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Integrated nutrient management in cowpea with the application of microbial inoculants

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ABSTRACT

Indian livestock sector is one of the largest in the world and fodder is vital component of profitable animal production. Legumes are one of the predominant crops of mixed crop-livestock systems providing highly nutritious fodder as well as contributing soil fertility. Nevertheless, the fodder production and quality in the country is not adequate to meet out the prerequisite of growing livestock population. Optimum nutrition is thus required for getting the maximum forage yield and quality. Nutrient Management is propounded as a promising strategy for addressing such challenges. Microbial inoculants being an important component of integrated nutrient management are eco-friendly and economical sources of nutrient. The benefit of combining organic and inorganic sources of nutrients in integrated nutrient management has proved superior to the use of each component individually. Thus, the present review will feature the need of integrated nutrient management, plant growth promoting rhizobacteria as microbial inoculants, role of microbial inoculants in integrated nutrient management of various leguminous crops and emerging examples of integrated nutrient management in cowpea. The realization attained from literature assessed herein will further help to understand the role of microbial inoculants in integrated nutrient management.

Key words: Cowpea, Fodder, Livestock, Microbial inoculants, Integrated nutrient management.

Indian livestock sector is one of the largest in the world with population of around 529.7 million. This sector had achieved an average growth rate of 4.8 per cent during the eleventh five year plan. Fodder is vital component of profitable animal production in India. It had contributed 3.6 per cent of national GDP during the eleventh year plan. Supplementation of green fodder has become indispensible for nourishing livestock productivity owing to their wealth in macro and micro nutrients. Nevertheless, the fodder production and quality in the country is not adequate to meet out the prerequisite of growing livestock population. To meet out this deficit, the green forage supply has to grow at 1.69% annually (IGFRI, Vision 2050). The only solution for bridging the gap between the demand and supply of green fodder is to maximize the fodder production by identifying advanced forage resources and expanding the fodder production with attainable farming system.

Legumes are one of the predominant crops of mixed crop-livestock systems providing highly nutritious fodder as well as contributing soil fertility through biological nitrogen fixation. Fodder cowpea (Fatokun *et al*., 2009) is capable of enhancing the sustainability of livestock production by refining seasonal fodder productivity along with high nutritive value. The productivity of green fodder cowpea is around 25-45 t/ha with seed production potential of 3 q/ha (Ahmad *et al*., 2017). According to Ministry of Agriculture report (2012), the area under cowpea production has gradually increased from 85,510 ha (2006) to 115,800 ha (2011). However, the average yield remained between 0.2 t-0.5 t/ha. Optimum nutrition is thus required for getting the maximum forage yield and quality. In Punjab, recommended dose of fertilizer for forage cowpea is 7.5kg N (16.5kg urea) as a start a dose and 22kg of P_2O_5 (140 kg single superphosphate) per acre at sowing (Anonymous 2018). However, application of imbalanced or excessive chemical fertilizers as nutrients result in declining nutrient-use efficiency making fertilizer utilization uneconomical and thereby contaminating environment and underground water quality, causing climate change and health threats.

Therefore, there is a need for potential nutrient sources which ought to be cheap and eco-friendly that enable farmers to minimize the use of chemical fertilizer together with conserving soil fertility. Integrated nutrient management is propounded as a promising strategy for addressing such challenges. Microbial inoculants being an important component of INM are eco-friendly and economical sources of nutrient. The use of microbial inoculants in agriculture has substantially increased during the past two decades, (Hayat *et al.,* 2010) as both public and private sector agricultural research and development communities are

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working to ameliorate the tribulations associated with modern agriculture. This review will feature the need of integrated nutrient management, plant growth promoting rhizobacteria as microbial inoculants, role of microbial inoculants in integrated nutrient management of various leguminous crops. This review will also include specific examples from emerging literature to understand the role of microbial inoculants in integrated nutrient management of cowpea.

