2017; and Vijaykumar and Brahmaprakash, 2018) [5, 1, 4, 10] reported enhanced growth and yield of crops inoculated. The enhanced growth was observed in all the treatments over uninoculated control could be attributed to the release of growth promoting substances besides their ability to provide three major (N, P and K) nutrients by microbial strains in consortia through their multiple mechanisms which is not possible by the single strain containing biofertilizer.

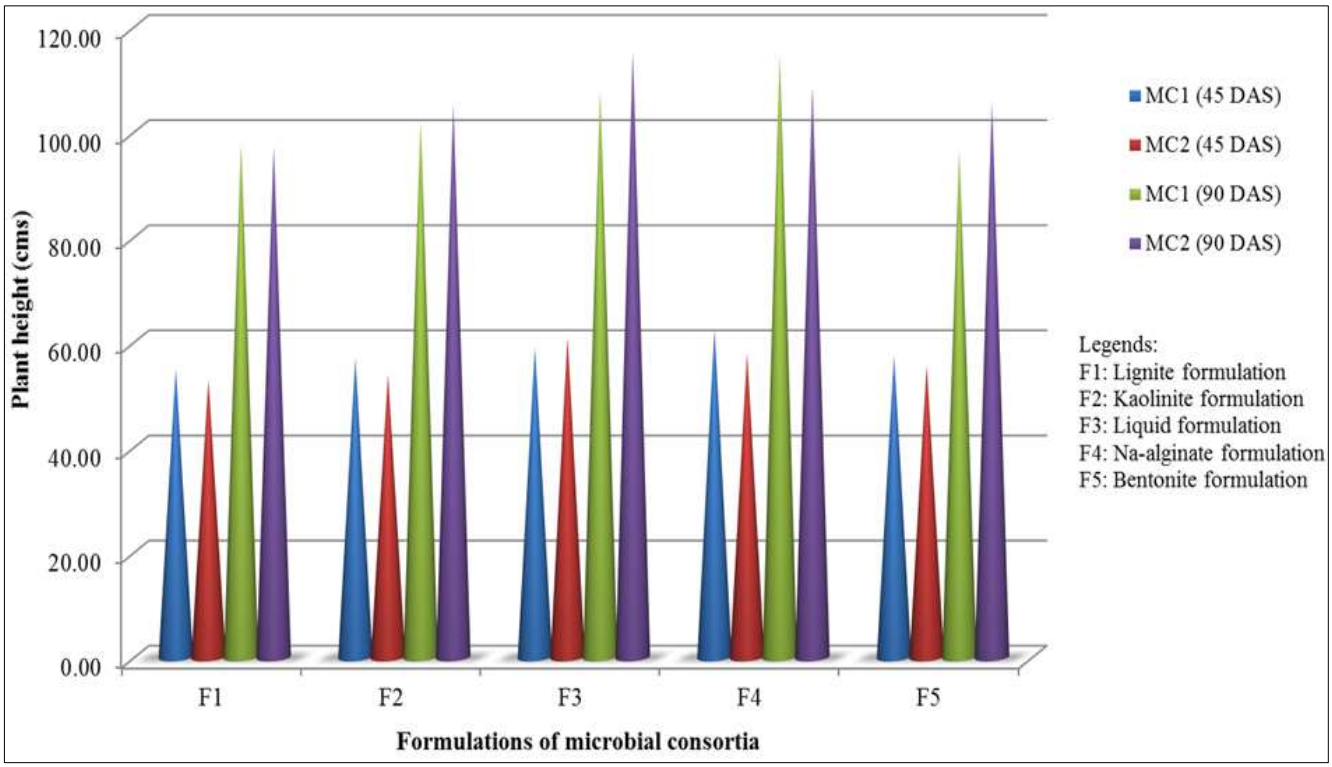

Fig 1: Effect of inoculation of different formulations of microbial consortia on plant height of maize

