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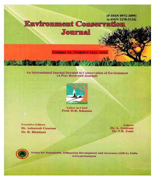

Effect of organic nutrient sources on the yield, nutrient uptake and nodulation in Cowpea (*Vigna unguiculata*) under mid-hill conditions of Western Himalayas

Tarun Sharma
Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, HP, India
Janardan Singh
Department of Organic Agriculture & Natural Farming, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, HP, India
Akashdeep Singh ✉
Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, HP, India
Rahul Sharma
Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, HP, India
Garima Chauhan
Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, HP, India

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ABSTRACT

Cowpea is *kharif* pulse grown mostly under rainfed conditions. It acts as a major protein source with 25 per cent content. Cowpea besides fixing atmospheric nitrogen continues to produce under harsh conditions such as low moisture and nutrient supply, which makes it a suitable candidate for dryland conditions. A field experiment was conducted during *kharif* 2019 at Research Farm, Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur to study the effect of organic nutrient sources on yield levels, nodulation, nutrient content and uptake of cowpea. Organic nutrient sources include farmyard manure, vermicompost, vermiwash, *Bijamrita*, *Jiwamrita* and *Ghanajiwamrita* can be prepared using on-farm inputs at a reasonable cost. These nutrient sources supply nutrients at a steady rate and in fewer amounts than inorganic fertilizers. The prime role of such organic sources is to sustain the soil ecosystems for longer functioning. The results of the experiment revealed that T_5 [Farm yard manure (10 t/ha) + *Ghanajiwamrita* at sowing (250 kg/ha)] was most effective and resulted in significantly higher yield level (grain yield -10.71 q/ha, straw yield - 53.14 q/ha and biological yield - 63.84 q/ha), nodulation (number of nodules - 31.7 per plant and weight of nodules - 0.47 g/plant), nutrient content (N- 3.54%, P - 0.41% and K - 1.36%) and uptake (N -141.08 kg/ha, P -19.86 kg/ha and K - 112.34 kg/ha) in cowpea.

Introduction

Post Green Revolution, India successfully achieved self-sufficiency in food grain production through increased productivity in cereal crops. The net availability of the food grains per capita per day increased from 144.1 kg year^{-1} in 1951 to 179.6 kg year^{-1} in 2019 whereas, in pulses, the net availability per capita per day decreased from 25 kg year^{-1} in 1961 to 17.5 kg year^{-1} in 2019 (Singh *et al.*, 2020). India is the largest producer as well as consumer of pulses, where production barely meets the consumption. The central reason for low pulse production is the lack of adequate inputs. These crops are generally preferred in rainfed areas resulting in poor productivity. Among pulses, Cowpea (*Vigna unguiculata*) is an important *kharif* crop that can be used either as a vegetable, grain or fodder crop. It is a major source of protein for the vegetarian populace containing about 25 per cent protein, 63.6 per cent carbohydrates, 1.9 per cent fat, 6.3 per cent fiber and vitamins such as thiamine (0.00074 per cent), riboflavin (0.00042 per cent) and niacin (0.0028 per cent) (Davis *et al.,* 2000). Due to

Corresponding author E-mail: *akash.agercultura@gmail.com*
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its low input requirement, the appreciable survival rate in the semi-arid regions and its ability to fix atmospheric nitrogen makes it a valuable crop for resource-poor farmers and is also well-suited to intercropping with other crops.The increased production through conventional agricultural practices involved the use of high yielding varieties resulting in increased dependence on fertilizers and pesticides to tap their genetic potential but at the cost of soil degradation, environmental pollution and in the long run affecting human health. Considering the stakes, an alternative to chemical farming was inevitable and led to the emergence of a new agricultural production system. Under this system, the chemicals were replaced by farmyard manure, vermicompost, vermiwash, green manuring, etc. These help to increase the soil organic matter content, which ultimately improves the soil pH, structure, water holding capacity, cation exchange capacity, and availability of macro and micronutrients (Alabadan *et al.,* 2009). Besides organic farming, Subhash Palekars's Natural Farming is also an alternative to chemical farming wherein on-farm products are used as inputs by converting them into formulations such as *Jiwamrita, Bijamrita* and *Ghanjiwamrita*. Apart from supplying nutrients, this method helps increase the microbial population such as phosphorus solubilizing bacteria, plant growth-promoting rhizobacteria, etc.