Need of integrated nutrient management

Major annual forage crops of our country are barley, cowpea, sorghum, lucerne, berseem, maize, pearl millet and oats. However, our country will face a major regional and national scarcity in green fodder production by 2030, because of changing food habits and more dietary reliance on livestock and its products (Anonymous, 2011). Though, fertilizers have played a noticeable role in increasing the productivity of crops but continuous and imbalance use of fertilizers results in deterioration of soil health (Dhavappriya *et al.,* 2015). A judicious and combined use of organic and inorganic sources of plant nutrients is required to maintain soil vigour and manage the efficiency of nutrients. The optimal and balanced use of nutrient inputs from inorganic and organic fertilizers is of fundamental importance for plant growth (Behera *et al*., 2007). Integrated nutrient management is a fundamental part of sustainable agriculture which requires the organization of resources in a way to fulfil the changing human needs without declining environmental quality and conserving vital natural resources. Integrated nutrient management (INM) is combined use of mineral fertilizers with organic resources like urban/rural wastes, crop residues, composts, cattle manures, green manures and biofertilizers (Antil, 2012). Such combined use of organic and inorganic sources of plant nutrient not only pushes the production and profitability of field crops, but also benefits in maintaining stable fertility status of the soil (Kannan *et al.,* 2013). The advantage of combining organic and inorganic sources of nutrient in integrated nutrient management has proved superior to the use of each component individually (Palaniappan and Annadurai, 2007).

Advantages of integrated nutrient management

INM augments the yield potential of crops over and above achievable yield through: (a) adequate mineralization, (b) reduced nitrogen losses through denitrification and nitrate leaching, (c) escalated nutrient use efficiency and recovery by crops and (d) improved soil health and productivity.

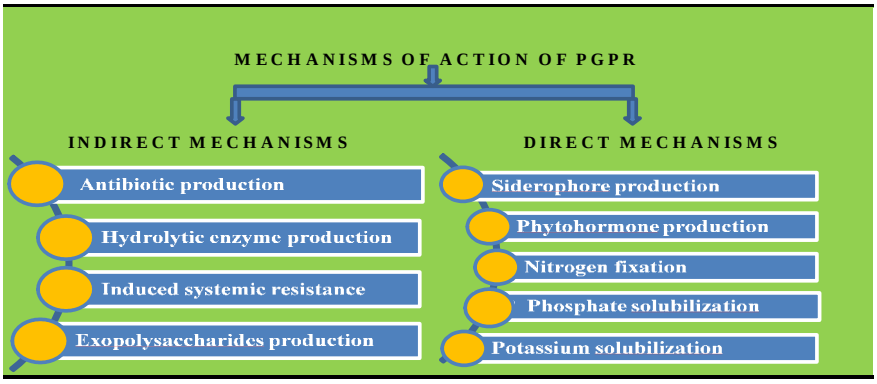
Moreover, it optimizes the soil conditions by improving its physical, biological, chemical and hydrological properties (Esilaba *et al*., 2004). The grain quality is comparatively superior under INM, which is accompanied by high profitability, improved soil health and sustainability (Behera *et al*., 2007).

Further, Nath *et al*. (2011) indicated that integrated nutrient management has the potential to expand microbial biomass carbon, soil enzymes activities, organic carbon and bacterial populations. Under INM practices the losses through volatilization, emissions, leaching, runoff and immobilization are minimized, while high nutrient-use efficiency is achieved (Zhang *et al.,* 2012). These changes in turn extend the nutrient pool of available nitrogen, phosphorus and potassium for plants growth (Marimuthu *et al.,* 2014).

INM requires nutrient application time and the amount to be in harmony with the crop nutrient supplies (Cassman *et al*., 2002). Farmers often apply huge quantity of N fertilizer before planting. Hence resulting in a large amount of inorganic N being available in the soil before it is required by rapid crop growth (Chen *et al*., 2006). This tribulation can be alleviated by the principle of INM that control the N losses and its detrimental effect on environment while attaining excessive crop productivity (Gruhn *et al*., 2000).

