Original Research Article

Impact of integrated nutrient management on soil nutrient status and yield in garlic (*Allium sativum* L.)

ABSTRACT

A two-year experiment was undertaken during rabi seasons of the year 2021 and 2022 to investigate the effect of integrated nutrient management on growth and yield in garlic. The experiment consisted of eighteen treatments with varying combination of inorganic fertilizers along with biofertilizers and organic manures like jeevamrit and beejamrit. Treatment T_{12} [(75 % Recommended dose of NPK (N: P_2O_5: K_2O-125:75:60) + 40 kg S/ha + Azotobacter + PSB + FYM (250 q ha^{-1})] resulted in minimum soil pH (6.82) and electrical conductivity (0.181 dSm^{-1}) as well as highest organic carbon (0.86 %), available N (258.84 kg ha^{-1}), P (26.72 kg ha^{-1}) contents. Further, the treatment T_{17} [(100 % Recommended dose of NPK + FYM (250 q ha^{-1})] recorded maximum available K (180.35 kg ha^{-1}) and treatment T_{16} [(100 % Recommended dose of NPK + 40 kg S/ha + FYM (250 q ha^{-1})] recorded highest S (44.98 kg ha^{-1}) contents. The highest gross income (₹ 13,71,900/ha), net income (₹ 10,23,204.48/ha) and B:C ratio (2.93) was recorded by the treatment T_{12} [(75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM (250 q ha^{-1})]. Thus, it can be concluded that integration of inorganic fertilizers with biofertilizers and organic manures helps in improving the yield and soil nutrient status.

KEYWORDS: Biofertilizers; garlic; jeevamrit; manures; soil fertility

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 (Memane et al. 2008). It has antiviral, antibacterial, antifungal and antiprotozoal properties. It is beneficial to the cardiovascular and immune system due to its antioxidant and anti-cancerous properties. It is described as a hot stimulant, carminative and antirheumatic and its oil is a powerful antiseptic mainly due to the presence of allicin an important organosulfur compound. It is used as a vermifuge for expelling round worms and has been recommended for cure of several ailments viz., wounds, ulcers, pneumonia, bronchitis and gastro- intestinal disorders (Hazra et al. 2011). Modern agriculture mainly depends upon inorganic fertilizers to fulfil nutrient demand of the crops. Application of fertilizers by farmers without information regarding soil- fertility status and crop requirement for nutrients adversely affect both crop and the soil (Ray et al. 2000). Application of synthetic chemical fertilizers alone can have deleterious effects on the soil health, water and ecosystem. Plant nutrition is one of the key factors influencing growth and yield of crop plants. Nutrients play an important role in internal metabolic activities in plant body. It is well known fact that long time inorganic fertilizers application leads to harmful effect on soil fertility, resulting in poor yield and quality of crops (Meena et al. 2016). Therefore, integration of inorganic fertilizers, organic manures and biofertilizers is capable to maintain the good soil health, productivity and fertility status of soil (Priyanshu et al. 2020).

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 (Acharya and Kumar 2018). 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. 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 (Krishna et al. 2017).

Biofertilizers containing living cells of different types of microorganisms which when applied to seed, plant surface or soil, colonize the rhizosphere or the interior of the plant and promote growth by converting nutritionally important elements like nitrogen and phosphorous from unavailable to available form through biological processes such as nitrogen fixation and solubilization of rock phosphate. It increases the soil fertility, improve soil structure, porosity, water holding capacity and enhance seed germination. 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 (Bhushan et al. 2020). 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.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Farm of the Department of Vegetable Science, College of Horticulture & Forestry, Neri, Hamirpur, HP during July, 2021 to October, 2021 and 2022. Geographically, Neri is located at an altitude of 650 m above mean sea level between 31^{o}41'47.6" N & 72^{o}28'6.3" E. Experimental site is 11 km away from Hamirpur city of Himachal Pradesh. The climate of the region is characterized as subtropical, with hot summers and mild to cool winters. Generally, December and January are coldest months, while May and June are hottest month. Majority of precipitation is received during monsoon period i.e. from June to September. The soil structure of experimental farm is to loam to 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 and the composite sample was prepared. 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 and available potassium. 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 1934). The Alkaline Potassium Permanganate Method was used to determine available N (Subbiah and Asija 1956), P was measured by the method given by Olsen (Olsen et al. 1954), K was measured by Normal Neutral Ammonium Acetate Method (Merwin and Peech 1951) and S was determined by 0.15% $CaCl_2$ extractant and turbidimetric method (Chesnin and Yien 1950). Mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1984) for Randomized Complete Block Design. 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.

