

## Evaluation of Integrated Nutrient Management Modules for Garlic (*Allium sativum* L.)

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**Abstract** Field experiments were conducted for three consecutive years during *rabi* of 2010-11 to 2012-13 to study the impact of different INM modules in garlic (*Allium sativum* L.). The pooled results indicated significant variation for various vegetative growth, bulb yield and yield attributing parameters, bulb qual-

ity as well as shelf life of harvested bulbs. Integrated application of 100:50:50:50 NPKS kg ha<sup>-1</sup> + FYM @ 20 tha<sup>-1</sup> (T<sub>2</sub>) significantly produced highest marketable bulb yield (44.70 q ha<sup>-1</sup>) as well as total bulb yield (55.75 q ha<sup>-1</sup>) closely followed by integrated application of @ 75:40:40:40 NPKS kg ha<sup>-1</sup> + FYM @ 7.5 tha<sup>-1</sup> + PM @ 3.75 tha<sup>-1</sup> (T<sub>6</sub>) in garlic variety, Agrifound White with higher BC ratio of 1.38 and 1.29, respectively. The results on storage study revealed significantly better efficacy of INM module, T<sub>2</sub> closely followed by T<sub>4</sub> (75:40:40:40 NPKS kg ha<sup>-1</sup> + PM @ 7.5 tha<sup>-1</sup>) and T<sub>8</sub> (75:40:40:40 NPKS kg ha<sup>-1</sup> + PM @ 3.75 tha<sup>-1</sup> + Vermicompost @ 3.75 tha<sup>-1</sup>) with respect to % of rotting (10.87 to 12.32%) and total loss while T<sub>2</sub> and T<sub>4</sub> for PLW (10.10 to 12.01%) after four months of storage.

**Keywords** Garlic, FYM, Poultry manure, Vermicompost, BC ratio.

### Introduction

Garlic (*Allium sativum* L.) belongs to *Alliaceae* and is the second most widely used cultivated bulb crop next only to onion. Garlic is not only cultivated as spice, seasoning and flavoring crop but also for its medicinal properties which is steadily gaining more importance in the world wide during recent years including our country, India. In general, garlic possess many medicinal properties ranging from positively affecting anything such as high blood pressure and lowering cholesterol to using it as a treatment for the common cold [1, 2].

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**Table 1.** Treatment details of INM modules for garlic.

Treatments	Treatment details
T <sub>1</sub>	Local recommendation (100:60:60:60 NPK kg ha <sup>-1</sup> + FYM @ 20 t ha <sup>-1</sup> )
T <sub>2</sub>	100:50:50:50 kg NPKS + 20 t FYM ha <sup>-1</sup> (DOGR Recommendation)
T <sub>3</sub>	75:40:40:40 kg NPKS + 15 t FYM ha <sup>-1</sup>
T <sub>4</sub>	75:40:40:40 kg NPKS+ 7.5 t Poultry Mamure (PM) ha <sup>-1</sup>
T <sub>5</sub>	75:40:40:40 kg NPKS + 7.5 t Vermicompost (VC) ha <sup>-1</sup>
T <sub>6</sub>	75:40:40:40 kg NPKS + 7.5 t FYM + 3.75 t PM ha <sup>-1</sup>
T <sub>7</sub>	75:40:40:40 kg NPKS + 7.5 t FYM + 3.75 t VC ha <sup>-1</sup>
T <sub>8</sub>	75:40:40:40 kg NPKS + 3.75 t PM + 3.75 t VC ha <sup>-1</sup>
T <sub>9</sub>	75:40:40:40 kg NPKS + 5 t FYM + 2.5 t PM + 2.5 t VC ha <sup>-1</sup>