Plant growth promoting rhizobacteria as microbial inoculants

The term plant growth promoting rhizobacteria (PGPR) was conceived for the first time by Kloepper *et al.* (1980) to describe the microbial population in the rhizosphere (the region of soil in the vicinity of plant roots) which colonize the roots of plants, enhance crop productivity and protect the environment. Plant growth promoting rhizobacteria help in expanding sustainable agriculture as they are eco-friendly and cost effective in addition improves soil fitness and maintain natural soil fauna (Kannan and Sureendar, 2009). PGPR act as biofertilizers or microbial inoculants as well as biopesticides (Das *et al*., 2013). The term “Biofertilizer” or “Microbial inoculants” is defined as a preparation containing latent or live cells of efficient strains of phosphate solubilizing, nitrogen fixing or cellulolytic microorganism that are used for application in seeds, soils or composting areas with the objective of increasing the number of microorganisms and accelerating the microbial process thereby augmenting the availability of nutrients that are easily assimilated by plants (Borasate, 2009). PGPR encourage plant growth by direct and indirect mechanisms. Indirect plant growth promotion is mediated by siderophores and antibiotics produced by PGPR that lessen or prevent the detrimental effects of plant pathogenic microorganisms (Afzal and Bano, 2008). Whereas, direct promotion of growth by PGPR include production of metabolites such as cytokinins and auxins that enhance plant growth through solubilization of insoluble phosphorus compounds by release of organic acids and phosphatases (Hadad *et al*., 2010). Many plant growth-promoting bacteria such as *Azotobacter*, *Azospirillum*, *Bacillus*, *Burkholderia*, *Flavobacterium*, *Pseudomonas* and *Pantoea* have shown to enhance growth and yield in many crops by production of IAA as reported by Ali *et al.* (2010). Similarly, ACC-deaminase producing bacteria includes *Bacillus*, *Burkholderia*, *Enterobacter cloacae*, *Methylobacterium oryzae*, *Pseudomonas fluorescens*, *P. putida*, *Pseudomonas* spp. and *Variovorax paradoxus* (Zabihi *et al*., 2011).



Thus, PGPR are commonly selected on the basis of certain features such as ability of biological nitrogen fixation or production of phytohormones such as siderophores, enzymes like 1-aminocyclopropane-1-carboxylate deaminase and rhizosphere-colonizing ability (Zahir *et al*., 2004).

Likewise, a wide range of siderophore-producing bacteria including *P. chlororaphis, Proteus* sp., *Alcaligenes faecalis*, *Pseudomonas* spp., *Bacillus*, *Burkholderia*, *Serratia, Pseudomonas aeruginosa*, *P. fluorescens* have shown to stimulate plant growth (Sayyed and Chincholkar, 2009). Similarly, soil bacteria in the genera, *Sinorhizobium, Rhizobium, Mesorhizobium, Allorhizobium* and *Bradyrhizobium* belonging to the family Rhizobiaceae, invade plant root systems and form root nodules (Martinez-Romero and Wang, 2000). Jeffreis *et al.* (2003) reported that benefitial pant-microbe interactions in the rhizosphere are determinants of plant health and soil fertility. The interactions in the rhizosphere play a vital role in transformation, mobilization and solubilisation of essential minerals from a limited nutrient pool in the soil and following uptake. Thus, the practice of using plant growth promoting rhizobacteria (PGPR) as crop inoculants for biofertilization, phytostimulation and biocontrol would be a positive substitution to decrease the use of chemical fertilizers which affect the atmosphere due to indiscriminate application.

Role of microbial inoculants in integrated nutrient management of various leguminous crops

Vessey (2003) described biofertilizer/ microbial inoculant is a substance which comprises of living microorganisms, which when applied to seed, plant surfaces, or soil colonizes the rhizosphere or interior of the plant and stimulates plant growth by strengthening the supply or availability of primary nutrients to the host plant (Vessey, 2003). Bio-fertilizers or Microbial inoculants are the essential components of INM. Microbial inoculants are more often mentioned as selected strains of beneficial soil microorganisms cultured in the laboratory and packed in appropriate carriers (Hari and perumal, 2010). These potential biological fertilizers would play a crucial role in productivity and sustainability of soil (Khosro and Yousef, 2012) and adding nutrients through natural processes of BNF, phosphate solubilizing and growth promoting substances (phytohormones).

