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Effect of Different Levels of Organic Manures and Munch Materials on Garlic (*Allium sativum* L.) under Fatehgarh Sahib Conditions

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Abstract

An investigation was carried out on "Effect of different levels of organic manures and munch materials on garlic (*Allium sativum* L.) under Fatehgarh Sahib condition" was conducted for two consecutive years (2018-19 and 2019-20) at Experimental Research Farm, Kharora, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab, India. The experiment comprised of sixteen treatments involving with four levels of factor O (Organic manures) *viz.,* O_0: No manure @ 0 t/ha, O_1: Farm yard manure (FYM) @ 20 t/ha, O_2: Vermicompost @ 5 t/ha, O_3: Poultry manure @ 10 t/ha and four levels of factor M (Mulch materials) *viz.,* M_0: No mulch @ 0 t/ha, M_1: Paddy straw @ 6 t/ha, M_2: Saw dust @ 10 t/ha, M_3: Rice husk @ 5 t/ha. The experiment was laid out in factorial randomized block design with three replications. The treatment consisted of O_0M_0: No Manure @ 0 t/ha + No Mulch @ 0 t/ha, O_0M_1: No Manure @ 0 t/ha + Paddy Straw @ 6 t/ha, O_0M_2: No Manure @ 0 t/ha + Saw Dust @ 10 t/ha, O_0M_3: No Manure @ 0 t/ha + Rice Husk @ 5 t/ha, O_1M_0: FYM @ 20 t/ha + No Mulch @ 0 t/ha, O_1M_1: FYM @ 20 t/ha + Paddy Straw @ 6 t/ha, O_1M_2: FYM @ 20 t/ha + Saw Dust @ 10 t/ha, O_1M_3: FYM @ 20 t/ha + Rice Husk @ 5 t/ha, O_2M_0: Vermicompost @ 5 t/ha + No Mulch @ 0 t/ha, O_2M_1: Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha, O_2M_2: Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha, O_2M_3: Vermicompost @ 5 t/ha + Rice Husk @ 5 t/ha, O_3M_0: Poultry Manure @ 10 t/ha + No Mulch @ 0 t/ha, O_3M_1: Poultry Manure @ 10 t/ha + Paddy Straw @ 6 t/ha, O_3M_2: Poultry Manure @ 10 t/ha + Saw Dust @ 10 t/ha, O_3M_3: Poultry Manure @ 10 t/ha + Rice Husk @ 5 t/ha. Pooled data over two years revealed that maximum plant height (68.56 cm), number of leaves per plant (8.41), leaf length (60.18 cm), neck thickness (4.34 cm), number of cloves per bulb (28.19), clove length (4.05 cm), clove width (1.41 cm), average weight of bulb (40.01 g), average weight of clove (3.04 g), marketable yield per hectare (155.83 q), total yield per hectare (390.97 q) were recorded with the application of vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha. In terms of economics revealed that the application of vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha produced the highest gross returns of Rs. 935000.00, highest net income of Rs. 778783.39 and highest benefit cost ratio (4.99).

***Key words*:** *Allium sativum* L., Organic manures, Munch materials, Growth, Yield, Economics

Garlic (*Allium sativum* L.) is an aromatic herbaceous bulbous plant belonging to the family Alliaceae. It is the second most widely cultivated bulb crop after onion. It is cross pollinated crop with chromosome number of 2n=16 [1]. Garlic is a multiple bulb consisting of 6-20 smaller bulblets or segments called cloves, covered with a protective thin membraneous sheath [2]. It has a relatively sparse, shallow root system and sensitive to moisture stress [3]. It is mainly used for flavouring and as seasoning vegetables and meat dishes. It is primarily grown from its cloves. Green tops are eaten fresh and cooked especially in tropical areas and consumption of immature bulbs as salad purpose [4]. Garlic is high nutritive value as compared to other bulbous crops. It is rich source of carbohydrates (29.0%), proteins (6.3%), minerals (0.3%) and essential oils (0.1-0.4%) and also contains appreciable quantities of fats, vitamin C and sulphur [5]. The inhalation of garlic oil or garlic juice has generally been recommended by doctors in case of pulmonary tuberculosis, cough and red eyes [6]. Garlic can inhibit toxic germs in the stomach, promotes secretion of gastric and stop synthesis of carcinogen and the amino acid 'Allicin', which has a hydro chlotestrolenic action is present in the aqueous extract of garlic which reduces cholesterol concentration in human blood [7]. Garlic therapy has also have been suggested in constipation, faulty digestion, inadequate food intake, chronic coughs, leprosy and many other diseases [8]. Garlic is local to Central Asia, Siberia and west of the Himalayas. It has been developed in England before 1540 AD and now generally developed everywhere throughout the world. Some writings suggest that garlic was grown in China as far back as 4000 years ago. China, India, Korea, Spain and USA are the significant garlic developing nations of which China produces 80% of world flexibly of garlic alone. The significant garlic producing states in India are Madhya Pradesh, Gujarat, Orissa, Rajasthan, Maharashtra and Uttar Pradesh. The territory and creation of garlic in the nation during 2018-19 is evaluated around 358 thousand hectare and 2910 thousand Metric tons

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and during 2019-20 covers an area around 363 thousand hectares with production of 2917 thousand Metric tons [9].

