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Quality parameters, physiological parameters and nutrient use efficiency of chickpea as influenced by fertilizer levels, biofertilizers and micronutrients in chickpea-fodder sorghum cropping sequence

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Abstract
A field experiment was undertaken during the *rabi* and summer season of the years 2013-14 and 2014-15 to study the effect of fertilizer levels, biofertilizers and micronutrients and their interactions on quality parameters, physiological parameters and nutrient use efficiency of chickpea in chickpea-fodder sorghum cropping sequence. Fertilizer level F_3 *i.e.*, 100 % RDF (25-50 kg NP ha^{-1}) had significant influence on quality parameters like protein content, N content & uptake by chickpea seed and straw, P content & uptake by chickpea seed and straw as well as physiological parameters like CGR and RGR and also on nutrient use efficiency *viz*., partial factor productivity (PFP), agronomic efficiency (AE), and recovery efficiency (RE) of chickpea over the other treatments F_2 (75 % RDF), F_1 (50 % RDF) and F_0 (Control) during both the years and in pooled results. Significantly higher protein content as well as nitrogen and phosphorus content and uptake in the chickpea seeds and straw were recorded under treatment B_1 (PSB + *Rhizobium* @ 5 ml kg^{-1} seed each).Crop growth rate (CGR) of chickpea recorded at 60 and 90 DAS were significantly affected due to biofertilizers application. Different parameters of nutrient use efficiency were increased due to biofertilizers treatment (B_1). Application of micronutrients treatment M_1 (Micronutrient mixture grade-V @ 20 kg ha^{-1}) had significant effect on nitrogen and phosphorus uptake by the seeds and straw of chickpea crop and also recorded higher values in different parameters of nutrient use efficiency of chickpea as compared to M_0 (Control). Significantly the highest nitrogen and phosphorus uptake by chickpea seeds and straw were recorded under treatment combination F_3B_1, which were statistically at par with treatment combination F_2B_1. The treatment combination $F_3B_1M_1$ recorded significantly the highest nitrogen uptake by chickpea seeds and straw, which was statistically at par with treatment combination $F_2B_1M_1$ in pooled analysis. Similar results were also found in case of phosphorus uptake by chickpea seeds and straw in pooled analysis. The treatment combination $F_1B_1M_0$ recorded the highest value of partial factor productivity, the treatment combination $F_2B_1M_1$ recorded the highest agronomic efficiency and recovery efficiency, while, treatment combination $F_1B_0M_0$ recorded the highest value of physiological efficiency (PE) during both the years and in mean data.

Keywords: Fertilizer levels, biofertilizers, micronutrients, chickpea, protein content, NP content and uptake, CGR, RGR, Nutrient use efficiency

1. Introduction
Among the legumes, chickpea *(Cicer arietinum* L.) is an important and unique food legume because of its use in the variety of food products like snacks, sweets, condiments, vegetables etc. It is also consumed in the form of processed whole seed (boiled, roasted, parched, fried, steamed sprouted etc.) or as dal flour. Chickpea is a good source of protein (18-22 per cent), carbohydrate (52-70 per cent), fat (4-10 percent), minerals and vitamins. It is also an excellent animal feed and it's straw has good forage value.
In India, chickpea is cultivated in about 8.25 million hectares, producing 7.33 million tones of seeds with the productivity of 889 kg ha^{-1}. In Gujarat, chickpea is grown in an area of 0.16 million hectares, producing 0.20 million tonnes with the productivity of 1236 kg ha^{-1} (Anon., 2016) [1]. In spite of the importance of this crop in our daily diet and in agricultural production, productivity of this crop is very low in India as well as in the Gujarat. Among the various factors affecting the crop production, integrated nutrient management plays a pivotal role in increasing the chickpea production. Balanced use of nutrients in the form of inorganic fertilizers, biofertilizers and micronutrients proved beneficial for increasing the crop production. In India, the crop and livestock enterprise constitute two functional components of mixed farming system. The fodder production is the back bone of livestock industries.

Under irrigated conditions, there is a scope for growing short duration crop like fodder sorghum (*Sorghum bicolor* L.) after chickpea as a sequence cropping.

With this background, field experiments was planned and conducted during *rabi* and summer seasons of the years 2013-14 and 2014-15 at Agricultural Research Station, Anand Agricultural University, Derol, Panchmahal (Gujarat) under middle Gujarat conditions.

