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RESEARCH PAPER

Effect of integrated nutrient management on yield and soil microbial population in garlic

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Abstract : A field experiment was conducted at Horticultural Research Station, Nanjanadu farm Ooty to study the effect of Integrated Nutrient Management on yield and the soil microbial populations in garlic. The experiment was carried out ina Randomized Blocks Design with 9 treatments and three replications. The plot size of 12 m^2 was laid out. The experiment was conducted for three years from 2011 -13 and the pooled data was analysed. Pooled analysis was done for the three-harvest data (2011, 2012, 2013). All the organic manures like farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM) and bio-fertilizers *viz.,* Azospirillum and Phosphorus Solubilizing Bacteria each @ 5 kg each/ ha was applied as a basal as per the treatment. 50 % of the recommended inorganic applied as basal at the time of planting and the remaining 50 % N was applied in two equal splits during 30 and 45 days after planting. The full dose of P, K and S applied at the time of planting as per the treatment schedule. The treatments received three levels of FYM (15, 7.5,5 t^{-1}/ha), Poultry Manure (7.5,3.75,2.5 t^{-1}/ha) and Vermi Compost (7.5,3.75,2.5 t^{-1}/ha). Observations are recorded on no. of leaves, Equatorial Diameter (ED), Polar Diameter (PD), Average Bulb Weight (ABW), A-grade bulbs (AGB), B grade bulbs (BGB), C grade bulbs (CGB), Marketable yield (MY) and Total yield (TY). Soil samples were collected at two stages (bulbing and at harvest) for microbial populations of total bacteria, fungi and actinomycetes. Results were compared among the treatments for total yield of garlic. Results revealed that the highest total as well as marketable yield was recorded in T_9 (75:40:40:40 Kg NPKS + 5 t FYM / ha + 2.5 t PM + 2.5 t VC/ ha) and T_6 (75:40:40:40 Kg NPKS + 7.5 t FYM / ha + 3.75 t PM/ ha). Among the nine treatments significantly the maximum plant height (68.65 cm), the number of leaves (8.17), neck thickness (3.47 cm), polar diameter (40.03 mm), equatorial diameter (36.83cm), the average weight of 10 bulbs (203.34 g). B grade bulbs (51. 27 %), minimum C grade bulbs (16. 11%), marketable yield (8.52 tonnes/ ha), total yield (10.61 tonnes/ ha) was recorded in the T_9 followed by T_6 (9.72 tonnes /ha). The population of bacteria, fungi and actinomycetes were found to be maximum at the harvesting stage when compared to the bulbing stage under treatment T_9.

Key Words : Integrated nutrient management, Garlic, Microbial population, Yield, Catalase, Peroxidase, Enzyme activity

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INTRODUCTION

Garlic belongs to the family, Alliaceae genus (*Allium sativum* L.) is one of the important commercial spice or a condiment among the Allium species grown throughout

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India, in almost every home, for seasoning and flavouring the food as it has got manifold uses including many medicinal properties. It is also important foreign exchange earner apart from meeting the domestic requirement of country. China is the leading producer followed by India. In India, the total area under garlic is 362,950 ha with the production of 2,916,970 tonnes and the productivity of 8.036 tonnes /ha. It has high nutritive value with many medicinal properties such as lowering cholesterol, regulating high blood pressure and common cold (Hammami and May,2012) and Block, 2010. In India, Production of garlic increased 104 per cent due to the introduction of high yielding varieties and application of chemical fertilizers. Garlic respond Continuous application of chemical fertilizers resulted deteriorated soil health by loss of soil organic carbon (hiltner and Parkin,1994).