Organic manure is eco-friendly, economical viable and have ecological sound. It improves the physical, chemical and biological properties of soil and also play a role for improve soil structure, water holding capacity and more extensive in root development. It also improves the quality of soil micro-flora and fauna activity, which provide available micro-nutrients to plants. Organic matter promotes biological activities and induces life for plants [10]. Farmyard manure is a fertilizer composed of waste products and produced by the farm animals, most commonly cows by using their dung and urine. The waste products contain valuable nutrients, which takes nitrogen that plant needs mostly for their growth and development. FYM is the extensively used as organic source of plant nutrients and helps to maintaining the organic carbon content in soil [11]. Vermicompost is a potential organic nutrient source which provides additional plant nutrients that are not found in inorganic fertilizers. Vermicompost are finely divided peat like material with high porosity, aeration, drainage and water holding capacity and usually contain most nutrients in available forms such as nitrates, phosphates, exchangeable calcium and soluble potassium [12]. Earthworms eat, grind and digest organic wastes with the help of aerobic and some anaerobic micro-flora, converting them into a much finger, humified and microbial active material [13]. Poultry manure improves physical, chemical and biological properties of soil and released nutrients can be used for growing crops [14].

Mulching is one of the good cultural practices for the favorable manipulation of micro-climate. The role of mulching on growth and production of plants is well recognized. Mulching in the semi-arid tropics has been suggested to conserve soil moisture [15-16], decrease soil temperature decrease run off and soil erosion and sometimes even substitutes the soil [17]. It protects the plants from loss of soil moisture by wind and soil evaporation and reduces the irrigation requirements [18]. Mulches help check weed growth and improve the soil structure and fertility by trapping nutrient-rich and wind-borne dust [19]. Mulches also help in better utilization of soil nutrients meeting up the need of irrigation and thus increase crop yield. Mulching economizes use of nitrogen fertilizer [20], need of organic fertilizer [21] and saves labour cost. Paddy straw is the common mulch, which are used for fruit and vegetable production. Though straw is poor in nutrient value but after decomposition, it makes soil more fertile. Among organic mulch materials, straw has a long life in comparison to other mulches. Straw mulch is the most useful in summer for moisture retention and heat protection [18]. Saw dust is carbon-rich organic material that needs certain microorganisms for its decomposition process. Saw dust is acidic in nature thus it is a good mulch choice for acid-loving plants such as rhododendrons and blueberries [16]. Rice husk as mulching materials improves water storage, moderates high soil temperature and helps to maintain soil organic matter [22]. It protects the soil surface again strain drop impact which causes the breakdown of aggregates to transportable sizes, improves soil structure, infiltration and also prevents soil erosion [23].

In India, expanding population has required the interest for immense amount of produce and quality seed, since seed is essential and least expensive information which empowers the vegetable cultivators to get most elevated returns per unit area and time. In this manner, so as to meet out vegetable necessity of the nation, there is a need to build the generation just as the profitability. Organic farming by using organic material makes positive role not only for soil and environment but also to the human health, promotes biological activities and induces life for plants. Natural manures and mulches are the wellsprings of plant supplements, which are taken from squanders of plants and creatures. After decay, it will discharge their supplements. As old as farming, the craft of gathering animals, plants and human squanders are utilized as natural compost, which is a decent wellspring of improving yield efficiency. Along these lines, utilization of organic manures and natural mulch has turned into an acknowledged way to improvement in soil and securing the earth. This methodology uses a reasonable blend of organic manure and mulch. Therefore, this investigation was undertaken to evaluate the effect of different organic manures and mulching on growth, yield attributes and economics of garlic crop, with the objective of identifying suitable organic manures and mulches treatments that maximize productivity of garlic under field condition.

MATERIALS AND METHODS

The study was carried out at Experimental Farm, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab, India during *Rabi* season 2018-19 and 2019-20 and it's situated between 30° 41' 51.93" N latitudes and 76° 24'36.1" E longitudes and at a mean height of 279 meter above sea level. The experimental soil was sandy loam having pH 7.3, EC 0.64 dS m^{-1}, 295.40 kg ha^{-1} available nitrogen, 22.43 kg ha^{-1} available phosphorus and 162.38 kg ha ha^{-1} available potassium. The experiment was laid out in factorial randomized block design (FRBD) with three replications. The experiment consisted of two factors such as Factor A: Organic manure (4 levels), O_0: No Manure @ 0 t/ha O_1: Farm Yard Manure @ 20 t/ha, O_2: Vermicompost @ 5 t/ha and O_3: Poultry Manure @ 10 t/ha and Factor B: Mulch materials (4 levels), M_0 : No Mulch @ 0 t/ha; M_1: Paddy Straw @ 6 t/ha; M_2: Saw Dust @ 10 t/ha and M_3: Rice husk @ 5 t/ha. There were 16 treatment combinations such as O_0M_0- No Manure @ 0 t/ha + No Mulch @ 0 t/ha; O_0M_1- No Manure @ 0 t/ha + Paddy Straw @ 6 t/ha; O_0M_2- No Manure @ 0 t/ha + Saw Dust @ 10 t/ha; O_0M_3- No Manure @ 0 t/ha + Rice Husk @ 5 t/ha; O_1M_0- FYM @ 20 t/ha + No Mulch @ 0 t/ha; O_1M_1 - FYM @ 20 t/ha + Paddy Straw @ 6 t/ha; O_1M_2- FYM @ 20 t/ha + Saw Dust @ 10 t/ha; O_1M_3- FYM @ 20 t/ha + Rice Husk @ 5 t/ha; O_2M_0- Vermicompost @ 5 t/ha + No Mulch @ 0 t/ha; O_2M_1- Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha; O_2M_2- Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha; O_2M_3- Vermicompost @ 5 t/ha + Rice Husk @ 5 t/ha; O_3M_0- Poultry Manure @ 10 t/ha + No Mulch @ 0 t/ha; O_3M_1- Poultry Manure @ 10 t/ha + Paddy Straw @ 6 t/ha; O_3M_2- Poultry Manure @ 10 t/ha + Saw Dust @ 10 t/ha and O_3M_3- Poultry Manure @ 10 t/ha + Rice Husk @ 5 t/ha. The recommended dose of FYM was applied at 50 t/ha at about 30 days before planting. 125 kg N was applied in three equal splits at 30, 45 and 60 DAS and 125 kg of P_2O_5 before planting. Afterwards the clove of garlic was planting on well-prepared field on 3rd week of the October, 2018 and 2019 at depth of 5 cm with seed rate 600kg/ha and spacing of 15 cm × 7.5 cm within and rectangular system of planting was followed to have more aeration space between the plants. There were 48-unit plots and the size of each unit plot was 2.5m × 2.0m = 5.0m^2. All appropriate cultural practices including weeding, watering, hoeing and insect-pest control were timely performed. The experimental plots were visited regularly in the morning and evening hours for observing the crop and forthcoming problems with them. Observations on different growth, yield and economics attributing characters were recorded from seven randomly selected plants from each replication to find out the significance difference of organic manures and mulch materials on growth yield and economics contributing characters of garlic crop. Observations were recorded on randomly selected plants with different characters i.e. plant height (cm), number of leaves plant^{-1}, leaf length (cm), neck thickness (cm), number of cloves/bulb, average clove weight (g), average bulb weight (g), marketable yield (q/ha), total yield (q/ha) and economics of treatments with following recommended procedures. The experimental data for various observations were analyzed by fisher's method of analysis of variance (ANOVA) as per outlined (24). The data were analyzed and are presented at the 5% level of significance.