2. Materials and Methods

A field experiment was conducted during the *rabi* and summer seasons of the years 2013-14 and 2014-15 at Agricultural Research Station, Anand Agricultural University, Derol-389 320, Ta.: Kalol, Dist.: Panchmahal (Gujarat). The experimental field had an even topography with a gentle slope having good drainage. The soil of the experimental field was loamy sand in texture, low in organic C, medium in available phosphorus and available potassium. The soil was low in respect to available Fe and medium in available Zn, where as it was high in available Mn and available Cu. The soil was slightly alkaline in reaction (7.9 pH). The experiment was laid out in factorial randomized block design with three replications. There were sixteen treatment combinations comprised of four treatments of fertilizers levels (F_3-100 % RDF *i.e.*, 25-50 kg NP ha^{-1}, F_2 -75 % RDF *i.e.*, 18.75-37.5 kg NP ha^{-1}, F_1 -50 % RDF *i.e.*, 12.5-25 kg NP ha^{-1} and F_0 – Control), two biofertilizers treatments (B_1- (PSB + *Rhizobium* @ 5 ml kg^{-1} seed each and B_0 - Control) and two micronutrients treatments (M_1 - Micronutrient mixture grade-V @ 20 kg ha^{-1} and M_0 - Control) applied on preceding *rabi* chickpea and their residual effect was evaluated on succeeding fodder sorghum crop in summer season. The pure seeds of chickpea: GG 1 was used in the experiment. Sowing was done manually in line in the previously opened furrows at 45 cm apart using the seed rate of 60 kg ha^{-1}. The fertilizer application was given as per the treatments. After harvest of the *rabi* chickpea, the fixed plots were cultivated with power tiller without disturbing the bunds of previous plots of chickpea. Furrows were opened in each plot at 30 cm apart and seeds of fodder sorghum variety S-1049 were sown manually in the previously opened furrows of each plot using seed rate of 60 kg ha^{-1}. The succeeding fodder sorghum crop was commonly fertilized with 50 % RDF *i.e.*, 40-20 NP kg ha^{-1}. All the recommended cultural practices was followed for both chickpea and fodder sorghum crop. The protein content in the seeds was calculated by multiplying nitrogen content (%) of the seeds with the conversion factor of 6.25. Nitrogen content in the seeds and straw was determined by Micro Kjheldahl's digestion method (Jackson, 1967) [6]. Then nitrogen uptake (kg ha^{-1}) was calculated by multiplying N content (%) and seed yield (kg ha^{-1}) divided by 100. Phosphorus content in the seed was determined by Vanadomolybdo phosphoric yellow colour method by Jackson (1967) [6]. Then phosphorus uptake by the seeds was calculated by multiplying P content (%) and seed yield (kg ha^{-1}) divided by 100. Crop Growth Rate (CGR) and Relative Growth Rate (RGR) were measured at 30, 60 and 90 DAS. The basic data on leaf area and dry matter production were used to calculate the various crop growths attributes by the method described by Watson (1952) [21] and Radford (1967). Nutrient use efficiency (NUE) was calculated as per following equations. (a) Partial factor productivity = Y/F (b) Agronomic efficiency = (Y-Y0)/F (c) Recovery efficiency =(U-U0)/F x 100 (d) Physiological efficiency = (Y-Yo)/U-Uo). Where, F = Amount of nutrient applied (Kg nutrient), Y = Yield of crop with nutrient applied (Kg grain), Y0 = Yield of crop with no nutrient applied, U = Nutrient uptake by crop with nutrient applied and U0 = Nutrient uptake by crop with no nutrient applied.

3. Results and Discussion

3.1 Effect of fertilizer levels on quality parameters

The data presented in the Table-1 indicated that the treatment F_3 (100% RDF) recorded significantly the highest protein content (20.48, 20.33 and 20.41 per cent during 2013-14, 2014-15 and on pooled basis, respectively) in chickpea seeds and remained statistically at par with treatment F_2 (75% RDF) and F_1 (50% RDF) during the individual years, while it was statistically at par with only treatment F_2 (75% RDF) on pooled basis. The lowest protein content in chickpea seed was obtained from F_0 (Control). This might be due to the fact that starter nitrogen provides vigorous start to plant resulting in good nodule formation, while phosphorus promotes better proliferation of roots and stimulate symbiotic nitrogen fixation due to increased nodulation, which might have resulted in increased assimilation of nitrogen by the plants resulted in increased protein synthesis. The results corroborate the findings of Patel (2011) [14] and Shah *et al.* (2016) [16].

It was noted that the treatment F_3 (100% RDF) recorded significantly the highest nitrogen content in chickpea seed *i.e.*, 3.28, 3.25 and 3.26 per cent and in straw *i.e.*, 0.59, 0.59 and 0.59 per cent during the years 2013-14 and 2014-15 and on pooled basis, respectively and remained statistically at par with treatment F_2 (75 % RDF) on pooled basis (Table 1 & 2). The results with respect to phosphorus content in chickpea seeds and straw revealed that the treatment F_3 (100% RDF) recorded significantly the highest phosphorus content in chickpea seeds *i.e.*, 0.35, 0.34 and 0.35 per cent and in straw *i.e.*, 0.121, 0.119 and 0.120 per cent during the years 2013-14, 2104-15 and on pooled basis, respectively while, it was at par with treatment F_2 (75% RDF) in pooled analysis (Table 2 & 4). This might be due to improved nutritional environment in the rhizosphere as well as in the plant system leading to enhanced translocation especially of N and P to reproductive structures *viz.* pods and seeds. The results corroborate the findings of Kumar *et al.* (2015) [9].

The result presented in Table 1, Table 2 and Table 4 revealed that treatment F_3 (100% RDF) recorded significantly the highest nitrogen uptake by seed *i.e.*, 82.10, 81.02 and 81.56 kg ha^{-1} and nitrogen uptake by straw *i.e.*, 17.80,17.58 and 17.69 kg ha^{-1} during the years 2013-14, 2104-15 and on pooled basis, respectively. The treatment F_3 (100% RDF) also recorded significantly the highest phosphorus uptake by chickpea seed *i.e.*, 8.72, 8.56 and 8.64 kg ha^{-1} and phosphorus uptake by straw *i.e.*, 3.66, 3.56 and 3.61 kg ha^{-1} over rest of the treatments F_2 (75% RDF), F_1 (50 % RDF) and F_0 (Control). Nutrient uptake is the function of seed and straw yields as well as their nutrient content, the significant increase in content of the nutrients coupled with increased seed and straw yields increased the uptake of N and P substantially. Similar findings have been reported by Patel (2011) [13] and Kumar *et al.* (2015) [9].

3.2 Effect of fertilizer levels on physiological parameters

The data furnished in Table 6 indicated that the crop growth rate of chickpea recorded at 30 DAS was not influenced significantly due to fertilizer levels. However, crop growth rate of chickpea recorded at 60 DAS (0.83, 0.84 and 0.83 g m^{-}

^{2}) and at 90 DAS (1.18, 1.15 and 1.16 g m^{-2}) were significantly influenced due to fertilizer level treatment F_3 (100 % RDF) during 2013-14, 2014-15 and in pooled analysis, respectively. In general, CGR depends mainly on the amount and intensity of intercepted energy and photosynthetic efficiency of the canopy. Higher CGR may be due to higher production of dry matter owing to greater LAI and higher light interception. The boosted root and shoot growth parameters due to increased supply of N and P may be because of the fact that application of N and P promotes plant growth by ensuring higher number of greener leaves *i.e.*, photosynthetic surface area with the increased photosynthesis as a result of increased metabolism of the absorbed plant nutrients. Similar findings have been reported by Shukla *et al.* (2013) [17] and Namvar *et.al.* (2011) [11].

