Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(6): 1070-1074
Received: 17-08-2020
Accepted: 05-10-2020

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Response of vegetable cowpea [*Vigna unguiculata* (L.) Walp.] to integrated nutrient management: A review

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Abstract
Biofertilizers are the substance that contains microbes, which helps in promoting the growth of plants and trees by increasing the supply of essential nutrients to the plants. It comprises living organisms which include mycorrhizal fungi, blue-green algae, and bacteria. Organic manures are natural products used by farmers to provide food (plant nutrients) for the crop plants. The combined use of biofertilizers and organic manures may give significant effect in cowpea crop such as plant height, pods per plant, dry leaf weight, plant height, increase fertility of soil, increase yield, quality as well as economy of crop.

Keywords: Biofertilizers, cowpea, organic manure, quality, yield

Introduction
Vegetable cowpea [*Vigna unguiculata* (L.) Walp.] belongs to the family *fabaceae* with chromosome number 2n= 22. It is known in India as lobia and is also known by other names such as black eyed pea, coupe, frile, southern pea and niebe. It is one of the important *kharif* crops grown for vegetable, grain, forage and green manuring purpose. According to Food and Agriculture Organization [1], it is an annual crop, and one of the very important and conventionally cultivated legume throughout the world, particularly in Africa, and some parts of Asia and the United States (US). Cowpea originated in central Africa where its wild types are found at the present time [2]. It might be assessed that, the gross area under its production is 12.5 million hectares per annum producing over 3 million tons around the world. Cowpea is broadly dispersed all through the tropics, but western and Central Africa account for 64% of the zone with almost 8 million hectares and around 2.4 million hectares in South and Central America, in Asia 1.3 million hectare and in South and East Africa approximately 0.8 million hectares [3].

In India, cowpea is grown as vegetable mainly in semi-arid and arid regions of Haryana, Punjab, West U.P. and Delhi with significant area in Rajasthan, Kerala, Karnataka, Tamil Nadu, Gujarat and Maharashtra and area covered under cowpea is 654 lakh hectares along with productivity of 916 kg per hectare and production of 599 lakh tonnes [4]. Cowpea is rich in protein, minerals and vitamins, generally preferred for its tender pods and fresh seeds but in some parts of the country dry seeds are also consumed [5, 6, 7]. Cowpea leaves contain 34.91% protein, 31.11% carbohydrates, 5.42% fat, 19.46% prebiotics, 65.21 mg iron, 1.62 g calcium, 1.66 g magnesium, 0.56 g phosphorus and 2.22 g sodium [8]. Cowpea crop can provide up to 88 kg nitrogen per hectare whereas in an effective crop of cowpea inoculated with *Rhizobium*, it could provide more than 150 kg per hectare of nitrogen which is enough for fulfilling 80-90 per cent of total requirement in plants [9].

Vermicompost is the process of conversion of organic waste materials into humus by continuous activity of earthworms [10]. Vermicompost provides the proper aeration, high porosity, water holding capacity and drainage apart from that it also contains nutrients and minerals in the form in which plants can uptake [11]. *Panchgavya* is a growth promoter made with five ingredients of cow such as urine, dung, curd, milk, ghee which helps in increasing the immunity of plants by 25% and promotes growth by 75% and without yield loss it can sustain the organic farming [12]. By chemical properties, *Panchgavya* contains the all required nutrients, growth hormones, and NPK along with fermentative micro-organisms *viz.* phosphobacteria, yeast, *Azotobacter* and *Lactobacillus* [13].

Rhizobium inoculation significantly affects the nodule formation in cowpea which helps in fixing nitrogen content in soil as well as increases the fertility of the soil [14]. Phosphorus solubilizing bacteria (PSB) release the acidic substances and convert the unavailable phosphorus to available form for plants. PSB might add 30 kg of phosphorus per hectare in the soil and enhance the yield of crop by 10-30% *viz.* legumes and vegetables etc. [15]. This review

provides an overview on the current research prospects of using a combination of different nutrient sources that have been used in vegetable cowpea to increase the yield and quality along with enriching the soil fertility.

Effect of integrated nutrient management

Effect on the growth of vegetable cowpea

A research was conducted in cowpea cultivar 'Pusa Komal' with 16 treatments that is different nutrient sources on yield, growth, uptake of nutrients and soil nutrients level on growth parameters and higher number of leaves, height of plant and branches per plant were recorded by treatment which included the application of 75% recommended dose of fertilizers + PSB + vermicompost + *Rhizobium* in comparison to only RDF [16].

