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Influence of Liquid Biofertilizers and Maize-legume intercropping on Growth and Yield of Maize (*Zea mays* L.)

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ABSTRACT

A field experiment was conducted during two consecutive *kharif* seasons of 2022 and 2023 at Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan). The experiment was conducted in split plot design comprising seven intercropping in main plots {Sole maize, maize + cowpea (1:1), maize + blackgram (1:1), maize + soybean (1:1), maize + cowpea (2:2), maize + blackgram (2:2), maize + soybean (2:2)} and four liquid biofertilizers (Control, *Azotobacter*, PSB, NPK consortia) in sub plots within three replication. The results revealed that the maximum plant height, dry matter accumulation, grain and stover yield was obtained under sole maize, which was statistically at par with maize + cowpea (2:2) and maize + blackgram (2:2). Among liquid biofertilizers, the maximum growth and yield was recorded under the application of NPK consortia which was equally effective with *Azotobacter* over PSB and control.

Key words: *Azotobacter, Intercropping, Biofertilizers, Yield, Plant height*

Introduction

The "Queen of Cereals" moniker comes from maize (*Zea mays* L.), which is incredibly productive and adaptable when compared to other cereal crops. The maize plant contains many marketable parts that are used to manufacture both food and non-food items. These parts include the grain, leaves, stalk, tassel and cob. Being a day-neutral and C_4 plant, it is the most versatile and widely grown crop in the world. This crop is grown in more than 166 countries worldwide in tropical, sub-tropical and temperate climates, from sea level to 3,000 metres above sea level.

Intercropping is a type of mixed cropping and defined as agricultural practice of cultivating two or more crops in the same piece of land at the same time. Intercropping has been acknowledged as a

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potentially advantageous method for increasing crop production in unit^{-1} time and unit^{-1} area, which can result in a significant yield advantage over solitary cropping. Maize-legume intercropping system is considered as suitable option since it has enough potential to replenish the soil nutrients, produce more yield and economic benefit. Thus, in a real sense, the intercropping of maize and legumes can increase yield and the system's overall sustainability of production (Maitra *et al.,* 2020a).

A healthy nutrient management system is essential for the production of the maize crop, which has high nutritional needs. With the help of biofertilizers, healthy plants can be cultivated while simultaneously it enhances the sustainability and quality of the soil. A biofertilizer is a substance that contains living micro-organisms that when applied to soil, seeds or plant surface, colonize the plant's rhizosphere or interior and encourage development by increasing the supply or availability of its primary nutrients. Liquid biofertilizer is a special formulation containing high number of desired microorganism with high shelf life and zero contamination. They are cost effective and as a source of plant nutrients to supplement inorganic fertilizers (Sivamurugan *et al*., 2018). As maize is known as nutrient exhaustive crop intercropping with legume crop and application of biofertilizers can improve the soil fertility with the yield benefits.

Materials and Methods

The experiment was conducted during two consecutive *kharif* seasons of 2022 and 2023, at Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur (Rajasthan). The trial was laid out in split plot design with seven intercropping in main plots {sole maize, maize + cowpea (1:1), maize + blackgram (1:1), maize + soybean (1:1), maize + cowpea (2:2), maize + blackgram (2:2), maize + soybean (2:2)} and four liquid biofertilizers in sub plots (Control, *Azotobacter*, PSB, NPK consortia) and replicated thrice. IQMH 203 maize variety was taken as test crop. Crop geometry was 60 cm x 25 cm and 90/30 cm x 25 cm. The soil of experimental site was clay-loam in texture, alkaline in reaction, medium in available nitrogen and phosphorus and high in available potassium.

Plant height was measured with the help of measuring scale from five randomly selected plant in centimeter and dry matter accumulation was weighed in gram per plant. After harvest of crop cob and stover was dried upto a constant weight then cobs were shelled. Yield was recorded by weighing the grains and stover in kilogram and converted in quintal ha^{-1}.

