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Effect of integrated nutrient management on growth and yield of garlic (*Allium sativum* L.)

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Abstract
An experiment was conducted during *Rabi* season 2018 at the Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab, India. The experiment was laid out in a randomized block design with three replications. The treatments consisted of Application of different combinations of fertilizers increased the growth and yield in garlic. The maximum plant height (58.83 cm), numbers of leaves (7.47) at 120 DAP. The maximum yield plot^{-1} (5.63 kg), yield ha^{-1} (15.00 t), average fresh weight (50.88 g), average dry weight of bulb (31.88 g), equatorial diameter (7.17 cm), polar diameter (4.93 cm), average fresh weight of cloves (30.52 g), number of cloves bulb^{-1} (24.33), length of cloves (4.73 cm), neck thickness (4.37 cm), dry matter content (42.17 per cent) were recorded with the application of (100 per cent RDF＋Vermicompost @ 6 t ha^{-1}＋ Sulphur @ 45 kg ha^{-1}). These results suggested that the optimum production of garlic can be obtained with application of (100 per cent RDF＋Vermicompost @ 6 t ha^{-1}＋ Sulphur @ 45 kg ha^{-1}).

Keywords: Integrated nutrient management, growth, yield attributes, RDF

Introduction
Garlic (*Allium sativum* L.) is the most widely cultivated *Allium* species after onion belonging to the family Alliaceae. It is native to Central Asia and Mediterranean region is considered as its secondary centre of origin. Garlic is one of the main *Allium* vegetable crops grown worldwide with respect to its production and economic value. Garlic is second most widely used spice after onion. It has long been recognized as a valuable spice for all over the world and is one of the most important remunerative bulbous spice and medicinal crop grown commercially.

Application of synthetic chemical fertilizers alone can have deleterious effect on soil health and can also lead to unsustainable yields, whereas integration of inorganic fertilizers with organic manures may reduce the use of synthetic fertilizers and improve the soil health as well as plant nutrient availability resulting in higher crop yields, besides being environmentally safe. Plant nutrition is one of the key factors influencing growth and yield of crop plants. Bulbous crops are heavy feeders, requiring optimum supplies of nitrogen, phosphorus, potassium and sulphur as well as other nutrients which can adversely affect growth, yield of bulbs under sub optimal levels in the soil.

In order to improve garlic production, different means of fertilizer application (type, time and rate) is considered to be the limiting factor which should be given due consideration and the production of vigorous sprouts is one among the foremost necessary factor of flourishing garlic production through balanced nutrient application. High yield of garlic can be obtained through efficient and balanced use of organic and inorganic compounds. Therefore, the importance of 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 (Brewster and Butler, 1989) [1].

The integrated nutrient management is helpful in increasing the growth and yield in garlic. The growth and yield potential of garlic can be increased by application of sulphur. The combination of sulphur and vermicompost performed better with respect to growth characters, yield and yield contributing characters. The plant hormones were extensively reported in worm processed materials possibly due to higher microbial populations (Krishnamoorthy and Vajranabhaian, 1986) [8].

Sulphur is essential for building up sulphur containing amino acids in plant cells, particularly in the early stages of plant growth. This deficiency is becoming acute over time due to extensive use of sulphur free fertilizer, intensive crop production and poor sulphur status of soil. Non-application of sulphur in sulphur deficient soils has often resulted in low yield of garlic. As such sulphur is a key nutrient in garlic production; therefore lack of its optimum supply in different plant parts limits the crop growth at any stage, resulting in yield reduction and also had poor utilization of macro and micronutrients.