In an experiment it was reported that due to seed inoculation with PSB + *Rhizobium* along with sowing of seeds at a distance of 60 x 30 i.e. (plant to plant and row to row distance) + 15:30:0 kg NPK per hectare significant enhanced height of cowpea plant that is by 48.19 cm, which was greater than other treatments [17]. In a research, it was observed that the effects of combination of organic inputs *viz.* FYM @ 25 tonnes per hectare + *Panchgavya* @ 3 per cent + neem cake @ 5 tonnes per hectare in cowpea gave significant result as plant height increased by 54.76 cm in first season and 54.01 cm in second season [18]. In a study it was revealed that by the use of biofertilizers *i.e.*, 2.4 kg per hectare *Rhizobium* + 2.5 kg per hectare PSB along with 2.64 ton per hectare neem cake + 0.66 ton per hectare vermicompost + 165 kg per hectare mustard cake enhance the height of plant by 57.73 cm. They also studied that it may be due to seed treatment with PSB + *Rhizobium* which hastened the root development [19].

In a research, it was noticed that height of the plant enhanced at 35 days after transplanting by 21.6 cm and at 70 days after transplanting it was increased by 125.5 cm due to application with 40 kg of phosphorus along with *Rhizobium*. This is because of phosphorus and *Rhizobium* which aided quick shoot and root development [20]. A research resulted that height of plants accelerated by 7 cm, 19.1 cm and 32.3 cm in 15, 30 and 45 days after transplanting, respectively due to inoculation of seeds with *Azospirillum*. This result was recorded due to *Azospirillum* which increased the availability of nitrogen and led to growth of plants [21].

A study concluded that at 50 days after sowing plant height enhanced by 45 cm due to treatment with PSB + 40 kg per hectare phosphorus + *Rhizobium* + 20 kg per hectare nitrogen and the reason behind it was addition of biofertilizers and nitrogen gave the facility of converting unavailable nitrogen to available forms that the plants can uptake [22]. In a study it was observed that organic fertilizers such as fish amino acid + biofertilizers + vermicompost + *Panchgavya* gave best result in cowpea plants by increasing the plant height by 56.17 cm, branches per plant by 28.93, leaves number per plant 57.07, pods length by 36.84 cm [23].

A research showed boost in the plant height at 30 and 60 days after sowing and at harvesting by 32.06 cm, 62.9 cm and 59.4 cm, respectively due to applications of 60 kg of phosphorus per hectare + PSB + *Rhizobium*. This was because of phosphorus which led to rapid growth of roots and *Rhizobium* and helped in making nitrogen available to plants [24]. In a field experiment it was conducted that in cowpea crop the use of mixed applications of organic manure and biofertilizers *viz.* vermicompost + PSB + farm yard manure + *Rhizobium* recorded the higher increment in growth parameters in terms of leaf area index, branches per plant, area of leaf, height of plant and in addition it also gave better result in root growth and nodules formation [25]. In an experiment it was concluded that by the application of 100 per cent of recommended dose of fertilizers at 60 days after sowing plant height enhanced by 44.38 cm and at harvesting stage by 46.66 cm while it was equal with the use of 50 per cent recommended dose of fertilizers plus 2 ton per hectare farm yard manure. Perhaps it was due to availability of nutrients which assists in production of auxin [4].

Effect on the yield and yield related attributes of vegetable cowpea

An experiment was carried out in cowpea during *kharif* season and it was observed that with the application of 30 kg of phosphorus, 15 kg of nitrogen in addition to inoculation of seeds with PSB + *Rhizobium*, the yield and yield attributing traits were found superior *i.e.*, pods per plant (8.23), seeds per pod (7.83), straw yield (19.20 quintals per hectare) and seed yield (8.85 quintals/ha). Furthermore, it was also reported that the application of PSB + *Rhizobium* inoculation increased pods per plant by 8.52, seed yield by 9.20 quintals per hectare, straw yield by 20.12 quintals per hectare and seeds per pod by 8.11 [26]. A study in cowpea recorded that with the use of NPK (16:16:16) fertilizer and cow dung combination the yield enhanced significantly than control and only NPK alone and the reason is because each fertilizers has its own function either it is organic or inorganic [27].

In cowpea crop, it was observed that the phosphorus and nitrogen applications by 60 and 30 kg per hectare, the pods number per plant and length of pod increased significantly than control (without fertilizers applications) [28]. In a study it was examined that cowpea when inoculated with bacterial fertilizers *i.e.*, phosphobecteria + *Azospirillum* + *Rhizobium* reported significant effect on number of pods per plant by 4.2 which was greater than other treatments [29].

An experiment carried out in cowpea and revealed the result that combination of 80 kg per hectare phosphorus and 40 kg per hectare nitrogen gave significant results in terms of seed yield which was improved by 1017 kg per hectare [30]. A field experiment was carried out in cowpea and it was found that the combined use of biofertilizers and organic manure such as PSB + vermicompost + FYM + *Rhizobium* gave the significant enhancement in yield by 46 per cent than control treatment [25].