Material and Methods

Experimental Site

The field experiment was conducted during the *kharif* season (June-November) 2019 at Research Farm, Department of Agronomy, CSK HPKV, Palampur, India. The experimental farm is situated at an elevation of 1290.8 meters above mean sea level at 76°3'E longitude and 32°6'N latitude. The soil at the experimental site was silty clay loam in texture and acidic in reaction with pH 5.38. The soil before the start of the experiment was low in available nitrogen (172 kg/ha), medium in available phosphorus (21.03 kg/ha) and potassium (248.49 kg/ha).

Treatment Details: The experiment was laid out in randomized complete block design (RCBD) with eight treatments and three replications. The treatments are T_1: *Bijamrita* (100 ml/kg of seed) + *Jiwamrita* (187.5 l/ha, 5%, 10%, and 10% respectively at 21,42 & 63 DAS), T_2: *Bijamrita* (100 ml/kg of seed) + *Ghanajiwamrita* at sowing (250 kg/ha), T_3: *Bijamrita* (100 ml/kg of seed) + *Jiwamrita* (187.5 l/ha, 5%, 10%, and 10% respectively at 21,42 & 63 DAS) + *Ghanajiwamrita* at sowing (250 kg/ha), T_4: Farm yard manure (10 t/ha), T_5: Farm yard manure (10 t/ha) + *Ghanajiwamrita* at sowing (250 kg/ha), T_6: Biofertilizer (*Rhizobium* + PSB @10g/kg of seed) + Farm yard manure (10 t/ha) + Vermiwash at 15,30 & 45 DAS (1:10), T_7: Biofertilizer (*Rhizobium* + PSB @ 10g/kg of seed) + Vermicompost (7.5 t/ha) + Vermiwash at 15,30 & 45 DAS (1:10) and T_8: Absolute control.

Statistical analysis

The data presented has been statistically analyzed by applying a Randomized Complete Block design by the method of "Analysis of Variance" as described by Gomez and Gomez (1984). The least significant difference at the 5 per cent level was worked out to determine the difference between the treatment means. The statistical analysis was done by using OPSTAT (http://14.139.232.166/opstat/onefactor.htm?flavor=One+Factor+Analysis) analysis software.

Results and Discussion

Effect on yield of the crop: The yield of the crop was significantly affected by the treatments. Significantly highest grain yield (10.71 q/ha) was obtained in T_5 (Farm Yard Manure + *Ghanajiwamrita*) while the lowest grain yield (7.67 q/ha) was recorded in T_8 (Absolute control). The results were in line with Yadav *et al.* (2017) and Sharma *et al.* (2020) where the combined application of solid organic manures *i.e.,* Farm Yard Manure + *Ghanajiwamrita* resulted in enhanced growth and yield for cowpea. The slow-release nature of FYM and *Ghanajiwamrita* made the availability of nutrients at periodic intervals thereby influencing the yield. The FYM is a major source of organic matter and storehouse of macro- and micronutrients on the other hand *Ghanajiwamrita* might have played a significant role in enhancing the biological activity of beneficial microbes (Jarvan *et al.,* 2017). The cumulative effect of these was reflected in grain yield for T_5. The omission of nutrient sources in T_8 (Absolute control) reduced the nutrient supply to the crop as compared to other treatments and resulted in the lowest yield levels. T_6 (Biofertilizers + FYM + Vermiwash) and T_7 (Biofertilizer + Vermicompost + Vermiwash) remain at par with T_4 (FYM) and T_3 (*Bijamrita* + *Jiwamrita* + *Ghanajiwamrita*) produced significantly higher grain yield over the rest of the treatments. Biofertilizer application along with organic nutrient sources such as FYM and vermicompost had a positive impact on root activity thereby enhancing available soil nutrients thus the yield in T_6 (Biofertilizers + FYM + Vermiwash) and T_7 (Biofertilizer + Vermicompost + Vermiwash) (Dekhane *et al.,* 2011; Yadav *et al.,* 2019). Organic farming input-based treatments performed at par with each other whereas among natural farming-based inputs, only the combined application of *Bijamrita* + *Jiwamrita* + *Ghanajiwamrita* in T_3 performed significantly better and was able to perform at par with organic nutrient sources such as FYM or vermicompost. Exclusion of any one of the natural farming-based inputs reduced the cumulative impact of the natural farming methodology and thus declined yield for T_1 (*Bijamrita* + *Jiwamrita*) and T_2 (*Bijamrita* + *Ghanajiwamrita* (250 kg/ha) (Table1).

