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Quality characters and yield of fodder maize as influenced by inorganics, organics and biological sources of nutrients

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Abstract
The nutrient management in fodder-based cropping sequence is a key to maximize the fodder production and its quality. It has been realized that integrated nutrient management is the best way of achieving higher productivity and enhancing the fodder quality. Keeping these in view field experiments were conducted at Vjayapur and Bagalkot District Cooperative Milk Union Ltd., Vijayapur, Dairy Farm to find out the effect of integrated nutrient management practices in augmenting the quality fodder yield of maize in fodder maize + cowpea intercrop during the S*ummer* season of 2021 and 2022. The experiment was laid out in split plot design with three replications. In main plot, three methods of biofertilizer application were imposed with one absolute control and in the sub plot four INM component like application of graded levels of recommended dose of nitrogen (75, 100 and 125% RDN) with vermicompost on the equivalent basis of 25, 50 and 75% of RDN was take on with one absolute control. The experimental results were confirmed that seed treatment with *Azospirillum* and soil application of Phosphobacteria significantly increased the green forage yield, dry fodder yield crude fiber yield and dry matter content of fodder maize with improved the quality attributes like crude protein, crude fiber, ether extract, ash content and acid insoluble ash content over other treatments and no biofertilizers applied plot. Likewise, application 75% recommended dose of N + recommended dose of P and K+ 25% N on equivalent basis of vermicompost excelled over other INM practices by registering higher values on yields and fodder quality characters. Interaction effect between methods of biofertilizers application and integrated nitrogen management practices was significant. However, seed treatment of *Azospirillum* and soil application of Phosphobacteria along with application 75% recommended dose of N + recommended dose of P and K+ 25% N on equivalent basis of vermicompost proved its superiority in resulting higher green fodder yield, dry fodder yield and crude protein yield with excellent fodder quality properties.

Keywords: Fodder maize, fodder quality, RDF, biofertilizer, vermicompost

Introduction
Maize (*Zea mays* L.) is a cereal crop that is widely grown under a wide range of climatic conditions and harvested for both food and fodder purposes around the world. After rice, wheat and sorghum, it is the fourth most important crop in India. Maize is an important crop in Indian agriculture, occupying 9.18 million hectares with a production of 27.23 million metric tonnes and a productivity of 2.97 t ha^{-1} (USDA 2019-2020). Karnataka is one of the major maize producing states in the country, with an area of 0.55 m ha with a production of 1.72 million tonnes and a productivity of 3127 kg ha^{-1} (Anon, 2017). Irrespective of the size of one's landholdings, livestock farming is an important subsistence occupation in Karnataka. The progress and economy of livestock depend on the availability of quality fodder in adequate quantities. Due to limited land and resources, the gap between the supply and demand of good quality forage keeps getting bigger. Moreover, the state needs 47.504 million tonnes of green and dry fodder to feed all of its 27.76 million livestock at their best nutrition level. This is more than 50% less than what it needs. Accordingly, research-based development programmes are required immediately to enhance the current fodder supply situation both quantitatively and qualitatively. The superior crossbreds and upgraded animals require an adequate and balanced diet for them to realize their full potential. The necessity of growing high-quality green fodder for animals has recently come to light (Shekar *et al*., 2020) [20].
Maize is a C4 plant has a higher yield potential which depends on the nutrient supplying capacity of the soil. The productivity of maize is largely dependent on its nutrient management. It is well known that maize is a heavy feeder of nutrients. In order to increase

crop yield, nutrient management through the application of organic manure and inorganic fertilizers is necessary (Biswasi *et al*., 2020) [30]. Potentially, intensive agriculture has depleted the resource base. The sustainability of production is dependent on the preservation of vital resources, notably soil. In the current context, where food security and livelihood issues have become national priorities, the use of high-analysis synthetic fertilizers to increase food production is unavoidable. The only way out of this perilous situation is to develop sustainable and nutrient balanced technology packages and cropping systems, which would increase food production sustainably without harming the precious environment.