RESULTS AND DISCUSSION

Growth parameters

Plant height (cm)

The pooled data pertaining to plant height at harvest has been presented in (Table 1). The result showed significant difference among different treatments for plant height at harvest. Among organic manures, O_2 (Vermicompost @ 5 t/ha) resulted maximum (63.16cm) plant height. This treatment i.e. O_2 (Vermicompost @ 5 t/ha) was followed by the treatment O_3 (Poultry manure @ 10 t/ha) having value of 62.35 cm. Minimum plant height (52.72 cm) was observed with O_0 (No manure @ 0 t/ha). The increase plant height might be due to enhanced availability of nutrients and production of promoting substances that caused cell elongation and multiplication [25]. Another possible reason might be due to organic manures improves soil texture and help plant to have a good root proliferation, which leads to improvement in plant height [11], [26-27]. Among mulch material, maximum plant height (62.67 cm) was recorded in M_1 (Paddy straw @ 6 t/ha). This treatment i.e. M_1 (Paddy straw @ 6 t/ha) was followed by the treatment M_2 (Saw dust @ 10 t/ha) having value of 61.88 cm. Whereas, minimum plant height (54.07 cm) was observed with M_0 (No mulch @ 0 t/ha). Mulching provides a favorable environment for better growth which results in more vigorous and healthier plants. Increase in physiochemical property of soil like as temperature, moisture, nutrient content and organic carbon content stimulate root growth which leads to the greater plant growth [28-30]. Under the interaction effect of organic manures and mulching, pooled data of both of the years were non-significant on plant height.

Table 1 Response of organic manures and mulching on plant height (cm), number of leaves/plant and leaf length (cm) in garlic (cv.PG-17)

Treatment details	Plant height (cm)			Number of leaves / plant			Leaf length (cm)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Organic manures (O)									
O_0 (No manure @ 0 t/ha)	52.32	53.12	52.72	5.71	5.98	5.84	43.95	45.07	44.51
O_1 (Farm yard manure @ 20 t/ha)	58.30	59.10	58.70	6.57	6.92	6.74	51.96	53.16	52.56
O_2 (Vermicompost @ 5 t/ha)	62.68	63.64	63.16	7.48	7.83	7.65	55.92	57.12	56.52
O_3 (Poultry manure @ 10 t/ha)	61.87	62.84	62.35	7.25	7.60	7.43	55.56	56.76	56.16
SEM (±)	1.44	1.46	1.45	0.17	0.23	0.18	1.34	1.38	1.36
CD (0.05)	2.94	2.99	2.97	0.35	0.46	0.38	2.74	2.83	2.78
Mulch materials (M)									
M_0 (No mulch @ 0 t/ha)	53.67	54.47	54.07	6.04	6.30	6.17	47.03	48.15	47.59
M_1 (Paddy straw @ 6 t/ha)	62.11	63.24	62.67	7.33	7.68	7.50	55.10	56.30	55.70
M_2 (Saw dust @ 10 t/ha)	61.48	62.28	61.88	7.08	7.43	7.26	54.36	55.56	54.96
M_3 (Rice husk @ 5 t/ha)	57.90	58.70	58.30	6.56	6.91	6.74	50.91	52.11	51.51
SEM (±)	1.44	1.46	1.45	0.17	0.23	0.18	1.34	1.38	1.36
CD (0.05)	2.94	2.99	2.97	0.35	0.46	0.38	2.74	2.83	2.78
Interaction (O*M)									
O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha)	50.53	51.33	50.93	5.36	5.38	5.37	40.30	41.17	40.73
O_0M_1 (No Manure @ 0 t/ha + Paddy Straw @ 6 t/ha)	53.86	54.66	54.26	6.08	6.43	6.26	47.10	48.30	47.70
O_0M_2 (No Manure @ 0 t/ha + Saw Dust @ 10 t/ha)	53.73	54.53	54.13	5.99	6.34	6.16	47.03	48.23	47.63
O_0M_3 (No Manure @ 0 t/ha + Rice Husk @ 5 t/ha)	51.13	51.93	51.53	5.41	5.76	5.58	41.38	42.58	41.98
O_1M_0 (FYM @ 20 t/ha + No Mulch @ 0 t/ha)	54.13	54.93	54.53	6.12	6.47	6.30	47.52	48.72	48.12
O_1M_1 (FYM @ 20 t/ha + Paddy Straw @ 6 t/ha)	60.13	60.93	60.53	6.94	7.29	7.12	54.41	55.61	55.01
O_1M_2 (FYM @ 20 t/ha + Saw Dust @ 10 t/ha)	59.93	60.73	60.33	6.70	7.05	6.87	54.23	55.43	54.83
O_1M_3 (FYM @ 20 t/ha + Rice Husk @ 5 t/ha)	59.00	59.80	59.40	6.51	6.86	6.69	51.67	52.87	52.27
O_2M_0 (Vermicompost @ 5 t/ha + No Mulch @ 0 t/ha)	55.73	56.53	56.13	6.43	6.78	6.60	50.35	51.55	50.95
O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha)	67.83	69.29	68.56	8.24	8.59	8.41	59.58	60.78	60.18
O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha)	66.27	67.07	66.67	7.94	8.29	8.12	58.32	59.52	58.92
O_2M_3 (Vermicompost @ 5 t/ha + Rice Husk @ 5 t/ha)	60.87	61.67	61.27	7.30	7.65	7.48	55.43	56.63	56.03
O_3M_0 (Poultry Manure @ 10 t/ha + No Mulch @ 0 t/ha)	54.30	55.10	54.70	6.23	6.58	6.40	49.96	51.16	50.56
O_3M_1 (Poultry manure @ 10 t/ha + Paddy straw @ 6 t/ha)	66.60	68.07	67.33	8.05	8.40	8.23	59.30	60.50	59.90
O_3M_2 (Poultry Manure @ 10 t/ha + Saw Dust @ 10 t/ha)	65.99	66.79	66.39	7.71	8.06	7.88	57.83	59.03	58.43
O_3M_3 (Poultry Manure @ 10 t/ha + Rice Husk @ 5 t/ha)	60.60	61.40	61.00	7.02	7.37	7.19	55.14	56.34	55.74
SEM (±)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Number of leaves per plant