Significantly the highest relative crop growth rate (RGR) of chickpea at 60 DAS (0.022, 0.023 and 0.023 g g^{-1} day^{-1} during 2013-14, 2014-15 and in pooled analysis, respectively) was recorded under fertilizer levels treatment F_3 (100 % RDF), while, it was non significant at 30 and 90 DAS (Table 7). This may be due to the fact that during the grand growth stages of the plant, the ratio between alive and dead tissues is high and almost entire cells of productive organs are activity engaged in vegetative matter production and consequently the RGR of plants is high, while with plant aging, the metabolic activity of tissues decreases and hence the tissues cannot contribute to the growth that results in RGR decreasing. Similar findings have been reported by Namvar *et.al.* (2011) [11].

3.3 Effect of fertilizer levels on nutrient use efficiency (NUE)

Fertilizer level F_1 (50 % RDF) recorded the highest partial factor productivity (53.33 kg kg^{-1}) and physiological efficiency (19.05 kg kg^{-1}) followed by treatment F_2 (75 % RDF) in mean data, while, higher values of agronomic efficiency (12.18 kg kg^{-1}) and recovery efficiency (68.03 %) were recorded under treatment F_2 (75% RDF) followed by treatment F_3 (100% RDF) in mean data (Table 8).The objective of efficient nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop, while minimizing nutrient losses from the field (Snyder and Bruulsema (2007) [20]; Fixen *et al.*, (2014) [4]. Thus, Partial factor productivity (PFP), agronomic efficiency (AE), recovery efficiency (RE) and physiological efficiency (PE) were improved with the application of fertilizers over control. Similar results was reported by Kakraliya *et al.* (2017) [8].

3.4 Effect of biofertilizers on quality parameters

The data presented in Table 1 showed that the treatment B_1 (PSB + *Rhizobium* @ 5 ml kg^{-1} seed each) recorded significantly higher protein content (20.16, 20.14 and 20.15 per cent during the years 2013-14, 2014-15 and on pooled basis, respectively) in chickpea seeds as compared to B_0 (Control). As nitrogen is a constituent of protein, biofertilizer treatment might have enhanced the nitrogen supply to the seed which resulted in higher protein content. The results are confirmed by the findings of Chaudhari *et al.* (1998) [2] and Jain *et al.* (1999) [7].

The treatment B_1 (PSB + *Rhizobium* @ 5 ml kg^{-1} seed each) recorded significantly higher nitrogen content in chickpea seed (3.22, 3.22 and 3.22 per cent) as well as in chickpea straw (0.58, 0.58 and 0.58 per cent) during the years 2013-14, 2014-15 and on pooled basis, respectively as compared to B_0 (Control). Similarly, the data given in Table 2 & 4 indicated that the treatment B_1 recorded significantly higher phosphorus content in chickpea seeds (0.35, 0.34 and 0.34 per cent) and in chickpea straw (0.119, 0.117 and 0.118 per cent) during the years 2013-14, 2014-15 and on pooled basis, respectively as compared to B_0 (Control).

Similarly, the data presented in the Table 1, Table 2 and Table 4 showed that significantly higher nitrogen uptake by chickpea seed (74.54, 74.96 and 74.75 kg ha^{-1}) and nitrogen uptake by chickpea straw (16.08, 16.16 and 16.12 kg ha^{-1}) were recorded with the application of treatment B_1 (PSB + *Rhizobium* @ 5 ml kg^{-1} seed each) as compared to B_0 (Control). The biofertilizers treatment B_1 also recorded significantly higher phosphorus uptake by chickpea seed (7.99, 7.93 and 7.96 kg ha^{-1}) as well as phosphorus uptake by chickpea straw (3.29, 3.27 and 3.28 kg ha^{-1}) during the years 2013-14, 2014-15 and in pooled analysis, respectively as compared to B_0 (Control). This could be owing to more availability of nitrogen through symbiotic nitrogen fixation and increased in availability of phosphorus by solubilizing phosphorus in the soil. As, nutrient uptake is the function of seed and straw yields as well as their nutrient content, the significant increase in content of the nutrients coupled with increased seed and straw yields increased the uptake of N and P substantially. The results confirmed the findings of Gangwar and Dubey (2012) [5], Das *et al.* (2013) [3] and Kumar *et al.* (2015) [9].

3.5 Effect of biofertilizers on physiological parameters

Crop growth rate recorded at 30 DAS of chickpea was not influenced significantly due to biofertilizers during the years 2013-14, 2014-15 and in pooled analysis.The data presented in Table 6 indicated that the treatment B_1 (PSB + *Rhizobium* @ 5 ml kg^{-1} seed each) recorded significantly higher crop growth rate at 60 DAS (0.76, 0.77 and 0.76 g m^{-2}) and at 90 DAS (1.09, 1.05 and 1.07 g m^{-2}) during 2013-14, 2014-15 and in pooled analysis, respectively) as compared to B_0 (Control). CGR depends mainly on the amount and intensity of intercepted energy and photosynthetic efficiency of the canopy. Higher CGR may be due to higher production of dry matter owing to greater LAI and higher light interception. (Namvar *et al.*, 2011) [11]. Relative crop growth rate of chickpea was not significantly influenced due to biofertilizers treatment at 30, 60 and 90 DAS (Table 7).

3.6 Effect of biofertilizers on nutrient use efficiency (NUE)

The result presented in Table 8 revealed that biofertilizers treatment B_1 (*Rhizobium* + PSB @ 5 ml kg^{-1} seed each) recorded higher partial factor productivity (34.4 kg kg^{-1}), agronomic efficiency (11.29 kg kg^{-1}), recovery efficiency (62.80 %) and physiological efficiency (17.96 kg kg^{-1}) as compared to B_0 (Control) in mean data. This might be due to the better N and P utilization of applied nutrients due to biofertilizers application. The results confirmed the findings of Panchal (2014) [12].

