academicJournals

Vol. 9(29), pp. 2214-2221, 17 July, 2014
DOI: 10.5897/AJAR2013.7799
Article Number: BFA892A46122
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Increasing efficiency of seed inoculation with bio-fertilizers through application of micronutrients in irrigated chickpea

T. C. Poonia* and M. S. Pithia

Pulses Research Station, Junagadh Agricultural University, Junagadh-362 001, Gujarat, India.

Received 12 January, 2014; Accepted 16 June, 2014

The present study was aimed to determine the efficiency of different combinations of seed inoculation with micronutrients [Ammonium Molybdate: $(NH_4)6Mo_7O_{24}$) and cobalt sulphate: $CoSO_4$] on chickpea plant height, nodule count and seed yield. The experiment was carried out for three consecutive winter seasons from 2010 - 2011 to 2012 - 2013 in Gujarat State of India. The inoculation treatments influenced significantly the chickpea plant height, nodules/plant and therefore, the seed yield. Application of recommended dose of fertilizers (RDF) + ammonium molybdate (2.0 g/kg seed) + Rhizobium (*Mesorhizobium ciceri*) + phosphate solubilizing bacteria (PSB species *Bacillus subtilis*) recorded significantly highest chickpea plant height (40.9 cm) and nodules/plant (26.5) and remained equivalent with application of RDF + ammonium molybdate (2.0 g /kg seed) + $CoSO_4$ (2.0 g /kg seed) + *Rhizobium* + PSB. In contrast, RDF without inoculation (control) had the lowest chickpea plant height (37.4 cm) and nodules/plant (21.0). Significantly, the highest chickpea seed yield (1882 kg/ha) was produced with combination of RDF + ammonium molybdate (1.0 g/kg seed) + *Rhizobium* + PSB over control (1538 kg/ha) and remained equal with RDF + ammonium molybdate (2.0 g/kg seed) + *Rhizobium* + PSB (1832 kg/ha) and RDF + *Rhizobium* + PSB (1805 kg/ha) and produced 22.4, 19.1, and 17.4% more seed yield over control, respectively.

Key words: Chickpea (*Cicer arietinum*), cobalt, molybdenum, *Mesorhizobium ciceri*, *Bacillus subtilis*, yield.

INTRODUCTION

Chickpea or Bengal gram or gram (*Cicer arietinum* L.) is one of the important annual grain legumes of the world which is used extensively as the primary source of protein for human beings as well as nitrogen for many cropping systems and is widely grown in all Indian States. India is the largest producer of chickpea accounting to 75% of the world production. Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Karnataka are the major chickpea producing States sharing over 95% area (Anonymous, 2011 - 2012). Being a leguminous and hardy crop chickpea does very well under dry tracts, which receive

*Corresponding author. E-mail: pooniatc@gmail.com

an annual rainfall of 60 to 100 cm. It prefers fairly cold weather but frost is deadly harmful, especially at flowering and grain formation stages. Hailstorm at maturity causes great damage to the crop. The best type of soil is clay loam with an efficient drainage and free from soluble salts preferably having neutral Ph (Vittal et al., 2005).

It is used in many forms as *dal*, *chhole*, in sweets and in some attractive dishes (Poonia and Pithia, 2011). Its leaves contain malic and citric acids, which are useful for stomach ailments, and it is best blood purifier. Its seed contains about 17 to 21% protein, 62% carbohydrates and good amount of fat; besides, being rich source of Ca, Fe, vitamin C, and B_1 (Singh, 1988). Its feed and straw are highly rich in nutrients. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. Chickpea meets 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 140 kg N ha^{-1} from air (Gaur et al., 2010). Currently in Gujarat State, chickpea is grown on 2399 thousand ha area, 2733 thousand metric tons production and productivity of 1139 kg/ha. During 2000 - 2001, the productivity was far below (517 kg/ha) than the national level (744 kg/ha). This is not because of availability of improved chickpea varieties seed but proper fertilizer to the crop, soil moisture and nutrient deficiencies leads to poor chickpea seed production.

Mineral nutrient deficiencies are a major constraint limiting legume nitrogen fixation and yield. Rhizobial growth and survival in soils is not usually limited by nutrient availability. Multiplication of Rhizobia in the legume rhizosphere is limited by low calcium availability. Nodule initiation is affected by severe cobalt deficiency through effects on Rhizobia. Nodule development is limited by severe boron deficiency via an effect on plant cell growth. Nodule function requires more molybdenum than does the host plant, and in some symbioses nitrogen fixation may be specifically limited by low availability of Ca, Co, Cu and Fe (Graham et al., 1988).