Maize is a highly esteemed fodder, commonly grown in the winter season. The fodder is excellent, highly nutritive and sustainable either in green or dry conditions and highly responsive to a nutrient management approach. The excessive and unbalanced use of chemical fertilizers has negatively impacted soil health and contaminated water bodies, thereby affecting fish fauna and posing a hazard to human and animal health (Yilmaz *et al*., 2010) [29]. The recycling and use of nutrients from organic manure and biological sources have been given more consideration for ensuring sustainable land use and agricultural production development (Oad *et al*., 2004) [14].

Material and Methods

The Field experiments were conducted during 2021 and 2022 to study the integrated nutrient management practices in fodder maize + cowpea intercropping and its residual impact on the succeeding green gram at Vijayapur and Bagalkot district Cooperative Milk Union Ltd., Vijayapur. Main Dairy farm, Bhutanal village, Vijayapur District, Karnataka which is located at $13^{0}17'24"$N North latitude and 77º47'60''E East longitude at an altitude of 650 m above mean sea level and which come under the Northern Dry Zone (ZONE-III) of Karnataka. The soil type at the experimental site is medium black and the texture of the soil is a clayey loam, belonging to the order *vertisols*. The analysis of soil samples report showed with low in available nitrogen (179.4 kgha^{-1}), medium in available phosphorus (28.4 kgha^{-1}), and high in available potassium (428.3 kgha^{-1}). The fodder variety was selected for maize (African tall) and cowpea (DFC-1). The soil pH and E.C. were showed 7.98 and 0.28 dsm^{-1} respectively. The experiment was laid out in split plot design with three replications. The details of the treatments imposing in main plots were BF_1 - Control (no biofertilizer), BF2 - Seed treatment with *Azospirillum*, BF_3 - Soil application of PSB and BF_4 - Seed treatment with *Azospirillum* + Soil application of PSB. Likewise, the treatments imposing in subplots were N_1 - Absolute control, N_2 - 100% of Recommended Dose of Nitrogen (RDN), N_3 - 75% RDN + 25% through vermicompost, N_4 - 50% RDN + 50% N through vermicompost and N_5 - 25% RDN + 75% N through vermicompost. The recommended dose of 200:50:40 kg of NPK ha^{-1} was followed. The N was applied in the form of urea, while phosphorus and potassium were applied in the form of DAP and MOP, respectively. The sowing operations were taken during February first week for fodder maize during both year 2021 and 2022. As per the treatments schedule, the application of vermicompost and biofertilizer was taken place at experimental plots. The results of the experimental data were calculated by Gomez and Gomez (1984) [5].

Results and Discussion

1. Green fodder yield

The data revealed that there was a significant difference was found amongst the treatments with the influence of biofertilizers in fodder maize (Table 1). Significantly higher (352.20 and 371.64 q ha^{-1}) fodder maize forage yield was found by the seed treatment with *Azospirillum* and soil application of Phosphobacteria during year 2021 and 2022, respectively. Later, a significantly lower forage yield was found with absolute control. When the treatments were collated with absolute control, it disclosed significantly higher (432.04 and 456.77 q ha^{-1}) maize forage yield with integrated application of 75% recommended dose of nitrogen (RDN) in the form inorganic fertilizers and 25% RDN through vermicompost during the year 2021 and 2022, respectively. This was followed by 100% RDN and 50% RDN + 50% N as vermicompost. Significantly lower maize forage yield was found in absolute control. The treatment combinations of seed treatment with *Azospirillum* and soil application of Phosphobacteria along with application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost excelled over all other treatments by recording the highest green fodder yield of 489.40 and 519.57 q ha^{-1}in the first and second experiment, respectively. This might be due to additional amount of nutrient supplied as well as beneficial effects of decomposed organic matter that derived in connection with physicochemical properties of the soil. These findings are conformity with the findings of Nanjappa *et al*. (2001) [11], Vadivel *et al*. (2001) [27], Mahesh *et al*. (2010) [9], Mukherjee (2014) [10], Rasool *et al*. (2015) [17], Thavaprakash *et al*. (2015) [23] and Kumar *et al*. (2015) [4, 7].