The world annual production of garlic is about 237.70 lakh tons from an area of 14.22 lakh hectares during 2011. China is leading producer of garlic (80.92%) followed by India (4.45%) while highest productivity is in Egypt (24.36 t ha<sup>-1</sup>) followed by China (23.09 t ha<sup>-1</sup>). The productivity of Indian garlic is very low 5.40 t ha<sup>-1</sup> as compared to other countries in the world [3]. During the year 2013-14, India produces 12.52 lakh tons of garlic from 2.31 lakh hectares with an average productivity of 5.4 t ha<sup>-1</sup> [4]. This is primarily due to cultivation of low yield potential varieties as well as exposed to various biotic and abiotic stresses. Imbalance application of nutrition is one of the major abiotic stresses which adversely affect the crop growth and productivity in garlic. The continuous and imbalanced use of inorganic fertilizers is adversely affecting the garlic production, besides causing environmental pollution. Organic manures are responsible for improving chemical, physical and physiochemical properties of soil. Organic manure is alternative practice to mineral fertilization [5]. It helps in improving soil structure [6] and soil biomass [7]. Organic manure improves soil structure and water holding capacity resulting more extensive root development and enhanced soil micro flora and fauna activity, which results in availability of micronutrients available to plants [8]. Maximum growth and yield in garlic can be obtained with the application of optimum dose of chemical fertilizers along with the appli-

cation of FYM and bio fertilizers under Gujarat condition [9]. Use of both organic as well as inorganic nutrient sources not only help in increasing the yield of crop but also act as a store house of nutrients for successive crop, besides improving the physical condition of soil. Keeping these in view, the present study was conducted to identify a suitable INM module (s) for garlic crop.

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## Materials and Methods

The experiment was carried out under Ass India Network Research Project on Onion and Garlic, College of Horticulture, Sambalpur under Orissa University of Agriculture & Technology (OUAT), Odisha, India during the *rabi* season of 2010-11 to 2012-13 by adopting randomized block design (RBD) with nine treatments replicated thrice. The details of treatments are presented in Table 1. The cloves of garlic variety Agrifound White were planted in plot size of 6 m × 2 m with a spacing of 15 cm × 10 cm. the pH, organic carbon, available nitrogen, phosphorus, potassium and sulfur were 6.24, 0.34%, 137.50 kg ha<sup>-1</sup>, 11.83 kg ha<sup>-1</sup>, 126.33 kg ha<sup>-1</sup> and 9.89 ppm, respectively. All the recommended package of practices was adapted uniformly to all the modules except the nutrition which were applied on the basis of treatment schedules to raise a good crop of garlic.

Ten plants from each plot were selected randomly and tagged for recording the observations on vegetative growth as well as bulb yield attributing parameters. The % of A (>3.5 cm size), B (2.5 to 3.5 cm size) and C (1.5 to 2.5 cm size) grade bulbs as well as bulb yield (both marketable and total) was worked out based on the plot yield. The marketable bulb yield in garlic includes the only the bulbs of A, B and C grades while the total bulb yield include marketable, unmarketable, sprouted and rotten bulbs. The data

**Table 2.** Impact of INM modules on growth and bulb yield and yield contributing parameters for garlic (Pooled results from 2010-11 to 2012-13). PH: Plant height, NOL: Number of leaves plant<sup>-1</sup>, NT: Neck thickness, AGA: A grade bulbs, AGB: B grade bulb, AGC: C grade bulbs, MY: Marketable yield, TY: Total yield, BC: Benefit cost.

Treatments	PH (cm)	NOL	NT (cm)	ABW (g)	AGA (%)	AGB (%)	AGC (%)	MY (q ha <sup>-1</sup> )	TY (q ha <sup>-1</sup> )	BC Ratio
T <sub>1</sub>	46.38	10.64	0.66	15.14	22.30	33.10	20.31	35.28	42.45	0.82
T <sub>2</sub>	49.68	11.30	0.78	17.18	24.90	32.55	16.55	44.70	55.75	1.38
T <sub>3</sub>	43.58	10.38	0.70	12.98	17.68	27.97	22.01	26.13	34.31	0.54
T <sub>4</sub>	48.62	10.56	0.75	15.93	20.14	35.49	16.57	39.40	51.87	1.15
T <sub>5</sub>	47.63	10.22	0.70	16.74	14.43	32.59	19.84	29.21	42.28	0.34
T <sub>6</sub>	50.38	10.84	0.76	16.72	18.90	30.90	22.03	40.59	53.37	1.29
T <sub>7</sub>	48.24	10.67	0.72	15.07	23.43	35.81	21.48	40.27	47.55	0.77
T <sub>8</sub>	48.26	10.62	0.68	15.40	18.35	32.04	19.31	36.70	47.71	0.73
T <sub>9</sub>	49.37	11.04	0.75	15.52	24.86	34.82	16.28	39.39	48.13	0.86
Mean	48.02	10.70	0.72	15.63	20.56	32.81	19.37	36.85	47.05	0.88
SEm	1.44	0.25	0.02	0.96	2.57	2.19	2.69	3.37	4.59	–
LSD (5%)	3.05	0.54	0.05	2.04	5.44	NS	NS	7.14	9.74	–
CV (%)	3.66	2.89	4.09	7.55	15.30	8.18	16.99	11.19	11.96	–

