



# Growth, Yield Attributes and Yield of Barley (*Hordeum vulgare* L.) under Different Levels of Fertilizer and Vermicompost Grown under Every Furrow and Alternate Furrow Irrigation Methods

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

A field experiment was conducted during the *Rabi* season of 2021-22 at the Agronomy Research Farm of CCS Haryana Agricultural University, Hisar in a split-plot design with two vermicompost levels *i.e.*, vermicompost @ 1.5 t ha<sup>-1</sup> and vermicompost @ 3.0 t ha<sup>-1</sup>, two irrigation methods *i.e.*, every furrow irrigation and alternate furrow irrigation method as the main plot treatments and three fertilizer levels at N<sub>40</sub>P<sub>20</sub>, N<sub>60</sub>P<sub>30</sub> and N<sub>80</sub>P<sub>40</sub> kg ha<sup>-1</sup> as subplot treatments and replicated three times. Among the vermicompost levels, vermicompost at 3.0 t ha<sup>-1</sup> recorded significantly higher no. of tillers; yield attributes *i.e.*, no. of effective tillers (12.88%), spike length (14.49%), no. of grains per spike (13.85%), 1000-grain weight (10.57%) and yield *i.e.*, grain yield (11.00%), biological yield (10.75%) than vermicompost at 1.5 t ha<sup>-1</sup>. Among methods of irrigation, every furrow irrigation recorded significantly higher in no. of tillers, yield attributes *i.e.*, no. of effective tillers (13.68%), spike length (14.49%), no. of grains per spike (11.51%), 1000-grain weight (9.37%); yield (grain yield (17.15%), biological yield (22.08%) and economics (gross and net returns (15.52 and 25.66%) than alternate furrow irrigation. Among fertilizer level, application of N<sub>80</sub>P<sub>40</sub> recorded significantly higher no. of tillers, spike length, no. of grains per spike, 1000-grain weight; yield (grain yield (13.02%), biological yield (15.81%), and economics (gross and net returns (13.72 and 24.49%) over other levels of fertilizer. Based on the study, it was found that vermicompost level, method of irrigation and fertilizer level has significant effect on no. of tillers, available NPK content in soil, yield attributes, yield and economics of barley.

**Keywords:** Barley; fertilizer; irrigation; vermicompost.

## 1. INTRODUCTION

Barley (*Hordeum vulgare* L.) is an important cereal crop grown in *Rabi* season in northern plains as well as in Northern hills of India, mainly under rainfed or limited irrigation condition on poor to marginal soils. The crop is grown mostly because of its low input requirement and better adaptability to harsh environment like drought, salinity, alkalinity and marginal lands [1]. In India, barley is grown over an area of 0.592 mha with a production of 1656.34 mt and yield of 2796 kg ha<sup>-1</sup> [2]. In Haryana, it is grown over an area of 0.92 m ha with a production of 30.96 m t and productivity of 3342 kg ha<sup>-1</sup>. The average productivity of barley in the state is far back to attainable yield of 45-50 q ha<sup>-1</sup> due to water and nutritional stresses [2]. Barley is mainly grown in south-west zone of Haryana under saline, rainfed conditions or with limited irrigation. Drought stress is a serious problem for its production because it affects simultaneously many traits through morphological, physiological and metabolic modification occurring in all plant organs. The water requirement is less than half which makes barley suitable for dry areas. One of the most crucial element required for healthy development, balanced growth, and increased crop production in all crops is water. Plant development and grain yield are both impacted by water shortage [3,4]. Water is a crucial element for healthy development, balanced growth, and increased crop production in all

crops, including barley. Water stress negatively impacts tillering, booting, and heading stages of barley growth. Vermicompost is an excellent soil amendment and a biocontrol agent, making it an eco-friendly organic fertilizer compared to chemical fertilizers [2]. The combined application of compost and mineral fertilizer on soil properties and crop productivity. The compost and mineral fertilizer treatments significantly lowered soil bulk density and iron content while increasing pH, electrical conductivity, and cation exchange capacity [5].

The integrated application of inorganic and organic fertilizers increases soil porosity, nutrient content, and proper plant nourishment. At the early growth stage, water stress has a negative impact on tillering, booting and heading. [6]. It is good if the farmers are going to secure an assured income through contract farming (IIWBR Director Gyanendra Singh told IVAN). One of the major barrier in enhancing the barley production is the declining effect on soil health due to the imbalanced and heavy use of chemical fertilizer. Alternate Furrow Irrigation (AFI) is the type of furrow irrigation in which the alternate furrows are in the field are irrigated at once. According to the field experiments conducted in 1997-98 semi-arid and arid regions over AFI, it was concluded that root development was significantly enhanced by AFI treatment. Alternate furrow irrigation can reduce irrigation water requirements and increase water use efficiency (WUE) which helps