Table 1: Effect of INM on the yields of fodder maize under fodder maize + cowpea intercropping.

Treatment	Green fodder yield (q ha^{-1})		Dry matter yield (q ha^{-1})	
	2021	2022	2021	2022
Bio fertilizers (BF)				
BF1	272.21	284.04	87.36	93.75
BF2	304.31	320.06	94.07	100.70
BF3	305.95	321.50	94.03	100.66
BF4	352.20	371.64	99.51	106.39
SEd	1.57	1.64	0.38	0.41
CD (p=0.05)	3.84	4.03	0.94	1.01
Levels of N and INM				
N1	145.45	150.44	74.49	80.46
N2	348.39	367.20	100.35	107.25

N3	432.04	456.77	107.13	114.28
N4	310.46	325.52	96.04	102.71
N5	306.98	321.62	90.71	97.17
SEd	2.42	2.55	0.45	0.48
CD (p=0.05)	4.94	5.20	0.91	0.97
Interactions effect				
BF1N1	120.50	121.55	69.15	74.92
BF1N2	298.77	312.38	90.52	97.00
BF1N3	401.33	421.49	101.53	108.42
BF1N4	269.00	281.24	90.45	96.94
BF1N5	271.43	283.55	85.15	91.47
BF2N1	150.69	156.67	74.43	80.38
BF2N2	345.17	364.01	101.86	108.81
BF2N3	419.00	443.39	107.22	114.42
BF2N4	310.80	326.14	96.10	102.75
BF2N5	295.88	310.07	90.75	97.14
BF3N1	154.28	160.57	74.56	80.54
BF3N2	346.98	364.96	101.72	108.68
BF3N3	418.44	442.61	107.14	114.30
BF3N4	314.19	329.28	96.00	102.62
BF3N5	295.88	310.07	90.75	97.14
BF4N1	156.31	162.97	79.82	85.99
BF4N2	402.65	427.45	107.31	114.51
BF4N3	489.40	519.57	112.61	119.99
BF4N4	347.85	365.42	101.61	108.51
BF4N5	364.75	382.79	96.18	102.93
BF x N				
SEd	4.61	4.85	0.89	0.95
CD (p=0.05)	9.61	10.12	1.88	2.00
N x BF				
SEd	4.85	5.11	0.89	0.95
CD (p=0.05)	9.88	10.40	1.82	1.94

2. Dry fodder yield

A gleam of the data revealed that there was marked increase in the dry matter yield of fodder maize (Table 1) was observed as a result of biofertilizers treatments and significantly higher dry fodder yield of 99.51 and 106.39 q ha^{-1} were noticed with the seed treatment of *Azospirillum* and soil application of Phosphobacteria over control. With regards to INM practices, application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost had a significantly higher dry fodder yield of 107.03 and 114.28 q ha^{-1} during the year 2021 and 2022. Concerning the interaction effects, combinations of seed treatment with *Azospirillum* and soil application of Phosphobacteria along with application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost proved its superiority in registering higher dry fodder yield of 112.61 and 119.99 q ha^{-1} during the year 2021 and 2022, respectively. The improved plant growth parameters like plant height, leaf to stem ratio and dry matter accumulation due to higher nutrient content and quick release of nitrogen from biofertilizer consortia and vermicompost might be the reason for higher green and dry matter yield. Similar kind of results was also reported by Uwah *et al*. (2014) [26], Kumar *et al*. (2015) [4, 7], Verma *et al*. (2016) [28], Naveen *et al*. (2021) [12] and Shekar *et al*. (2020) [20].