Chickpea crop do not need much nutrition and usually can be grown on the marginal lands. Gupta et al. (1991) and Hale et al. (2001) stated that the molybdenum is a component of some bacterial nitrogenase and, therefore, is especially important for plants that live in symbiosis with nitrogen-fixing bacteria. In another research, it was found that molybdenum is also essential for nitrate reductase and nitrogenase enzyme activity (Westermann, 2005) and R*hizobium* bacteria fixing nitrogen needs molybdenum during the fixation process (Vieira et al., 1998).

Molybdenum is a trace element found in the soil and is required for growth of most biological organisms including plants (Agarwala et al., 1978). Deficiency of molybdenum cause poor assimilation of atmospheric nitrogen fixation in chickpea. Molybdenum is responsible for the formation of nodule tissue and increase in nitrogen fixation and without it microbial activity depressed with poor nitrogen fixation. Sharma et al. (1989) reported that inoculation with *Rhizobium* strains resulted in a significant increase in chickpea seed yield. In contrast, a competitive and persistent rhizobial strain is not expected to express its full capacity for nitrogen fixation if limiting factors (e.g., salinity, unfavorable soil pH, nutrient deficiency, mineral toxicity, temperature extremes, insufficient or excessive soil moisture, inadequate photosynthesis, plant diseases, and grazing) impose limitations on the vigor of the host legume (Peoples et al., 1995). Availability of soil moisture and mineral nutrients are the most factors that limit nitrogen fixation.

The chickpea production practices adopted by most Indian farmers are ancient and traditional with no or few input application. Inadequate agronomic practices like insufficient fertilizer use and seed inoculation, late planting, inadequate seed rate, poor weed control and no use of micronutrients significantly cause poor productivity of chickpea. Application of recommended dose of fertilizers (RDF) and seed inoculation are recommended as the most agronomic research practice to achieve higher chickpea seed yield. The inoculation of chickpea seed is not adopted by majority of the farmer's due to insufficient knowledge about inoculation and doubts. Chickpea responds positively to inoculation when grown in soils that contain native chickpea rhizobia (Sharma et al., 1983). Many researchers studied to determine effect of soil moisture and micronutrients on nitrogen fixation. Dudhade et al. (2009) reported 9.89% increased yield due to application of *Rhizobium* to chickpea seed.

The seed inoculation must be emphasized not only for the benefit of chickpea inoculation, but also for the combination of that with micronutrients in order to obtain higher yields. Jain et al. (2007) reported that *Rhizobium* (*Rhizobium leguminosarum*) inoculation along with application of phosphorus (40 kg/ha), Zn (4 kg/ha), Mo (0.6 kg/ha), and Boron (0.1 kg/ha) resulted in the highest plant height, nodulation, and dry matter production of green gram cv. Pusa Vishal at Uttar Pradesh district of India. Togay et al. (2008) found that seed treatment with ammonium molybdenum has a positive effect on growth, yield parameters and yield in legume crops.

The study was conducted in order to analyze the effect of different micronutrients [Ammonium Molybdate:$(NH_4)6Mo_7O_{24}$) and cobalt sulphate:$CoSO_4$] and seed inoculation [*Rhizobium* through *Mesorhizobium ciceri* and phosphate solubilizing bacteria (PSB) through *Bacillus subtilis*] on chickpea seed yield.

The main objective of the study is to determine the efficiency of seed inoculation in combination with bio-fertilizers through application of micronutrients and their effects on chickpea seed yield.

MATERIALS AND METHODS

Field trials were carried out in Junagadh district in South Saurashtra region of Gujarat State (India) and receive an average rainfall of

Table 1. Mean monthly air temperature and total monthly precipitation during 2010 - 2011 to 2012 - 2013 and long-term (1965 to 2010).