3.7 Effect of micronutrients on quality parameters

The results presented in Tables 1, Table 2 and Table 4 revealed that application of micronutrients did not show significant influenced on the protein content, nitrogen content in the seeds and straw as well as phosphorus content in the seeds and straw of chickpea. However, the nitrogen and phosphorus uptake by the seeds and of chickpea had significant and positive effect with application of

micronutrients treatment M_1 (Micronutrient mixture grade-V @ 20 kg ha^{-1}) as compared to M_0 (Control). Significantly higher nitrogen uptake by chickpea seed (70.70, 71.33 and 71.01 kg ha^{-1}), nitrogen uptake by chickpea straw (15.75, 15.37 and 15.56 kg ha^{-1}), phosphorus uptake by chickpea seed (7.59, 7.53 and 7.56 kg ha^{-1}) and phosphorus uptake by chickpea straw (3.24, 3.10 and 3.17 kg ha^{-1}) during the years 2013-14, 2014-15 and on pooled basis, respectively were found under treatment M_1 (Micronutrient mixture grade-V @ 20 kg ha^{-1}) over M_0 (Control).This might be due to an enhancement in absorption and assimilation of the micronutrients which provided balanced nutrition to the crops for higher growth and thereby nutrients uptake which ultimately resulted into higher yield of the crops. The results are akin to Patel and Singh (2010) [14] and Singh *et al.* (2015) [18].

3.8 Effect of micronutrients on physiological parameters

Physiological parameters like, crop growth rate (CGR) and relative crop growth rate (RGR) of chickpea recorded at 30, 60 and 90 DAS were not influenced significantly due to the micronutrients treatment M_1 (Micronutrient mixture grade-V @ 20 kg ha^{-1}) (Table 6 and 7).

3.9 Effect of micronutrients on nutrient use efficiency (NUE)

The result presented in Table 8 revealed that micronutrients treatment M_1 (Micronutrient mixture grade-V) recorded higher partial factor productivity (32.7 kg kg^{-1}), agronomic efficiency (9.59 kg kg^{-1}), recovery efficiency (54.27 %) and physiological efficiency (18.17 kg kg^{-1}) of chickpea than M_0 (Control) in mean data. This might be due to the efficient nutrient use by providing economically optimum nourishment to the crop, while minimizing nutrient losses from the field (Snyder and Bruulsema (2007) [20] and Fixen *et al.*, (2014) [4].

3.10 Interaction effects of fertilizer levels, biofertilizers and micronutrients on quality parameter

The results on all the interaction effects of fertilizer levels, biofertilizers and micronutrients did not showed any significant influence on the protein content, nitrogen and phosphorus content in chickpea seeds and straw during both the years as well as on pooled basis (Table 1, Table 2 and Table 4).

According to the data observed in the Table 3(a) and Table 5(a), significantly the highest nitrogen uptake by chickpea seed (89.32 kg ha^{-1}), nitrogen uptake by chickpea straw (19.19 kg ha^{-1}), phosphorus uptake by chickpea seed (9.46 kg ha^{-1}) and phosphorus uptake by chickpea straw (3.92 kg ha^{-1}) were recorded under treatment combination F_3B_1 over the other treatment combinations *viz.*, F_0B_0, F_0B_1, F_1B_0, F_1B_1, F_2B_0 and F_3B_0 in pooled analysis. However, it was remained statistically at par with F_2B_1.

In the interaction (F x B x M) of combined application of fertilizer, biofertilizers and micronutrients, treatment combination $F_3B_1M_1$ recorded significantly the highest nitrogen uptake by chickpea seed (95.87 kg ha^{-1}) and straw (20.70 kg ha^{-1}) over the other treatment combinations *viz.*, $F_0B_0M_0$, $F_0B_0M_1$, $F_0B_1M_0$, $F_0B_1M_1$, $F_1B_0M_0$, $F_1B_0M_1$, $F_1B_1M_0$, $F_1B_1M_1$, $F_2B_0M_0$, $F_2B_0M_1$, $F_2B_1M_0$, $F_3B_0M_0$, $F_3B_0M_1$ and $F_3B_1M_0$ in pooled results. However, it was statistically at par with treatment combination $F_2B_1M_1$. Significantly the lowest nitrogen uptake by chickpea seed (45.62 kg ha^{-1}) and straw (10.44 kg ha^{-1}) was recorded under treatment combination $F_0B_0M_0$ in pooled analysis [(Table 3(b)].

Similar results were also found in case of phosphorus uptake by chickpea seed and straw. [(Table 5(b)]. Significantly the highest phosphorus uptake by the chickpea seeds (10.12 kg ha^{-1}) and chickpea straw (4.27 kg ha^{-1}) were recorded under treatment combination $F_3B_1M_1$ over the other treatment combinations and it was statistically at par with treatment combination $F_2B_1M_1$, while, significantly the lowest phosphorus uptake by chickpea seeds (4.85 kg ha^{-1}) and chickpea straw (2.18 kg ha^{-1}) were recorded under treatment combination $F_0B_0M_0$ in pooled results. As nutrient uptake is the function of seed and straw yield as well as their nutrient content, the significant increase in content of the nutrients coupled with increased seed and straw yield increased the uptake of N and P substantially. The results are in accordance with Singh e*t al.* (2017) [19] and Kumar *et al.* (2016) [10].

3.11 Interaction effects of fertilizer levels, biofertilizers and micronutrients on physiological parameters

Interaction effects among different fertilizer levels, biofertilizers and micronutrients treatments were found non-significant with respect to crop growth rate (CGR) and relative growth rate (RGR) of chickpea recorded at 30, 60 and 90 DAS during both the years as well as on pooled basis (Table 6 and Table 7).