3. Crude protein yield

The effect of treatments on crude protein yield during 2021 and 2022 was purveyed in Table 2. Seed treatment with *Azospirillum* and soil application of Phosphobacteria significantly recorded maximum crude protein yield of 7.91 and 8.68 q ha^{-1} during the year 2021 and 2022, respectively. While minimum crude protein yield was found in control. A considerable effect was found between the treatments as influenced by different fertilizer levels. The crude protein yield of fodder maize was found to be significantly higher (9.07 and 9.92 q ha^{-1}) in the application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost during 2021 and 2022, respectively. However, lower crude protein yield was found with control as compared to others. With regards to interaction effects, consolidations of seed treatment with *Azospirillum* and soil application of Phosphobacteria along with application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost noticed higher crude protein yield of 9.88 and 10.86 q ha^{-1} in the years of 2021 and 2022, respectively. This might be due to the supply of nutrients from seed treatment with *Azospirillum* and soil application of PSB leads to increase in crude protein yield as a result of enhanced dry matter yield and greater crude protein content. This was in accordance with findings of Dabhi *et al*. (2017) [3], Neelar (2011) [13], Thakur *et al*. (2011) [22] and Patel *et al*. (2018).

Table 2: Effect of INM on crude protein and crude fibre yield (q ha^{-1}) of fodder maize under fodder maize + cowpea intercropping.

Treatment	Crude protein yield (q ha^{-1})		Crude fibre yield (q ha^{-1})	
	2021	2022	2021	2022
Bio fertilizers (BF)				
BF1	5.93	6.63	24.27	27.01
BF2	7.09	7.85	25.82	28.60
BF3	7.06	7.81	25.79	28.55
BF4	7.91	8.68	26.98	29.79
SEd	0.03	0.04	0.11	0.12
CD (p=0.05)	0.08	0.09	0.26	0.29
Levels of N and INM				
N1	4.08	4.76	21.72	24.42
N2	8.06	8.90	27.17	29.95
N3	9.07	9.92	28.55	31.38
N4	7.25	7.95	26.10	28.87
N5	6.52	7.18	25.05	27.82
SEd	0.05	0.06	0.12	0.13
CD (p=0.05)	0.11	0.12	0.25	0.27
Interactions effect				
BF1N1	3.34	4.02	20.66	23.35
BF1N2	6.40	7.10	24.93	27.63
BF1N3	8.17	8.78	27.20	30.10
BF1N4	6.23	7.00	24.78	27.48
BF1N5	5.52	6.26	23.78	26.48
BF2N1	4.05	4.72	21.66	24.35
BF2N2	8.39	9.26	27.55	30.35
BF2N3	9.15	10.05	28.65	31.45
BF2N4	7.31	8.00	26.16	29.00
BF2N5	6.54	7.20	25.10	27.85
BF3N1	4.10	4.78	21.78	24.48
BF3N2	8.30	9.14	27.42	30.23
BF3N3	9.10	10.00	28.55	31.35
BF3N4	7.25	7.94	26.10	28.85
BF3N5	6.54	7.20	25.10	27.85
BF4N1	4.81	5.52	22.78	25.48
BF4N2	9.17	10.12	28.78	31.57
BF4N3	9.88	10.86	29.78	32.63
BF4N4	8.22	8.87	27.35	30.15
BF4N5	7.46	8.04	26.20	29.10
BF x N				
SEd	0.10	0.11	0.24	0.26
CD (p=0.05)	0.21	0.23	0.51	0.56
N x BF				
SEd	0.11	0.12	0.24	0.26
CD (p=0.05)	0.22	0.24	0.51	0.54