Material and Methods

An experiment was conducted during *Rabi* season 2018, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib to study the effect of integrated nutrient management on growth and yield of garlic (*Allium sativum* L.). The experiment was laid out in randomized block design with ten integrated nutrient management treatments *viz.* T_1- Control, T_2- 100 % RDF, T_3- 100 % RDF ＋ Vermicompost @ 4 t ha^{-1}, T_4- 100 % RDF ＋ Vermicompost @ 6 t ha^{-1}, T_5- 100 % RDF ＋ Sulphur @ 30 kg ha^{-1}, T_6- 100 % RDF ＋ Sulphur @ 45 kg ha^{-1}, T_7- 100 % RDF ＋Vermicompost @ 4 t ha^{-1} ＋ Sulphur @ 30 kg ha^{-1}, T_8- 100 % RDF ＋Vermicompost @ 4 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}, T_9- 100 % RDF ＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 30 kg ha^{-1}, T_{10}- 100 % RDF ＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}. The treatments were replicated thrice. The soil texture of experimental site was having sandy loam with pH (7.5). It was moderately fertile, with available nitrogen (290 kg ha^{-1}), available phosphorus (15.14 kg ha^{-1}), available potassium (127 kg ha^{-1}), available sulphur (12.40 kg ha^{-1}), organic carbon (0.59 %) and electrical conductivity (0.30 dS m^{-1}). The garlic variety PG-17 was transplanted at a spacing of 15 cm x 7.5 cm. The recommended dose of fertilizers for garlic is 125, 62.5 kg of N, P_2O_5 and FYM 50 t ha^{-1}, respectively. The experimental site was kept free from weeds by pre emergence herbicide and manual weeding. Plant protection measures and irrigation whenever required were provided in same manner for all the treatments. Manual harvesting was done when crop reached at maturity stage. After that bulbs of different treatments were collected separately. Yield attributes were recorded after harvesting of crop. Thus, bulb yield of each plot was recorded in kg and then converted into tonnes ha^{-1}. Statistical data was analyzed by standard procedure.

Result and Discussion

The result of the present study (Table-1) indicated that growth parameters such as plant height, and number of leaves at 30, 60, 90 and 120 DAP were significantly influenced by different levels of integrated nutrient management. The maximum plant height (19.43 cm) at 30, (32.20 cm) at 60, (42.53 cm) at 90 and (58.83 cm) at 120 DAP was recorded in treatment T_{10} (100 per cent RDF ＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}). The increase in plant height may be due to major nutrient supplied by the inorganic fertilizers will be utilized quickly by the crop and all other micro and macro nutrients available in organic manures will be released slowly and the increased root system of the plants might have resulted in an increased uptake of nutrients which were used in photosynthesis (Bhandari *et al.*, 2012) [2]. The higher and better above ground growth may be attributed to enhanced photosynthetic activity which could have been the result of increased chlorophyll synthesis in presence of desired amount of sulphur. Plant height increased gradually with increasing levels of sulphur (Zaman *et al.*, 2011) [19]. Combination of vermicompost and sulphur helped to increase availability of major nutrients which being the constituent of protein and protoplasm, vigorously inducing the vegetative development of the plants (Joshi and Kelkar, 1951) [7]. The findings of present investigation are in close conformity with those of (Reddy *et al*. 2005) in onion, (Gowda *et al*. 2007) [5] in garlic, (Suthar, 2009) [14, 15] in garlic, Jawadagi *et al*. (2012) [6] in onion and (Verma *et al*. 2013) [17] in garlic, who reported that plant height increased significantly with the application of vermicompost.

The maximum number of leaves per plant (3.67) at 30, (5.03) at 60, (6.53) at 90 and (7.47) at 120 DAP was recorded in treatment T_{10} (100 per cent RDF ＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}). This effect could be attributed to the solubilization effect of plant nutrients by addition of sulphur and due to the role of sulphur in the elongation of stem or stalk resulting in more number of leaves per plant (Jawadagi *et al*., 2012) [6]. Vermicompost is known to contain micronutrients apart from major nutrients. Besides this, vermicompost has been reported to contain several plant growth promoters, enzymes, beneficial bacteria and mycorrhizae (Gupta, 2005) [4]. Therefore, the availability of higher quantity of nutrients, improvement in the physical properties of soil and increased activity of microbes with higher levels of organics might have helped in increasing number of leaves. The number of leaves per plant was increased in response to increasing amount of vermicompost (Degwale, 2016) [3].

Yield attributes, which determine yield, is the resultant of the vegetative development of the plant. The data pertaining to yield attributes presented in (Table-2 & 3) revealed significant differences among various treatments. The data revealed that the maximum average fresh weight of bulb (50.88 g), average dry weight of bulb (31.88 g), equatorial diameter of bulb (7.17 cm), polar diameter of bulb (4.93 cm), length of clove (4.73 cm), number of cloves $bulb^{-1}$ (24.33), average fresh weight of cloves $bulb^{-1}$ (30.52 g), neck thickness (4.37 cm), yield per plot (6.00 kg), yield per hectare (15.00 t) was recorded in treatment T_{10} (100 per cent RDF＋Vermicompost @ 6 t ha^{-1}＋ Sulphur @ 45 kg ha^{-1}). Maximum dry matter (57.10 %) was obtained in T_4 (100 per cent RDF＋Sulphur @ 30 kg ha^{-1}). The maximum bulbing ratio (61.37) was recorded in treatment T_7 (100 per cent RDF＋Vermicompost @ 4 t ha^{-1}＋ Sulphur @ 30 kg ha^{-1}).