Effect on pH and organic carbon

The addition of organic amendments to the soil altered the pH status of the soil but the change was not found to be significant. Although, it was observed that the treatments T_1, T_2 and T_4 showed a marked decrease in their pH values (Table 2). Natural farming formulations tend to increase the microbial population in the soil which resulted in increased mineralization, resulting in the formation of organic acids. McCauley *et al.* (2009) in their findings revealed that the addition of organic matter makes the soil biologically active resulting in the slow release of acids which in time would help reduce the soil pH in the area of their study. Similarly, there were no significant changes in the organic carbon status of the soil under different treatments. The highest change in the organic carbon status was also recorded in treatment comprising FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha).

Effect on nutrient content

The nutrient content in the grains was significantly affected by the treatments. Significantly highest nutrient content of the primary major macronutrients was recorded under T_5 (FYM @10 t/ha + *Ghanajiwamrita* @250 kg/ha) followed by T_6 (Biofertilizers (*Rhizobium* and PSB) + FYM @ 10 t/ha + Vermiwash (1:10)) and T_7 (Biofertilizers (*Rhizobium* and PSB) + Vermicompost @7.5 t/ha + Vermiwash (1:10)). This might be due to the application of organic manures which enhanced the nutrient availability at various growth stages of the crop due to their slow-release nature thus offsetting the leaching losses (Hameedi *et al.,* 2016; Khan *et al.*, 2017; Patil 2013). The lowest nutrient content was recorded in T_8 (Absolute Control) which was primarily due to the absence of any specific external nutrient sources (Table 3).

Effect on available nutrients: The treatment comprising of FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha) (T_5) was significantly higher in terms of available nitrogen and was also found to be at par with treatments T_7 (Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10)), T_4 (FYM @ 10t/ha) and T_6 (Biofertilizers (*Rhizobium* and PSB) + FYM (10 t/ha) + Vermiwash (1:10)). This may be due to the richness of different organic nutrient sources in nitrogen as compared to other nutrient elements (Table 3). Organic manures besides acting as nutrient sources, elevated microbial activity in the rhizosphere that improved the nitrogen fixation ability of cowpea and increased available nitrogen content in the soil (Jarvan *et al.,* 2017). *Ghanajiwamrita* acted as the microbial pool whereas *Rhizobium* inoculation-based treatments directly enhanced the crop root-*Rhizobium* symbiotic activity which resulted in a suitable micro-climate for nodule-based nitrogen fixation. Shang *et al.* (2020) in their study came to a similar conclusion that the addition of organic manures and biofertilizers from various bacteria tends to improve the soil nutrient status to varying degrees. In terms of available phosphorus and potassium, the highest was observed under treatment T_5 (FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha)) followed by T_7 (Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10)). These treatments were also found to be statistically at par with each other. The solubilizing action of soil microbes and chelating compounds released from crop roots treated with *Rhizobium* and PSB were responsible for liberating insoluble phosphorus from cation-based complexes and thus increasing the availability of phosphorus and potassium from unavailable forms into soil solution (Dekhane *et al.,* 2011).

Table 1: Effect of different treatments on the yield in cowpea

Treatment	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)
T_1 *Bijamrita* + *Jiwamrita*	8.64	36.86	45.50
T_2 *Bijamrita* + *Ghanajiwamrita* (250 kg/ha)	7.87	36.93	44.79
T_3 *Bijamrita* + *Jiwamrita* + *Ghanajiwamrita* (250 kg/ha)	9.17	38.44	47.62
T_4 FYM (10 t/ha)	9.40	41.75	51.15
T_5 FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha)	10.71	53.14	63.84
T_6 Biofertilizers (*Rhizobium* and PSB) + FYM (10 t/ha) + Vermiwash (1:10)	9.91	50.76	60.67
T_7 Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10)	9.79	43.47	53.26
T_8 Absolute control	7.67	35.71	43.39
SEm±	0.25	1.98	2.01
CD ($P \leq 0.05$)	0.77	6.00	6.09

Table 2: Effect of different treatments on pH and organic carbon status of soil

Treatment	pH	Organic Carbon (%)
T_1 *Bijamrita* + *Jiwamrita*	5.24	0.72
T_2 *Bijamrita* + *Ghanajiwamrita* (250 kg/ha)	5.27	0.73
T_3 *Bijamrita* + *Jiwamrita* + *Ghanajiwamrita* (250 kg/ha)	5.42	0.72
T_4 FYM (10 t/ha)	5.28	0.75
T_5 FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha)	5.47	0.77
T_6 Biofertilizers (*Rhizobium* and PSB) + FYM (10 t/ha) + Vermiwash (1:10)	5.34	0.75
T_7 Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10)	5.38	0.73
T_8 Absolute control	5.4	0.70
SEm±	0.05	0.01
CD ($P \leq 0.05$)	NS	NS