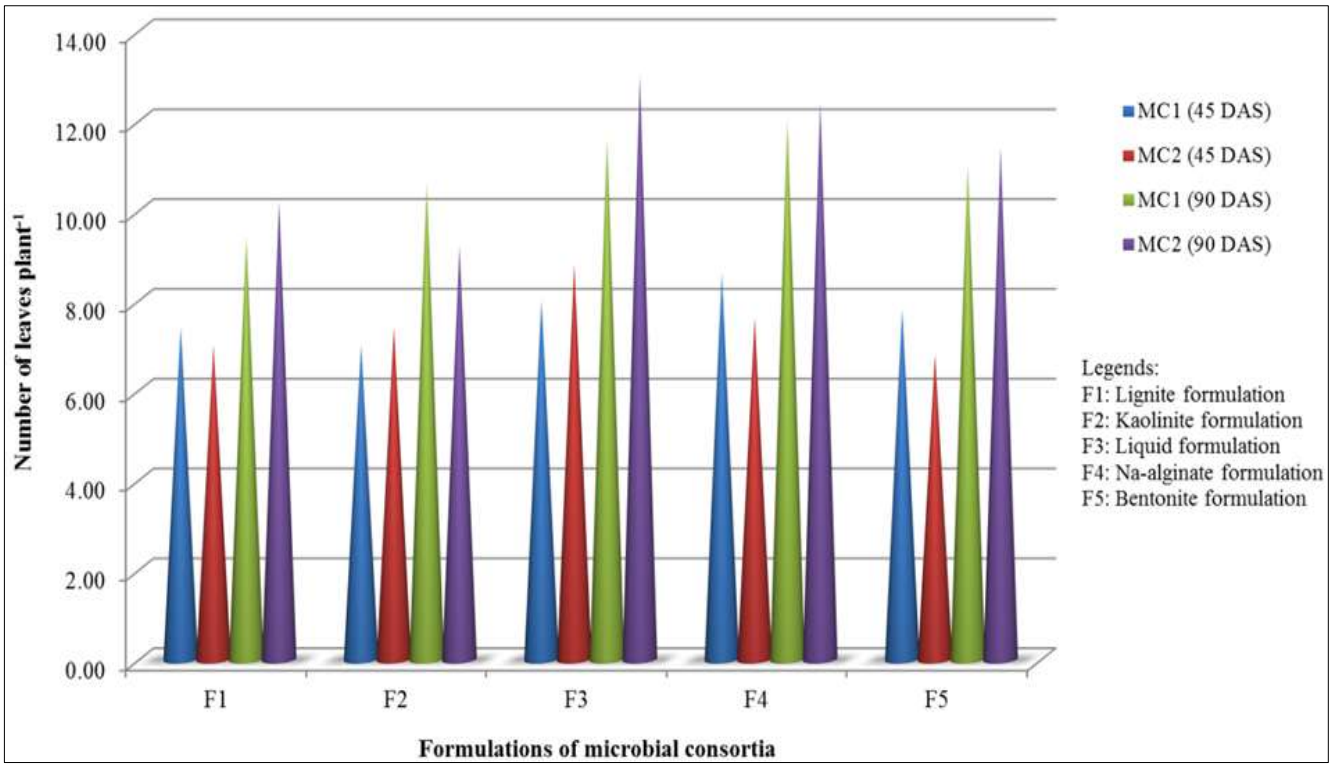

Fig 2: Effect of inoculation of different formulations of microbial consortia on number of leaves plant^{-1} of maize