The maximum average fresh weight of bulb, average dry weight of bulb, equatorial diameter of bulb, polar diameter of bulb, length of clove, number of cloves $bulb^{-1}$, average fresh weight of cloves $bulb^{-1}$, neck thickness, yield per plot, yield per hectare may be due to application of sulphur in improving uptake of nutrient by root system, increased chlorophyll content, photosynthesis activity and protein content in crop plants (Patidar *et al*., 2017) [12]. Due to application of vermicompost in soil improved nutrient availability and improvement in physical condition of soil which provides balanced nutritional environment both in soil rhizosphere and plant system. Application of vermicompost was in conformity with the earlier findings of (Suthar, 2008) in garlic and (Patidar *et al.* 2017) [12] in garlic. The application of the vermicompost which helps in promoting the sink size in terms of bulb size and vermicompost relatively contains more exchangeable plant nutrient than those by other plant growth media (Nainwal *et al.*, 2015) [11]. Similar results were also reported by (Yadav *et al.* 2017) [18] and (Mishra and Prasad, 1966). Sulphur had significant effects on dry matter content and increased progressively with increasing levels of sulphur. This might be possible due to maximum vegetative growth which enhanced maximum photosynthesis and accumulation of more dry matter (Zaman *et al*., 2011) [19].

Table 1: Effect of integrated nutrient management on growth attributes of garlic

Treatments	Treatment details	Plant height (cm)				Number of leaves plant^{-1}			
		30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1	Control	11.60	22.77	34.77	40.63	1.27	2.60	3.23	4.17
T_2	100 % RDF	12.60	23.60	36.60	44.23	2.23	3.17	4.03	5.13
T_3	100 % RDF ＋Vermicompost @ 4 t ha^{-1}	17.30	27.97	40.20	54.46	2.77	4.60	6.03	6.97
T_4	100 % RDF ＋Vermicompost @ 6 t ha^{-1}	14.81	25.07	35.73	52.43	2.23	3.30	4.23	5.30
T_5	100 % RDF ＋Sulphur @ 30 kg ha^{-1}	15.77	26.53	38.80	46.25	2.53	4.07	4.63	5.63
T_6	100 % RDF ＋ Sulphur @ 45 kg ha^{-1}	13.60	24.60	36.60	50.46	2.07	4.10	4.50	5.50
T_7	100 % RDF ＋Vermicompost @ 4 t ha^{-1}＋ Sulphur @ 30 kg ha^{-1}	15.90	26.53	39.83	51.27	2.60	3.70	4.10	5.10
T_8	100 % RDF＋Vermicompost @ 4 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}	16.33	27.43	36.20	48.37	2.27	3.70	3.93	4.67
T_9	100 % RDF＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 30 kg ha^{-1}	18.53	30.83	40.87	56.19	3.47	4.77	6.23	7.10
T_{10}	100 % RDF＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}	19.43	32.20	42.53	58.83	3.67	5.03	6.53	7.47
	SE(m)±	0.30	0.47	0.67	1.05	0.09	0.12	0.12	0.15
	CD $_{(0.05)}$	0.90	1.38	1.98	3.11	0.28	0.35	0.35	0.45