Month	Long-term average (1965 - 2010)				2010 - 2011				2011 - 2012				2012 - 2013			
	Maximum temp. (°C)	Minimum temp. (°C)	RH (%)	Rainfall (mm)	Maximum temp. (°C)	Minimum temp. (°C)	RH (%)	Rainfall (mm)	Maximum temp. (°C)	Minimum temp. (°C)	RH (%)	Rainfall (mm)	Maximum temp. (°C)	Minimum temp. (°C)	RH (%)	Rainfall (mm)
October	36.3	20.9	64	7.9	35.0	23.0	44	0.0	35.4	23.0	53	0.0	37.0	21.5	30	0.0
November	33.9	17.0	57	3.5	32.0	20.0	49	0.0	34.7	20.	49	0.0	33.8	15.3	23	0.0
December	31.3	11.5	56	0.5	28.8	11.9	32	0.0	31.1	13.7	47	0.0	32.1	15.7	25	0.0
January	30.1	10.8	54	0.1	31.0	14.0	23	0.0	28.6	11.4	50	0.0	28.1	11.6	45	0.0
February	32.6	14.0	53	0.3	33.0	15.0	19	0.0	30.7	14.6	52	0.0	31.2	13.3	36	0.0
March	36.6	18.7	54	0.3	38.0	22.0	16	0.0	36.6	18.5	40	0.0	36.0	17.7	37	0.0
Total	-	-	-	12.6	-	-	-	0.0	-	-	-	0.0	-	-	-	0.0
Mean	33.5	15.5	-	-	33.0	17.7	-	-	32.9	16.9	-	-	33.0	15.9	-	-

* RH, Relative humidity.

680 mm with a variability of 61% on average. But in chickpea growing season the rainfall is negligible during the experimentation. The mean monthly maximum and minimum temperature are 33.5 and 15.5°C and 12.6 mm mean seasonal rainfall, based on long-term average (Table 1). The soil structure has a medium black clay soil with alluvial characteristics. It contains 204 kg/ha available nitrogen, 99.5 kg/ha available potassium, 226 kg/ha available phosphorus, 0.08 ppm/kg soil weight molybdenum, 11.61 mg/kg Fe, 1.13 mg/kg Zn, 14.15 mg/kg Mn, 1.93 mg/kg Cu and 0.82% organic carbon. The soils were saline in reactions (pH = 7.8 - 8.1). The average monthly temperature during the growing period in the experimental years (respectively 33.0, 32.9, and 33.0°C) was lower than climatic data of long-term period (33.5°C). Total amount of precipitation during the growing period in all the 3 years were nil (0.0 mm) which were lower than average of long-term period (12.6 mm).

The experiments were designed in a randomized block design with six replications in each year. Plantings were made on 30 November, 2010, 18 November, 2011 and 23 November, 2012. The plot size was 5.0 × 2.7 m. Each plot had six rows. Inter and intra spacing was kept 45 and 10 cm, respectively. Plot size was 4.0 × 1.8 m (7.2 m^2) at harvest time. Each plot had two rows at the beginning and at the end of the plot for protection which were removed before harvest. A popular local released cultivar named

GG 1 with a seed rate of 60 kg/ha was tested in all the 3 years containing 36 total plots.

The study contains the following treatments:

T_1 = RDF (20-40-00 NPK kg/ha = Control)
T_2 = RDF + *Rhizobium* (through *M. ciceri)* + PSB (through *B. subtilis*)
T_3= RDF + 1.0 g ammonium molybdate/kg seed + *Rhizobium* (through *M. ciceri*) + PSB *(*through *B. subtilis*)
T_4 = RDF + 2.0 g ammonium molybdate/kg seed + *Rhizobium* (through *M. ciceri*) + PSB (through *B. subtilis*)
T_5 = RDF + 2.0 g $CoSO_4$/kg seed + *Rhizobium* (through *M. ciceri)* + PSB (through *B. subtilis*)
T_6 = RDF + 2.0 g ammonium molybdate/kg seed + 2.0 g $CoSO_4$/kg seed + *Rhizobium* (through *M. ciceri*) + PSB (through *B. subtilis*)

In this experiment, RDF were applied to all treatments as per recommended package of practices. The basal dose of fertilizers ((20-40-00 NPK kg/ha) were applied with a hand and placed into the top 5 to 10 cm depth of soil at sowing time. All plots were fertilized with 20 kg/ha nitrogen and 40 kg/ha phosphorus. Nitrogen source was urea (46% nitrogen) and phosphorus source was di-ammonium phosphate (16% nitrogen and 46% phosphorus) in this experiment. Seed inoculation was performed with and without application of ammonium molybdate $[(NH_4)6Mo_7O_{24}]$ and cobalt sulphate ($CoSO_4$) as described in the treatments. The *Rhizobium* (*M. ciceri*) and PSB that is, PSB (*B. subtilis*) culture were supplied from Senior Microbiologist, Department of Microbiology, Choudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (India).