It was observed that the use of RDF (recommended dose of fertilizers) 125% accounted significant increase in seed yield that is 1697.6 kg per hectare than other treatments which is due to proper availability of nutrients to plants [31]. In a field experiment it was stated that the combined application of neem cake @ 0.5 million tonnes per hectare + *Rhizobium* gave significant result in green pod length of cowpea that was 19.26 cm followed by the application of neem cake at 0.25 million tonnes per hectare + poultry manure at 2.5 million tonnes per hectare + *Rhizobium* (19.20 cm) [32].

In an experiment it was stated that the higher number of pods per plant (13.0), higher seeds per pod (10.7), seed yield of cowpea (1033 kg per hectare) were obtained from treatments under 50 per cent nitrogen (castor cake) + 50 per cent nitrogen through vermicompost + PSB than other treatments [33]. In a research it was reported that *Rhizobium* + PSB + 100 per cent RDF application induced 11.48 g of seed index in cowpea which was higher than other treatments, this was due to proper uptake of fertilizers (inorganic and biofertilizers) by plants [34]. In a study it was concluded that combined effects of organic manure and biofertilizers *i.e.*, *Rhizobium* +

vermicompost @ 2 ton per hectare + PSB and farm yard manure @ 5 ton per hectare increased pods per plant, length of pod, test weight of seed and seeds number in each pod *i.e.* (27.01, 27.50, 140.05 and 13.5, respectively) than rest of the treatments [35].

Effect on the quality of vegetable cowpea

A research was conducted on cowpea with two *Rhizobium* cultures and 5 levels of P fertilizer and result concluded significant enhance in number of nodules per plant because of the combination of 100 kg per hectare phosphorus + *Rhizobium* [36]. In a research the effect of levels of fertility on uptake of nutrients and effects of biofertilizers in cowpea was observed and study proved enhancement of nitrogen and phosphorus content in treatments which were inoculated with *Rhizobium*. Furthermore, they also resulted that inoculation with *Rhizobium* boost the availability of phosphorus and nitrogen in soil [37].

Seed inoculation with *Rhizobium* and PSB was found to be superior over control. So also, inoculation of seed with *Rhizobium* + PSB significantly enhanced the uptake of nitrogen 75.29 kg per hectare and phosphorus 9.32 kg per hectare as well as protein content 26.81% in cowpea [26]. In a research it was found that inoculation with *Rhizobium* + phosphobacteria gave an expressive enhancement in protein content, carbohydrates, chlorophyll content, nitrogen percentage, amino acid and phosphorus in cowpea than other treatments *viz*. application of *Rhizobium* alone and control [38].

In an experiment it was observed that the percentage of crude fiber content in vegetable cowpea significantly enhanced by the use of goat manure + EM- bokashi by 6.60 per cent as compared to other treatments [39].

An experiment carried out in sandy loamy soil and recorded that with 40 kg per hectare phosphorus + 20 kg of nitrogen per hectare enhanced dry matter in row per meter as well as in yield than the less doses of fertilizers (N & P) [40]. In a study it was showed that dose of NPK fertilizers application with 20 kg of nitrogen used as basal dose + 40 kg of potassium also as basal along with 80 kg of phosphorus gave significant result at flowering stage by increasing the no. of nodules as well as weight of nodules per plant over the less phosphorus levels [41].

In a study conducted, it was observed that the growth and nodulation in cowpea resulted in greater yield along with application of 67.75 kg per hectare of phosphorus and 35 kg of potassium per hectare and addition of inoculation with PSB + *Rhizobium* with phosphorus @ 80 kg per hectare (P) [42]. In a research the chlorophyll content (58.8 mg per gram) of fresh leaf plant of cowpea was increased by inoculating with biofertilizer (*Rhizobium*) + inorganic fertilizer (40 kg nitrogen per hectare) [43].

In an experiment it was reported that collaborative effects of PSB + foliar spray of boron + molybdenum and *Rhizobium* gave great increment in the number of nodules by 27.83 in cowpea crop and the reason behind it is the use of biofertilizers which helped in formation of enzymes by boron and molybdenum as well as enhanced the availability of nutrients to plant which boost up the nodules formation [44]. In a field research it was observed that the combination of vermicompost @ 2 ton per hectare + 100 per cent recommended dose of fertilizers + PSB and *Rhizobium* significantly enhanced protein content by 26.31 per cent in seeds which was higher than others, this is because of collective inoculation effects of PSB + *Rhizobium* [45].