Application of chemical fertilizers has played a crucial role in replenishment of nutrients removed by crops and crop yield increase. However, continuous use of chemical fertilizers alone over the years resulted in loss of soil organic carbon and deteriorated soil health. Soil organic matter is a key component that defines soil quality (Doran and Parkin 1994) which acts as a reservoir of plant nutrients and serves as a substrate for soil microorganisms (Dutta *et al.,* 2003). For sustaining garlic production addition of organic manures is essential for restoring the soil quality, however it has low nutrient content. The rhizosphere is that region of the soil and the root influence enhanced microbial activity (Hiltner, 1904). A plant is a partner in the biocentric system and all the physiological changes it undergoes during vegetation are reflected in the feature of coexisting microorganisms. The rhizosphere region provides better sites for the isolation of beneficial microorganisms than the bulk soil. Increasing microbial activity due application of organic amendments reported by several findings (Elliott and Lynch, 1994), microbial diversity (Girvan *et al.*, 2004 and Grayston *et al.*, 2004) densities of bacteria (Maheswarappa, 1999).

The positive effects of application of organic manures on soil pH, microbial population and soil enzyme activities were observed (Maheswarappa *et al.,* 1999). Addition of organic manures is essential for restoring soil quality and sustaining garlic production (Han *et al.*, 2016). Integrated nutrient management of combined application of organic manures with chemical fertilizers and biofertilizers increases the yield, quality and nutrient uptake (Chand *et al*., 2006; Thangasamy and Lawande 2015; Han *et al*., 2016; Ganeshamurthy *et al*., 2017; Thangavelu and Lawande *et al.*, 2018.

Yadav and Lourduraj (2007) observed that the application of 50 percent N through composted poultry manure and 50 percent N through green leaf manure increased significantly the microbial population and enzymes activity, which was superior to recommended NPK through fertilizers. The addition of organic matter increased the microbial count compared to fertilizers treatments. Among the organic sources, FYM showed the highest mean bacterial counts followed by crop residues+ urea and Leucaena + urea treatment. The total microbial count was more when FYM on crop residues were added (Bhakare *et al*., 2008). Application of poultry manure in daincha increased bacterial, fungal and actinomycetes population in soil (Boomiraj, 2003 and Somasundaram, 2003). Boomiraj and Lourduraj (2004) reported that the application of poultry manure increased the soil microbial and enzyme activity in poultry manure applied soil compared to other organic manures (Prsanthrajan *et al*., 2008). Vermicompost containing a higher amount of growth-promoting substances, vitamins and enzymes, increased the microbial population. The highest bacterial and fungal population was associated with the application of 75 per cent N as vermicompost with *Azospirillum*, which was five times higher than the 100 per cent urea received plot (Kannan *et al*., 2005). Vermicompost is a potential source due to the presence of readily available plant nutrients, plant growth hormones, vitamins, enzymes, antibiotics and a number of beneficial micro-organisms (Usha *et al*., 2006).

Along with Farm Yard Manure, there is a need to use alternate sources of other manures *viz.,* vermicompost, poultry manure and biofertilizers due to reducing population of cattle in India. Considering these issues a field experiment was conducted at Horticultural Research Station, Nanjanadu farm Ooty to study the effect of Integrated Nutrient Management on garlic involves three organic manures alone or in combinations with inorganic fertilizers on yield and the microbial populations. The purpose of this study aims to investigate, the potential of organic fertilizers to improve rhizosphere microbial populations to obtain higher crop yield without the need for tremendous inorganic fertilizers.