Seed inoculation was performed just before sowing. No pesticide was used at sowing to seed and soil. The first irrigation was done after seed sown in plots. The second irrigation was at vegetative growth stage, third was done at flowering stage, and the fourth one was done at pod filling stage. These growth stages were selected as the reports of Silim and Saxena (1986) and Zaman and Malik (1988). Weeds were controlled by hand hoeing done twice (at vegetative stage and the beginning of the flowering) by hand hoe every year. Plots were harvested manually in March to determine seed yield and yield components. Plant height (cm) and nodules per plant were measured on five randomly selected plants from all plots at each year. Nodules were counted by excavating the roots of five random selected plants from the central rows of each plot at the flowering stage. A spade was used to uproot an undisturbed soil sample (approximately 20-cm depth) containing the roots. The nodules were counted separately from each plot. The seed yield was measured after mature plants harvested manually from four rows each 4.0 m in length and threshed. The data were analyzed as a randomized block design. All the data were subjected to

Table 2. Effect of seed inoculation through bio-fertilizers and molybdenum / cobalt on chickpea plant height and root nodulation.

Treatment	Plant height (cm)				Nodules/plant			
	2010 - 2011	2011 - 2012	2012 - 2013	Pooled	2010 - 2011	2011 - 2012	2012 - 2013	Pooled
RDF (20-40-00 NPK kg/ha = Control)	37.5	39.0	35.7	37.4	20.3	21.0	21.8	21.0
RDF + *Rhizobium (through M. ciceri)* +PSB (through *B. subtilis*)	37.2	38.3	37.3	37.6	24.2	23.3	23.8	23.8
RDF + 1.0 g ammonium molybdate/kg seed + *Rhizobium* (through *M. ciceri*) + PSB (through *B. subtilis*)	37.3	39.5	38.3	38.3	25.0	23.4	23.4	23.9
RDF + 2.0 g ammonium molybdate/kg seed + *Rhizobium* (through *M. ciceri)* +PSB (through *B. subtilis*)	37.7	42.7	42.4	40.9	27.2	26.8	25.5	26.5
RDF + 2.0 g $CoSO_4$/kg seed +*Rhizobium* (through *M. ciceri* + PSB (through *B. subtilis*)	38.8	39.9	35.7	38.1	27.2	24.3	23.4	24.9
RDF + 2.0 g ammonium molybdate/kg seed + 2.0 g $CoSO_4$/kg seed +*Rhizobium* (through *M. ciceri*) + PSB (through *B. subtilis*)	37.2	43.1	36.9	39.1	27.5	25.6	25.1	26.1
S.Em±	0.69	1.53	1.60	0.80	0.52	1.04	0.78	0.48
CD at 5%	NS	NS	NS	2.3	1.1	3.0	2.3	1.4
LSD (= 0.05)	4.5	9.3	10.4	8.5	5.0	10.5	8.0	8.1
Interaction (Y × T)								
S. Em ±	-	-	-	1.35	-	-	-	0.81
LSD (= 0.05)	-	-	-	NS	-	-	-	NS

analyses of variance (ANOVA) for all treatments using Statistical Analysis System (version 9.3). Results of ANOVA for single experiments were combined over years. The significance of the treatments and years were determined at the 0.05 and 0.01 probability levels using appropriate F-values. The F-protected least significant difference (LSD = 0.05) and standard error of the mean (S.Em±) were calculated according to Cochran and Cox (1967).

RESULTS AND DISCUSSION

Plant height (cm)

The applications of *Rhizobium* and PSB seed inoculation with ammonium molybdate/cobalt sulphate had statistically significant effect on the plant height. Gupta and Gangwar (2012) in a similar study found the same result in chickpea plant height. Sharma et al. (1983) reported that the effect of fertilizer application was positive on plant height. The plant height was not affected significantly across the years (Table 2) whereas in pooled analysis plant height had a significant effect. Significantly, highest plant height (40.9 cm) was recorded with application of RDF + 2.0 g ammonium molybdate/kg seed + *Rhizobium* + PSB over rest of the treatments. The same treatment remained equivalent with application of RDF + 2.0 g ammonium molybdate/kg seed + 2.0 g $CoSO_4$/kg seed + *Rhizobium* + PSB which produced a plant height of 39.1 cm. The lowest plant height (37.4 cm) was obtained from control plot (RDF alone).