In an experiment it was stated that effects of *Rhizobium* in cowpea increased the protein content in grain by 19.62 per cent and in pods by 6.56 per cent than no inoculation and also observed that total protein yield was 323.0 kg per hectare by *Rhizobium* inoculated treatment and 277.3 kg per hectare in without *Rhizobium* inoculated treatment [46]. A study carried out in cowpea crop, with use of organic manure supplements and biofertilizers and desirable result was found in treatment with combination of fish amino acid + vermicompost + biofertilizers + *Panchgavya* in terms of root nodules at harvest (21.73) which was more than rest of the treatments [23].

A research conducted during two years 2014 and 2015 in cowpea resulted that the application of 60 kg per hectare phosphorus and 30 kg per hectare of nitrogen gave the better result in term of protein content in year 2014 by 18.41 per cent and 18.06 per cent, and further more in year 2015 by 18.73 per cent and 18.65 percent, because the phosphorus and the nitrogen play vital role in production of amino acid which leads the way to increased protein content [47]. In an experiment it was evaluated that under the treatment of 50 per cent nitrogen through FYM + PSB + 50 per cent nitrogen through vermicompost the higher protein content in seeds of cowpea was reported *i.e.,* 22.50 per cent [33].

Effect on the economy of vegetable cowpea

In an experiment it was found that 3 sprays of banana pseudostem enriched sap @ 1.0% gave the greater net return of 149347 rupees per hectare along with the BCR (benefit cost ratio) that is 3.3:1 in cowpea followed by (19:19:19) mixed fertilizers at the rate of 0.5 per cent, accounted the net return of 146260 rupees per hectare along with the BCR 3.4:1 [48]. A field experiment conducted in cowpea with organic manure + biofertilizers (2.5 million ton per hectare poultry manure + 0.25 million ton per hectare neem cake and r*hizobium*) gave the higher net returns by 136682 rupees per hectare and benefit cost ratio by 5.54 which was more than other treatments [32].

In a research it was recorded that due to combined use of 100 per cent recommended dose of fertilizers + 2 ton per hectare vermicompost gave more net returns that is 44421 rupees than other treatments *viz.* control, only 100 per cent RDF and 75 per cent RDF + 2 ton per hectare vermicompost [45]. In a research it was observed that the combination of biofertilizers (PSB + VAM and *Rhizobium*) gave the better result in almost all parameters such as plant height (65.21 cm), number of total nodules (24.86), number of effective nodules (20.11), dry matter accumulation at flowering (2.12 g) and at harvest (3.94 g) and also number of pods per plant (12.28), number of seeds per pod (8.86), test weight (76.54 g), seed yield per pod (5.12 g), straw yield (7.12 g per pod) and biological yield (12.24 g per pod) which was higher than other bio-inoculants treatment and it automatically gave more profit with the use of biofertilizers [49].

In an experiment it was investigated that the biofertilizers and organic manure are the source of nitrogen on yield and quality of cowpea and showed the greater net return (42371 rupees per hectare) along with the benefit cost ratio 2.83 with the treatment *i.e.,* recommended dose of fertilizers 20 +40+0 kg per hectare (NPK) [33]. In a field experiment it was concluded that inoculation of PSB + *Rhizobium* upgraded the protein content, yield as well as economics in cowpea as 45137 rupees net returns [45]. The reason was, *Rhizobium* combined with phosphorus enhanced the availability of nitrogen to plant

and due to PSB enhanced the availability of other nutrients to soil and have accounted better result [50, 51].

An experiment indicated that, the application of organic manure *viz.* vermicompost with different doses and 4.0 ton per hectare of dose of vermicompost gave the notable higher net returns in cowpea that is 39816 rupees per hectare over other doses of treatments [52]. In a research significant higher net returns in cowpea were observed by two combined applications of organic manure *viz.* polutry manure @ 2 ton per hectare and 60 kg per hectare of phosphorus [53].

Conclusion

In all the above studies, the available information related to the use of combined fertilization *viz.* organic manure + NPK + biofertilizers has been summarized. The biofertilizers (microbial inoculants) play a vital role in sustainable farming and its rapid microbial activities enhanced availability of all nutrients to soil and plant and converts the unavailable nutrients like nitrogen, phosphorus to available form which can give more yield. Inarguably, inorganic fertilizers also give the promising and rapid effects but when used alone then many hazardous effects are being observed in soil due to excessive use of inorganic fertilizers, therefore, combined fertilizers *viz*. organic manure and biofertilizers are more beneficial to soil as well as help in enhancing fruit quality, yield and growth and also manage the nutrients like nitrogen, phosphorus through natural ways by the bacteria and provides growth hormones which stimulate the plant growth.

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