(Source: <https://www.nrcs.usda.gov/resources/education-and-teaching-materials/soil-texture-calculator>)

The land was prepared for sowing as per requirement of the barley crop. Vermicompost were applied 15 days before sowing. At the time of sowing, a full dose of P and half dose of N were applied as a basal dose, and a remaining dose of N was applied as a top dress after the first irrigation as per treatment. Urea and vermicompost were applied on the basis of treatments. Barley was sown on beds using bed planter at the rate of 100 kg seed ha<sup>-1</sup>. Two irrigations, one at Germination and Seedling stage and second at flowering were applied in alternate furrows. One hand weeding and one spray of algrip @ 20 g ha<sup>-1</sup> at 32 DAS. No plant protection measures were applied. Harvesting was done using sickle at the net plot area and bundles were left in the field to dry under the sun. A plot thresher was used to thresh the grain and the yield was recorded. During the growing season of the barley crop, the following observations were made. Number of total tillers were counted per meter row length from each plot at 45, 60, 90 DAS and at harvest.

**Yield attributes and yield:** The following observations on yield components and yield were made at three different locations in the field. Number of spikes per meter row length at three separate locations from each plot, the number of spikes were counted per meter of row length, and the average was taken. Three spikes were chosen at random in each plot during harvest time to measure its length. Number of grains spike<sup>-1</sup> at maturity, three spikes were chosen at random in each plot to represent the whole plot, and each one was collected and threshed manually, the grains counted separately. For statistical purposes, mean values were taken. Test weight (gm) after threshing, a random sample of each plot was obtained. Sample was spread out on a table and 1000 grains were hand counted for grains weight. Biological yield after harvesting and sun drying, the net harvested crop yield weighed in each plot was recorded and converted to kilograms per hectare (kg ha<sup>-1</sup>). Grain yield, Grains were sorted from biological yield produced from each net plot using a plot thresher. The net grain yield was measured and converted to kg per hectare (kg ha<sup>-1</sup>). For statistical purposes, mean values were taken

**Economics (₹ ha<sup>-1</sup>):** The gross returns (₹ ha<sup>-1</sup>) of different treatments were computed using the rate for economic and by product fixed by the Directorate of Farm, CCS HAU, Hisar. Net returns on the basis of approved inputs and practices cost determined by Directorate of Farm, CCS

HAU, Hisar the cost of cultivation and gross returns (₹ ha<sup>-1</sup>) of various treatments were computed. The entire cost of cultivation for each treatment was subtracted from the gross income for each treatment to calculate net returns (₹ ha<sup>-1</sup>).

Net returns = Gross returns – cost of cultivation

Benefit-cost ratio: The benefit-to-cost ratio was calculated using the following formula:

$$B:C = \frac{\text{Gross returns (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

### 3. RESULTS

#### 3.1 Number of Total Tillers (no./m<sup>2</sup>)

The examination of the data provided in (Table 1) revealed a significant impact of different levels of vermicompost and different irrigation methods on the total tiller count of barley at all growth stages, namely 45, 60, 90 DAS, and at harvest. The application of vermicompost @ 3.0 t ha<sup>-1</sup> vermicompost led to an increase in the number of tillers by 11.41%, 11.20%, 13.26%, and 13.06% at 45, 60, 90 DAS over application of vermicompost @ 1.5. The increase in number of total tillers of barley due to every furrow irrigation was 8.68, 9.97 and 6.42 per cent, respectively at 45, 60, 90 DAS and at harvest over alternate furrow irrigation. The increase in number of total tillers per plant due to application of fertilizers at N<sub>80</sub>P<sub>40</sub> level was 10.14, 9.68 and 6.02 per cent at 45, 60, 90 DAS over application of fertilizers at N<sub>40</sub>P<sub>20</sub> level, respectively.

#### 3.2 Yield Attributes and Yield

##### 3.2.1 Number of effective tillers/m<sup>2</sup>

The data pertaining to (Table 2) showed that number of effective tillers were significantly affected by vermicompost levels and by irrigation methods. Increasing vermicompost @ 3.0 t ha<sup>-1</sup> progressively increased number of effective tillers. Vermicompost @ 3.0 t ha<sup>-1</sup> recorded 12.88 per cent higher effective tillers over vermicompost @ 1.5 t ha<sup>-1</sup>. The increase in number of effective tillers due to every furrow irrigation was 13.68 per cent over alternate furrow irrigation. The increase in number of effective tillers due to application of N<sub>80</sub>P<sub>40</sub> level was 8.21 per cent over application of N<sub>40</sub>P<sub>20</sub> level.