recorded were statistically analyzed as per the standard procedure [10].

## Results and Discussion

The pooled results over three years presented in Table 2 indicated significant variations among all the INM modules for all the parameters under study except the % of B and C grade bulbs.

The plant height of garlic varied significantly among the INM modules ranging from 43.58 cm (T<sub>3</sub>) to 50.38 cm (T<sub>6</sub>). Integrated application of 75:40:40 NPKS kg ha<sup>-1</sup> + FYM @ 7.5 tha<sup>-1</sup> + Poultry Manure (PM) @ 3.75 tha<sup>-1</sup> (T<sub>6</sub>) had produced significantly highest plant height (50.38 cm) than rest of the INM modules tested. However, statistical parity was observed for all the INM modules except T<sub>1</sub> and T<sub>3</sub>.

Similarly, number of leaves plant<sup>-1</sup> varies from 10.22 (T<sub>5</sub>) to 11.30 (T<sub>2</sub>). Significantly maximum number of leaves plant<sup>-1</sup> (11.30) was recorded in the plot

receiving the INM module consisting of 100:50:50:50 NPKS kg ha<sup>-1</sup> + FYM @ 20 tha<sup>-1</sup> (T<sub>2</sub>, DOGR recommendation) than rest of the INM modules evaluated except T<sub>6</sub> and T<sub>9</sub> where statistical parity were observed. Similar trend was also observed for neck thickness, which ranges from 0.66 cm in T<sub>1</sub> to 0.78 cm in T<sub>2</sub>.

The pooled results over three years indicated significantly higher vegetative growth in garlic with the integrated application of both organics and inorganic in INM module T<sub>2</sub> (100:50:50:50 NPKS kg ha<sup>-1</sup> + FYM @ 20 tha<sup>-1</sup>), T<sub>6</sub> (75:40:40:40 NPKS kg ha<sup>-1</sup> + FYM @ 7.5 tha<sup>-1</sup> + PM @ 3.75 tha<sup>-1</sup>) and T<sub>9</sub> (75:40:40:40 NPKS kg ha<sup>-1</sup> + FYM @ 5.0 tha<sup>-1</sup> + PM @ 2.5 tha<sup>-1</sup> + Vermicompost @ 2.5 tha<sup>-1</sup>). The vigorous growth of garlic in terms of vegetative growth might be due to higher uptake of NPKS. Further, overall increase in growth parameters may be due to sulfur increasing the root system of plants which might have resulted in an increase uptake of nutrients which were utilized in the photosynthesis. A similar result was also observed in garlic [11].

**Table 3.** Impact of INM modules on storage and bulb quality of garlic (Pooled results from 2010-11 to 2012-13).

Treatment details	Cumulative storage loss after 4 months			Bulb quality at harvest
	PLW (%)	Rotting (%)	Total losses (%)	TSS (°Brix)
T <sub>1</sub>	17.78	16.28	34.06	35.63
T <sub>2</sub>	12.01	10.87	22.88	40.60
T <sub>3</sub>	17.40	17.70	35.09	34.04
T <sub>4</sub>	10.10	11.09	21.19	37.65
T <sub>5</sub>	17.03	13.72	30.75	37.78
T <sub>6</sub>	15.13	13.26	28.39	38.40
T <sub>7</sub>	18.89	17.30	36.20	38.94
T <sub>8</sub>	14.06	12.32	26.38	38.84
T <sub>9</sub>	14.53	14.05	28.59	38.90
Grand mean	15.22	14.07	29.28	37.91
SE(m) ±	1.47	1.32	2.46	0.91
LSD (5%)	3.12	2.80	5.22	1.93

