**Effect of Spacing and Organic Manures on Growth, Yield and Economics of Wheat (*Triticum aestivum* L.)**

**ABSTRACT**

The experiment aims to study the effect of spacing and organic manures on the growth, yield and economics of wheat (*Triticum aestivum* L.). The field experiment was conducted at the Agronomy Research Farm, Agriculture Department, Jigyasa University (Formerly Himgiri Zee University), Dehradun, Uttarakhand during the *Rabi* season 2021- 2022. The experiment consisted of three different spacing (20 cm x 10 cm, 22.5 cm x 10 cm and 22.5 cm x 15 cm) and four levels of organic manure (0, 10 t/ha FYM, 10 t/ha VC and 10 t/ha FYM + 10 t/ha VC). Twelve treatments were laid down in Factorial Randomized Block Design with three replications of each. Results of the field experiment revealed that the highest yield parameters of the wheat crop were observed in spacing 22.5 cm x 15 cm in number of tillers, plant height, dry weight, grain yield, straw yield and harvest index which reached 372.8 tillers m-2, 83.3 cm, 973.7 g, 3.68 t/ha, 5.12 t/ha and 41.57 % while the spacing of 20 cm x 10 cm show lowest yield parameters. The organic manure levels OM4 (10 t/ha FYM + 10 t/ha VC) showed a significant superiority for the characteristic of plant height, spike length, test weight, and biological yield, with means of 87.5 cm, 13.5 cm, 42.86 g, and 9.54 t/ha, respectively. The treatment of T12**(**22.5 cm x 15 cm + 10 ton/ha FYM + 10 ton/ha VC) recorded the highest gross return (Rs. 142905 Rs/ha), net returns (Rs 83740.2 Rs/ha) and B: C ratio (1.41) respectively.

**Keywords:** Growth, Spacing, Wheat, Yield, Organic manure, economics, FYM, Vermicompost.

1. **Introduction**

“Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide and belongs to the family Poaceae. It is the second most important food crop globally just after rice. Wheat is consumed in different forms around the world based on their food habits and culture whereas, in India, wheat is primarily consumed in the form of *'Chapati*,' which is a type of unleavened flatbread. Wheat is highly nutritious, with approximately 70% of its composition consisting of nutrients. It contains protein (10-12%), fat (2.0%), minerals (1.8%), crude fibres (2.2%), and various vitamins such as thiamine, riboflavin, and niacin.

In the world, the total production of wheat for the winter season of 2021 is estimated at about 4234 thousand tons, as well the production of wheat straw was estimated at 10,463 thousand tons” **(Directorate of Agricultural Statistics, 2021).** According to FAO estimates, “the world would require around 840 million tonnes of wheat by 2050 from its current production level of 642 million tonnes. This demand excludes the requirement of animal feed and the adverse impacts of climate change on wheat production. To meet this demand, developing countries should increase their wheat production by 77% and more than 80% of demand should come from vertical expansion” (FAO , 2009; Prasanghi & Umesha , 2023) .

Among various agronomic practices, spacing plays a crucial role in maintaining the optimum plant stand. The spacing between wheat plants can affect germination, crop growth parameters such as spike length, number of spikelets and number of grains per spike, and grain and straw yield. It is well-known that maximizing grain yield per unit area involves balancing plant population and minimizing competition within and between plants. The importance of proper row spacing for maximizing light interception, penetration, and distribution within the crop canopy (**Rahel and Asfaw, 2016)**). This, in turn, improves the average light utilization efficiency of the leaves, positively affecting the crop's yield. **(Mehmood *et al*., 2012).** In summary, the right row spacing is essential for ensuring resource availability, optimizing tillering and yield components in wheat, and maximizing light utilization efficiency, all of which contribute to higher crop yields.

The optimal use of organic manures increases plant inputs, crop field, and water efficiency **(Zhang *et al.,* 2016)**. “Judicious use of Organic manures, such as farmyard manure (FYM) and vermicompost improves chemical, Physical and biological properties and increases crop productivity. Among different sources of organic manure, vermicompost is the most important manure for nutrient supplementation or management for increasing crop production. It is the best method among all other composting techniques as it is cost-effective and eco-friendly and vermicomposting is very effective in sanitizing organic waste, especially the waste of biological origin” **(Sahariah *et al.,* 2019).** The improved soil conditions foster better root development, nutrient uptake, and overall plant health. **(Das *et al.,* 2019).**

The individual and integrated effect of organic sources like vermicompost and FYM on the wheat crop at different spacing can significantly enhance the nutrient response efficiency and can help in maximizing crop productivity of desired quality. Therefore, understanding the effects of crop spacing and organic manures on the yield is of primary interest to achieving yield targets. Keeping these facts in view, the present experiment was undertaken with the following objectives:

1. To study the effect of organic manures on the growth and yield of wheat.
2. To study the effect of crop spacing on growth and yield of wheat.
3. To study the interaction between crop spacing and organic manures and their effect on growth, yield and economics of wheat.
4. To study the economics of wheat under different levels of organic manures and crop spacing.