Vedram *et al*. (2002) observed that moong bean responded significantly higher to the application of Zn, sulphur, nitrogen with *Rhizobium* and *Azotobacter* inoculation and resulted in increased nutrient uptake as compared to their respective control.

Mathew and hameed (2002) reported that the inoculation of PSM +AMF at 30 kg P_2O_5/ ha resulted in highest green pod of 4451 kg per ha and haulm of 8915 kg per ha yields, net return of 15673 rupees per ha and benefit cost ratio of 1.54.

Singh *et al*. (2006) observed that in pea inoculation of *Rhizobium* + VAM + PSB along with 75% NPK resulted in significantly higher yield. Negi *et al*. (2006) also studied the effect of microbial inoculants (*Rhizobium leguminosarum* + *Pseudomonas striata*) @ 250 g per 10 kg seed, nutrient sources (FYM @ 20 t per ha and NPK @ 25:25:25 kg/ha) and lime (@ 4 t per ha) on growth and yield of garden pea. The results showed that composite inoculation of microbial inoculants significantly improved the growth and yield of pea over uninoculated control.

Stancheva *et al*. (2006) evaluated the effects of combined inoculation of pea plants with *Rhizobium* and vesicular arbuscular mycorrhiza on nodule formation and nitrogen fixation activity and demonstrated that with dual inoculation of pea plants results in increased plant biomass, nodules parameters, N-fixation activity at varying levels compared to single inoculation with *Rhizobium leguminosarum* (strain D293) and depended on vesicular arbuscular mycorrhiza fungi species.

Meena and Mann (2006) studied the application of mixture of phosphate solubilizing bacteria (PSB) and *Rhizobium trifolii* along with 20 kg nitrogen +60 kg phosphorous in berseem and noted highest green fodder of 65.45 tonnes per ha, dry matter yield of 16.98 tonnes per ha and protein content of 19.7% in berseem.

Patel *et al.* (2007) concluded that application of FYM @ 5 t/ha along with *Rhizobium* and PSB recorded significantly higher number of pods per plant (28.70) and higher grain (1171 kg ha^{-1}) and straw (1014 kg ha^{-1}) yield in chickpea.

Likewise, inoculation of *Rhizobium*, vesicular arbuscular mycorrhiza and Nitrogen levels in green gram resulted a significant enhancement in nodule dry weight, spore density,

Table 1: Biofertilizer production in India during the period from 2008-09 to 2011-12.

State	2008-2009 MT	2009-2010 MT	2010-2011 MT	2011-2012 MT
Andhra Pradesh	168.136	1345.28	999.60	1126.35
Assam	129.3552	121.04	130.00	68.33
Bihar	-	-	136.26	75.00
Chhatishgarh	-	-	-	276.34
Delhi	1165.1	1021.85	1205.00	1617.00
Gujarat	1149.695	1309.19	6318.00	2037.35
Goa	-	0	443.40	0
Haryana	14.25	6.195	6.53	914.41
Himachal Pradesh	-	8.5	9.00	1.29
Jharkhand	15.0	15.0	0.00	8.38
Karnataka	11921.057	3695.5	6930.0	5760.32
Kerala	1187.001	1936.451	3257.00	904.17
Madhya Pradesh	848.448	1587.6775	2455.57	2309.06
Maharashtra	1249.87	1861.33	2924.00	8743.69
Mizoram	1.996	2.5	2.00	
Nagaland	16.0092	18.25	21.50	13.00
Odissa	405.03	289.867	357.66	590.12
Punjab	1.14	301.232	2.50	692.2222
Pondicherry	561.7924	452.79	783.00	509.45
Rajasthan	353.67	805.571	819.75	199.78
Tamil Nadu	4687.818	3732.5862	8691.00	3373.81
Tripura	14.68	278.402	850.00	1542.85
Uttar Pradesh	885.5174	962.6417	1217.45	8695.08
Uttarakhand	48.23	32.00	45.00	263.01
West Bengal	241.24	256.5	393.39	603.20

Source: Compiled by NCOF (Data as provided by Production Units / State Governments).
https://ncof.dacnet.nic.in/OrganicInputproductionstatistics/BFandOFProductionstatistics 2010-11to2011-12.pdf.

rhizobial counts and root colonization over the control (Singh *et al.,* 2009).

