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Effect of Integrated Nutrient Management on Soil Nutrient Status in Garlic (*Allium sativum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted during rabi season, 2021 to investigate the effect of integrated nutrient management on soil nutrient status in garlic. The study was structured around eighteen treatments with combinations of inorganic fertilizers, biofertilizers and organic manures like Jeevamrit and Beejamrit. The treatment T_{12} [(75 % RDF + 40 kg Sulphur/ha + Azotobacter + Phosphate Solubilizing Bacteria + FYM (25t/ha)] resulted in minimum soil pH (6.82) and electrical conductivity (0.181 dSm^{-1}) as well as highest organic carbon (0.86 %), available Nitrogen (258.84 kg ha^{-1}), Phosphorus (26.72 kg ha^{-1}) contents. Further, the treatment T_{17} [(100 % RDF + FYM (25t/ha)] recorded maximum available Potassium (180.35 kg ha^{-1}) and treatment T_{16} [(100 % RDF +

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40 kg S/ha + FYM) recorded highest S (44.98 kg ha^{-1}) contents. Thus, it can be concluded that integration of inorganic fertilizers with biofertilizers and organic manures helps in improving the soil nutrient status.

Keywords: Biofertilizers; garlic; Jeevamrit; manures; soil fertility.

1. INTRODUCTION

"Garlic (*Allium sativum* L.) is popularly grown as Allium species after onion belonging to the family Alliaceae. It is an important vegetable crop of India since ancient times. It is originated in Central Asia and used as a vegetable as well as for medicinal purposes. It contains high amount of carbohydrates (29%), proteins (6.3%), minerals (0.3%) and essential oils (0.1- 0.4%) and contains appreciable quantities of fat, vitamins C and sulphur" [1]. "It has antiviral, antibacterial, antifungal and antiprotozoal properties. Because of its anti-inflammatory and anti-carcinogenic qualities, it is good for the immune system and cardiovascular system. Its oil is a potent antiseptic mostly because of the presence of allicin, an important organosulfur molecule and classified as a hot stimulant, carminative, and antirheumatic" [2]. "Modern agriculture mainly depends upon inorganic fertilizers to fulfil the nutrient demand of the crops" [3]. "Application of fertilizers by farmers without information regarding soil fertility status and crop requirement for nutrients adversely affects both crop and the soil" [4]. "Plant nutrition is one of the key factors influencing growth and yield of crop plants" [5]. "Nutrients play an important role in internal metabolic activities in plant body" [6]. "Therefore, integration of inorganic fertilizers, organic manures and biofertilizers is capable to maintain the good soil health, productivity and fertility status of soil" [7].

"Organic manure is an eco-friendly, economically viable and ecologically sound that also played a significant role in improving physical, chemical and biological properties of soil. It acts as an excellent substrate for soil microbes and increases the proportion of carbon and nitrogen, directly stimulating the population and activity of microorganisms" [7]. "Application of organic manure increases organic elements availability in soil, thereby improving the nutrient use efficiency of crops" [8]. "Microorganisms living in the soil are important for decomposing, mineralizing, and recycling organic matters" [9]. "Microbial populations intensively induce the production of phytohormones such as gibberellin and auxin in plant roots grown in fertile soil with rich organic manures which stimulate plant growth" [10]. "Jeevamrit is one of the major liquid manures which is prepared from cow urine and dung. Use of Jeevamrit promotes higher growth, yield and quality of crop" [11].