Table 3: Effect of different treatments on the content in grain and availability of nutrients in soil

Treatment	N (%)	P (%)	K (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
T_1 *Bijamrita* + *Jiwamrita*	3.37	0.35	1.17	160.6	17.7	218.5
T_2 *Bijamrita* + *Ghanajiwamrita* (250 kg/ha)	3.34	0.34	1.13	154.1	16.5	217.4
T_3 *Bijamrita* + *Jiwamrita* + *Ghanajiwamrita* (250 kg/ha)	3.41	0.365	1.23	165.5	19.3	219.4
T_4 FYM (10 t/ha)	3.42	0.37	1.25	168.0	20.9	223.1
T_5 FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha)	3.54	0.41	1.36	169.8	21.4	231.6
T_6 Biofertilizers (*Rhizobium* and PSB) + FYM (10 t/ha) + Vermiwash (1:10)	3.50	0.39	1.33	166.2	20.1	222.7
T_7 Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10)	3.47	0.38	1.29	168.7	21.1	227.2
T_8 Absolute control	3.26	0.33	1.08	152.3	13.4	203.5
SEm±	0.017	0.0051	0.014	1.324	0.246	1.68
CD ($P \leq 0.05$)	0.052	0.0154	0.041	4.017	0.746	5.12

**** Jiwamrita applied @ 5,10 and 10 % at 21,42 and 63 DAS, respectively; Vermiwash applied at 15, 30 and 45 DAS***

The higher nutrient composition of vermicompost was responsible for improving nutrient availability in vermicompost- based treatments. Riba *et al.* (2018) reported that the addition of FYM in the crop in association with inorganic fertilizers improved the yield of the crop.

Effect on uptake by crop: The treatments significantly affected the uptake of nitrogen, phosphorus, and potassium by the crop plants (Table 4). Significantly highest uptake of the major macronutrients was recorded under T_5 (FYM @10 t/ha + *Ghanajiwamrita* @259 kg/ha) followed by T_6

Table 4: Effect of different treatments on the total uptake of nutrients in cowpea

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
T_1 *Bijamrita* + *Jiwamrita*	94.40	12.09	71.00
T_2 *Bijamrita* + *Ghanajiwamrita* (250 kg/ha)	90.55	11.57	68.33
T_3 *Bijamrita* + *Jiwamrita* + *Ghanajiwamrita* (250 kg/ha)	100.43	13.23	75.43
T_4 FYM (10 t/ha)	107.66	14.68	84.96
T_5 FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha)	141.08	19.86	112.34
T_6 Biofertilizers (*Rhizobium* and PSB) + FYM (10 t/ha) + Vermiwash (1:10)	130.57	18.32	105.05
T_7 Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10)	113.94	15.78	90.24
T_8 Absolute control	84.80	10.68	64.41
SEm±	1.36	0.18	1.02
CD ($P \leq 0.05$)	4.15	0.56	3.09

Table 5: Effect of different treatments on the nodulation in cowpea

Treatment	Number of nodules per plant	Dry weight of nodules per plant (g)
T_1 *Bijamrita* + *Jiwamrita*	20.8	0.21
T_2 *Bijamrita* + *Ghanajiwamrita* (250 kg/ha)	29.0	0.35
T_3 *Bijamrita* + *Jiwamrita* + *Ghanajiwamrita* (250 kg/ha)	23.1	0.33
T_4 FYM (10 t/ha)	20.7	0.21
T_5 FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha)	31.7	0.47
T_6 Biofertilizers (*Rhizobium* and PSB) + FYM (10 t/ha) + Vermiwash (1:10)	22.0	0.25
T_7 Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10)	28.5	0.28
T_8 Absolute control	20.1	0.20
SEm±	1.0	0.01
CD ($P \leq 0.05$)	3.03	0.04

Table 6: Effect of different treatments on the economics in cowpea

Treatment	Cost of Cultivation (₹/acre)	Gross Returns (₹/acre)	Net Returns (₹/acre)
T_1 *Bijamrita* + *Jiwamrita*	12941.45	33945.09	21003.64
T_2 *Bijamrita* + *Ghanajiwamrita* (250 kg/ha)	14408.44	31444.17	17035.73
T_3 *Bijamrita* + *Jiwamrita* + *Ghanajiwamrita* (250 kg/ha)	14964.88	35914.99	20950.11
T_4 FYM (10 t/ha)	16430.25	37191.14	20760.89
T_5 FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha)	17644.31	43260.72	25616.41
T_6 Biofertilizers (*Rhizobium* and PSB) + FYM (10 t/ha) + Vermiwash (1:10)	17462.2	40305.87	22843.67
T_7 Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10)	25555.92	38727.09	13171.17
T_8 Absolute control	12383.39	30619.10	18235.71
SEm±	-	900.59	900.59
CD ($P \leq 0.05$)	-	2731.52	2731.52