3.12 Combine effect of fertilizer levels, biofertilizers and micronutrients on nutrient use efficiency (NUE)

The combine effects of fertilizer levels, biofertilizers and micronutrients, interactions presented in the Table 9 are described below.

1. Partial factor productivity (PFP): The data showed that treatment combination $F_1B_1M_0$ recorded the highest values of partial factor productivity (57.91 kg kg^{-1}) in mean data followed by treatment combination $F_1B_1M_1$ (55.18 kg kg^{-1}).
2. Agronomic efficiency (AE): The data revealed that treatment combination $F_2B_1M_1$ recorded the highest values of agronomic efficiency (21.12 kg kg^{-1}) in mean data followed by treatment combination $F_3B_1M_1$ (16.55 kg kg^{-1}).
3. Recovery efficiency (RE):The data showed that treatment combination $F_2B_1M_1$ recorded the highest values of recovery efficiency (114.07 per cent) in mean data followed by treatment combination $F_3B_1M_1$ (90.50 %).
4. Physiological efficiency (PE): The perusal of data indicated that the treatment combination $F_1B_0M_0$ recorded the highest values of physiological efficiency (23.33 kg kg^{-1}) in mean data.

This might be due to the efficient nutrient use by providing economically optimum nourishment to the crop, while minimizing nutrient losses from the field (Fixen *et al.*, (2014) [4], Snyder and Bruulsema (2007) [20] and Kakraliya *et.al.* (2017) [8].

Table 1: Protein content, nitrogen content in seed and nitrogen uptake by seed as influenced by fertilizer levels, biofertilizers and micronutrients

Treatments	Protein content (%)			N content in seed (%)			N uptake by seed (kg ha^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Fertilizer levels (F)									
F_0=Control	18.84	18.36	18.60	3.01	2.94	2.98	54.37	53.02	53.70
F_1=50% RDF	19.49	19.54	19.51	3.12	3.13	3.12	63.54	62.56	63.05
F_2=75% RDF	20.10	20.28	20.19	3.22	3.24	3.23	73.45	74.84	74.14
F_3=100% RDF	20.48	20.33	20.41	3.28	3.25	3.26	82.10	81.02	81.56
S. Em.±	0.36	0.41	0.27	0.06	0.07	0.04	1.72	2.37	1.46
C.D. (P= 0.05)	1.04	1.19	0.77	0.17	0.19	0.12	4.96	6.83	4.13
Biofertilizers (B)									
B_0= Control	19.30	19.11	19.20	3.09	3.06	3.07	62.19	60.76	61.48
B_1= PSB + Rhizobium	20.16	20.14	20.15	3.22	3.22	3.22	74.54	74.96	74.75
S.Em.±	0.26	0.29	0.19	0.04	0.05	0.03	1.21	1.67	1.03
C.D. (P= 0.05)	0.74	0.84	0.55	0.12	0.13	0.09	3.50	4.83	2.92
Micronutrients (M)									
M_0= Control	19.57	19.35	19.46	3.13	3.10	3.11	66.03	64.39	65.21
M_1= Micronutrient mixture grade-V	19.89	19.90	19.90	3.18	3.18	3.18	70.70	71.33	71.01
S.Em.±	0.26	0.29	0.19	0.04	0.05	0.03	1.21	1.67	1.03
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	3.50	4.83	2.92
Interactions									
F × B	NS	NS	NS	NS	NS	NS	Sig.	NS	Sig.
F × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
B × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
F × B × M	NS	NS	NS	NS	NS	NS	Sig.	NS	Sig.
Y x F, Y x B, Y x M, Y x F x B, Y x F x M, Y x B x M, Y x F x B x M	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	6.34	7.27	6.82	6.34	7.27	6.82	8.70	12.08	10.51

Table 2: Nitrogen content in straw, nitrogen uptake by straw and phosphorus content in seed as influenced by fertilizer levels, biofertilizers and micronutrients

Treatments	N content in straw (%)			N uptake by straw (kg ha^{-1})			P content in seed (%)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Fertilizer levels (F)									
F_0=Control	0.54	0.53	0.54	11.93	11.75	11.84	0.32	0.31	0.32
F_1=50% RDF	0.56	0.56	0.56	14.10	13.77	13.93	0.34	0.33	0.33
F_2=75% RDF	0.58	0.58	0.58	16.33	15.80	16.07	0.35	0.34	0.34
F_3=100% RDF	0.59	0.59	0.59	17.80	17.58	17.69	0.35	0.34	0.35
S. Em.±	0.01	0.01	0.01	0.46	0.42	0.31	0.006	0.007	0.005
C.D. (P= 0.05)	0.03	0.03	0.02	1.33	1.21	0.88	0.02	0.02	0.01
Biofertilizers (B)									
B_0= Control	0.56	0.55	0.56	14.00	13.28	13.64	0.33	0.32	0.33
B_1= PSB + *Rhizobium*	0.58	0.58	0.58	16.08	16.16	16.12	0.35	0.34	0.34
S.Em.±	0.01	0.01	0.00	0.33	0.30	0.22	0.012	0.014	0.009
C.D. (P= 0.05)	0.02	0.02	0.01	0.94	0.86	0.62	0.01	0.01	0.01
Micronutrients (M)									
M_0= Control	0.56	0.56	0.56	14.32	14.08	14.20	0.34	0.33	0.33
M_1= Micronutrient mixture grade-V	0.57	0.57	0.57	15.75	15.37	15.56	0.34	0.34	0.34
S.Em.±	0.01	0.01	0.00	0.33	0.30	0.22	0.004	0.005	0.003
C.D. (P= 0.05)	NS	NS	NS	0.94	0.86	0.62	NS	NS	NS
Interactions									
F × B	NS	NS	NS	NS	Sig.	Sig.	NS	NS	NS
F × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
B × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
F × B × M	NS	NS	NS	NS	NS	Sig.	NS	NS	NS
Y x F, Y x B, Y x M, Y x F x B, Y x F x M, Y x B x M, Y x F x B x M	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	5.71	5.88	5.80	10.64	9.86	10.26	6.13	7.11	6.63