Results and Discussion

Growth parameters

Intercropping: It is explicitly clear from pooled data (Table 1) that the maximum plant height (181.72 cm) was recorded under sole maize which was statistically at par with maize + cowpea (2:2) and maize + blackgram (2:2) intercropping system over rest of the treatments. Further, maize + cowpea (2:2) showed maximum plant height (179.50 cm), which was statistically at par with maize + blackgram (2:2) and maize + soybean (2:2) but significantly superior over maize + cowpea (1:1), maize + blackgram (1:1), maize + soybean (1:1) with the tune of 6.10, 9.91 and 14.40 per cent, respectively. The maximum dry matter accumulation was also recorded under sole maize (160.80 g plant^{-1}) followed by maize + cowpea (2:2), maize + blackgram (2:2) and maize + soybean (2:2) and superior over maize + cowpea (1:1), maize + blackgram (1:1) and maize + soybean (1:1) by 7.28, 7.65 and 7.67 per cent, respectively. However,

Table 1. Effect of liquid biofertilizers and intercropping on mean plant height and dry matter accumulation of maize

Treatments	Plant height (cm)	Dry matter accumulation (g plant^{-1})
Intercropping		
Sole maize	181.72	160.80
Maize + cowpea (1:1)	169.17	149.90
Maize + blackgram (1:1)	163.32	149.38
Maize + soybean (1:1)	156.90	149.36
Maize + cowpea (2:2)	179.50	158.89
Maize + blackgram (2:2)	177.51	156.97
Maize + soybean (2:2)	174.59	156.43
SEm±	2.29	1.97
CD (P=0.05)	6.68	5.74
Liquid biofertilizers		
Control	153.91	146.93
Azotobacter	177.76	157.22
PSB	175.10	155.03
NPK consortia	180.49	158.95
SEm±	1.41	1.14
CD (P=0.05)	3.98	3.21

amongst intercropping the maximum dry matter accumulation (158.89 g plant^{-1}) was recorded under maize + cowpea (2:2) and remained statistically at par with maize + blackgram (2:2) and maize + soybean (2:2) while significantly superior over maize + cowpea (1:1), maize + blackgram (1:1) and maize + soybean (1:1) by 6.00, 6.37 and 6.38 per cent, respectively. The maximum leaf area index was recorded under maize + cowpea (2:2) which was statically at par with maize + blackgram (2:2) and maize + soybean (2:2) at 25, 50 and 75 DAS (Table 2).

Table 2. Effect of liquid biofertilizers and intercropping on mean leaf area index of maize

Treatments	Leaf area index		
	25 DAS	50 DAS	75 DAS
Intercropping			
Sole maize	0.355	3.460	5.426
Maize + cowpea (1:1)	0.350	3.218	5.383
Maize + blackgram (1:1)	0.343	3.218	5.327
Maize + soybean (1:1)	0.334	3.218	5.156
Maize + cowpea (2:2)	0.473	4.597	7.251
Maize + blackgram (2:2)	0.468	4.555	7.197
Maize + soybean (2:2)	0.468	4.551	7.196
SEm±	0.006	0.057	0.073
CD (P=0.05)	0.019	0.166	0.212
Liquid biofertilizers			
Control	0.336	3.743	5.963
Azotobacter	0.421	3.853	6.188
PSB	0.413	3.817	6.141
NPK consortia	0.425	3.910	6.243
SEm±	0.004	0.041	0.052
CD (P=0.05)	0.012	0.114	0.145

The growth in sole maize might be primarily due to no competition faced by sole maize for above and below ground resources. Since both species shared resources and nutrients from the same pool, dry matter accumulation of maize was significantly lower due to interspecies competition when legumes were present (Maitra *et al*., 2020b; Manasa *et al*., 2021).