The pooled data of both of the years in respect to number of leaves as influenced by organic manures and mulching has been presented in the (Table 1). Data revealed that among organic manures, O_2 (Vermicompost @ 5 t/ha) resulted in maximum (7.65) number of leaves which was statistically at par with the treatment O_3 (Poultry manure @ 10 t/ha) (7.43), whereas O_0 (No manure @ 0 t/ha) gave minimum number of leaves (5.84). More number of leaves per plant was obtained when the plants were supplied with ample quantity of organic manures as compared to control. The organic manures could improve the general condition of the soil and decomposed by micro-organisms and plant could make use of organic matter of varied nature [26]. Vermicompost contain plant growth promoters, enzymes, beneficial bacteria and mycorrhizae. Therefore, activity of microbes with higher level of organics might have helped in increasing number of leaves [25], [31]. Among mulch, maximum number of leaves (7.50) were recorded in M_1 (Paddy straw @ 6 t/ha) followed by the treatment M_2 (Saw dust @ 10 t/ha) having (7.26) leaves. Minimum (6.17) number of leaves were observed with M_0 (No mulch @ 0 t/ha). Among mulch, maximum number of leaves (7.50) were recorded in M_1 (Paddy straw @ 6 t/ha). The positive response of the paddy straw on leaf number may be due to improved water content of soil, heat energy and addition of some organic nitrogen and other minerals which improves nutrient status of soil that leads to increase the vegetative growth of plant and increases leaf number per plant in wheat [33]. Another possible reason might be due to addition of nutrient from straw mulch and reduction of competition [34-36]. The combined effect of organic manures and mulching was found non-significant on number of leaves in both of the trails.

Leaf length (cm)

An examination of pooled data for leaf length has been presented in (Table 1). The results showed significant difference among different treatments for leaf length. Among organic manures, O_2 (Vermicompost @ 5 t/ha) resulted maximum leaf length (55.52 cm), which was statistically at par with the treatment O_3 (Poultry manure @ 10 t/ha) was recorded (56.16 cm). Minimum leaf length (44.51cm) was observed with O_0 (No manure @ 0 t/ha). Among mulch material, maximum leaf length (55.70 cm) was recorded in M_1 (Paddy straw @ 6 t/ha). This treatment i.e. M_1 (Paddy straw @ 6 t/ha) was followed by the treatment M_2 (Saw dust @ 10 t/ha) having value of leaf length (54.96 cm) whereas, minimum leaf length (47.59 cm) was observed in M_0 (No mulch @ 0 t/ha). The increased leaf length may be due to the enhanced availability of nutrients and production of promoting substances that might have caused cell elongation and multiplication [26]. One of the possible reasons that vermicompost contain plant growth promoters, enzymes, beneficial bacteria and mycorrhizae [31]. Therefore, activity of microbes with higher level of organics might have helped in increasing leaf length [32] in garlic. The interaction effect of organic manures and mulching, pooled data of both of the years were non-significant on leaf length.

Table 2 Response of organic manures and mulching on neck thickness (cm)and number of cloves/bulb and Average clove weight (g) in garlic (cv. PG-17)