MATERIAL AND METHODS

The experiment was conducted at Nanjanad farm, Horticultural Research Station, Tamil Nadu Agricultural University, Ooty (11.24 N latitude, 76.42 E longitude, 2200 m above MSL) on garlic Gundalpet type during 2010 - 13, *Rabi* season. The crop was planted on a ridge at a spacing of 15X10 cm. The experiment was conducted in a Randomized Block Design with three replications on lateritic soil with 5.4 pH. T_1 is the local recommendation (as per TNAU recommendation), T_2 - 100:50:50:50 Kg NPKS + 20 t^{-1} FYM / ha (DOGR recommendation), T_3 - 75:40:40:40 Kg NPKS + 15 t^{-1} FYM / ha, T_4 - 75:40:40:40 Kg NPKS + 7.5 t^{-1} PM /ha, T_5-75:40:40:40 Kg NPKS+7.5 t^{-1} VC/ ha, T_6 - 75:40:40:40 Kg NPKS+7.5 t^{-1} FYM/ha +3.75 t^{-1} PM/ha, T_7- 75:40:40:40 Kg NPKS + 7.5 t^{-1} FYM / ha +3.75 t^{-1} VC/ ha, T_8 - 75:40:40:40 Kg NPKS + 3.75 t^{-1} PM / ha +3.75 t^{-1} VC/ ha, T_9 - 75:40:40:40 Kg NPKS + 5 t -1 FYM / ha + 2.5 t^{-1} PM + 2.5 t^{-1} VC/ ha. All organic manures like Farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM) and bio-fertilizers *viz.,* Azospirillum and Phosphorus Solubilizing Bacteria (each @ 5 kg / ha) were applied as a basal as per the treatment. Fifty percent inorganic N was applied as basal at the time of planting and the remaining 50 % N was applied in two equal splits during 30 and 45 days after planting. A full dose of P, K and S were applied at the time of planting as per the treatments. After harvest, bulbs were cured in shade for 10-15 days to remove the excess moisture and weight was recorded. Bulb yield per hectare was calculated and expressed as kg/ha. Microbial populations (Bacteria, actinomycetes and fungi) of soils were determined by serial dilution and plate count method (Allen, 1953).

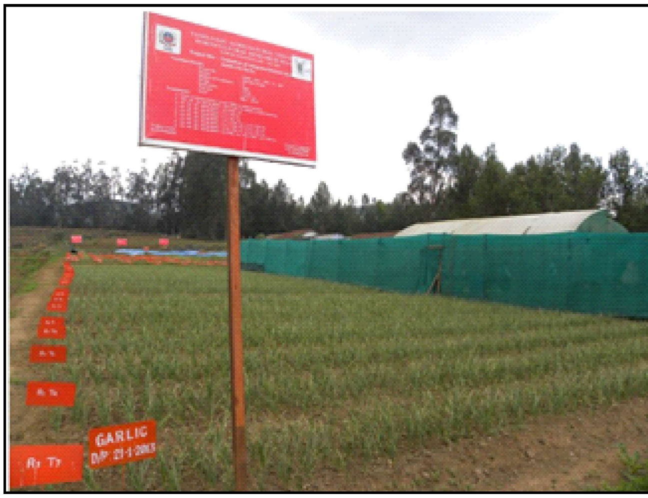
Results and Discussion

Any nutrient management practice should aim at higher yield and sustaining the available soil microbial population or to enhance the same so as to improve the soil fertility status. In the present study, The highest total yields, as well as marketable yield, were recorded in T_9 followed by and T_6.). Among the nine treatments significantly the maximum plant height (68.65 cm), the number of leaves (8.17), neck thickness (3.47 cm), polar diameter (40.03 mm), equatorial diameter (36.83cm), the average weight of 10 bulbs (203.34 g). B grade bulbs (51.27 %), minimum C grade bulbs (16. 11%), marketable yield (8.52 tonnes/ ha), total yield (10.61 tonnes/ ha) was recorded in the T_9 followed by T_6 (9.72 tonnes /ha). The treatment T_6 was found significantly superior to other treatments. Among the nine treatments Total yield (10.61 t/ha) was recorded in the T_9 with the application of 5 t^{-1} FYM / ha + 2.5 t^{-1} PM + 2.5 t^{-1} VC/ ha. The results showed that use of (75 % recommended NPKS along with organic manures) 75:40:40:40 Kg NPKS + 5 t^{-1} FYM / ha + 2.5 t^{-1} PM + 2.5 t^{-1} VC/ ha increased garlic yield over (100% NPKS+20 t ha) 100:50:50:50 Kg NPKS + 20 t^{-1} FYM / ha (DOGR recommendation) (Table 1 and Fig.1). The highest garlic yield was recorded in