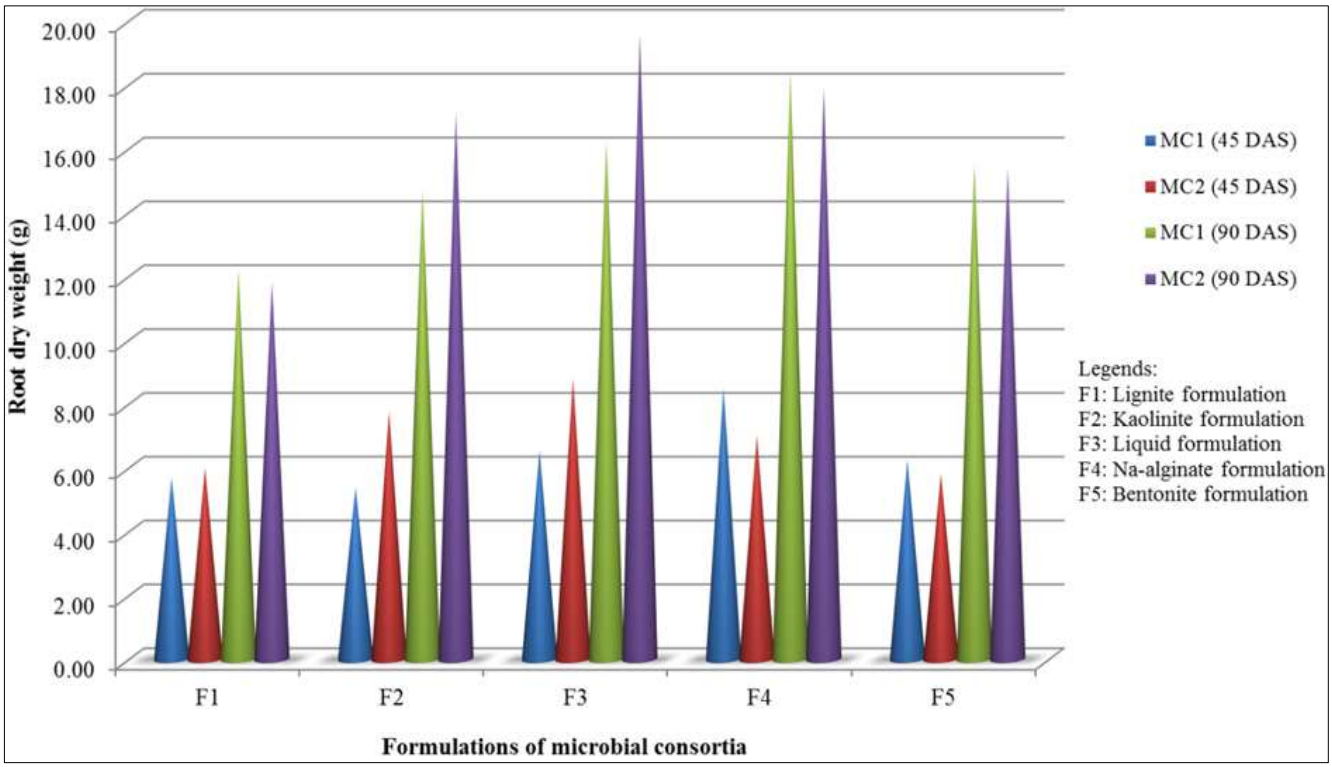

Fig 3: Effect of inoculation of different formulations of microbial consortia on root dry weight of maize

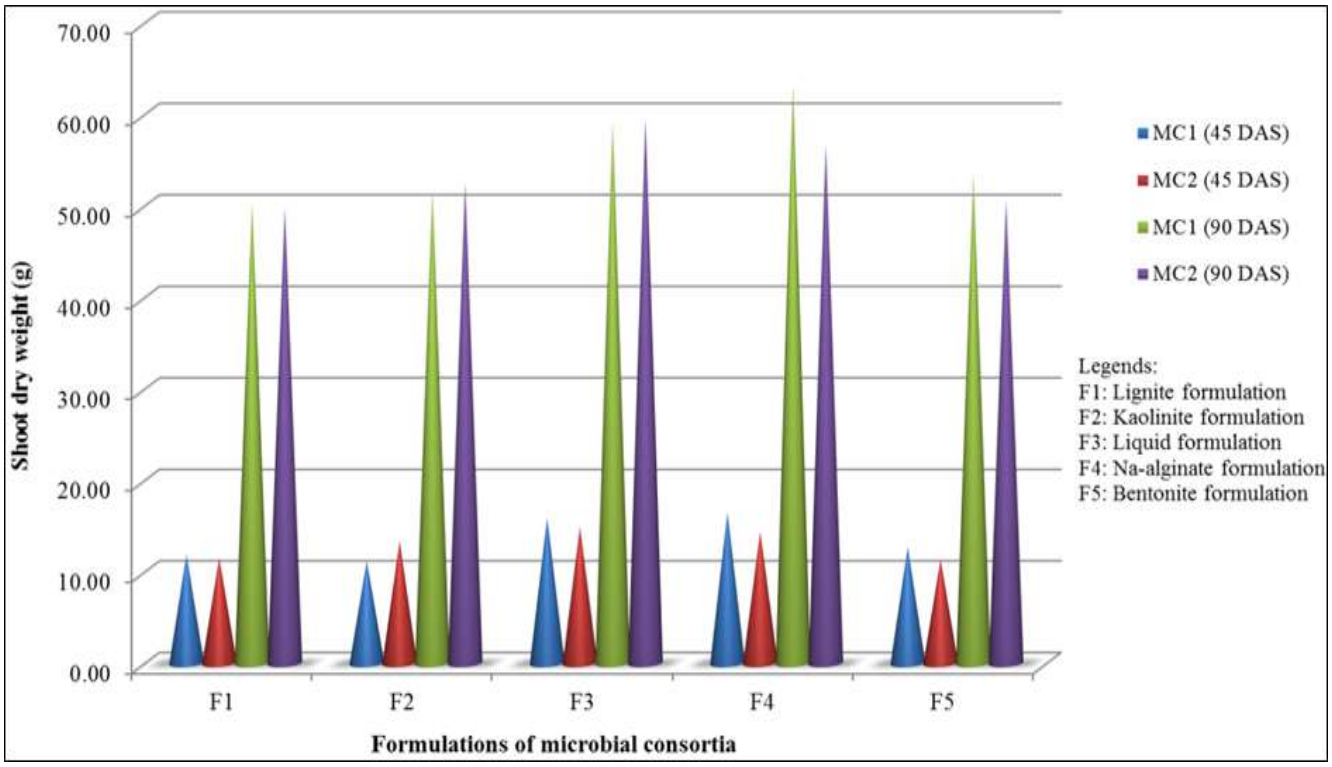

Fig 4: Effect of inoculation of different formulations of microbial consortia on shoot dry weight of maize