"Biofertilizer or microbial inoculants is a preparation containing live or latent cells of microorganism that augments such microorganism and accelerate the microbial process leading to mobilizing non-usable nutritive element into plant-used form" [12]. "Biofertilizers are cost-effective and renewable sources of plant nutrients" [10]. "It is an eco-friendly approach to minimizing inorganic fertilizer and better crop productivity and also soil fertility status through biological activity in the rhizosphere" [13]. "Besides mobilizing the nutrients, it helps in nutrient uptake, develop the plant growth hormones provides well nutrient uptake and increased tolerances regarding drought and moisture stress and prevents the phytopathogens attack" [14]. "There are numerous microbes used in agriculture fields and mostly used species as biofertilizers are Rhizobium, Azotobacter, Azospirilum, Phosphate solubilizing bacteria (PSB), Vesicular arbuscular mycorrhiza (VAM), etc. the nitrogen-fixing microorganism are symbiotic or free living. Azotobacter represents the main group of heterotrophic free-living bacteria generating ammonia for their use and providing the plant with nitrogen as an exchange for carbon and protected habitat" [15]. "In garlic, research has shown that applying biofertilizer in addition to NPK fertilizer can lower fertilizer use without affecting the crop yield" [16].

"Azotobacter is a free living non-symbiotic nitrogen fixing bacteria and it produces auxins, gibberellins, cytokinin and some antibiotic metabolites role for benefit of the plant growth, yield and quality. Phosphate Solubilizing Bacteria solubilizes phosphorus to increase soil fertility and biological activities" [10]. "Azotobacter enhance the seed's capacity to germinate by 20-30%. Moreover, to promote vegetative growth biofertilizers replace artificial nitrogen and phosphorus by 25% while also increasing crop harvest by 20–30%" [17]. "Azotobacter not only impact on growth promotion, it is also associated with the suppression of pathogenic disease of plants" [12]. "Therefore, the importance of the integrated nutrient supply in sustaining productivity is emphasized to restore and sustain soil health and productivity in the long run which otherwise is likely to deteriorate due to continuous and intensive cultivation without adequate nutrient management" [18].

2. MATERIALS AND METHODS

The experiment was conducted at the Experimental Farm of the Department of Vegetable Science, College of Horticulture & Forestry, Neri, Hamirpur, HP, India during rabi season of 2021. Geographically, Neri is located at an altitude of 650 m above mean sea level between 31ºº41'47.6" N & 72º28'6.3" E. The climate of the region is characterized as subtropical, with hot summers and mild to cool winters. Majority of precipitation is received during monsoon period i.e. from June to September. The soil at the research location was sandy clay loam with pH ranging from 6.8 to 7.0. Before planting of the crop, random soil samples were collected from different spots of the experimental site from a depth of 0-15 cm with the help of auger and the composite sample was prepared. After the termination of the experiment, the soil sample from each plot was taken and analysed for available nutrients by following standard protocols. These samples were air-dried, crushed and passed through a 2 mm sieve and stored in cloth bags for chemical analysis of parameters such as soil pH, electrical conductivity, organic carbon and for available nitrogen, available phosphorous, available potassium and sulphur. The pH and EC of soil samples were measured using a digital pH meter and an electrical conductivity meter, respectively. Organic carbon content of the samples was determined using the Chromic and Titration method proposed by Walkley and Black [19]. The Alkaline Potassium Permanganate Method was used to determine available Nitrogen (N) [20], Phosphorus (P) was measured by the method given by Olsen [21], Potassium (K) was measured by Normal Neutral Ammonium Acetate Method [22] and Sulphur (S) was determined by 0.15% $CaCl_2$ extractant and turbidimetric method [23]. The initial value of soil pH (7.03), electrical conductivity (0.248 dSm^{-1}), organic carbon (0.64 %), available N (208.43 kg/ha), P (13.52 kg/ha), K (140.24 kg/ha) and S (31.06 kg/ha) contents in soil before the start of the experiment. Benefit Cost Ratio = Net return / Total cost of the cultivation Benefit Cost Ratio is directly proportional to the net return; i.e. higher the Cost Benefit Ratio will result in the higher net return [24].