Among different levels of organics, application of FYM @ 20 tha<sup>-1</sup> (T<sub>2</sub>) alone or combination of FYM @ 7.5 tha<sup>-1</sup> + PM @ 3.75 tha<sup>-1</sup> (T<sub>6</sub>) or FYM @ 5 tha<sup>-1</sup> + PM @ 2.5 tha<sup>-1</sup> + Vermicompost @ 2.5 tha<sup>-1</sup> (T<sub>6</sub>) were statistically at par with each other and recorded significantly better vegetative growth parameters. Organics are known to contain micronutrients apart from major nutrients. Therefore, the availability of higher quantity of nutrients, improvement in soil physical properties of soil and increased activity of microbes with higher dose of organics might have helped in increasing better vegetative growth parameters. Similar reported of higher levels of FYM significantly increased both plant height and number of leaves plant<sup>-1</sup> in onion [12].

The average bulb weight ranging from 12.98 g (T<sub>3</sub>) to 17.18 g (T<sub>2</sub>) with a mean bulb weight of 15.63 g. Significantly heaviest bulbs (17.18 g) was recorded in T<sub>2</sub>, than rest of the INM treatments. However, statistical parity was recorded among the all the INM treatments except T<sub>3</sub> and T<sub>7</sub>.

In the present study, the pooled results indicated significant variations among INM modules only for % of A grade bulbs while non-significant variations for both B and C grade bulbs. The % of A, B and C grade bulb varies from 14.43% (T<sub>5</sub>) to 24.90% (T<sub>2</sub>), 27.97% (T<sub>3</sub>) to 35.81% (T<sub>7</sub>) as well as 16.55% (T<sub>2</sub>) to 22.03% (T<sub>6</sub>), respectively. The DOGR recommended plots (T<sub>2</sub>) recorded significantly highest % of A grade bulbs of 24.90% than rest of the INM modules tested. However, statistical parity was recorded among all the INM modules except treatment T<sub>3</sub>, T<sub>6</sub> and T<sub>8</sub>.

Thus, the present pooled results revealed the superiority of DOGR recommendation (T<sub>2</sub>) as best INM module for garlic crop as compared to other INM modules, which might be due to uptake and utilization of higher NPKS nutrients along with higher levels of FYM, producing better vegetative growth parameters, in turn better bulb yield attributing parameters.

The pooled results on both marketable and total bulb yield in garlic indicated significant variations among the tested INM modules (Table 2). The marketable bulb yield varies from 26.13 qha<sup>-1</sup> (T<sub>3</sub>) to 44.70 qha<sup>-1</sup> (T<sub>2</sub>) with average yield of 36.85 qha<sup>-1</sup> while that of total bulb yield from 34.31 qha<sup>-1</sup> (T<sub>3</sub>) to 55.75 qha<sup>-1</sup> (T<sub>2</sub>) with a mean yield of 47.05 qha<sup>-1</sup> among different INM modules. Significantly highest marketable and total bulb yield was recorded in DOGR recommended treatment, T<sub>2</sub>. However, statistical parity was recorded among all the INM modules except treatment T<sub>1</sub>, T<sub>3</sub> and T<sub>5</sub>. This might be due to higher uptake of NPKS by garlic crop, resulting better vegetative growth parameters, in turn higher bulb yield in garlic. Further, at higher levels of organics, irrespective of sources, improved soil physical conditions might have resulted in better root growth, nutrient absorption, subsequently better bulb development. Increased bulb yield in onion with increased FYM as in case of DOGR recommendation, T<sub>2</sub>, have also been observed in onion [13]. The present study also indicate the better efficacy of INM module T<sub>2</sub>, T<sub>6</sub> and T<sub>9</sub> towards higher vegetative growth, viz., plant height, number of leaves plant<sup>-1</sup> and neck girth, which in turn increased the bulb yield. It has been reported that bulb yield was positively and significantly associated with plant height, number of leaves plant<sup>-1</sup>, leaf length and