Table 3(a): Nitrogen uptake by chickpea seed and straw as influenced by F x B interaction

Treatments	N uptake by seed (kg ha^{-1})				N uptake by straw (kg ha^{-1})			
	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3
	2013-14				**2013-14**			
B_0	51.55	59.35	63.17	74.70	11.77	13.24	14.35	16.64
B_1	57.19	67.73	83.73	89.50	12.09	14.96	18.32	18.95
S.Em.±	2.43				0.65			
C.D. (P= 0.05)	7.01				NS			
C.V.%	8.70				10.64			
	2014-15				**2014-15**			
B_0	48.76	57.38	64.00	72.90	11.13	12.68	13.59	15.73
B_1	57.28	67.74	85.68	89.15	12.36	14.85	18.01	19.43
S.Em.±	3.35				0.59			
C.D. (P= 0.05)	NS				1.71			
C.V.%	12.08				9.86			
	Pooled				**Pooled**			
B_0	50.16	58.36	63.58	73.80	11.45	12.96	13.97	16.18
B_1	57.24	67.73	84.70	89.32	12.22	14.90	18.16	19.19
S.Em.±	2.07				0.62			
C.D. (P= 0.05)	5.85				1.25			
C.V.%	10.51				10.26			

Table 3(b): Nitrogen uptake by chickpea seed and straw as influenced by F x B x M interaction

Treatments	N uptake by seed (kg ha^{-1})				N uptake by straw (kg ha^{-1})			
	B_0		B_1		B_0		B_1	
	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1
	2013-14				**2013-14**			
F_0	47.24	55.86	58.64	55.74	10.73	12.80	12.47	11.70
F_1	57.29	61.41	68.87	66.59	12.51	13.97	14.69	15.23
F_2	63.24	63.10	75.85	91.60	14.25	14.46	16.67	19.96
F_3	74.08	75.32	83.06	95.95	16.13	17.16	17.15	20.75
S.Em.±	3.43				0.92			
C.D. (P= 0.05)	9.91				NS			
C.V.%	8.70				10.64			
	2014-15				**2014-15**			
F_0	44.00	53.52	55.73	58.84	10.15	12.11	12.56	12.16
F_1	54.92	59.84	69.20	66.28	11.73	13.64	15.08	14.61
F_2	61.24	66.75	75.88	95.47	13.10	14.07	16.32	19.71
F_3	71.68	74.12	82.50	95.79	15.48	15.97	18.20	20.66
S.Em.±	3.37				0.84			
C.D. (P= 0.05)	NS				NS			
C.V.%	12.08				9.86			
	Pooled				**Pooled**			
F_0	45.62	54.69	57.18	57.29	10.44	12.46	12.51	11.93
F_1	56.10	60.62	69.03	66.44	12.12	13.81	14.89	14.92
F_2	62.24	64.93	75.87	93.53	13.67	14.27	16.49	19.84
F_3	72.88	74.72	82.78	95.87	15.80	16.57	17.67	20.70
S.Em.±	2.92				0.62			
C.D. (P= 0.05)	8.27				1.76			
C.V.%	10.51				10.26			

Table 4: Phosphorus uptake by seed, phosphorus content in straw and phosphorus uptake by straw as influenced by fertilizer levels, biofertilizers and micronutrients

Treatments	P uptake by seed (kg ha^{-1})			P content in straw (%)			P uptake by straw (kg ha^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Fertilizer levels (F)									
F_0=Control	5.83	5.67	5.75	0.112	0.107	0.110	2.47	2.39	2.43
F_1=50% RDF	6.89	6.63	6.76	0.115	0.113	0.114	2.88	2.76	2.82
F_2=75% RDF	7.91	7.83	7.87	0.119	0.117	0.118	3.34	3.22	3.28
F_3=100% RDF	8.72	8.56	8.64	0.121	0.119	0.120	3.66	3.56	3.61
S. Em.±	0.19	0.23	0.15	0.002	0.002	0.001	0.10	0.08	0.07
C.D. (P= 0.05)	0.56	0.66	0.42	0.005	0.005	0.004	0.29	0.24	0.19
Biofertilizers (B)									
B_0= Control	6.69	6.42	6.55	0.115	0.112	0.113	2.88	2.68	2.78
B_1= PSB + *Rhizobium*	7.99	7.93	7.96	0.119	0.117	0.118	3.29	3.27	3.28

S.Em.±	0.14	0.16	0.11	0.001	0.001	0.001	0.07	0.06	0.05
C.D. (P= 0.05)	0.39	0.47	0.30	0.004	0.004	0.002	0.21	0.17	0.13
Micronutrients (M)									
M_0= Control	7.08	6.82	6.95	0.115	0.113	0.114	2.94	2.86	2.90
M_1= Micronutrient mixture grade-V	7.59	7.53	7.56	0.118	0.115	0.117	3.24	3.10	3.17
S.Em.±	0.14	0.16	0.11	0.001	0.001	0.001	0.07	0.06	0.05
C.D. (P= 0.05)	0.39	0.47	0.30	NS	NS	NS	0.21	0.17	0.13
Interactions									
F × B	Sig.	NS	Sig.	NS	NS	NS	NS	Sig.	Sig.
F × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
B × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
F × B × M	Sig.	NS	Sig.	NS	NS	NS	NS	NS	Sig.
Y x F, Y x B, Y x M, Y x F x B, Y x F x M, Y x B x M, Y x F x B x M	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	9.08	11.04	10.08	5.31	5.23	5.27	11.43	9.84	10.69

Table 5(a): Phosphorus uptake by chickpea seed and straw as influenced by F x B interaction