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, T_1 = Cowurine + Jeevamrit + FYM (250 q/ha), T_2 = Beejamrit + Jeevamrit + FYM (250 q/ha),T_3 = Azotobacter + PSB(Phosphate solubilizing bacteria) + FYM (250 q/ha), T_4 = 75 % Recommended dose of NPK + Azotobacter + FYM (250 q/ha), T_5 = 75 % Recommended dose of NPK + PSB + FYM (250 q/ha), T_6 = 75 % Recommended dose of NPK + Azotobacter + PSB + FYM (250 q/ha), T_7 = 50 % Recommended dose of NPK + Azotobacter + FYM (250 q/ha), T_8 = 50 %

Recommended dose of NPK + PSB + FYM (250 q/ha), T_9 = 50 % Recommended dose of NPK + Azotobacter + PSB + FYM (250 q/ha), T_{10} = 75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + FYM (250 q/ha), T_{11} = 75 % Recommended dose of NPK + 40 kg S/ha + PSB + FYM (250 q/ha), T_{12} = 75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM (250 q/ha), T_{13} = 50 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + FYM (250 q/ha), T_{14} = 50 % Recommended dose of NPK+ 40 kg S/ha + PSB + FYM (250 q/ha), T_{15} = 50 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM (250 q/ha), T_{16} = 100 % Recommended dose of NPK + 40 kg S/ ha + FYM (250 q/ha), T_{17} = 100 % Recommended dose of NPK (125:75:60 kg/ha) + FYM (250 q/ha).

Sowing was done on 19^{th} October 2021. Seeds were sown in the lines at a spacing of 20 X 10 cm. The soil structure of experimental farm is loam to clay loam with pH ranging from 6.8 to 7.0. 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 variety is long day type and bulbs are bigger in size (5 – 6.5 cm diameter) and creamy white colour with pinkish tinge. It reaches maturity in 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 fulldoses 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 (250 q/ha) were applied during field preparation in the respective treatments. Cloves were treated with cowurine 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.

Preparation of jeevamrit and beejamrit

Jeevamrit

Jeevamrit is a mixture of cow dung, cow urine, jaggery, pulse floor and living soil. For preparation of jeevamrit, required quantities of ingredients were thoroughly mixed in water and allowed to ferment for 7 days. Ingredients were stirred once in morning and once in evening in clockwise direction. Jeevamrit @ 10 % drenching was given at fortnight interval in the respective treatments. Table 1 shows the standardized technique for preparation of jeevamrit as suggested by Sreenivasa et al. (2010).

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

Beejamrit

Palekar (2007) suggested the standardized technique of preparing beejamrit. This is a mixture of cow dung, cow urine, lime and living 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 pot, 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 bund of field in that water and stir well. Lastly add 5 litres of cow urine & lime water and stir well. Beejamrit is ready to use.

RESULTS AND DISCUSSION

Physiochemical properties of soil

pH of soil

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 %

Recommended dose of NPK + 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 (Kurrey et al. 2018).

Electrical conductivity of soil (dSm^{-1})

Maximum electrical conductivity (0.244 dSm^{-1}) was observed in treatment T_{17} (100 % Recommended dose of NPK + FYM). While, minimum electrical conductivity (0.181 dSm^{-1}) was recorded in treatment T_{12} (75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM).

Soil Organic Carbon (%)

The highest soil organic carbon (0.86 %) was observed in treatment T_{12} (75 % Recommended dose of NPK + 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 resulting in an increase in organic carbon of soil (Kurrey et al. 2018).

Available Nitrogen (kg/ha)

The data presented in Table 2 revealed that maximum available nitrogen (258.84 kg/ha) was recorded in treatment T_{12} (75 % Recommended dose of NPK + 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 (Choudhary et al. 2015).

Available Phosphorus (kg/ha)

Maximum available phosphorus (26.72 kg/ha) was recorded in treatment T_{12} (75 % Recommended dose of NPK + 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 (Singh and Singh 2017).

Available Potassium (kg/ha)

The data presented in Table 2 revealed that the maximum available potassium (180.35 kg/ha) was observed in treatment T_{17} (100 % Recommended dose of NPK + 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.

Available Sulphur (kg/ha)

Maximum available sulphur (44.98 kg/ha) was observed in treatment T_{16} (100 % Recommended dose of NPK + 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-} (Solanki et al. 2020).

Economics of Garlic Cultivation

Perusal of data given in Table 3, indicated that maximum bulb yield (228.65 q/ha) was recorded in treatment T_{12} (75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM) and minimum (90.95 q/ha) was observed in treatment T_0 (Control). Maximum gross income (₹ 13,71,900 /ha) was recorded in treatment T_{12} (75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM) and minimum (₹ 5,45,700 /ha) was observed in treatment T_0 (Control). Maximum total cost of cultivation (₹ 3,49,967.40 /ha) was recorded in treatment T_{16} (100 % Recommended dose of NPK + 40 kg S/ ha + FYM) and minimum (₹ 2,95,280 /ha) was observed in treatment T_0 (Control). Net income (₹ 10,23,204.48 /ha) was recorded maximum in treatment T_{12} (75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM) and minimum net income (₹ 2,50,420 /ha) was observed in treatment T_0 (Control). Highest B:C ratio (2.93) was recorded in treatment T_{12} (75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM) and minimum (0.78) was observed in treatment T_2 (Beejamrit + Jeevamrit + FYM).