Bhardwaj *et al*. (2010) demonstrated that combined application of FYM, crop residue and dual inoculation of *Azotobaceria*/*Rhizobium* with vesicular arbuscular mycorrhiza produced a yield response and quality in par with application of 75% recommended NPK in French bean. This might be due to positive effect of bio-fertilizers and organics on soil health.

Ramana *et al.* (2010) evaluated the impact of VAM and PSB along with graded dose of fertilizers on growth, yield attributes and yield of French bean. Further, revealed that the application of 75 per cent RDF along with VAM @ 2 kg/ ha and PSB @ 2.5 kg/ha significantly improved the plant height, number of branches/ plant, leaf area and dry weight.

El-Shaikh *et al.* (2010) recorded that application of 22.5 kg of phosphorus and inoculation with VAM in pea cultivar improved total green pod yield along with highest number of pods per plant.

Choudhary *et al.* (2011) observed that application of 25 kg N and 50 kg P_2O_5 and 40 kg K_2O along with *Rhizobium,* VAM and PSB produced significantly higher available nitrogen and available phosphorous in groundnut. Jha *et al.* (2012) demonstrated the impact of single and dual phosphate solubilizing bacteria (PSB) strain inoculations on overall growth of mungbean. These results were obtained on par with SSP and commercial biofertilizers of PSB (*Bacillus polymyxa*) and MC (*Pseudomonas striata*) as standard reference.

Another, field experiment was conducted in soybean by Kumar *et al.* (2012) who reported the application of 100% recommended dose of nitrogen through urea, *Rhizobium* and phosphate solubilizing bacteria resulted in significantly higher plant height at harvest (104.7 cm), number of nodules/ plant at 50 DAS (23.5), green weight of nodule/plant at 50 DAS (96.0 mg), number of green pods/plant at harvest (31.74 g), seed yield (910 kg/ ha) and stover yield (2737 kg/ ha), over other treatments.

Lingaraju *et al.* (2016) reported that microorganisms with phosphate solubilizing ability (PSB) escalates the availability of soluble phosphate and revamp growth of plant by improving biological nitrogen fixation (BNF). Further, Makoi *et al.* (2013) demonstrated that rhizobia inoculation significantly increased the uptake of Magnesium (Mg), Potassium (K), Nitrogen (N), Phosphorus (P) and Calcium (Ca) in *P. vulgaris* parts.

Emerging examples of integrated nutrient management in cowpea

Cowpea (family fabaceae) is one of the most significant leguminous forage crops. It is the only essential *kharif* fodder cum pulse crop for rain fed as well as irrigated areas. In India, it has a production of about 2.21 million tones with 3.9 million hectares area under cultivation and national productivity of 683kg/ha (Mandal *et al.,* 2009).

The area under fodder crops in punjab is approximately 0.86 million hectares and the yearly production is about 67.27 million tonnes of green fodder (Anonymous, 2018). In Punjab, cowpea is grown predominantly for fodder starting from March to mid-July. Due to its fast growing nature, it supplies nutritious and palatable fodder during *kharif* when there is scarcity of green fodder. It is an important component of traditional cropping systems as it fixes quite substantial amount of N as well as contributes to soil fertility particularly in smallholder farming systems where little or no fertilizer is used. Like other legumes, cowpea fixes atmospheric nitrogen through biological nitrogen fixation (BNF), a symbiotic association between soil dwelling bacteria (commonly between rhizobia and legume host plants). In addition, it has high economic returns and high nutritional value (Akibode, 2011). There are many works on growth and yield of cowpea in response to Rhizobia (Ahmed and Kibret, 2014). However, for cowpea to provide an adequate supply of N, they require rhizobia either through the presence of effective native rhizobia, or through inoculation. In combination with effective rhizobia and proper management, cowpea yields can be enhanced. Cowpea can fix up to 88 kg N/ha while in an effective cowpea-*Rhizobium* symbiosis it can fix more than 150 kg N/ha which can supply 80-90% of plants total N requirement (Kormata *et al.,* 2000).