Treatments	P uptake by seed (kg ha^{-1})				P uptake by straw (kg ha^{-1})			
	F_0	**F_1**	**F_2**	**F_3**	**F_0**	**F_1**	**F_2**	**F_3**
	2013-14				**2013-14**			
B_0	5.53	6.45	6.84	7.92	2.45	2.69	2.95	3.43
B_1	6.13	7.33	8.97	9.52	2.49	3.07	3.73	3.89
S.Em.±	0.27				0.14			
C.D. (P= 0.05)	0.79				NS			
C.V.%	9.08				11.43			
	2014-15				**2014-15**			
B_0	5.17	6.09	6.72	7.71	2.31	2.54	2.74	3.16
B_1	6.18	7.16	8.95	9.41	2.47	2.98	3.69	3.96
S.Em.±	0.32				0.12			
C.D. (P= 0.05)	NS				0.35			
C.V.%	11.04				9.84			
	Pooled				**Pooled**			
B_0	5.35	6.27	6.78	7.81	2.38	2.61	2.85	3.29
B_1	6.15	7.25	8.96	9.46	2.48	3.03	3.71	3.92
S.Em.±	0.21				0.09			
C.D. (P= 0.05)	0.60				0.26			
C.V.%	10.08				10.69			

Table 5(b): Phosphorus uptake by chickpea seed and straw as influenced by F x B x M interaction

Treatments	P uptake by seed (kg ha^{-1})				P uptake by straw (kg ha^{-1})			
	B_0		**B_1**		**B_0**		**B_1**	
	M_0	**M_1**	**M_0**	**M_1**	**M_0**	**M_1**	**M_0**	**M_1**
	2013-14				**2013-14**			
F_0	5.06	6.01	6.31	5.95	2.23	2.68	2.59	2.39
F_1	6.17	6.73	7.40	7.26	2.53	2.85	3.05	3.10
F_2	6.80	6.88	8.14	9.80	2.91	2.99	3.40	4.05
F_3	7.84	8.00	8.91	10.12	3.29	3.56	3.48	4.29
S.Em.±	0.38				0.20			
C.D. (P= 0.05)	1.11				NS			
C.V.%	9.08				11.43			
	2014-15				**2014-15**			
F_0	4.65	5.69	6.02	6.34	2.12	2.49	2.52	2.41
F_1	5.82	6.36	7.32	7.01	2.37	2.70	3.07	2.89
F_2	6.49	6.94	7.97	9.93	2.64	2.83	3.40	3.99
F_3	7.59	7.82	8.70	10.12	3.10	3.22	3.67	4.25
S.Em.±	0.23				0.16			
C.D. (P= 0.05)	NS				NS			
C.V.%	11.04				9.84			
	Pooled				**Pooled**			
F_0	4.85	5.85	6.17	6.14	2.18	2.58	2.56	2.40
F_1	6.00	6.54	7.36	7.13	2.45	2.78	3.06	3.00
F_2	6.65	6.91	8.06	9.87	2.78	2.91	3.40	4.02
F_3	7.71	7.91	8.80	10.12	3.19	3.39	3.58	4.27
S.Em.±	0.30				0.13			
C.D. (P= 0.05)	0.84				0.37			
C.V.%	10.08				10.69			

Table 6: Crop growth rate (CGR) at 30,60 and 90 DAS as influenced by fertilizer levels, biofertilizers and micronutrients

Treatments	CGR (g m^{-2}) at 30 days			CGR (g m^{-2}) at 60 days			CGR (g m^{-2}) at 90 days		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Fertilizer levels (F)									
F_0=Control	0.55	0.55	0.55	0.66	0.68	0.67	0.95	0.91	0.93
F_1=50% RDF	0.56	0.56	0.56	0.71	0.72	0.72	1.02	0.99	1.01
F_2=75% RDF	0.57	0.57	0.57	0.77	0.77	0.77	1.09	1.04	1.06
F_3=100% RDF	0.59	0.58	0.58	0.83	0.84	0.83	1.18	1.15	1.16
S. Em.±	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.02
C.D. (P= 0.05)	NS	NS	NS	0.04	0.04	0.03	0.07	0.09	0.06
Biofertilizers (B)									
B_0= Control	0.56	0.56	0.56	0.73	0.74	0.73	1.03	0.99	1.01
B_1= PSB + *Rhizobium*	0.58	0.58	0.58	0.76	0.77	0.76	1.09	1.05	1.07
S.Em.±	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01
C.D. (P= 0.05)	NS	NS	NS	0.03	0.03	0.02	0.05	0.06	0.04
Micronutrients (M)									
M_0= Control	0.56	0.57	0.56	0.74	0.74	0.74	1.05	1.00	1.03
M_1= Micronutrient mixture grade-V	0.57	0.57	0.57	0.75	0.76	0.75	1.07	1.04	1.05
S.Em.±	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions									
F × B	NS	NS	NS	NS	NS	NS	NS	NS	NS
F × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
B × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
F × B × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x F, Y x B, Y x M, Y x F x B, Y x F x M, Y x B x M, Y x F x B x M	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	7.27	7.63	7.45	6.51	5.75	6.14	8.40	10.31	9.37

Table 7: Relative growth rate (RGR) at 30,60 and 90 DAS as influenced by fertilizer levels, biofertilizers and micronutrients