Table 2: Effect of integrated nutrient management on yield attributes of garlic

Treatments	Treatment details	Average fresh weight of bulb (g)	Average dry weight of bulb (g)	Equatorial diameter of bulb (cm)	Polar diameter of bulb (cm)	Clove Length (cm)	Number of cloves bulb^{-1}
T_1	Control	26.0z2	17.08	3.77	2.30	2.17	12.33
T_2	100 % RDF	28.33	20.10	4.00	3.17	2.57	14.67
T_3	100 % RDF ＋Vermicompost @ 4 t ha^{-1}	47.17	29.73	6.17	3.87	3.83	22.00
T_4	100 % RDF ＋Vermicompost @ 6 t ha^{-1}	40.06	17.14	5.00	2.60	2.45	20.00
T_5	100 % RDF ＋Sulphur @ 30 kg ha^{-1}	28.04	18.03	5.43	2.77	2.62	17.67
T_6	100 % RDF ＋S @ 45 kg ha^{-1}	31.88	18.58	5.93	3.73	3.38	18.00
T_7	100 % RDF ＋Vermicompost @ 4 t ha^{-1} ＋Sulphur @ 30 kg ha^{-1}	40.32	24.55	4.43	3.30	2.78	19.67
T_8	100 % RDF＋Vermicompost @ 4 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}	40.83	24.72	6.03	3.17	3.03	16.00
T_9	100 % RDF＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 30 kg ha^{-1}	47.53	30.00	6.73	4.43	3.94	23.67
T_{10}	100 % RDF＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}	50.88	31.88	7.17	4.93	4.73	24.33
	SE(m)±	1.18	0.80	0.19	0.12	0.11	0.63
	CD $_{(0.05)}$	3.52	2.39	0.56	0.34	0.32	1.86

Table 3: Effect of integrated nutrient management on yield attributes of garlic

Treatments	Treatment details	Average fresh weight of cloves bulb^{-1} (g)	Neck thickness (cm)	Yield plot^{-1} (kg)	Yield ha^{-1} (t)	Dry matter (%)	Bulbing ratio
T_1	Control	21.02	1.70	3.40	8.50	34.03	45.19
T_2	100 % RDF	21.71	2.07	4.53	11.33	28.91	51.70
T_3	100 % RDF ＋ Vermicompost @ 4 t ha^{-1}	29.01	3.40	5.13	12.83	36.95	55.10
T_4	100 % RDF ＋Vermicompost @ 6 t ha^{-1}	24.02	2.47	4.13	10.33	57.10	50.33
T_5	100 % RDF ＋Sulphur @ 30 kg ha^{-1}	24.63	2.77	4.58	11.46	35.77	50.96
T_6	100 % RDF ＋Sulphur @ 45 kg ha^{-1}	23.29	2.07	4.63	11.59	41.79	34.80
T_7	100 % RDF ＋Vermicompost @ 4 t ha^{-1} ＋ Sulphur @ 30 kg ha^{-1}	23.32	2.70	4.80	12.00	39.00	61.37
T_8	100 % RDF ＋Vermicompost @ 4 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}	26.21	3.07	5.08	12.69	39.31	50.85
T_9	100 % RDF ＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 30 kg ha^{-1}	29.04	4.07	5.23	13.08	36.90	60.41
T_{10}	100 % RDF ＋Vermicompost @ 6 t ha^{-1} ＋ Sulphur @ 45 kg ha^{-1}	30.52	4.37	6.00	15.00	37.31	60.92
	SE(m)±	0.52	0.09	0.14	0.35	1.96	2.98
	CD $_{(0.05)}$	1.53	0.28	0.42	1.04	5.83	8.86

According to (Gupta, 2005) [4] increase in dry matter content may due to the presence of micronutrients apart from major nutrients in vermicompost. The increase in neck thickness as well as equatorial diameter of the bulb will results into increase in bulbing ratio of garlic which might be due to the application of vermicompost which might have contained great quantity of microorganisms, especially bacteria, and a high concentration of plant hormones such as auxins, gibberellins and cytokinins in earthworm-processed sewage sludge (Tomati *et al*., 1987) [16].

Conclusion

On the basis of the forgoing discussion it can be concluded that the Integrated nutrient management is help in increasing the growth and yield in garlic. The growth and yield potential of garlic can be increased by application of (100 per cent RDF + Vermicompost @ 6 t ha^{-1} + Sulphur @ 45 kg ha^{-1}). The treatment T_{10} (100 per cent RDF+ Vermicompost @ 6 t ha^{-1}+ Sulphur @ 45 kg ha^{-1}) was performed better with respect to growth characters [plant height (cm) and number of leaves $plant^{-1}$], yield and yield contributing characters [average fresh and dry weight of bulb (g), equatorial and polar diameter of bulb (cm), clove length (cm), number of cloves $bulb^{-1}$, average fresh weight of cloves $bulb^{-1}$, neck thickness (cm), yield $plot^{-1}$(kg), yield ha^{-1}(t), dry matter (%) and bulbing ratio.

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