The plant height in chickpea tended to increase in *Rhizobium*, PSB, and micronutrients inoculated treatments compared to uninoculated plots. This was attributed due to quick release of available nitrogen synthesized by root rhizobia to the plant at the time of vegetative growth. The high soil nitrogen fixation and its quick availability in rhizosphere derivation from better nodulation cause excessive vegetative growth. All of these beneficial attributes might be effective on plant vegetative growth. Yagmur and Kaydan (2011)

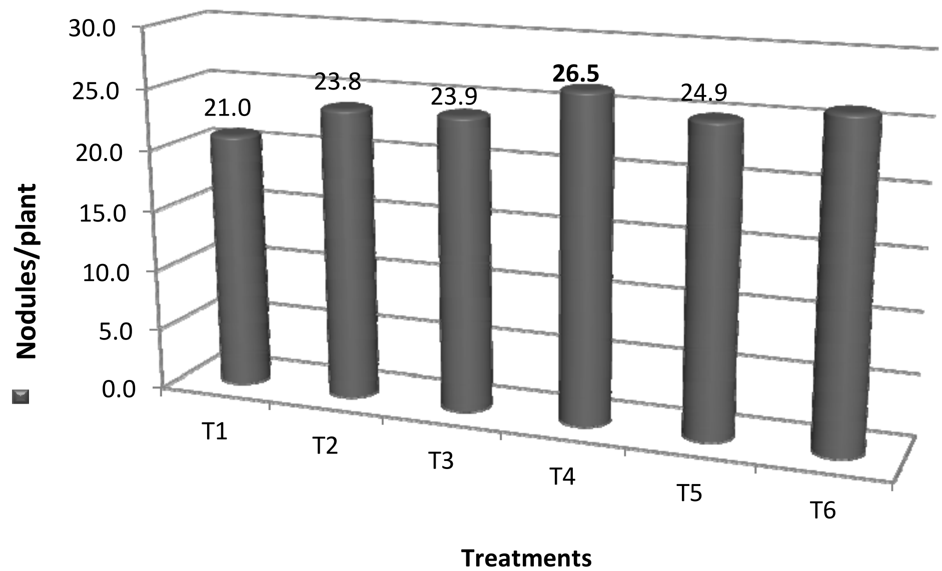

Figure 1. Significant effects of seed inoculation treatments on nodules/plant.

reported that seed inoculation and nitrogen fertilizers were increased the plant height in chickpea. Gupta and Gangwar (2012) reported that application of ammonium molybdate either soil application or through seed treatment in combination with *Rhizobium* + PSB + RDF significantly increased plant height and nitrogen uptake in chickpea over control (RDF alone).

Number of nodules per plant

It was found that chickpea seed inoculation with *Rhizobium* and PSB through application of ammonium molybdate and cobalt sulphate significantly influenced the number of nodules on the root system. Therefore, inoculated seed with *Rhizobium*, PSB, and ammonium molybdate/cobalt sulphate had statistically significant effect on the nodule count per plant. The number of nodules per plant was affected significantly in all the years by application of ammonium molybdate/cobalt sulphate as seed inoculation to chickpea. According to pooled data in Table 2, the highest number of nodules (26.5 nodules/plant) were recorded from the application of RDF + 2.0 g ammonium molybdate/kg seed + *Rhizobium* + PSB and remained equivalent to T6 (RDF + 2.0 g ammonium molybdate/kg seed + 2.0 g $CoSO_4$/kg seed + *Rhizobium* + PSB). The lowest nodules (21.0 nodules/plant) one was obtained from the application of RDF alone. Chickpea plots inoculated with *Rhizobium*, PSB, and 2.0 g ammonium molybdate/cobalt sulphate gave higher nodules per plant compared to without or lower dose micronutrients amended plots. Groups that are significantly different in nodule count per plant are also graphically depicted in Figure 1.

Moreover, inoculation with 2.0 g ammonium molybdate/cobalt sulphate was found significantly superior. There was a constructive increase in number of nodules per plant with the combination of ammonium and cobalt as seed inoculation because of the synergistic effect of both in nodule formation as mentioned by Gupta et al. (1991) and Hale et al. (2001). The increased nodulation in inoculated seeds with higher doses of molybdenum/cobalt could be attributed to better plant development through efficient utilization of molybdenum/cobalt for nodule formation by the plant grown from inoculated seeds.

Seed yield (kg/ha)

Six treatments of this study on seed yield of irrigated chickpea (*C. arietinum* L.) were significantly different ($p < 0.05$) in years 2010 - 2011, 2011 - 2012, and pooled data (Table 3). Groups that are significantly different in chickpea seed yield are also graphically depicted in Figure 2. In pooled data the best effects were obtained on seed yield from the treatment of RDF + 1.0 g ammonium molybdate/kg seed + *Rhizobium* + PSB and remained equivalent to the treatments of RDF + 2.0 g ammonium molybdate/kg seed + *Rhizobium* + PSB and RDF + *Rhizobium* + PSB as 1882, 1832, 1805 kg/ha, respectively. The lowest seed yield was determined from control (T1) plots as 1538 kg/ha.