**** Jiwamrita applied @ 5,10 and 10 % at 21,42 and 63 DAS, respectively; Vermiwash applied at 15, 30 and 45 DAS***

(Biofertilizers (*Rhizobium* and PSB) + FYM @ 10 t/ha + Vermiwash (1:10)) and T_7 (Biofertilizers (*Rhizobium* and PSB) + Vermicompost @7.5 t/ha + Vermiwash (1:10)). The lowest total uptake was recorded in T_8 (Absolute Control). The organic manure is able to improve the soil aeration which resulted in better root growth thereby promoting root development. This resulted in higher crop yield and hence the uptake of nutrients (Chaudhary *et al.*, 2016). Biofertilizer application especially of *Rhizobium* is reported to enhance root activity resulting in better nutrient uptake in T_6 (Biofertilizers (*Rhizobium* and PSB) + FYM @ 10 t/ha + Vermiwash (1:10)) and T_7 (Biofertilizers (*Rhizobium* and PSB) + Vermicompost @7.5 t/ha + Vermiwash (1:10)) (Yadav *et al.,* 2019).

Effect on nodulation: The effect of different treatments on the number of nodules per plant and the dry weight of nodules per plant were significant. The treatment T_5 (Farm Yard Manure + *Ghanajiwamrita*) recorded the highest total number of nodules (169.8) as well as dry weight per plant (21.4 g). This might be the effect of *Ghanajiwamrita* which can enhance the microbial population resulting in increased nodulation (Table 4). This treatment was found to be statistically at par with T_7 (Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10)) and T_4 (FYM (10 t/ha) (Table 5). Due to the improved number of nodules, the effect of the increased dry weight of the nodules was also observed. The organic-rich soil has the potential to host beneficial microorganisms for a longer duration in the soil due to the availability of food material which may be the reason for the increase in nodulation of the crops (Guriqbal *et al.*, 2010; Singh *et al.*, 2012). Further, *Ghanajiwamrita* has a tendency to improve the microbial population which enhances the biological activity while vermicompost enhances soil enzyme activity. Their combined application is responsible for increased nodulation (Bajracharya and Rai 2009).

Cost of Cultivation: The highest cost of cultivation (₹ 25555.92/acre) was observed for T_7 (Biofertilizer + Vermicompost + Vermiwash) whereas the lowest cost of cultivation (₹ 12383.39/acre) was observed for T_8 (Absolute Control). The highest cost of cultivation for T_8 was due to the higher cost of vermicompost application whereas the lowest cost of cultivation in absolute control was due to the lack of costs involved for nutrient application (Table 6).

Gross Returns: Gross returns were significantly affected by different treatments. The highest gross returns (₹ 43261/acre) were recorded for the treatment consisting of combined application of farm yard manure and *Ghanajiwamrita* (T_5), whereas the lowest gross returns (₹ 30619/acre) were recorded for absolute control (T_8) (Table 6). Such differences in gross returns among treatments were due to different yield levels observed in these treatments.

Net Returns: Significant effects of different treatments were observed on net returns. The highest value of net returns (₹ 25616/acre) was observed for T_5 wherein a combined application of farm yard manure and Ghanajiwamrita was done (Table 6). The lowest net returns (₹ 18235/acre) were recorded for T_8 (absolute control). Differences in gross returns and cost of cultivation lead to such significant differences in net returns among treatments.

Conclusion

From the study, it can be concluded that soil pH and organic carbon were not affected by the different organic sources whereas available nitrogen, phosphorus and potassium were significantly influenced. The treatment T_5 (FYM (10 t/ha) + *Ghanajiwamrita* (250 kg/ha)) emerged to be the best treatment in terms of yield, nutrient content, available nutrients, uptake of nutrients and nodulation. This was followed by T_6 Biofertilizers (*Rhizobium* and PSB) + FYM (10 t/ha) + Vermiwash (1:10) and T_7 Biofertilizers (*Rhizobium* and PSB) + Vermicompost (7.5 t/ha) + Vermiwash (1:10).

Conflict of interest

The authors declare that they have no conflict of interest.

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