Treatment details	Neck thickness (cm)			Number of cloves / bulb			Average clove weight (g)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Organic manures (O)									
O_0 (No manure @ 0 t/ha)	1.81	2.16	1.99	19.75	20.79	20.27	2.02	2.16	2.09
O_1 (Farm yard manure @ 20 t/ha)	2.35	2.60	2.47	22.88	23.93	23.40	2.35	2.53	2.44
O_2 (Vermicompost @ 5 t/ha)	3.22	3.42	3.32	25.54	26.50	26.02	2.66	2.87	2.77
O_3 (Poultry manure @ 10 t/ha)	3.06	3.30	3.18	24.85	26.01	25.43	2.57	2.75	2.66
SEM (±)	0.16	0.18	0.16	0.51	0.51	0.49	0.06	0.07	0.06
CD (0.05)	0.32	0.38	0.33	1.04	1.05	1.01	0.12	0.15	0.13
Mulch materials (M)									
M_0 (No mulch @ 0 t/ha)	2.01	2.30	2.15	20.98	21.99	21.49	2.13	2.27	2.20
M_1 (Paddy straw @ 6 t/ha)	3.20	3.44	3.32	24.59	25.71	25.15	2.59	2.79	2.69
M_2 (Saw dust @ 10 t/ha)	2.92	3.12	3.02	24.02	25.19	24.61	2.47	2.69	2.58
M_3 (Rice husk @ 5 t/ha)	2.32	2.62	2.47	23.43	24.34	23.88	2.40	2.57	2.49
SEM (±)	0.16	0.18	0.16	0.51	0.51	0.49	0.06	0.07	0.06
CD (0.05)	0.32	0.38	0.33	1.04	1.05	1.01	0.12	0.15	0.13
Interaction (O*M)									
O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha)	1.55	1.97	1.76	19.46	20.41	19.93	1.99	2.13	2.06
O_0M_1 (No Manure @ 0 t/ha + Paddy Straw @ 6 t/ha)	2.03	2.28	2.16	19.95	21.27	20.61	2.06	2.21	2.14
O_0M_2 (No Manure @ 0 t/ha + Saw Dust @ 10 t/ha)	1.97	2.22	2.10	19.83	20.88	20.35	2.01	2.16	2.09
O_0M_3 (No Manure @ 0 t/ha + Rice Husk @ 5 t/ha)	1.69	2.18	1.94	19.77	20.59	20.18	2.00	2.14	2.07
O_1M_0 (FYM @ 20 t/ha + No Mulch @ 0 t/ha)	2.10	2.35	2.23	20.95	22.00	21.47	2.12	2.23	2.18
O_1M_1 (FYM @ 20 t/ha + Paddy Straw @ 6 t/ha)	2.49	2.74	2.62	23.76	24.81	24.29	2.49	2.70	2.59
O_1M_2 (FYM @ 20 t/ha + Saw Dust @ 10 t/ha)	2.48	2.73	2.61	23.46	24.51	23.99	2.43	2.64	2.54
O_1M_3 (FYM @ 20 t/ha + Rice Husk @ 5 t/ha)	2.31	2.56	2.44	23.35	24.40	23.88	2.36	2.57	2.46
O_2M_0 (Vermicompost @ 5 t/ha + No Mulch @ 0 t/ha)	2.22	2.47	2.35	22.36	23.38	22.87	2.28	2.43	2.35
O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha)	4.22	4.47	4.34	27.66	28.71	28.19	2.94	3.15	3.04
O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha)	3.77	3.82	3.80	26.66	27.71	27.19	2.78	3.11	2.95
O_2M_3 (Vermicompost @ 5 t/ha + Rice Husk @ 5 t/ha)	2.67	2.92	2.79	25.48	26.19	25.84	2.65	2.80	2.73
O_3M_0 (Poultry Manure @ 10 t/ha + No Mulch @ 0 t/ha)	2.15	2.40	2.28	21.15	22.20	21.67	2.13	2.27	2.20
O_3M_1 (Poultry manure @ 10 t/ha + Paddy straw @ 6 t/ha)	4.06	4.27	4.17	26.98	28.03	27.51	2.88	3.12	3.00
O_3M_2 (Poultry Manure @ 10 t/ha + Saw Dust @ 10 t/ha)	3.44	3.69	3.57	26.15	27.65	26.90	2.66	2.84	2.75
O_3M_3 (Poultry Manure @ 10 t/ha + Rice Husk @ 5 t/ha)	2.59	2.84	2.72	26.12	26.17	25.64	2.61	2.79	2.70
SEM (±)	0.31	0.37	0.32	1.01	1.03	0.99	0.12	0.15	0.13
CD (0.05)	0.64	0.75	0.66	2.07	2.10	2.02	0.25	0.30	0.26

Yield parameters

Neck thickness (cm)

The pooled data of both of the years in respect to the neck thickness as influenced by organic manures and mulching has been presented in the (Table 2). Data revealed that among organic manures, O_2 (Vermicompost @ 5 t/ha) resulted in maximum (3.32 cm) neck thickness which was statistically at par with the treatment O_3 (Poultry manure @ 10 t/ha), whereas O_0 (No manure @ 0 t/ha) gave minimum value (1.99 cm). Among mulch material, M_1 (Paddy straw @ 6 t/ha) resulted maximum neck thickness (3.32 cm), which was statistically at par with the treatment M_2 (Saw dust @ 10 t/ha). Minimum neck thickness (2.15 cm) was observed with M_0 (No mulch @ 0 t/ha). In interaction O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha) resulted in maximum (4.34 cm) neck thickness, which was statistically superior over the other treatments and statistically at par with O_3M_1 (Poultry Manure @ 10 t/ha + Paddy Straw @ 6 t/ha) having (4.17 cm) and O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha) having (3.80 cm) neck thickness. Whereas, O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha) resulted in the minimum (1.76 cm) neck thickness. In case of organic manures, increasing in neck thickness may be due to enhanced availability of nutrients and production of promoting substances that might have positive effect cell elongation and multiplication [32]. Another possible reason might be due that vermicompost increases the essential soil micronutrients and promotes microbial population, which ultimately promotes the neck thickness [37-38]. The increase in neck thickness under mulching conditions might be due to the availability of more amount of soil moisture, temperature and humidity due to mulching. It is established that mulching is an advantageous tool for the conserving soil moisture and thus, get the positive and significant result in the case of neck thickness [39-41].