These results indicated that seed inoculation affects on chickpea significantly when plots were treated with molybdenum/cobalt at 1.0 or 2.0 g/kg seed. The seed inoculated with *Rhizobium* and PSB with molybdenum/cobalt at 2.0 g/kg seed has small increases

Table 3. Effect of seed inoculation through bio-fertilizers and molybdenum / cobalt on chickpea seed yield (kg/ha).

Treatment	Chickpea seed yield (kg/ha)				Chickpea fodder yield (kg/ha)			
	2010 - 2011	2011 - 2012	2012 - 2013	Pooled	2010 - 2011	2011 - 2012	2012 - 2013	Pooled
RDF (20-40-00 NPK kg/ha = Control)	1486	1948	1181	1538	1895	1940	1301	1712
RDF + *Rhizobium (through M. ciceri)* + PSB *(*through *B. subtilis*)	1796	2267	1352	1805	2027	2880	1407	2105
RDF + 1.0 g ammonium molybdate/kg seed +*Rhizobium* (through *M. ciceri*) + PSB *(*through *B. subtilis*)	1817	2421	1403	1882	1919	3049	1392	2120
RDF + 2.0 g ammonium molybdate/kg seed + *Rhizobium* (through *M. ciceri)* +PSB *(*through *B. subtilis*)	1778	2343	1376	1832	1842	2901	1325	2022
RDF + 2.0 g CoSO4 /kg seed + *Rhizobium* (through *M. ciceri* + PSB *(*through *B. subtilis*)	1667	2248	1339	1752	1738	2737	1415	1963
RDF + 2.0 g ammonium molybdate/kg seed + 2.0 g $CoSO_4$/kg seed + *Rhizobium* (through *M. ciceri*)+ PSB (through *B. subtilis*)	1647	2114	1321	1727	1778	2726	1408	1971
S.Em±	61.7	99.8	51.0	41.2	68.3	116.4	41.2	130.7
CD at 5%	180	291	NS	116	NS	339	NS	NS
LSD (= 0.05)	8.9	10.9	9.4	10.3	9.0	10.5	7.4	10.1
Interaction (Y × T)								
SEm ±	-	-	-	73.9	-	-	-	81.5
LSD (= 0.05)	-	-	-	NS	-	-	-	230.0

in seed yield. It was concluded that application of RDF + 1.0 g ammonium molybdate/kg seed + *Rhizobium* + PSB had 22.4% increases in seed yield over control treatment (RDF alone). Though, treatment T4 (RDF + 2.0 g ammonium molybdate/kg seed + *Rhizobium* + PSB) determined 3.3% lower yield but statistically remained at par with treatment T3.

Seed yield had highly depended on plant height and nodulation count under irrigated conditions. Higher yield was determined from treatment T3 and T4 was a reflection of high nitrogen supply due to good nodulation when inoculated with molybdenum/cobalt fertilizers, resulting in high nitrogen fixation and better plant growth and yield contributing parameters. Deo and Kothari (2002) stated that seed treatment with 3.5 g sodium molybdate/kg seed enhance the seed yield in chickpea.

Fodder yield (kg/ha)

The effect of seed inoculation with *Rhizobium* and PSB through application of molybdenum/cobalt and years was found not significant (Table 3) except in 2011 - 2012 year alone. In the year 2011 -2012, highest fodder yield (3049 kg/ha) was obtained from treatment RDF + *Rhizobium* + PSB inoculated with 2.0 g ammonium molybdate/kg seed. Moreover, the treatment statistically remained at par with all treatments except control (RDF alone). The lowest fodder yield (1940 kg/ha) was determined from plots of RDF alone without inoculation.

Economics

Economic analysis (Table 4) indicated that maximum net income rupees 48146/ha was obtained in the treatment T3 where chickpea