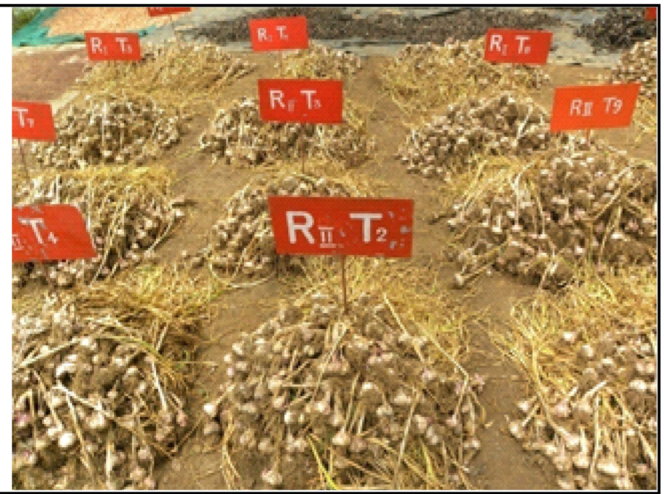
Table 1 : Effect of INM on growth and yield contributing characteristics on garlic (Pooled mean of 2011 to 2014)

Treatment details	Plant height (cm)	No. of leaves	ED (mm)	PD (mm)	NT (mm)	ABW (10) (g)	AGA (%)	AGB (%)	AGC (%)	MY (t ha^{-1})	TY (t ha^{-1})
T_1	64.82	6.78	39.16	32.47	2.87	162.55	29.59	29.74	40.67	7.68	8.74
T_2	65.96	7.28	40.33	33.44	2.82	171.72	31.47	30.40	38.13	8.21	9.54
T_3	65.55	7.13	40.89	33.11	2.97	175.71	32.88	33.23	33.89	8.38	9.62
T_4	65.72	7.30	39.02	33.32	2.77	171.13	32.20	31.45	36.34	8.26	9.89
T_5	51.66	6.83	40.72	33.52	2.80	180.17	33.04	32.91	34.06	8.21	9.52
T_6	67.88	7.73	39.99	34.10	3.17	184.97	35.15	41.53	27.58	9.02	10.43
T_7	66.02	7.25	39.04	34.01	2.42	176.47	33.58	30.66	24.20	8.42	9.82
T_8	63.41	7.55	39.11	34.05	2.63	174.52	33.77	35.26	30.97	7.96	9.94
T_9	69.72	8.13	42.10	35.89	3.45	182.83	36.96	48.19	14.85	9.69	10.91
Mean	64.53	7.33	40.04	33.77	2.88	175.56	33.18	34.82	31.19	8.43	9.82
SEd	3.14	0.796	0.604	0.818	0.204	20.526	1.329	3.272	5.127	1.464	0.8073
CD at 0.05%	6.48	1.644	1.247	1.688	0.421	42.36	2.743	6.754	10.58	3.022	1.666
CV%	6.88	15.84	2.13	3.43	10.04	17.01	5.67	13.29	23.24	25.57	13.81

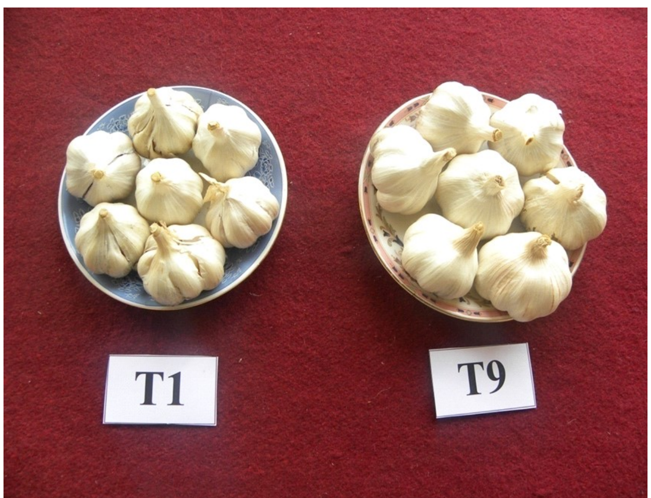
ED – Equatorial Diameter, PD – Polar Diameter, ABW – Average Bulb eight, AGB – A grade bulbs, BGB – B grade bulbs, C- c grade bulbs
My – Marketable yield, TY – Total yield