Number of cloves per bulb

An examination of pooled data for number of cloves per bulb has been presented in (Table 2). The results showed significant difference among different treatments for number of cloves per bulb. The data recorded that among organic manures, O_2 (Vermicompost @ 5 t/ha) resulted maximum number of cloves per bulb (26.02), which was statistically at par with the treatment O_3 (Poultry manure @ 10 t/ha) was. Minimum number of cloves per bulb (20.27) was observed with O_0 (No manure @ 0 t/ha). Among mulch material, M_1 (Paddy straw @ 6 t/ha) resulted maximum number of cloves per bulb (25.15), which was statistically at par with the treatment M_2 (Saw dust @ 10 t/ha). Minimum number of cloves per bulb (21.49) was observed with M_0 (No mulch @ 0 t/ha). Combined effect of organic manures and mulching was found to be significant on number of cloves per bulb. In interaction O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha) resulted in maximum (28.19) number of cloves per bulb, which was statistically superior over the other treatments and statistically at par with O_3M_1 (Poultry Manure @ 10 t/ha + Paddy Straw @ 6 t/ha) having (27.51) number of cloves per bulb, O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha) having (27.19) and O_3M_2 (Poultry Manure @ 10 t/ha + Saw Dust @ 10 t/ha) having (26.90) number of cloves per bulb. Whereas, O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha) resulted in the minimum (19.93) number of cloves per bulb. This might be due to gradual and steady release of nutrients during the growth period as well as enhanced biological activity and proper nutrition to crop [42] Similarly, vermicompost increases the essential soil micronutrients and promotes microbial population, which ultimately promotes the number of cloves [43-44]. Among mulch material, M_1 (Paddy straw @ 6 t/ha) resulted maximum number of cloves per bulb (25.15). The reason for higher yield in the paddy straw mulch might be due to decreased soil temperature and more efficient conservation of water, which favoured growth of the crop [45]. The increased root density enhanced better uptake of water and nutrients and ultimately increased number of cloves per garlic. Furthermore, paddy straw mulch prevented the weeds and thus plants grew without any competition [46-47].

Average clove weight (g)

An examination of pooled data for average clove weight has been presented in (Table 2). The results showed significant difference among different treatments for average clove weight. The data recorded that among organic manures, O_2 (Vermicompost @ 5 t/ha) resulted maximum average clove weight (2.77 g), which was statistically at par with the treatment O_3 (Poultry manure @ 10 t/ha) was. Minimum average clove weight (2.09 g) was observed with O_0 (No manure @ 0 t/ha). Among mulch material, M_1 (Paddy straw @ 6 t/ha) resulted maximum average clove weight (2.69 g), which was statistically at par with the treatment M_2 (Saw dust @ 10 t/ha) was recorded (2.58 g). Minimum average clove weight (2.20 g) was observed with M_0 (No mulch @ 0 t/ha). Within the interaction, combined effect of organic manures and mulching was found to be significant on average clove weight. In interaction O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha) resulted in maximum (3.04 g) average clove weight, which was statistically superior over the other treatments and statistically at par with O_3M_1 (Poultry Manure @ 10 t/ha + Paddy Straw @ 6 t/ha) and O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha). Whereas, O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha) resulted in the minimum (2.06 g) average clove weight. The increase in clove weight may be ascribed to several growth promoters, enzymes, beneficial bacteria and mycorrhyzae contained in vermicompost that led to high mean clove weight through facilitating improved leaf growth and photosynthetic activities thereby increasing portioning of assimilate to storage organ [48]. Among mulch material, M_1 (Paddy straw @ 6 t/ha) resulted maximum average clove weight (2.69 g). The possible reason may be due to the covering the soil with mulch material assures better water retention, improves its aggregation and protects from sudden temperature changes which positively influence yield component resulting increased bulb weight and also weight of cloves [49-50].

Average bulb weight (g)

The Pooled data of both of the years in respect to the average bulb weight as influenced by organic manures and mulching has been presented in the (Table 3). Data revealed that among organic manures, O_2 (Vermicompost @ 5 t/ha) resulted in maximum (34.43 g) bulb weight, which was statistically at par with the treatment O_3 (Poultry manure @ 10 t/ha) was recorded (33.48 g), whereas, O_0 (No manure @ 0 t/ha) gave minimum value (24.20 g). Among mulch material, M_1 (Paddy straw @ 6 t/ha) resulted maximum bulb weight (33.94 g), which was statistically at par with the treatment M_2 (Saw dust @ 10 t/ha). Minimum average bulb weight (24.95 g) was observed with M_0 (No mulch @ 0 t/ha). Combined effect of organic manures and mulching was found to be significant on average bulb weight. In interaction O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha) resulted in maximum (40.01 g) average bulb weight, which was statistically superior over the other treatments and statistically at par with O_3M_1 (Poultry Manure @ 10 t/ha + Paddy Straw @ 6 t/ha) having (38.82 g) average bulb weight, O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha) having (37.83 g) and O_3M_2 (Poultry Manure @ 10 t/ha +

Saw Dust @ 10 t/ha) having (35.72 g) average bulb weight. Whereas, O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha) resulted in the minimum (23.84 g) average bulb weight. This might due to vermicompost may be ascribed to several growth promoters, enzymes, beneficial bacteria and mycorrhyzae activities; thereby, increasing portioning of assimilates to storage organ [31, 51]. The increased bulb weight produced in the paddy straw was possibly for efficient use of available soil moisture, inhibition of weed growth, protection of surface soil erosion, reduction in nutrient loss from soil etc., which might result in the production of big sized bulb, resulting in increased bulb weight [45-47].