Treatments	RGR (g g^{-1} day^{-1}) at 30 days			RGR (g g^{-1} day^{-1}) at 60 days			RGR (g g^{-1} day^{-1}) at 90 days		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Fertilizer levels (F)									
F_0=Control	0.023	0.023	0.023	0.020	0.021	0.021	0.010	0.010	0.010
F_1=50% RDF	0.023	0.023	0.023	0.021	0.021	0.021	0.010	0.010	0.010
F_2=75% RDF	0.024	0.024	0.024	0.022	0.022	0.022	0.010	0.010	0.010
F_3=100% RDF	0.025	0.024	0.025	0.022	0.023	0.023	0.010	0.010	0.010
S. Em.±	0.001	0.001	0.001	0.0004	0.0005	0.0003	0.0003	0.0002	0.0002
C.D. (P= 0.05)	NS	NS	NS	0.001	NS	0.001	NS	NS	NS
Biofertilizers (B)									
B_0= Control	0.023	0.023	0.023	0.021	0.022	0.021	0.010	0.010	0.010
B_1= PSB + *Rhizobium*	0.024	0.024	0.024	0.022	0.022	0.022	0.010	0.010	0.010
S.Em.±	0.001	0.001	0.00041	0.0003	0.0004	0.00024	0.0002	0.0002	0.00012
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Micronutrients (M)									
M_0= Control	0.023	0.024	0.024	0.021	0.021	0.021	0.010	0.010	0.010
M_1= Micronutrient mixture grade-V	0.024	0.023	0.024	0.021	0.022	0.022	0.010	0.010	0.010
S.Em.±	0.001	0.001	0.000	0.0003	0.0004	0.0002	0.0002	0.0002	0.0001
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions									
F × B	NS	NS	NS	NS	NS	NS	NS	NS	NS
F × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
B × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
F × B × M	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x F, Y x B, Y x M, Y x F x B, Y x F x M, Y x B x M, Y x F x B x M	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	10.33	13.61	12.07	6.66	8.78	7.80	8.55	7.45	8.03

Table 8: Partial factor productivity, Agronomic efficiency, Recovery efficiency and Physiological efficiency as influenced by fertilizer levels, biofertilizers and micronutrients

Treatments	Partial factor productivity (kg kg^{-1})			Agronomic efficiency (kg kg^{-1})			Recovery efficiency (%)			Physiological efficiency (kg kg^{-1})		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean
Fertilizer levels (F)												
F_0=Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.73	13.89	13.81
F_1=50% RDF	54.34	53.12	53.73	10.81	11.21	11.01	59.08	66.11	62.59	19.25	18.86	19.05

F_2=75% RDF	40.54	40.79	40.66	11.51	12.85	12.18	63.60	72.46	68.03	19.34	18.12	18.73
F_3=100% RDF	33.37	33.11	33.24	11.60	12.16	11.88	62.69	66.39	64.54	19.31	18.06	18.68
Biofertilizers (B)												
B_0= Control	29.6	29.1	29.4	6.06	6.43	6.25	33.27	36.30	34.78	17.69	16.67	17.18
B_1= PSB + *Rhizobium*	34.5	34.4	34.4	10.90	11.68	11.29	59.42	66.18	62.80	18.13	17.79	17.96
Micronutrients(M)												
M_0= Control	31.3	30.9	31.1	7.75	8.15	7.95	41.40	45.22	43.31	17.47	16.46	16.96
M_1= Micronutrient mixture grade-V	32.8	32.7	32.7	9.21	9.96	9.59	51.28	57.26	54.27	18.35	18.00	18.17

Table 9: Partial factor productivity, Agronomic efficiency, Recovery efficiency and Physiological efficiency as influenced by combination of fertilizer levels, biofertilizers and micronutrients

Treatment combinations	Partial factor productivity (kg kg^{-1})			Agronomic efficiency (kg kg^{-1})			Recovery efficiency (%)			Physiological efficiency (kg kg^{-1})		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean
$F_0B_0M_0$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$F_0B_0M_1$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.63	21.71	20.17
$F_0B_1M_0$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.28	16.67	18.98
$F_0B_1M_1$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	17.20	16.10
$F_1B_0M_0$	50.28	48.55	49.42	6.75	6.64	6.70	35.30	37.12	36.21	23.74	22.92	23.33
$F_1B_0M_1$	53.25	51.59	52.42	9.71	9.68	9.70	52.56	57.64	55.10	18.23	16.54	17.38
$F_1B_1M_0$	58.27	57.56	57.91	14.73	15.64	15.19	76.69	90.00	83.35	18.78	17.84	18.31
$F_1B_1M_1$	55.57	54.79	55.18	12.03	12.88	12.45	71.78	79.67	75.72	16.25	18.13	17.19
$F_2B_0M_0$	36.27	35.81	36.04	7.24	7.87	7.56	39.03	40.07	39.55	17.56	20.41	18.99
$F_2B_0M_1$	35.17	36.22	35.70	6.15	8.28	7.21	39.43	52.76	46.10	22.92	15.97	19.44
$F_2B_1M_0$	41.59	41.04	41.32	12.56	13.10	12.83	68.98	75.80	72.39	18.01	17.47	17.74
$F_2B_1M_1$	49.13	50.09	49.61	20.10	22.14	21.12	106.94	121.21	114.07	18.89	18.62	18.75
$F_3B_0M_0$	30.90	30.15	30.53	9.13	9.20	9.17	48.10	49.23	48.66	22.10	18.08	20.09
$F_3B_0M_1$	31.27	30.74	31.00	9.50	9.78	9.64	51.71	53.61	52.66	18.31	17.76	18.03
$F_3B_1M_0$	33.33	33.71	33.52	11.56	12.75	12.16	63.13	69.54	66.33	18.29	18.27	18.28
$F_3B_1M_1$	37.98	37.85	37.92	16.21	16.89	16.55	87.81	93.20	90.50	18.54	18.12	18.33

Conclusion

On the basis of results of two years of field experiment on chickpea- fodder sorghum cropping sequence in loamy sand soil of middle Gujarat,, it can be concluded that higher level of fertilizer dose increased the quality parameter, physiological parameter and nutrient use efficiency in chickpea. Higher protein content, N & P content and uptake by seed and straw, CGR and Nutrient use efficiency in chickpea was obtained with the application of biofertilizers *viz*., PSB and *Rhizobium*. Application of micronutrients increased the N and P uptake by seed and straw. Combined application of fertilizer, biofertilizer and micronutrients to the chickpea crop resulted in higher N and P uptake by seed and straw as well as improved nutrient use efficiency.

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