**2. Materials and Methods**

A field experiment was carried out at the Agronomy Research Farm, Agriculture Department, Himgiri Zee University, Dehradun, Uttarakhand, India, during the *Rabi* season 2021- 2022, which is located at 31° 21' 50" N latitude and 78° 18' 27"E longitude to study the effect of different spacing and levels of organic manure on the growth, yield and economics of wheat (*Triticum* *aestivum* L.) crop.

The experiment was laid out in Factorial Randomized Block Design which consists of twelve treatments viz., T1: 20 cm x 10 cm + No Organic Manure, T2: 20 cm x 10 cm + 10 tonnes/ha FYM, T3: 20 cm x 10 cm + 10 tonnes/ha Vermicompost, T4: 20 cm x 10 cm + 10 tonnes/ha FYM + 10 tonnes/ha Vermicompost, T5: 22.5 cm x 10 cm + No Organic Manure, T6: 22.5 cm x 10 cm + 10 tonnes/ha FYM, T7: 22.5 cm x 10 cm + 10 tonnes/ha Vermicompost, T8: 22.5 cm x 10 cm + 10 tonnes/ha FYM + 10 tonnes/ha Vermicompost, T9: 22.5 cm x 15 cm + No Organic Manure, T10: 22.5 cm x 15 cm + 10 tonnes/ha FYM, T11: 22.5 cm x 15 cm + 10 tonnes/ha Vermicompost and T12: 22.5 cm x 15 cm + 10 tonnes/ha FYM + 10 tonnes/ha Vermicompost.

The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction having pH of 7.80. The recommended dose of fertilizer is 120:60:60 of N:P: K kg/ ha was applied. Nitrogen was applied in two split doses; one at the time of sowing and the left half dose at the time of first irrigation.

Observations were recorded for different treatments. In order to secure the effect of different treatments, the following growth parameters such as plant height, dry matter accumulation and number of tillers/ m2 and yield parameters such as number of spikes per square meter, spike length, number of grains per spike, test weight, grain yield, straw yield, biological yield and harvest index were recorded and statistically analyzed using analysis of variance (ANOVA).

**3. Results and Discussion**

**3.1. Growth attributes**

The result of the experiment revealed that the effect of spacing and organic manure levels on plant height, dry matter accumulation and the total number of tillers per meter square at harvest of wheat was found significant. Among the different treatments, the Treatment T12 (22.5 cm x 15 cm + 10 ton/ ha FYM + 10 ton/ ha Vermicompost) registered maximum value for plant height (19.9, 40.0, 68.0 and 90.1 cm at 30, 60, 90 DAS and at harvest, respectively), dry matter accumulation at successive stages (55.4, 196.5, 525.2 and 1117.5 g at 30, 60, 90 DAS and at harvest, respectively) and total number of tillers at harvest (400, respectively) and remained at par with 22.5 cm x 10 cm spacing with 10 t/ha FYM + 10 t/ha Vermicompost. Wider spacing between plants reduces the competition among them for essential resources such as light, water, space, and nutrients. When plants are given more space, they can develop a higher leaf area index per plant and utilization within the crop canopy which contributes to enhanced plant growth. A similar result was also observed by **Ghafari *et al*., 2017**, **Iqbal *et al*., 2020** and **Shapep and Mahmoud, 2023**. When plants are grown in closer proximity, they compete for resources such as light, water, air, and nutrients, which can stimulate the development of more tillers. The relationship between row spacing, plant density, and tiller production is an important consideration in optimizing crop management practices and maximizing crop yield potential (**Ali *et al.,* 2016)**.