Table 3 Response of organic manures and mulching on average bulb weight (g), marketable yield (q/ha) and total yield (q/ha) in garlic (cv. PG-17)

Treatment details	Average bulb weight (g)			Marketable yield (q/ha)			Total yield (q/ha)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Organic manures (O)									
O_0 (No manure @ 0 t/ha)	23.94	24.45	24.20	84.67	98.67	91.67	228.37	243.37	235.87
O_1 (Farm yard manure @ 20 t/ha)	28.86	29.83	29.35	118.83	133.97	126.40	288.93	303.93	296.43
O_2 (Vermicompost @ 5 t/ha)	33.91	34.95	34.43	133.00	148.92	140.96	334.50	352.50	343.50
O_3 (Poultry manure @ 10 t/ha)	32.63	34.33	33.48	130.33	145.25	137.79	325.07	340.43	332.75
SEM (±)	1.34	1.32	1.28	2.61	3.12	2.80	8.39	8.29	8.31
CD (0.05)	2.74	2.71	2.61	5.34	6.36	5.73	17.13	16.94	16.96
Mulch materials (M)									
M_0 (No mulch @ 0 t/ha)	24.60	25.31	24.95	97.33	112.42	104.88	255.20	270.20	262.70
M_1 (Paddy straw @ 6 t/ha)	33.42	34.47	33.94	128.50	144.00	136.25	326.37	339.73	333.05
M_2 (Saw dust @ 10 t/ha)	31.49	33.16	32.32	124.67	139.55	132.11	307.03	324.70	315.87
M_3 (Rice husk @ 5 t/ha)	29.83	30.63	30.23	116.33	130.83	123.58	288.27	305.60	296.93
SEM (±)	1.34	1.32	1.28	2.61	3.12	2.80	8.39	8.29	8.31
CD (0.05)	2.74	2.71	2.61	5.34	6.36	5.73	17.13	16.94	16.96
Interaction (O*M)									
O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha)	23.78	23.91	23.84	77.33	92.33	84.83	218.80	233.80	226.30
O_0M_1 (No Manure @ 0 t/ha + Paddy Straw @ 6 t/ha)	24.13	24.93	24.53	93.33	108.33	100.83	237.47	252.47	244.97
O_0M_2 (No Manure @ 0 t/ha + Saw Dust @ 10 t/ha)	23.99	24.63	24.31	88.00	101.00	94.50	230.40	245.40	237.90
O_0M_3 (No Manure @ 0 t/ha + Rice Husk @ 5 t/ha)	23.87	24.34	24.11	80.00	93.00	86.50	226.80	241.80	234.30
O_1M_0 (FYM @ 20 t/ha + No Mulch @ 0 t/ha)	24.50	25.63	25.06	96.00	111.00	103.50	253.87	268.87	261.37
O_1M_1 (FYM @ 20 t/ha + Paddy Straw @ 6 t/ha)	31.85	32.99	32.42	127.33	142.33	134.83	303.47	318.47	310.97
O_1M_2 (FYM @ 20 t/ha + Saw Dust @ 10 t/ha)	30.86	32.00	31.43	126.67	142.20	134.43	301.47	316.47	308.97
O_1M_3 (FYM @ 20 t/ha + Rice Husk @ 5 t/ha)	28.24	28.70	28.47	125.33	140.33	132.83	296.93	311.93	304.43
O_2M_0 (Vermicompost @ 5 t/ha + No Mulch @ 0 t/ha)	25.14	25.94	25.54	110.67	126.00	118.33	279.73	294.73	287.23
O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha)	39.45	40.58	40.01	148.00	163.67	155.83	382.80	399.13	390.97
O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha)	37.27	38.40	37.83	142.67	160.33	151.50	357.33	376.33	366.83
O_2M_3 (Vermicompost @ 5 t/ha + Rice Husk @ 5 t/ha)	33.77	34.90	34.33	130.67	145.67	138.17	318.13	339.80	328.97
O_3M_0 (Poultry Manure @ 10 t/ha + No Mulch @ 0 t/ha)	24.97	25.77	25.37	105.33	120.33	112.83	268.40	283.40	275.90
O_3M_1 (Poultry manure @ 10 t/ha + Paddy straw @ 6 t/ha)	38.25	39.38	38.82	145.33	161.67	153.50	381.73	388.87	385.30
O_3M_2 (Poultry Manure @ 10 t/ha + Saw Dust @ 10 t/ha)	33.83	37.60	35.72	141.33	154.67	148.00	338.93	360.60	349.77
O_3M_3 (Poultry Manure @ 10 t/ha + Rice Husk @ 5 t/ha)	33.45	34.59	34.02	129.33	144.33	136.83	311.20	328.87	320.03
SEM (±)	2.68	2.65	2.55	5.23	6.23	5.60	16.78	16.59	16.61
CD (0.05)	5.47	5.41	5.21	10.67	12.72	11.46	34.27	33.88	33.94

Marketable yield (q/ha)

The pooled data of both of the years in respect to the marketable yield as influenced by organic manures and mulching has been presented in the (Table 3). Data revealed that among organic manures, O_2 (Vermicompost @ 5 t/ha) resulted in maximum (140.96 q) the marketable yield, which was statistically at par with the treatment O_3 (Poultry manure @ 10 t/ha), whereas, O_0 (No manure @ 0 t/ha) gave minimum value (91.67 q). Among mulch material, M_1 (Paddy straw @ 6 t/ha) resulted maximum marketable yield (136.25 q), which was statistically at par with the treatment M_2 (Saw dust @ 10 t/ha) was recorded (132.11 q). Minimum marketable yield (104.88 q) was observed with M_0 (No mulch @ 0 t/ha). Within the interaction, combined effect of organic manures and mulching was found significant on marketable yield. In interaction O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha) resulted maximum (155.83 q) marketable yield, which was statistically superior over the other treatments and statistically at par with O_3M_1 (Poultry Manure @ 10 t/ha + Paddy Straw @ 6 t/ha) having (153.50 q) marketable yield, O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha) having (151.50 q) and O_3M_2 (Poultry Manure @ 10 t/ha + Saw Dust @ 10 t/ha) having (148.00 q) marketable yield. Whereas, O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha) resulted in the minimum (84.83 q) marketable yield. This might be due to efficient translocation of photosynthates to bulbs thereby increasing bulb size and hence increase in dry accumulation of bulbs [52-55]. Among mulch material, M_1 (Paddy straw @ 6 t/ha) resulted maximum marketable yield per plot and per hectare (6.81 kg and 136.25 q) respectively. This may be because organic amendment and mulch gave higher bulb yield compare to unmulched condition. Organic amendment and mulching favors the reduction of evaporation leading to higher soil moisture content, a reduction in weed growth and the decomposition of added mulches might have also contributed to increase the supply of nutrients and moisture for overall increase in crop yields [56-58].