Field view of the experiment at Nanjanadu Farm, Ooty



Harvested garlic kept for curing



Garlic and cloves of T_9 and T_1 treatments details - 75:40:40:40 Kg NPKS + 5 t FYM / ha + 2.5 t PM + 2.5 t VC/ ha

Fig. 1: Field view, garlic and cloves of treatment T_9

treatments receiving 75% RDF+5 t^{-1} FYM+ 2.5 PM +2.5 t^{-1} VC ha (T_9) followed by T_6 - 75:40:40:40 Kg NPKS + 7.5 t^{-1} FYM / ha + 3.75 t^{-1} PM/ ha. Application of the local dose 75:40:40 kg/ha NPK and 40 Kg Sulphur without organic manures had the lowest garlic yield. The results indicated that combined application of inorganic fertilizers, two or more organic sources and biofertilizers increased garlic yield when compared to inorganic fertilizers alone (T_1). Sachan *et al*. (2017) reported that integrated -1 use of NPK (75%) + FYM (2.5 t^{-1} ha) + poultry manure -1 -1 (2.5 t^{-1} ha) + vermicompost (2.5 t^{-1} ha) increased okra yield and protein content compared to the integrated use of a recommended dose of fertilizers and single organic manure. Thangasamy and Lawande (2015) reported similar results in onion. The increased yield with the application of inorganic nutrient uptake with the application of plant nutrients directly through organic manures and indirectly through solubilization of unavailable nutrients of intermediate organic molecules produced during decomposition of added manures (Mitra *et al.,* 2010). This indicated that the integration of two or more sources of organic manures with inorganic fertilizers could help in reducing 25 per cent inorganic fertilizer without affecting garlic yield. Increased okra yield and protein content compared to the integrated use of a recommended dose of fertilizers and single organic manure integrated with NPK (75%) + FYM (2.5 t ha^{-1}) + poultry manure (2.5 t ha^{-1}) + vermicompost (2.5 t ha^{-1})

reported by Sachan *et al*. (2017) and similar results were also reported by Thangasamy and Lawande (2015) in onion and Thangasamy and Lawande (2018) in garlic. The integrated nutrient management might be attributed to the growth and yield characters due to the high accumulation of carbohydrates which resulted in higher garlic yield. The same report was also reported by Bhandari *et al*., 2012 and Tripathy *et al*., 2016.

The microbial population increased at harvest. Increasing levels of organic manure increased the microbial population in the soil which may be due to the appreciable supply of secondary elements and micronutrients. Another plausible explanation might be the role of organic carbon available with VAM, Vermicompost, and FYM. Moreover, the release of root exudates, sloughed cells and decaying root tissues in the rhizosphere might have contributed to the microbial population, which is found to be influenced substantially by the application of integrated nutrients. All these factors might have led to an increased level of nutrients in the rhizosphere which influenced the population load. It is a well-established fact that the rhizosphere activity is dependent upon plant nutrient status (Turner and Newman, 1984; Turner *et al*., 1985; Robert, 1995).