breadth [14]. Similar reports of the better efficacy of INM module T<sub>2</sub>, T<sub>6</sub> and T<sub>9</sub> in garlic was also recorded under Pune, Rahuri, Junagarh, Kanpur, Hissar and Coimbatore conditions [4].

The study also revealed superiority of poultry manure over vermicompost and FYM at lower doses. Similar reports were also reported in cassava [15] and garlic [16].

Integrated application of inorganic fertilizers along with combined application of FYM, poultry manure and vermicompost recorded significantly higher bulb yield in garlic. This might be due to better uptake and utilization of nutrients by garlic crop when applied from different sources rather than their sole application. The integrated approach might be attributed to increased growth of plants in respect of plant height, number of leaves, neck thickness etc. the healthy top growth might be responsible for higher rate of photosynthates and accumulation of carbohydrates which resulted increased average bulb weight and ultimately in higher bulb yield. Similar report was also reported in garlic [17].

The BC ratio calculated on the basis of three years research results also revealed better efficacy of treatment, T<sub>2</sub>, the DOGR recommendation than rest of the INM modules evaluated (Table 2). Highest BC ratio of 1.38 was recorded in T<sub>2</sub>, closely followed by T<sub>4</sub> (1.15). Hence, from producer's point of view, both T<sub>2</sub> and T<sub>4</sub> are better INM modules for garlic. On the other hand, lowest BC ratio of 0.34 was calculated for T<sub>3</sub>.

The impact of different INM modules on shelf life of garlic bulbs indicated significant variations among different INM modules for shelf life and TSS of garlic bulbs (Table 3). Cumulative storage loss after four months of storage revealed significantly lowest Physiological Loss in Weight (PLW) in bulbs produced by T<sub>4</sub> (10.10%), closely followed by T<sub>2</sub> (12.01) than rest of the INM modules. The pooled results data also indicated significant variation among the INM modules which ranges from 10.78% (T<sub>2</sub>) to 17.70% (T<sub>3</sub>) with a mean value of 14.07% for cumulative rotting while from 21.19 (T<sub>4</sub>) to 36.20% (T<sub>7</sub>) with average of 29.28% for total cumulative losses after

four months of storage under ambient condition. Significantly lowest % of rotting and total losses was recorded in plots receiving INM module of T<sub>2</sub>, T<sub>4</sub> and T<sub>8</sub> than rest of the treatment schedules. The results clearly indicate the superiority of T<sub>2</sub>, T<sub>4</sub> and T<sub>8</sub> than rest of the treatments. The present study also indicates the superiority of poultry manure to reduce the storage losses under ambient conditions when applied with inorganic fertilizers, thereby enhance the shelf life of garlic bulbs.

Similarly, the TSS varies from 34.04% (T<sub>3</sub>) to 40.60% (T<sub>2</sub>) in variety, Agrifound White Significantly highest TSS of 40.60% was recorded in T<sub>2</sub> than rest of the treatments. However, statistical parity was recorded with T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub> and T<sub>9</sub> (38.80 to 38.94%).

## Conclusion

The results obtained from three years field trials, it may be concluded that integrated application of inorganic fertilizers @ 100:50:50:50 NPKS kg ha<sup>-1</sup> and organic sources as FYM @ 20 tha<sup>-1</sup> (T<sub>2</sub>) not only increases the vegetative growth, bulb yield and yield attributing parameters but also increases bulb quality as well as shelf life garlic bulbs under ambient condition. The next best INM module was integrated application of @ 75:40:40:40 NPKS kg ha<sup>-1</sup> + FYM @ 7.5 t ha<sup>-1</sup> + PM @ tha<sup>-1</sup> (T<sub>6</sub>) in garlic.

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