Total yield (q/ha)

The pooled data of both of the years contain total yield has been presented in (Table 3). The result showed significant difference among different treatments for total yield. Among organic manures, O_2 (Vermicompost @ 5 t/ha) resulted in maximum (343.50 q) total yield. This treatment i.e. O_2 (Vermicompost @ 5 t/ha) was followed by the treatment O_3 (Poultry manure @ 10 t/ha) having value (332.75 q). Minimum total yield (235.87 q) was observed with O_0 (No manure @ 0 t/ha). Within the mulch material, M_1 (Paddy straw @ 6 t/ha) resulted maximum total yield (333.05 q), which was statistically at par with the treatment M_2 (Saw dust @ 10 t/ha) was recorded (315.87 q). Minimum total yield (262.70 q) was observed with M_0 (No mulch @ 0 t/ha). Among interaction, combined effect of organic manures and mulching was found to be significant on total yield. In interaction O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha) resulted in maximum (390.97 q) total yield, which was statistically superior over the other treatments and statistically at par with O_3M_1 (Poultry Manure @ 10 t/ha + Paddy Straw @ 6 t/ha) having (385.30 q) total yield and O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha) having (366.83 q) total yield. Whereas, O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha) resulted in the minimum (226.30 q) total yield. This might be due to the fact that organic manure supplied to balanced nutrition to the crop, improved soil condition; thereby, resulting in better growth and development leading to higher yield attributes and yield [51]. The other possible reason that humic acids released from VC enhanced nutrient uptake by the plants by increasing the permeability of root cell membrane and stimulating root growth [59]. Covering the soil with mulch material assures better water retention, improves its aggregation and protects from sudden temperature changes which positively influence yield component resulting increased bulb weight [39], [49].

Economics parameters

Observation on economics of various treatments were presented in (Table 4). The cost of cultivation, Gross return, Net return and B:C ratio of the garlic production, as affected by various treatments revealed that maximum net returns and benefit: cost ratio was computed by the application of organic manure and mulch materials. Higher cost of cultivation (172716.61 Rs ha^{-1}) was recorded in treatment O_3M_2 (Poultry Manure @ 10 t/ha + Saw Dust @ 10 t/ha) with B:C of (4.14). However, minimum cost of cultivation was recorded in treatment O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha). Treatment O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha) was observed as best treatment exhibiting maximum B:C of (4.99) with gross and net return of (935000.00 Rs ha^{-1} and 778783.39 Rs ha^{-1}) respectively [60-62].

Table 4 Economics of various treatments of garlic PG17

Treatments	Cost cultivation (Rs./ha^{-1})	Gross income (Rs./ha^{-1})	Net return (Rs./ha^{-1})	B:C Ratio
O_0M_0 (No Manure @ 0 t/ha + No Mulch @ 0 t/ha)	132716.61	507800.00	375083.39	2.83
O_0M_1 (No Manure @ 0 t/ha + Paddy Straw @ 6 t/ha)	138716.61	605000.00	466283.39	3.36
O_0M_2 (No Manure @ 0 t/ha + Saw Dust @ 10 t/ha)	147716.61	567000.00	419283.39	2.84
O_0M_3 (No Manure @ 0 t/ha + Rice Husk @ 5 t/ha)	133966.61	519000.00	385033.39	2.87
O_1M_0 (FYM @ 20 t/ha + No Mulch @ 0 t/ha)	152716.61	621000.00	468283.39	3.07
O_1M_1 (FYM @ 20 t/ha + Paddy Straw @ 6 t/ha)	158716.61	809000.00	650283.39	4.10
O_1M_2 (FYM @ 20 t/ha + Saw Dust @ 10 t/ha)	167716.61	806600.00	638883.39	3.81
O_1M_3 (FYM @ 20 t/ha + Rice Husk @ 5 t/ha)	153966.61	797000.00	643033.39	4.18
O_2M_0 (Vermicompost @ 5 t/ha + No Mulch @ 0 t/ha)	150216.61	710000.00	559783.39	3.73
O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha)	156216.61	935000.00	778783.39	4.99
O_2M_2 (Vermicompost @ 5 t/ha + Saw Dust @ 10 t/ha)	165216.61	909000.00	743783.39	4.50
O_2M_3 (Vermicompost @ 5 t/ha + Rice Husk @ 5 t/ha)	151466.61	829000.00	677533.39	4.47
O_3M_0 (Poultry Manure @ 10 t/ha + No Mulch @ 0 t/ha)	157716.61	677000.00	519283.39	3.29
O_3M_1 (Poultry Manure @ 10 t/ha + Paddy Straw @ 6 t/ha)	163716.61	921000.00	757283.39	4.63
O_3M_2 (Poultry Manure @ 10 t/ha + Saw Dust @ 10 t/ha)	172716.61	888000.00	715283.39	4.14
O_3M_3 (Poultry Manure @ 10 t/ha + Rice Husk @ 5 t/ha)	158966.61	821000.00	662033.39	4.16

CONCLUSION

The findings from this study highlight the importance of optimizing organic manure and mulch materials application for enhancing garlic growth and yield. The results indicate that applying O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha) has a significant positive impact on various growth and yield parameters. This study suggests that the O_2M_1 (Vermicompost @ 5 t/ha + Paddy Straw @ 6 t/ha) is sufficient and potentially more effective for achieving the best yield outcomes in garlic production. However, it is advised that this recommendation be validated through on-farm testing in different environmental and soil conditions to ensure its consistency and reliability across various contexts. Such trials would help confirm that this vermicompost and paddy straw mulch can reliably maximize fruit yield per unit area, making it a practical recommendation for commercial garlic cultivation.

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