2.1 Experimental Design and Crop Management

Experiment was laid out in Randomized Complete Block Design with eighteen treatments and three replications at a spacing of 20 X 10 cm in a plot size of 1X 1m accommodating 50 plants in each plot. The experiment comprised of eighteen treatments viz., T_0: Control (No amendment), T_1: Organic sources [Cow urine, Jeevamrit, FYM (25t/ha)], T_2: Beejamrit + Jeevamrit + FYM, T_3: Azotobacter + PSB (Phosphate solubilizing bacteria) + FYM[25t/ha]), T_4: 75 % Recommended dose of Fertilizers + Azotobacter + FYM, T_5: 75 % RDF + PSB + FYM, T_6: 75 % RDF + Azotobacter + PSB + FYM, T_7: 50 % RDF + Azotobacter + FYM, T_8: 50 % RDF + PSB + FYM, T_9: 50 % RDF + Azotobacter + PSB + FYM, T_{10}: 75 % RDF + 40 kg Sulphur/ha + Azotobacter + FYM, T_{11}: 75 % RDF + 40 kg S/ha + PSB + FYM, T_{12}: 75 % RDF + 40 kg S/ha + Azotobacter + PSB + FYM, T_{13}: 50 % RDF + 40 kg S/ha + Azotobacter + FYM, T_{14}: 50 % RDF + 40 kg S/ha + PSB + FYM, T_{15}: 50 % RDF + 40 kg S/ha + Azotobacter + PSB + FYM, T_{16}: 100 % RDF + 40 kg S/ ha + FYM, T_{17}: 100 % Recommended dose of Fertilizers (125:75:60 kg/ha) + FYM.

Sowing was done on 19th October 2021. Seeds were sown in the lines at a spacing of 20 X 10 cm. The experimental field was thoroughly ploughed 1 to 2 times with the help of tractor followed by planking. All the stubble and weeds were removed. Agrifound Parvati variety developed by National Horticulture Research and Development Foundation, Nasik, Maharashtra was used for the present study. This is long day type and bulbs are bigger in size (5 – 6.5 cm diameter) and creamy white colour with pinkish tinge with maturity duration of 220-240 days. Calculated amount of inorganic fertilizers Nitrogen, Phosphorous (P_2O_5), Potassium (K_2O) and Sulphur (125:75:60:40 kg/ha) were applied in the form of urea (203.8 kg/ha), SSP (Single super phosphate) [356.25 kg/ha], MOP (Muriate of potassium) [75 kg/ha] and Bentonite Sulphur (44.45 kg/ha) in respective treatments before sowing of seed. One-third dose of N along with the full doses of P_2O_5 and K_2O were applied as basal dose. Remaining one-third dose of N applied after a month of planting and one-third dose applied after 50 days of planting. Organic manures such as FYM (25t/ha) were applied during field preparation in the respective treatments. Cloves were treated with cow urine and Beejamrit as per treatments and planted. Biofertilizers *viz*., Azotobacter and Phosphate Solubilizing Bacteria were applied after 15 days of sowing. No fertilizer was applied in the control plot. Cloves were soaked in the solution of 10 % cow urine and 10 % solution of Beejamrit, sole application for one hour before sowing as per treatments. Azotobacter @ 200 g/ha, Phosphate Solubilizing Bacteria @ 200 g/ha and mixture of Azotobacter + Phosphate Solubilizing Bacteria @ 200 g/ha were applied along with FYM as per the treatment combination. These biofertilizers were mixed thoroughly with FYM and kept for overnight and applied next day as per the different treatment combinations.

2.2 Preparation of Jeevamrit and Beejamrit

2.2.1 Jeevamrit

Jeevamrit is a mixture of cow dung, cow urine from a local breed, jaggery, pulse floor and fertile soil in a plastic container. The soil should be either virgin or forest soil or from own organic farm where crop/vegetation health is best. For preparation of jeevamrit, required quantities of ingredients were thoroughly mixed in water and allowed to ferment for 7 days. Ingredients were stirred for at least ten minutes once in morning and once in evening in clockwise direction with wooden stick. Jeevamrit @ 10 % drenching was given at fortnight interval in the respective treatments. Table 1 shows the standardized technique for preparation of Jeevamrit [24].