##### 3.2.2 Spike length (cm)

The perusal of data in (Table 2) revealed that the effect of vermicompost level and irrigation method on spike length was found significant. Application of vermicompost @ 3.0 t ha<sup>-1</sup> was 14.49 over vermicompost @ 1.5 t ha<sup>-1</sup>. Irrigation method of every furrow irrigation significantly increased the spike length over alternate furrow

irrigation. The per cent increase due to every furrow irrigation was 14.49 over alternate furrow irrigation. The increase in spike length due to application of fertilizers at N<sub>80</sub>P<sub>40</sub> level was 21.21 per cent over application of fertilizers at N<sub>40</sub>P<sub>20</sub> level.

**Table 1. Number of total tillers at different stages of barley as influenced by vermicompost, fertilizer and irrigation methods**

Treatments	Number of total tillers (no/m <sup>2</sup> )			
	45 DAS	60 DAS	90 DAS	At harvest
<b>Main plot (Vermicompost levels x Irrigation Methods)</b>				
<b>Vermicompost levels</b>				
Vermicompost @ 1.5 t/ha	504.8	514.4	542.8	523.6
Vermicompost @ 3.0 t/ha	562.4	572.0	614.8	592.0
SEm±	9.6	14.0	10.0	9.6
CD (P=0.05)	33.2	48.4	34.4	32.8
<b>Irrigation methods</b>				
Every furrow irrigation	556.0	569.2	596.8	574.8
Alternate furrow irrigation	511.6	517.6	560.8	540.8
SEm±	9.6	14.0	10.0	9.6
CD (P=0.05)	33.2	48.4	34.4	32.8
<b>Sub plot</b>				
<b>Fertilizer levels (kg/ha)</b>				
N <sub>40</sub> P <sub>20</sub>	501.2	512.4	558.0	527.6
N <sub>60</sub> P <sub>30</sub>	548.0	555.2	587.2	569.6
N <sub>80</sub> P <sub>40</sub>	552.0	562.0	591.6	576.4
SEm±	8.8	8.8	8.8	10.0
CD (P=0.05)	26.4	26.4	26.4	29.6

**Table 2. Yield attributes of barley as influenced by vermicompost, fertilizer and irrigation methods**

Treatments	Yield attributes			
	Number of effective tillers/m <sup>2</sup>	Spike length (cm)	Number of grains per spike	1000-grain weight (g)
<b>Main plot (Vermicompost levels x Irrigation Methods)</b>				
<b>Vermicompost levels</b>				
Vermicompost @ 1.5 t/ha	425.6	6.9	36.1	35.0
Vermicompost @ 3.0 t/ha	480.4	7.9	41.1	38.7
SEm±	8.4	0.2	0.8	0.7
CD (P=0.05)	28.8	0.6	2.9	2.4
<b>Irrigation methods</b>				
Every furrow irrigation	482.0	7.9	40.7	38.5
Alternate furrow irrigation	424.0	6.9	36.5	35.2
SEm±	8.4	0.2	0.8	0.7
CD (P=0.05)	28.8	0.6	2.9	2.4
<b>Sub plot</b>				
<b>Fertilizer levels (kg/ha)</b>				
N <sub>40</sub> P <sub>20</sub>	418.4	6.6	35.1	34.8
N <sub>60</sub> P <sub>30</sub>	462.0	7.7	39.5	37.2
N <sub>80</sub> P <sub>40</sub>	478.4	8.0	41.2	38.6
SEm±	8.8	0.2	1.0	0.8

CD (P=0.05)	26.4	0.6	3.0	2.5
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### 3.2.3 Number of grains per spike

Data in (Table 2) further revealed that vermicompost @ 3.0 t ha<sup>-1</sup> significantly influenced the number of grains per spike of barley by 13.85% over vermicompost @ 1.5 t ha<sup>-1</sup>. Irrigation method of every furrow irrigation significantly increased the number of grains per spike by 11.51 % over alternate furrow irrigation. The increase in number of grains per spike due to application of fertilizers at N<sub>80</sub>P<sub>40</sub> level was 17.38 per cent over application of fertilizers at N<sub>40</sub>P<sub>20</sub> level.

### 3.2.4 1000-grain weight (g)

Data in (Table 2) revealed that vermicompost @ 3.0 t ha<sup>-1</sup> and every furrow irrigation method significantly influenced the 1000-grain weight of barley over vermicompost @ 1.5 t ha<sup>-1</sup> and alternate furrow irrigation. The increase in 1000-grain weight due to application of vermicompost @ 3.0 t ha<sup>-1</sup> was 10.57 per cent over application of vermicompost @ 1.5 t ha<sup>-1</sup>. The per cent increase due to every furrow irrigation was 9.37 over alternate furrow irrigation.