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

T_0 = Control, T_1 = Cowurine + Jeevamrit + FYM (250 q/ha), T_2 = Beejamrit + Jeevamrit + FYM (250 q/ha),T_3 = Azotobacter + PSB + FYM (250 q/ha), T_4 = 75 % Recommended dose of NPK + Azotobacter + FYM (250 q/ha), T_5 = 75 % Recommended dose of NPK + PSB + FYM (250 q/ha), T_6 = 75 % Recommended dose of NPK + Azotobacter + PSB + FYM (250 q/ha), T_7 = 50 % Recommended dose of NPK + Azotobacter + FYM (250 q/ha), T_8 = 50 % Recommended dose of NPK + PSB + FYM (250 q/ha), T_9 = 50 % Recommended dose of NPK + Azotobacter + PSB + FYM (250 q/ha), T_{10} = 75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + FYM (250 q/ha), T_{11} = 75 % Recommended dose of NPK + 40 kg S/ha + PSB + FYM (250 q/ha), T_{12} = 75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM (250 q/ha), T_{13} = 50 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + FYM (250 q/ha), T_{14} = 50 % Recommended dose of NPK+ 40 kg S/ha + PSB + FYM (250 q/ha), T_{15} = 50 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM (250 q/ha), T_{16} = 100 % Recommended dose of NPK + 40 kg S/ ha + FYM (250 q/ha), T_{17} = 100 % Recommended dose of NPK (125:75:60 kg/ha) + FYM (250 q/ha).

Table 3 Effect of integrated nutrient management on economics of garlic cultivation

Treatment	Total bulb yield (q/ha)	Total cost of cultivation (₹/ha)	Gross Income(₹/ha)	Net Income (₹/ha)	B:C ratio
T_0	90.95	2,95,280	5,45,700	2,50,420	0.84
T_1	136	3,77,080	8,16,000	4,38,920	1.16
T_2	112.20	3,77,085	6,73,200	2,96,115	0.78
T_3	137.37	3,41,180	8,24,220	4,83,040	1.41
T_4	144.50	3,47,295.52	8,67,000	5,19,704.48	1.49
T_5	146.20	3,47,195.52	8,77,200	5,30,004.48	1.52
T_6	207.40	3,47,695.52	12,44,400	8,96,704.48	2.57
T_7	152.15	3,45,123.64	9,12,900	5,67,776.36	1.64
T_8	146.20	3,45,023.64	8,77,200	5,32,176.36	1.54
T_9	175.10	3,45,523.64	10,50,600	7,05,076.36	2.04
T_{10}	206.55	3,48,295.52	12,39,300	8,91,004.48	2.55
T_{11}	172.55	3,48,195.52	10,35,300	6,87,104.48	1.97
T_{12}	228.65	3,48,695.52	13,71,900	10,23,204.48	2.93
T_{13}	157.25	3,46,123.64	9,43,500	5,97,376.36	1.72
T_{14}	168.30	3,46,023.64	10,09,800	6,63,776.36	1.91
T_{15}	223.55	3,46,523.64	13,41,300	9,94,776.36	2.87
T_{16}	169.15	3,49,967.40	10,14,900	6,64,932.60	1.89
T_{17}	152.15	3,48,967.40	9,12,900	5,63,932.60	1.61

T_0 = Control, T_1 = Cowurine + Jeevamrit + FYM (250 q/ha), T_2 = Beejamrit + Jeevamrit + FYM (250 q/ha),T_3 = Azotobacter + PSB + FYM (250 q/ha), T_4 = 75 % Recommended dose of NPK + Azotobacter + FYM (250 q/ha), T_5 = 75 % Recommended dose of NPK + PSB + FYM (250 q/ha), T_6 = 75 % Recommended dose of NPK + Azotobacter + PSB + FYM (250 q/ha), T_7 = 50 % Recommended dose of NPK + Azotobacter + FYM (250 q/ha), T_8 = 50 % Recommended dose of NPK + PSB + FYM (250 q/ha), T_9 = 50 % Recommended dose of NPK + Azotobacter + PSB + FYM (250 q/ha), T_{10} = 75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + FYM (250 q/ha), T_{11} = 75 % Recommended dose of NPK + 40 kg S/ha + PSB + FYM (250 q/ha), T_{12} = 75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM (250 q/ha), T_{13} = 50 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + FYM (250 q/ha), T_{14} = 50 % Recommended dose of NPK+ 40 kg S/ha + PSB + FYM (250 q/ha), T_{15} = 50 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM (250 q/ha), T_{16} = 100 % Recommended dose of NPK + 40 kg S/ ha + FYM (250 q/ha), T_{17} = 100 % Recommended dose of NPK (125:75:60 kg/ha) + FYM (250 q/ha).

Conclusion

Based on the results of this study, it can be concluded that overall treatment T_{12} (75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM) performed best in terms of yield and nutrient status of soil in garlic. Highest B:C ratio (2.93) was also recorded in treatment T_{12} (75 % Recommended dose of NPK + 40 kg S/ha + Azotobacter + PSB + FYM) and minimum (0.78) was observed in treatment T_2 (Beejamrit + Jeevamrit + FYM). Hence, the combined application of organic manures and inorganic fertilizers with biofertilizers helps in improving the yield and physiochemical properties of soil.

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