Organic manures supply nutrients to plants and stimulate growth, improving soil fertility and nutrient availability for plants. The increase in plant height, dry weight and number of tillers was observed with the use of organic manures and spacing has been reported by **Godara and Kumar, 2022,** **Shapep and Mahmoud, 2023** and **Verma *et al*., 2023.** When FYM and vermicompost were applied in the same field, it resulted in higher micro-nutrient content compared to when no organic manure was added and it might be due to higher micro-nutrient supply with vermicompost and FYM. Both VC and FYM are organic sources of nutrients that can improve soil fertility and nutrient availability for plants. They are rich in organic matter and contain various essential nutrients, including micro-nutrients such as iron, zinc, copper, manganese, and others. This result conformed with the findings of **Barlas *et al.,* 2018 and Verma *et al.,* 2018.**

**Table 1.** Effect of spacing and organic manures on growth attributing characters at harvest of wheat

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant Height (cm)\*** | **Dry Weight (g m-2) \*** | **No. of Tillers (m-2)** |
| **T1** | 70.3l | 812.1l | 330l |
| **T2** | 76.0i | 852.7h | 335i |
| **T3** | 77.6h | 840.2i | 338h |
| **T4** | 82.9e | 943.9e | 364e |
| **T5** | 70.4k | 812.6k | 333k |
| **T6** | 79.0g | 895.4g | 340g |
| **T7** | 80.4f | 925.4f | 346f |
| **T8** | 89.6b | 1005.6b | 389b |
| **T9** | 70.8j | 813.2j | 335j |
| **T10** | 84.5d | 976.6d | 382c |
| **T11** | 87.7c | 987.3c | 374d |
| **T12** | 90.1a | 1117.5a | 400a |
| **CD ≤0.05** | 2.092 | 16.971 | 7.976 |

**\*** Each value mentioned in each column is a mean of triplicates. Significance level assigned by alphabetical at P≤0.05.

**3.2 Yield attributes**

The data portrayed that the maximum no. of grains per spike (50), spike length (13.9 cm), no. of spike (m-2) (390), test weight (43.16 g), grain yield (4.23 t/ha), straw yield (5.61 t/ha), biological yield (9.84 t/ha) and harvest index (42.99 %) in T12 (22.5 cm x 15 cm + 10 ton/ ha FYM + 10 ton/ ha Vermicompost) which was at par with Treatment T8 (22.5 cm x 10 cm + 10 ton/ ha FYM + 10 ton/ ha Vermicompost) with no. of grains per spike (49), spike length (13.7 cm), no. of spike (m-2) (387), test weight (43.06 g), grain yield (4.19 t/ha), straw yield (5.58 t/ha), biological yield (9.77 t/ha) and harvest index (42.8 %). The minimum no. of tiller plant-1 (4.75), no. of ear plant-1 (4.15), ear length (7.15 cm), weight of ear (2.65 g), no. of grain spike-1 (38.65), grain weight plant-1 (1.75 g) and test weight (36.85 g). Wider spacings facilitated better utilization of resources for plants. Wider spacings reduced competition between plants for water, nutrients, light and space leading to better growth of plants and yield and yield attributes i.e., length of ear head and number of grains per ear head. This was in conformity with the findings of **Hussain *et al*., 2012.** Similar findings were reported by **Pandey *et* *al*., 2013** and **Kulkarni *et al*., 2018.** Plants with wider spacing performed better compared to those with closer spacing. With wider spacing, each plant has access to a larger portion of the soil, allowing for better nutrient uptake observed by **Singh *et al.*, 2019.**

The application of both FYM and VC together is beneficial for soil fertility and nutrient availability for plants. Organic manures, such as FYM and VC, are rich in nutrients that can enhance plant growth. Similar findings were observed by **Verma *et al*., 2018.** When these organic manures are added to the soil, they provide essential nutrients like nitrogen, phosphorus, and potassium, along with other micronutrients, which are essential for plant development. The increased availability of nutrients likely contributed to the observed improvement in spike length, test weight, biological yield and harvest index. This result was similar to **Fazily**, **2020. Gebrehiwot *et al*., 2020** also observed that organic manure gives a higher yield. A similar result was observed by **Ibrahim *et al*., 2015.**