The bacterial population exhibited significant differences among the treatments during harvest at lower depths of soil in garlic. Among the various treatments, (T_9 5 t^{-1} FYM / ha + 2.5 t^{-1} PM + 2.5 t^{-1}VC/ ha) registered the maximum and T_1 registered the minimum population at both the stages (Table 2). The population of fungi showed significant differences among the treatments in both stages. Among the various treatments, T_9 (5 t t^{-1} FYM / ha + 2.5 t^{-1} PM + 2.5 t^{-1} VC/ ha) registered the maximum population and T_1 registered the minimum population. Among these, more populations of fungi could be seen in T_9 treatments at harvest. Significant differences among the treatments were recorded for the population of actinomycetes at both stages. T_1 registered the lowest population and T_9 registered the maximum population at harvest. The lowest population was observed in T_1 at the bulbing stage. At the harvest stage, the population dynamics was higher in all the treatments, due to the effect of a greater number of dead and decayed roots available in the clump at later stages.

Table 2 : Effect of integrated nutrient management on yield and the population of total bacteria, fungi and actinomycetes at different stages of garlic

Treatments	Bacteria (x 10^7 CFU/g of oven dry soil)		Fungi (x 10^3 CFU/g of oven dry soil)		Actinomycetes (x 10^3 CFU/g of oven dry soil)		Total yield (t ha^{-1})
	Bulbing stage	At harvest	Bulbing stage	At harvest	Bulbing stage	At harvest	
T1 - Local recommendation	7.7	29.4	5.46	6.2	1.93	2.6	7.92
T2 -100:50:50:50 Kg NPKS + 20 t FYM / ha (DOGR recommendation)	8.1	30.0	8.13	21.8	2.10	2.8	8.30
T3 - 75:40:40:40 Kg NPKS + 15 t FYM / ha	9.3	35.2	10.93	29.6	2.10	3.0	8.39
T4 - 75:40:40:40 Kg NPKS + 7.5 t PM /ha	9.5	36.6	11.00	33.8	3.0	4.3	8.83
T5 - 75:40:40:40 Kg NPKS + 7.5 t VC / ha	10.0	39.2	12.50	36.8	3.0	4.6	8.65
T6 - 75:40:40:40 Kg NPKS + 7.5 t FYM / ha + 3.75 t PM/ ha	15.8	54.0	15.8	44.8	3.50	5.6	9.72
T7 - 75:40:40:40 Kg NPKS + 7.5 t FYM / ha +3.75 t VC/ ha	13.2	48.0	12.2	40.3	3.0	4.8	8.68
T8 - 75:40:40:40 Kg NPKS + 3.75 t PM / ha +3.75 t VC/ ha	15.2	52.8	12.0	42.6	3.47	5.4	8.71
T9 - 75:40:40:40 Kg NPKS + 5 t FYM / ha + 2.5 t PM + 2.5 t VC/ ha	19.6	59.0	17.4	48.55	3.96	5.8	10.61
SED	0.307	1.601	0.303	0.2584	2.895	0.1729	8.859
CD (0.05%)	0.652	3.416	0.642	0.5478	0.075	0.3666	0.600
Cv (%)	3.13	4.59	3.17	0.94	0.1596	4.98	1.272

Bacteria and fungi are the primary consumers of dead organic matter in the soil. Dead organic matter originates from plant residues, decaying roots, decaying microorganisms (Bloem *et al.*, 1997) and root exudates (Alexander, 1977). Thus, the microbial load is high even at harvest.

Combined applications of organic sources of vermicompost, poultry manure and FYM with inorganic sources have provided a conducive environment for the activity of the microbial population. This is in line with the findings of Sutopo and Kuwatsuka (1992), who suggested that poultry manure application stimulated microbial proliferation and the process related to N recycling in soil. A relatively higher population in T_9 may be also ascribed to the release of more phenolic compounds as it serves as a special attractant for soil bacteria (Bauer and Anolles, 1991). Similarly, the combined supply of FYM, Poultry manure and Vermicompost created a contusive environment for the multiplication of microorganisms throughout the crop period. The population showed an increasing trend after each stage of the crop. Thereby increase in the yield of crops was observed. Similar results were reported by Goyal *et al.* (1999) and Lee *et al*. (2010) in onion.