Table 1. Ingredients used for preparation of Jeevamrit

Ingredient	Quantity
Cow dung	10 kg
Cow urine	10 L
Jaggery	2 kg
Pulse Flour	2 kg
Fertile Soil	1 kg
Water	200 L

2.2.2 Beejamrit

Palekar [25] suggested the standardized technique of preparing beejamrit. This is a mixture of cow dung, cow urine, lime and fertile soil. For preparation of beejamrit take 5 kg fresh cow dung in cloth & tie it with rope. Arrange to dip this cow dung in the bucket containing 20 litres of water up to 12 hours. In other container, add 50 gm of lime in one liter of water, let it stable for night. Next morning, squeeze the bundle of cow dung in same water thrice continuously, so that all essence of cow dung will get accumulated in it. Add handful of soil from the field’s edge into this mixture and mix thoroughly. Lastly add 5 litres of cow urine & lime solution and stir well. Beejamrit is ready to use according to treatment plan.

3. RESULTS AND DISCUSSION

3.1 Physiochemical Properties of Soil

3.1.1 Soil pH, EC, OC, available N, available P, available K and available S

Data presented in Table 2 revealed that maximum soil pH (7.07) was obtained by the treatment T_0 (Control) and minimum soil pH (6.82) was recorded in treatment T_{12} (75 % RDF + 40 kg S/ha + Azotobacter + PSB + FYM). This might be due to release of organic acids during the process of decomposition may be attributed to decline in soil pH [26]. Similar findings shown by Choudhary et al. [6] reported that reduction in pH of soil in the plots receiving organic manures may be due to production of organic acids during decomposition of organic manures which neutralize the sodium salts present in the soil and increase the hydrogen ions concentration. Maximum electrical conductivity (0.244 dSm^{-1}) was observed in treatment T_{17} (100 % RDF + FYM). While, minimum electrical conductivity (0.181 dSm^{-1}) was recorded in treatment T_{12} (75 % RDF + 40 kg S/ha + Azotobacter + PSB + FYM). The observed results on electrical conductivity with the findings of Abu-Zahra et al. [27] and Sharma et al. [28] where the electrical conductivity at the end of the crop season was reduced in organic matter applications, while it was increased in the conventional chemical fertilizer applications. The highest soil organic carbon (0.86 %) was observed in treatment T_{12} (75 % RDF + 40 kg S/ha + Azotobacter + PSB + FYM). Whereas, lowest soil organic carbon (0.62 %) was recorded in treatment T_0 (Control). Organic manures and biofertilizers application might have created environment favourable for the formation of humic acid, which stimulated the activity of soil microorganisms, increasing in organic carbon of soil [26]. This could be due to rapid multiplication of bacteria applied through soil application in more suitable medium of organic manure, especially FYM and biofertilizers. Similar findings also reported by Jayathilake et al. [29]. Lower organic carbon content might be due to no addition of fertilizer, manure or biofertilizer in control.

The data presented in Table 2 revealed that maximum available nitrogen (258.84 kg/ha) was recorded in treatment T_{12} (75 % RDF + 40 kg S/ha + Azotobacter + PSB + FYM) and minimum (197.80 kg/ha) was observed in treatment T_0 (Control). The increase in available nitrogen might be due to direct absorption of nitrogen by the soil which enhanced microbial activity and consequent released to organic complexing substances [6]. The increase in available N with the application of Azotobacter might be due to improved nitrogen availability in the rhizosphere and addition of organic manure may also be attributed to higher microbial activity in the integrated nutrient management treatments which favoured the conversion of the organically bound nitrogen into inorganic form as reported byThakur et al. [30]. Nainwal et al. [31] also reported that available nitrogen can be highest by addition of nitrogenase fertilizers like Azotobacter applying with NPK. Similar findings were reported by Singh and Singh [32] and [33]. Maximum available phosphorus (26.72 kg/ha) was recorded in treatment T_{12} (75 % RDF + 40 kg S/ha + Azotobacter + PSB + FYM) and minimum (12.70 kg/ha) was observed in treatment T_0 (Control). This might be due to activity of phosphate solubilizing bacteria which resulted into release of organic acids that are responsible for conversion of unavailable P to available P [32]. Maheshwari et al. [12] studied shown that biofertilizers might have lead to better root development, better transportation of water uptake and deposition of nutrients resulting in increased availability of phosphorus. The increase in available phosphorus content of soil due to the incorporation of organic manures may be attributed to the direct addition of phosphorus as well as solubilization of phosphorus through release of various organic acids during the decomposition of organic matter [34]. Similar results are in line with Chaudhary et al. [35].