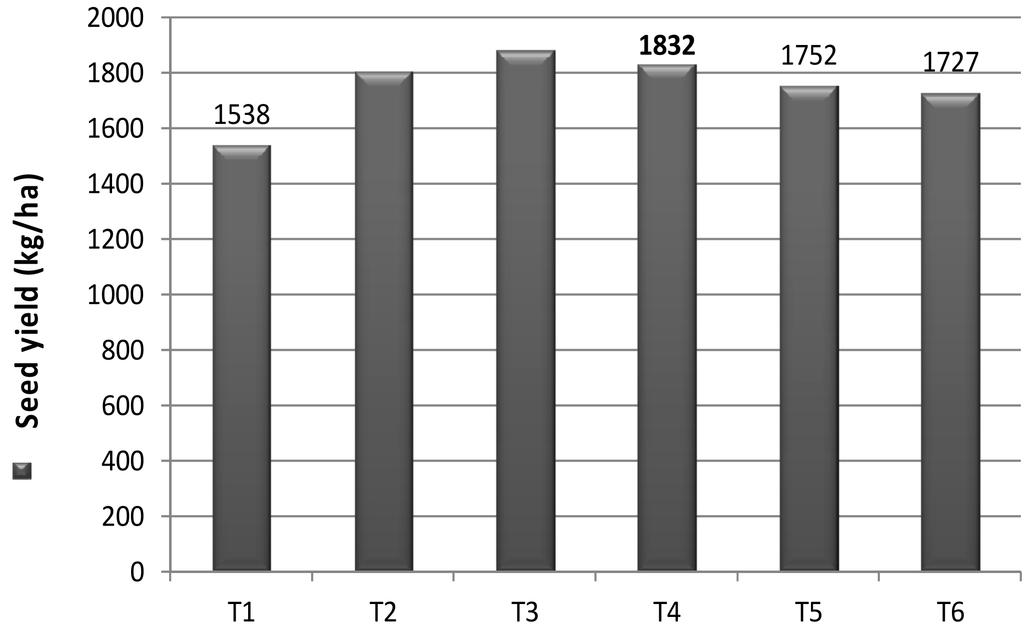

Figure 2. Significant effects of seed inoculation treatments on chickpea seed yield.

Table 4. Effect of different seed inoculation treatments on economics of chickpea production.

Treatment	Pooled chickpea seed yield (kg/ha)		Gross return (Rupees/ha)	Cost of cultivation (Rupees/ha)	Net return (Rupees/ha)	Benefit : Cost ratio
	Seed	Straw				
RDF (20-40-00 NPK kg/ha = Control)	1538	1712	54857	18126	36731	2.03
RDF + *Rhizobium (through M. ciceri)* +PSB (through *B. subtilis*)	1805	2105	64438	18277	46161	2.52
RDF + 1.0 g ammonium molybdate/kg seed +*Rhizobium* (through *M. ciceri)* + PSB (through *B. subtilis*)	1882	2120	67142	18996	48146	2.53
RDF + 2.0 g ammonium molybdate/kg seed + *Rhizobium* (through *M. ciceri)* + PSB (through *B. subtilis*)	1832	2022	65333	19716	45617	2.30
RDF + 2.0 g $CoSO_4$/kg seed + *Rhizobium* (through *M. ciceri* +PSB (through *B. subtilis*)	1752	1963	62498	19476	43022	2.20
RDF + 2.0 g ammonium molybdate/kg seed + 2.0 g $CoSO_4$/kg seed + *Rhizobium* (through *M. ciceri*) + PSB (through *B. subtilis*)	1727	1971	61628	20916	40712	1.95

*Selling price (Rupees/kg): Chickpea seed: 35.0, Chickpea fodder: 0.60.

seed is treated with 1.0 g ammonium molybdate/kg seed with *Rhizobium* and PSB. The same treatment determined a maximum benefit cost ratio of 2.53 followed by treatment T2 plots. Moreover, application of ammonium molybdate and cobalt sulphate above 1.0 g dosage/kg seed had not showed significant improvement on the economics of chickpea seed production but improved the nodulation count in chickpea to some extent which benefits in soil nitrogen economy.

Conclusion

According to the results, inoculation practices were dwelled upon at farmer's field through application of molybdenum as micronutrient for inoculation to save nitrogen fertilizing cost and contaminating nitrate to clean water. Therefore, the greater economic benefits can be obtained when the chickpea seed is treated with *Rhizobium* (through *M. ciceri)* + PSB (through *B. subtilis*) microbial fertilizers should be inoculated with ammonium molybdate at 1.0 g/kg seed under assured irrigated conditions in South Saurashtra region of Gujarat State (India).

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Agarwala SC, Sharma CP, Farooq S, Chatterjee C (1978). Effects of molybdenum deficiency on the growth and metabolism of corn plants raised in sand culture. Can. J. Bot. 56:1905-1909.http://dx.doi.org/10.1139/b78-227

Anonymous (2011-12). Project Coordinators Report on Chickpea, All India Coordinated Research Project on Chickpea, Indian Institute of pulses Research, Kalyanpur, Kanpur, India. P. 50.