**Table 2.** Effect of spacing and organic manures on yield attributing characters at harvest of wheat

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **No. of grains per spike\*** | **Spike length (cm)\*** | **No. of spike (m-2) \*** | **Test Weight (g)\*** | **Grain Yield (t/ha) \*** | **Straw Yield (t/ha) \*** | **Biological Yield (t/ha) \*** | **Harvest Index\*** |
| **T1** | 33l | 9.4la | 230l | 40.06l | 2.48l | 3.89l | 6.37l | 38.88l |
| **T2** | 36i | 11.91i | 326i | 41.13i | 3.35i | 4.7i | 8.05i | 41.62f |
| **T3** | 38h | 12.0h | 330h | 41.46h | 3.44h | 4.8h | 8.24h | 41.75d |
| **T4** | 44e | 13.0d | 352e | 42.36e | 3.74e | 5.27e | 9.01e | 41.51i |
| **T5** | 35j | 9.8k | 233j | 40.56k | 2.58k | 3.97k | 6.55k | 39.40k |
| **T6** | 40g | 12.2g | 342g | 42.03f | 3.52g | 4.94g | 8.46g | 41.61g |
| **T7** | 42f | 12.7f | 346f | 41.76g | 3.68f | 5.16f | 8.84f | 41.63e |
| **T8** | 49b | 13.7b | 387b | 43.06b | 4.19b | 5.58b | 9.77b | 42.89b |
| **T9** | 34k | 10.0j | 232k | 40.90j | 2.65j | 4.0j | 6.65j | 39.85j |
| **T10** | 46d | 12.9e | 358d | 42.60d | 3.83d | 5.3d | 9.13d | 41.95c |
| **T11** | 47c | 13.3c | 368c | 42.83c | 3.96c | 5.58c | 9.54c | 41.51h |
| **T12** | 50a | 13.9a | 390a | 43.16a | 4.23a | 5.61a | 9.84a | 42.99a |
| **CD ≤0.05** | 0.795 | 1.01 | 8.26 | 1.021 | 0.167 | 0.097 | 0.151 | N/A |

**\*** Each value mentioned in each column is a mean of triplicates. Significance level assigned by alphabetical at P≤0.05.

**3.3 Economics analysis**

The result of the experiment revealed that the maximum net return (Rs. 83740.2 /ha), gross return ((Rs. 142905 /ha) and Benefit: cost ratio (1.41) were found in treatment T12 (22.5 cm x 15 cm + 10 ton/ ha FYM + 10 ton/ ha Vermicompost). Whereas, the lowest net return (Rs. 40702.7 /ha), gross return ((Rs. 87867.5 /ha) and B: C ratio (0.86) was obtained from control i.e., T1 (20 cm x 10 cm + no organic manure added). Spacing with organic manure levels recorded statistically higher net returns and B: C ratio. The increase in profits with 22.5 cm x 15 cm spacing over close spacing and with the combination of FYM and VC at @ 10 ton/ha, each overcontrol was owing to an increase in yield with little cost incurred. This result was observed by **Ali *et al.* (2020), Fazily *et al. (*2019),** **Sharma *et al.* (2018) and Fazily (2020).**

**Table 3.** Effect of Spacing and organic manures on the economics of wheat

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Gross Returns (Rs/ha)**  | **Net return (Rs/ha)**  | **B: C Ratio** |
| **T1** | 87867.5l | 40702.7l | 0.86l |
| **T2** | 114975i | 59810.2i | 1.08h |
| **T3** | 117880h | 60715.2h | 1.06i |
| **T4** | 128520e | 69355.2e | 1.17g |
| **T5** | 90986k | 43821.2k | 0.92k |
| **T6** | 120820g | 65655.2g | 1.19f |
| **T7** | 126280f | 69115.2f | 1.20e |
| **T8** | 141715b | 82550.2b | 1.39b |
| **T9** | 92925j | 45760.2j | 0.97j |
| **T10** | 130935d | 75770.2d | 1.37d |
| **T11** | 136080c | 78915.2c | 1.38c |
| **T12** | 142905a | 83740.2a | 1.41a |

**\*** Each value mentioned in each column is a mean of triplicates. Significance level assigned by alphabetical at P≤0.05.

**4. Conclusion**

It is concluded that the application of organic manure at a dose of 10 tonnes/ ha FYM + 10 tonnes/ ha vermicompost with spacing 22.5 cm x 15 cm (Treatment 12), was recorded as effective in promoting crop growth, yield attributes and increasing benefit: cost ratio of wheat crop. The low dose of organic manure with less spacing decreased the crop growth, and yield attributes and reduced the economic value of the crop. Despite narrow spacing, wider spacing reduces the competition for essential resources such as light, water, space, and nutrients. Consequently, a high leaf area index per plant and improved plant growth were observed. The use of organic manures, such as farmyard manure (FYM) and vermicompost improves not only improves chemical, physical and biological properties of soil but found effective in increasing crop productivity. Thus, the application of organic manures offers a sustainable and environment-friendly approach to cropping cereals with greater economic returns.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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