Table 2. Effect of integrated nutrient management on pH, EC (dSm^{-1}) and organic carbon (%), available N (kg/ha), P (kg/ha), K (kg/ha) and S (kg/ha) in soil

Treatment	pH	EC (dSm^{-1})	Organic Carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available S (kg/ha)
T_0	7.07	0.232	0.62	197.80	12.70	138.68	34.68
T_1	7.01	0.236	0.68	216.74	15.76	144.00	37.34
T_2	7.03	0.235	0.67	220.44	15.73	144.74	36.67
T_3	6.99	0.193	0.73	225.70	17.27	144.20	39.02
T_4	6.98	0.224	0.78	229.47	19.41	152.00	39.34
T_5	6.96	0.223	0.75	227.22	21.00	145.68	37.69
T_6	6.88	0.183	0.82	253.95	24.73	167.77	39.35
T_7	6.97	0.208	0.74	234.14	19.76	144.07	36.69
T_8	7.01	0.218	0.75	228.11	19.86	146.00	38.68
T_9	6.95	0.192	0.81	235.41	21.46	154.68	38.68
T_{10}	7.02	0.193	0.80	243.77	20.39	158.83	42.50
T_{11}	6.97	0.211	0.79	238.41	20.36	163.74	42.85
T_{12}	6.82	0.181	0.86	258.84	26.72	170.00	43.00
T_{13}	7.03	0.195	0.77	240.81	22.54	155.70	42.01
T_{14}	7.01	0.186	0.76	230.54	21.38	147.37	41.34
T_{15}	6.90	0.184	0.83	250.70	22.71	150.68	41.16
T_{16}	7.02	0.242	0.72	242.40	22.30	177.71	44.98
T_{17}	7.04	0.244	0.70	247.90	22.42	180.35	38.35
Mean	6.98	0.210	0.75	234.57	20.36	154.78	39.68
$CD_{(0.05)}$	0.03	0.004	0.02	3.09	1.25	2.46	1.56
SE(m)	0.01	0.001	0.01	1.07	0.43	0.85	0.54
C.V.	0.33	1.018	2.06	0.79	3.69	0.95	2.3

The data presented in Table 2 revealed that the maximum available potassium (180.35 kg/ha) was observed in treatment T_{17} (100 % RDF + FYM) and minimum (138.68 kg/ha) was recorded in treatment T_0 (Control). Greater availability of nutrients from inorganic sources might have increased available K in soil. Organic manures application may be attributed to the direct addition of potassium to the available pool of soil and favourable effect of FYM on available K might also be due to the reduction in fixation and release of K due to interaction of organic matter with clay [3]. Maximum available Sulphur (44.98 kg/ha) was observed in treatment T_{16} (100 % RDF + 40 kg S/ha + FYM) and minimum (34.68 kg/ha) was observed in treatment T_0 (Control). The increase in the available Sulphur content might be due to the application of Sulphur which increased the number of Sulphur consuming microorganism and accelerate the conversion of sulphur to SO_4^{2-} [36]. Sulphur application increased the uptake of N, P, K and S which might have influenced the synthesis and translocation of stored materials as reported by Rizk et al. [37]. These results are in conformity with Chandel et al. [38], Gomez and Merwin [39,40] and Magray et al. [14].

4. CONCLUSION

Based on the results of this study, it can be concluded that overall treatment T_{12} (75 % RDF + 40 kg S/ha + Azotobacter + PSB + FYM) performed best in terms of yield and nutrient status of soil in garlic. Hence, the combined application of organic manures and inorganic fertilizers with biofertilizers helps in improve the physiochemical properties of soil.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

We hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have not been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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