Cochran WG, Cox GM (1967). Experimental Designs. 2nd edition. John Willey and Sons Inc. New York.

Deo C, Kothari ML (2002). Effect of modes and levels of Mo application on grain yield, protein content and nodulation of chickpea grown on loamy sand soil. Communications in Soil Sci. Plant Anal. 3:2905-2915. http://dx.doi.org/10.1081/CSS-120014490

Dudhade D, Deshmukh GP, Harer PN, Patil JV (2009). Impact of Frontline Demonstrations of Chickpea in Maharashtra. Legume. Res. 32(3):2206-208.

Gaur PM, Tripathi S, Gowda CLL, Ranga Rao GV, Sharma HC, Pande S, Sharma M (2010). Chickpea Seed Production Manual. Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. P. 28.

Graham WO, Nantakorn B, Michael J. D (1988). Mineral constraints to nitrogen fixation, Plant. Soil: 108(1):93-110. http://dx.doi.org/10.1007/BF02370104

Gupta G, Grund B, Radhika N (1991). Photosynthesis and nitrogenae activity in soybean treated with sulphur dioxide and molybdenum. Plant Sci. 79 (2):157-161.http://dx.doi.org/10.1016/0168-9452(91)90102-E

Gupta SC, Gangwar S (2012). Effect of molybdenum, iron and microbial inoculants on symbiotic traits, nutrient uptake and yield of chickpea. J. Food Legumes. 25(1):45-49.

Hale KL, McGrath SP, Lombi E, Stack MS, Terry N, Pickering IJ, Graham NG, Pilon- Smits EAH (2001). Molybdenum Sequestration in Brassica Species. A Role for Anthocyanins. Plant Physiol. 126:1391-1402.http://dx.doi.org/10.1104/pp.126.4.1391

Jain AK, Sudhir K, Panwar JDS (2007). Role of Rhizobium, phosphorus and micronutrients on growth and modulation of green gram (Vigna radiata (L.) Wilczek). Advances in Plant Sci. 20(2):337-339.

Peoples MB, Ladha JK, Herridge DF (1995). Enhancing legume N2 fixation through plant and soil management. Plant Soil, 174:83–101.http://dx.doi.org/10.1007/BF00032242

Poonia TC, Pithia MS (2011). Impact of Frontline Demonstrations of Chickpea in Gujarat. Legume Res. 34(4):304-307.

Silim SN, Saxena MC (1986). Response of Supplementary irrigation. In Annual Report, Food Legume Improvement Programme, ICARDA, Aleppo, Syria.

Sharma AK, Haribendra S, Sushi S, Singh H, Singh S (1989). Response of Cicer arietinum L. to rhizobial and N fertilization. Indian J. Agron. 34:381-383.

Sharma LC, Saxena S, Jain RK, Prasad J, Reddy BN (1983). Survey for nodulation in gram in Rajasthan. International Chickpea Newsletter 9:24-25.

Singh SS (1988). Crop management under irrigated nd rainfed conditions. Kalyani Publishers, Rajedranager, Ludhiana, India, P. 470.

Togay Y, Togay N, Dogan Y (2008). Research of on the effect of P and Mo applications on the yield and yield parameters in lentil (Lens culinaris Medic.). African J. Biotechnol. 7:1256-1260.

Vieira RF, Cardoso EJBN, Vieira C, Cassini STA (1998). Foliar application of molybdenum in common beans. Nitrogenase and reductase activities in a soil of high fertility. J. Plant Nutr. 21:169-180.http://dx.doi.org/10.1080/01904169809365391

Vittal KPR, Masood Ali, Ravindra Chary G, Maruthi Sankar GR, Srijaya T, Udaya Bhanu M, Ramakrishna YS, Samra JS (2005). District based Promising Technologies for Rainfed Chickpea Based Production System in India. All India Co-ordinated Research Project for Dryland Agriculture, Central Research Institute for Dryland Agriculture, Indian Council. Agric. Res. Hyderabad, P. 119.

Westermann DT (2005). Nutritional requirements of potatoes. Am. J. Potato Res. 82:301-307

Yagmur M, Kaydan D (2011). Plant growth and protein ratio of spring sown chickpea with various combinations of Rhizobium inoculation, nitrogen fertilizer and irrigation under rainfed condition. Afr. J. Agric. Res. 6(12):2648-2654.

Zaman A, Malik S (1988). Effect of irrigation levels and mulches on yield attributes and yield of green gram in laterite soil. Environ. Ecol. 6:437-440.