Giller (2001) estimated that cowpea can fix up to 200 kg N under field conditions. Cowpea yield was significantly higher with complementary application of inorganic and organic fertilizers than from sole organic and inorganic fertilizer treatments (Ayoola and Makinde 2007).

While Swaroop and Rathore (2002) noted the impact of phosphorous (0, 40, 80 and 120 kg per ha), potassium (0, 60 and 120 kg per ha), *Rhizobium* application, nitrogen (20 kg per ha) and *Rhizobium* + nitrogen on green pod yield, nutrient contents in pods and economics of vegetable cowpea variety Ar ka Garima. The treatment 80 Kg P, 60 kg

Table 2: Microbial inoculants for different leguminous crops.

Bactarial strains	Crops	References
Bradyrhizobium japonicum	Soybean	Trimurtulu and Rao, (2014)
Rhizobium spp.	Clover	Ashwathy *et al.* (2012)
Bradyrhizobium USDA 3456	Cowpea	Kyei-Boahen, (2017)
Bacillus megateriumvar. phosphaticum	Soybean	Trimurtulu and Rao, (2014)
Rhizobia	Legumes	Bedmar *et al.* (2005)
Rhizobia	Legumes	Thamer *et al.* (2011)
Bradyrhizobiumjaponicum CB1809	Soybean	Reichman, (2007)
Pseudomonas sp.	Chickpea	Tank and Saraf, (2009)
Rhizobium sp. RP5	Pea	Wani, (2008)
A. brasilence, Bacillus pumilus	Legume trees	Bashan *et al.* (2009)
Sinorhizobium meliloti	Alfalfa	John *et al.* (2010)

Table 3: Commercial products of microbial inoculants for various leguminous crops.

Product	Bactarial strains	Crops	References
Cell-Tech®	*Rhizobia*	Legume crops	Fraile, 2015
Nitragin Gold®	*Rhizobia*	Legume crops	Fraile, 2015
TagTeam®	rhizobia + *Penicillium bilaii*	Legume crops	Fraile, 2015
Nodulator®	*Bradyrhizobium japonicum*	Legume crops	Fraile, 2015
Nodulator® N/T	*Bacillus subtilis MBI 600* + *BradyrhizobiumJaponicum*	Legume crops	Fraile, 2015
Nodulator® PRO	*Bacillus subtilis* + *Bradyrhizobium japonicum*	Legume crops	Fraile, 2015
Nodulator® XL	*Rhizobium leguminosarum biovar viceae* 1435	Legume crops	Fraile, 2015
EVL coating®	PGPR consortia	Legume crops	Fraile, 2015
Nitrofix®	*Azospirillum* sp.	Legume crops	Fraile, 2015
Bioativo®	PGPR consortia	Legume crops	Fraile, 2015
Azotobacterin®	*Azospirillum brasilense* B-4485	Legume crops	Fraile, 2015
Nitragin TM	*Rhizobium* spp.	Soybean	Ashwathy, 2012
Rhizocote	*Rhizobium* spp.	Legumes	Ashwathy, 2012
Nodosit	*Rhizobium* spp.	Legumes	Ashwathy, 2012
Rhizonit	*Rhizobium* spp.	Legumes	Ashwathy, 2012
Nodulaid	*Rhizobium* spp.	Legumes	Ashwathy, 2012

K and 20 kg N/ha with *Rhizobium* inoculation contributed to the maximum yield of green pods (147.34 q/ha).