4. Crude fibre yield

When treatments were compared with a standard control, there was a higher and significant breach in crude fibre yield of fodder maize (Table 2). Consequentially higher (26.98 and 29.79 q ha^{-1}) crude fibre yield of fodder maize was obtained when seed treatment was done with seed treatment with *Azospirillum* and soil application of Phosphobacteria but the control treatment showed lower crude fibre yield of fodder maize in the year 2021 and 2022, respectively. Among the INM levels, significantly higher (28.55 and 31.38 q ha^{-1}) crude fibre yield was recorded with application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost. And, the lowest with control treatment in the year 2021 and 2022, respectively. The biofertilizer and INM levels interactions, higher crude fibre yield was observed with the conjoint practice of seed treatment with *Azospirillum* and soil application of Phosphobacteria along with application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost resulted in higher crude fibre yield of 29.78 and 32.63 q ha^{-1}. The enhanced fibre yield due to increased dry matter yield with higher level of INM practice. This assumption is well justified that higher nutrient status of plants from bio-fertilizers supply leading to translocation within the plant system. This is in conformity with findings of Shekar *et al*. (2020) [20] and Naveen *et al*. (2021) [12]. Similarly, Safari *et al*. (2014) also reported that dry matter content and forage yield of corn increased with increase in the amount of N application and the highest dry matter content and forage yield was obtained in 150 and 225 kg/ha nitrogen application which was in line with the results obtained in the present investigation.

5. Quality characters of fodder maize

Data projected in Table 3 flashed that there was a pronounced distinction retrieved in biofertilizers treatments and INM practices. Among the biofertilizer treatments, seed treatment

with *Azospirillum* and soil application of Phosphobacteria significantly registered higher crude protein content of 7.64 and 7.72 per cent, crude fibre content of 27.95 and 28.95 per cent, ash content of 10.83 and 11.21 per cent and acid insoluble ash content of 2.65 and 2.69 per cent. However, non-biofertilizer applied plot showed lesser fodder qualities. Likewise, application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost resulted higher fodder quality parameters by registering maximum vales of crude protein content of 8.35 and 8.47 per cent, crude fibre content of 27.32 and 28.20 per cent, ash content of 11.28 and 11.61 per cent and acid insoluble ash content of 2.80 and 2.81 per cent but the treatment with absolute control showed lower fodder qualities in the year 2021 and 2022, respectively. Concerning the interaction effects between the application of biofertilizers and INM practices, amalgamations of seed treatment with *Azospirillum* and soil application of Phosphobacteria along with application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost excelled over rest of the treatment in registering higher crude protein content of 8.77 and 9.07 per cent, crude fibre content of 26.45 and 27.25 per cent, ash content of 11.67 and 11.97 per cent and acid insoluble ash content of 2.94 and 2.95 per cent during 2021 and 2022, respectively. The influence of nutrients presents in the vermicompost and seed treatment with *Azospirillum* and soil application of PSB helps in cell differentiation and cell elongation which has resulted in more functional leaves for a longer period of time. This prediction as well reasonable treatment greater nutrient content of plants with biofertilizer and fertilizer levels of organic nutrients, led higher translocation within the plant system. Bhillare (2007) opined that more crude protein content at higher nitrogen levels was because of more uptake of nitrogen which is a constituent of protein, amino acids and amides. The increased in protein content and protein yield may be due to more uptake of nutrient with combine application of nutrient sources. The results are also supported by Dixit *et al.* (2015), Kumar *et al.* (2018) [20], Patel and Thanki (2022) [15]. The increased protein synthesis and decreased pectin, cellulose and hemicellulose contents, which are major constituents of crude fibre (Tiwana *et al*., 2003) [24] similar observations, have been made by Ibrahim *et al*. (2006) [6] and Reza *et al*. (2012) [18].

Table 3: Effect of INM on the quality parameters of fodder maize under fodder maize + cowpea intercropping.