Nitrate reductase(NR) activity differed significantly among the treatments at bulbing and maturity stages (Table 3). In general, there was a marked increase in enzyme activity from bulbing to the maturity stage. Among the treatments, T_9 (5 t FYM / ha + 2.5 t^{-1} PM + 2.5 t^{-1} VC/ ha) registered the highest activity followed by T_6. Treatment T_1 registered the lowest activity at the two stages. Catalase activity, in general, showed higher value with advancement in crop growth irrespective of the treatments. However, among them, T_9 (5 t^{-1} FYM / ha + 2.5 t^{-1} PM + 2.5 t^{-1} VC/ ha) had higher activity at the bulbing and maturity stages (Table 2). Peroxidase activity also exhibited a similar trend as that of catalase activity. The differences in the enzyme activity were significantly influenced by the treatments at bulbing and harvesting stages. T_9 exhibited the highest enzyme activity followed by T_5, whereas T_1 registered the lowest enzyme activity (Table 3). This increase might be attributed to the consecutive addition of energy-rich materials which increased the enzyme activities and ultimately the viable microbial population. This is in line with the result of Asmar *et al*. (1992) and Siwik-Ziomek and Szczepanek (2019).

Conclusion:

In the present experiment, substantial improvement in the microbial count was noticed at harvest. The population showed an increasing trend from bulbing to the maturity stage of the crop. The yield of garlic is also increased in treatment where the higher microbial population was observed with maximum enzyme activities. This increase might be attributed to the consecutive addition of energy-rich organic supplement materials which increased the enzyme activities and ultimately the viable microbial population. By the combined use of two or more organic manures with 75% RDF (75:40:40:40 kg NPKS ha^{-1}) the garlic yield can be increased apart from saving 25 per cent inorganic

Table 3 : Effect of integrated nutrient management on NR (µg of NO_2 g^{-1}hr^{-1}), catalase (µg of H_2O_2 g^{-1}min^{-1}) and peroxidase enzyme activity (min^{-1}) at the time of bulb formation

Treatments	Bulbing stage	At harvest	Bulbing stage	At harvest	Bulbing stage	At harvest
T_1 - TNAU recommendation	667.15	818.43	3.166	4.593	0.041	0.054
T_2 -100:50:50:50 Kg NPKS + 20 t FYM / ha (DOGR recommendation)	600.28	860.43	3.200	5.727	0.039	0.065
T_3 - 75:40:40:40 Kg NPKS + 15 t FYM / ha	600.46	883.37	3.212	6.233	0.030	0.069
T_4 - 75:40:40:40 Kg NPKS + 7.5 t PM /ha	818.43	886.52	3.185	7.363	0.038	0.074
T_5 - 75:40:40:40 Kg NPKS + 7.5 t VC / ha	843.23	900.65	4.593	7.370	0.046	0.074
T_6 - 75:40:40:40 Kg NPKS + 7.5 t FYM / ha + 3.75 t PM/ ha	903.65	1226.96	5.727	9.077	0.064	0.077
T_7 - 75:40:40:40 Kg NPKS + 7.5 t FYM / ha +3.75 t VC/ ha	860.43	1133.75	6.233	7.893	0.054	0.066
T_8 - 75:40:40:40 Kg NPKS + 3.75 t PM / ha +3.75 t VC/ ha	883.37	1193.91	7.363	8.773	0.059	0.069
T_9 - 75:40:40:40 Kg NPKS + 5 t FYM / ha + 2.5 t PM + 2.5 t VC/ ha	1200.52	1568.66	7.370	10.453	0.074	0.077
SED	4.566	6.089	0.029	0.026	0.002	0.002
CD (0.05%)	9.680	12.909	0.063	0.055	0.005	0.006
Cv (%)	60.68	98.71	0.75	0.43	6.58	4.98

fertilizers.

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