Kahlon and Sharanappa (2006) reported that application of 50 kg P_2O_5, 20 kg S, 10 kg $ZnSO_4$/ha along with PSB (*Bacillus megaterium*) and VAM (*Glomus mosseae*) in cowpea resulted in a greater uptake of nitrogen (155 kg/ha), phosphorus (33.6 kg/ha), potassium (57.4 kg/ha), sulphur (11.5 kg/ha), zinc (135 g/ha), iron (255 g/ha), copper (88.6 g/ha) as compared to other treatments.

Band *et al.* (2007) showed that application of 75% RDF (90 kg N and 60 kg P_2O_5 ha^{-1}), 25% N through FYM and biofertilizers (*Rhizobium* + PSB) resulted in higher plant height (36.04 cm), number of leaves per plant (11.20), number of branches per plant (5.93) and leaf area per plant at 60 DAS (131.10 dm2) as compared to other treatments.

Band *et al*. (2007) reported that the application of 100% recommended nitrogen in cowpea was on par with the application of 75% recommended nitrogen + 25% nitrogen through FYM or vermicompost and 75% recommended nitrogen + 25% nitrogen through FYM or vermicompost + biofertilizers (*Rhizobium* + PSB [phosphate-solubilizing bacteria]). Thus, there was a saving of 25% N fertilizer due to integration of FYM or vermicompost, and biofertilizers such as *Rhizobium* and PSB with fertilizers.

Singh *et al.* (2007) showed that *Rhizobium* inoculation along with 30 kg N and 60 kg P_2O_5/ha produced significantly higher number of pods per plant, length per pod, seed index, seed and straw yield of cowpea over control. Accordingly, Cowpea can fix about 40 kg N/ha from nodules in the presence of right rhizobia strain which can satisfy the crop nitrogen requirements. Das *et al.* (2011) demonstrated that number of leaves, plant height, number of pods, branches per plant, diameter and length of pods were significantly improved by the application of 75 per cent RDF+ Vermicompost+*Rhizobium*+PSB as compared to recommended dose fertilizer which resulted in saving of 25 per cent chemical fertilizer.

Prasad *et al.* (2012) also evaluated that the inoculation of PSB+ *Rhizobium* along with 20 kg N per ha in cowpea considerably augmented the growth factors such as crop growth rate, plant height, plant dry weight, number of root nodules per plant and yield attributing characters including seed index, grains per pod, pods per plant and grain and haulm yield. Pramanik and Bera (2012) also observed that in cowpea plant, height significantly improved by inoculation with biofertilizers (PSB, *Rhizobium* and VAM). Senthilkumar and Sivagurunathan (2012) reported more number of pods in cowpea by combined inoculation of *Phosphobacteria, Rhizobium* and *Azospirillum*. Kumar and Pandita (2016) studied that integrated use of inorganic fertilizers and vermicompost at 2.5 t/ha resulted in significantly better seed yield and seed quality parameters than the control. It was at par with intermingled use of inorganic fertilizers and biofertilizer inoculation (*Rhizobium*+PSB) +VAM 10 kg/ha.

Likewise the field experiment conducted by Patel *et al*. (2012) on effect of integrated nutrient management on yield and economics of cowpea revealed that application of 20 kg N and 40 kg P_2O_5/ha along with PSB and *Rhizobium* inoculation significantly increased seed yield over application of 10 kg N + 20 kg P_2O_5/ ha but it was at par with application of 10 kg N + 20 kg P_2O_5 /ha along with PSB which indicated that PSB+ *Rhizobium* or only PSB inoculation saved 50 percent nitrogen and phosphorus as chemical fertilizers. The highest benefit cost ratio value was recorded with the application of 10 kg N + 20 kg P_2O_5 per ha along with PSB+ *Rhizobium* inoculation.

CONCLUSION

This review portray that there is a tremendous scope for increasing the yield potential of cowpea by use of microbial inoculants thereby enhancing the nutrient availability and better plant growth.

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