Treatment	Crude protein content (%)		Crude fibre content (%)		Ash content (%)		Acid insoluble Ash content (%)	
	2021	2022	2021	2022	2021	2022	2021	2022
Bio fertilizers (BF)								
BF1	6.47	6.41	29.38	30.56	9.83	10.29	2.33	2.40
BF2	7.23	7.26	28.46	29.53	10.49	10.89	2.53	2.57
BF3	7.23	7.20	28.40	29.57	10.42	10.85	2.51	2.56
BF4	7.69	7.72	27.95	28.95	10.83	11.21	2.65	2.69
SEd	0.04	0.03	0.19	0.19	0.05	0.05	0.01	0.01
CD (p=0.05)	0.09	0.08	0.45	0.47	0.13	0.13	0.03	0.03
Levels of N and INM								
N1	5.41	5.46	30.01	31.31	9.33	9.82	2.17	2.23
N2	7.79	7.91	27.72	28.81	10.91	11.28	2.67	2.69
N3	8.35	8.47	27.32	28.20	11.28	11.61	2.80	2.81
N4	7.32	7.15	28.75	29.89	10.34	10.77	2.49	2.55
N5	6.90	6.75	28.94	30.04	10.12	10.57	2.40	2.49
SEd	0.05	0.05	0.12	0.12	0.07	0.08	0.02	0.02
CD (p=0.05)	0.10	0.10	0.24	0.25	0.15	0.16	0.04	0.04
Interactions effect								
BF1N1	5.00	5.09	30.48	31.69	9.13	9.65	2.11	2.16
BF1N2	6.73	6.65	28.97	30.35	9.89	10.35	2.36	2.43
BF1N3	7.85	7.62	28.44	29.41	10.70	11.10	2.58	2.65
BF1N4	6.58	6.52	29.47	30.58	9.78	10.25	2.33	2.41
BF1N5	6.20	6.16	29.55	30.77	9.65	10.12	2.27	2.37
BF2N1	5.37	5.44	30.17	31.33	9.26	9.78	2.16	2.21
BF2N2	8.03	8.23	27.38	28.32	11.19	11.50	2.74	2.74
BF2N3	8.40	8.65	27.22	27.98	11.45	11.73	2.87	2.87
BF2N4	7.40	7.20	28.68	30.15	10.44	10.85	2.47	2.56
BF2N5	6.97	6.78	28.88	29.87	10.13	10.59	2.40	2.48
BF3N1	5.45	5.48	29.75	31.22	9.39	9.86	2.18	2.25
BF3N2	8.00	8.03	27.55	28.86	11.00	11.44	2.73	2.73
BF3N3	8.39	8.56	27.18	28.15	11.32	11.63	2.79	2.79
BF3N4	7.34	7.13	28.66	29.73	10.26	10.72	2.45	2.54
BF3N5	6.97	6.78	28.88	29.87	10.13	10.59	2.40	2.48
BF4N1	5.83	5.82	29.64	31.02	9.52	9.99	2.22	2.30
BF4N2	8.41	8.73	26.98	27.69	11.54	11.84	2.87	2.88
BF4N3	8.77	9.07	26.45	27.25	11.67	11.97	2.94	2.95
BF4N4	7.96	7.73	28.22	29.11	10.87	11.26	2.70	2.70
BF4N5	7.47	7.27	28.44	29.66	10.57	10.97	2.53	2.61
BF x N								

SEd	0.10	0.10	0.28	0.30	0.14	0.15	0.03	0.04
CD (p=0.05)	0.20	0.20	0.63	0.65	0.30	0.31	0.07	0.07
N x BF								
SEd	0.10	0.10	0.24	0.25	0.15	0.16	0.04	0.04
CD (p=0.05)	0.21	0.21	0.49	0.51	0.30	0.32	0.08	0.08

Conclusion

Based on the results of present investigation, it can be concluded that combinations of seed treatment with *Azospirillum* and soil application of Phosphobacteria along with application of 75% Recommended Dose of Nitrogen (RDN) + recommended dose of P and K + 25% N on equivalent basis of vermicompost was found suitable for higher yield and also producing better quality fodder.

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