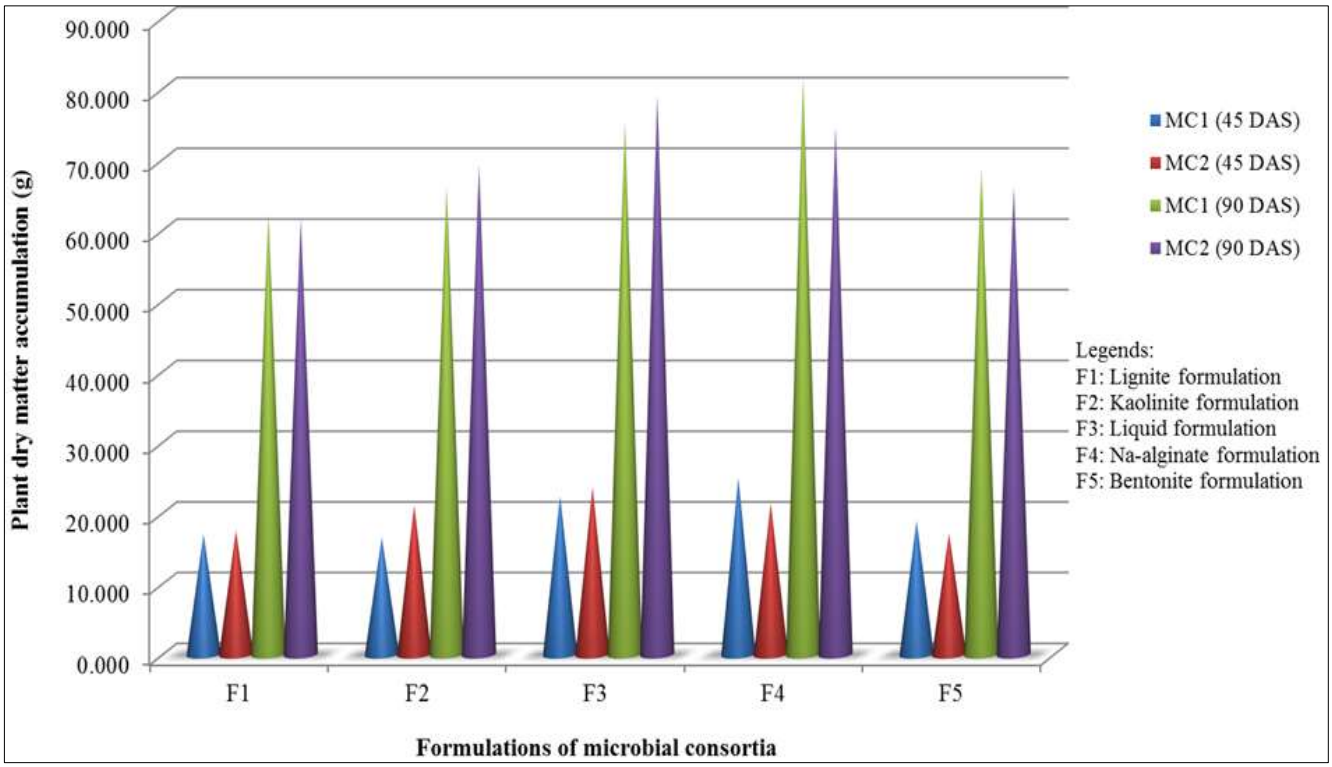

Fig 5: Effect of inoculation of different formulations of microbial consortia on plant dry matter accumulation of maize

It was concluded that among all plants treated with different formulations of MC consortia, Na-alginate and liquid formulations proved their effectiveness on maize growth attributes irrespective of microbial consortium used and also over both dual inoculation and uninoculated control. This study helped in identifying the importance of carrier material in effectiveness of a microbial consortium as the constituent biofertilizer strains in each consortium remained the same but the carrier material used were different. The findings are useful for further development of biofertilizer consortia consisting of a nitrogen fixer, a P-solubilizing bacterium and K-solubilizing bacterium formulated in liquid and Na-alginate entrapment and to study their effect under field conditions.

Conclusion

Among all plants treated with different formulations of MC consortia, Na-alginate and liquid formulations proved their effectiveness on maize growth attributes irrespective of microbial consortium used and also over both dual inoculation and uninoculated control. This study helped in identifying the importance of carrier material in effectiveness of a microbial consortium as the constituent biofertilizer strains in each consortium remained the same but the carrier material used were different. The findings are useful for further development of biofertilizer consortia consisting of a nitrogen fixer, a P-solubilizing bacterium and K-solubilizing bacterium formulated in liquid and Na-alginate entrapment and to study their effect under field conditions.

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