Liquid biofertilizers: It is clear from Table 1 that the plant height (180.49 cm), dry matter accumulation (158.95 g plant^{-1}) and leaf area index was substantially increased by the application of NPK consortia it was equally effective with the application of *Azotobacter* but statistically higher as compare to PSB and control. The involvement of all type of biofertilizer sources in consortiums, such as Nitrogen-fixing, Phosphorus-solubilizing, and Potassium-mobilizing bacteria, may be the likely cause the increase in growth parameters (Tandon *et al*., 2021). The prominent increment in plant height due to NPK consortia is possibly due to increased auxin production capacity by the microbes in the rhizosphere (Singh *et al*., 2013).

Yield

Intercropping: On pooled basis, maximum grain yield (53.76 q ha^{-1}) was recorded under sole maize which was statistically at par with maize + cowpea (2:2) and maize + blackgram (2:2) but higher than maize + soybean (2:2), maize + cowpea (1:1), maize + blackgram (1:1) and maize + soybean (1:1) which represent 5.42, 8.86, 12.34 and 14.41 per cent increase in yield, respectively. Data further indicate that maize + cowpea (2:2) recorded maximum grain yield (52.20 q ha^{-1}) which was statistically at par with maize + blackgram (2:2). It was significantly higher over rest of the intercropping.

Further, the data on pooled basis indicates that sole maize recorded maximum stover yield (86.44 q ha^{-1}) which was followed by maize + cowpea (2:2) and maize + blackgram (2:2). It was higher by 5.12, 7.50, 8.55 and 10.01 per cent over maize + soybean (2:2), maize + cowpea (1:1), maize + blackgram (1:1) and maize + soybean (1:1), respectively. These results might be due to reduced maize-legume competition for light, nutrient leads higher dry matter ac-

Table 3. Effect of liquid biofertilizers and intercropping on mean yield of maize

Treatments	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})
Intercropping		
Sole maize	53.76	86.44
Maize + cowpea (1:1)	49.39	80.41
Maize + blackgram (1:1)	47.86	79.63
Maize + soybean (1:1)	46.99	78.58
Maize + cowpea (2:2)	52.20	85.33
Maize + blackgram (2:2)	51.89	83.66
Maize + soybean (2:2)	51.00	82.23
SEm±	0.89	1.13
CD (P=0.05)	2.59	3.30
Liquid biofertilizers		
Control	45.75	76.90
Azotobacter	51.61	83.79
PSB	51.14	82.64
NPK consortia	53.26	85.97
SEm±	0.56	0.67
CD (P=0.05)	1.57	1.87

cumulation with higher source to sink relation. According to Chhetri and Sinha (2020) the establishment of both temporal and spatial complementarities may have contributed to the rise in yield attributes in intercropping systems by preventing competition for nitrogen and allowing for the potential current transfer of fixed nitrogen to the crop. Similar results were obtained by Kumar *et al.* (2018) and Khan *et al.* (2018).

Liquid biofertilizers: In pooled analysis, significantly higher grain yield (53.26 q ha^{-1}) was recorded under NPK consortia over rest of the intercropping treatments. The significant increased in grain yield of maize due to NPK consortia was 3.18, 4.15 and 16.41 per cent over *Azotobacter*, PSB and control, respectively. However, during both the year it was statistically at par with *Azotobacter* and PSB.

The maximum stover yield (85.97 kg ha^{-1}) was recorded by the application of NPK consortia. It was statistically at par with *Azotobacter* but higher by 4.04 and 11.79 per cent over PSB and control, respectively. The consortia that gave treatments with the same level of nutrient management showed a higher response than the treatments that received a single type of biofertilizer in addition to inorganic fertilizers. This finding was corroborating with Tandon *et al*., 2021.

Conclusion

The study showed that sole maize was better in growth and yield than maize intercropped with legume but maize + cowpea (2:2) was also more productive and profitable than other intercropping treatments. Among the liquid biofertilizers, NPK consortia was better than single nutrient fixation formulation *i.e.*, *Azotobacter*, PSB and control in terms of growth and yield.

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Conflict of interest

There is no any disagreement on the present study.
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