The increase in 1000-grain weight due to application of fertilizers at N<sub>80</sub>P<sub>40</sub> level was 10.92

per cent over application of fertilizers at N<sub>40</sub>P<sub>20</sub> level.

### 3.2.5 Grain yield (kg ha<sup>-1</sup>)

A disquisition to data given in (Table 3) exhibited that grain yield was significantly affected by levels of vermicompost and irrigation methods. The treatment of vermicompost @ 3.0 t ha<sup>-1</sup> progressively increased grain yield. Vermicompost @ 3.0 t ha<sup>-1</sup> recorded 11.00 per cent higher grain yield over vermicompost @ 1.5 t ha<sup>-1</sup>. The per cent increase due to every furrow irrigation was 17.15 over alternate furrow irrigation. Application of fertilizers at N<sub>80</sub>P<sub>40</sub> level which was remained at par with application of fertilizers at N<sub>60</sub>P<sub>30</sub> level, recorded significantly maximum grain yield as compared to application of fertilizers at N<sub>40</sub>P<sub>20</sub> level. The increase in grain yield due to application of fertilizers at N<sub>80</sub>P<sub>40</sub> level was 13.02 per cent over application of fertilizers at N<sub>40</sub>P<sub>20</sub> level.

### 3.2.6 Biological yield (kg ha<sup>-1</sup>)

The perusal of data in (Table 3) revealed that progressive increase was observed in biological yield with increase in vermicompost levels and by every furrow irrigation method. Maximum

**Table 3. Yield and economics of barley as influenced by vermicompost, fertilizer and irrigation methods**

Treatments	Yield (kg/ha)			Economics	
	Grain yield	Biological yield	Total cost (₹ /ha)	Gross returns (₹ /ha)	Net returns (₹ /ha)
<b>Main plot (Vermicompost levels x Irrigation Methods)</b>					
<b>Vermicompost levels</b>					
Vermicompost @ 1.5 t/ha	4253	9709	64308	133939	69631
Vermicompost @ 3.0 t/ha	4721	10753	70308	148582	78274
<b>SEm±</b>	81	181	-	-	-
<b>CD (P=0.05)</b>	278	624	-	-	-
<b>Irrigation methods</b>					
Every furrow irrigation	4842	11248	68308	153145	84837
Alternate furrow irrigation	4133	9214	66308	129376	63068
<b>SEm±</b>	81	181	-	-	-
<b>CD (P=0.05)</b>	278	624	-	-	-
<b>Sub plot</b>					
<b>Fertilizer levels (kg/ha)</b>					
N <sub>40</sub> P <sub>20</sub>	4169	9334	66048	130647	64599
N <sub>60</sub> P <sub>30</sub>	4581	10549	67728	144568	76840
N <sub>80</sub> P <sub>40</sub>	4712	10810	68148	148566	80418
<b>SEm±</b>	80	157	-	-	-

<b>CD (P=0.05)</b>	239	468	-	-	-
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**Table 4. Available NPK content in soil after harvest of barley as influenced by vermicompost, fertilizer and irrigation methods**

Treatments	Available nutrients (kg/ha)		
	Available N	Available P <sub>2</sub> O <sub>5</sub>	Available K <sub>2</sub> O
<b>Main plot (Vermicompost levels x Irrigation Methods)</b>			
<b>Vermicompost levels</b>			
Vermicompost @ 1.5 t/ha	129.8	17.3	247.9
Vermicompost @ 3.0 t/ha	147.8	19.9	270.6
<b>SEm+</b>	3.9	0.4	5.1
<b>CD (P=0.05)</b>	13.6	1.3	17.8
<b>Irrigation methods</b>			
Every furrow irrigation	141.5	18.9	261.9
Alternate furrow irrigation	136.1	18.2	256.6
<b>SEm+</b>	3.9	0.4	5.1
<b>CD (P=0.05)</b>	NS	NS	NS
<b>Sub plot</b>			
<b>Fertilizer levels (kg/ha)</b>			
N <sub>40</sub> P <sub>20</sub>	128.9	17.1	255.0
N <sub>60</sub> P <sub>30</sub>	133.9	19.0	260.6
N <sub>80</sub> P <sub>40</sub>	137.5	19.7	262.1
<b>SEm+</b>	2.4	0.4	4.6
<b>CD (P=0.05)</b>	7.1	1.2	NS
<b>Initial status</b>	125.5	16.3	241.3

biological yield was obtained with vermicompost @ 3.0 t ha<sup>-1</sup> recorded 10.75 per cent higher biological yield over vermicompost @ 1.5 t ha<sup>-1</sup>. Irrigation method of every furrow irrigation recorded 22.08 per cent higher over alternate furrow irrigation method. The increase in biological yield due to application of fertilizers at N<sub>80</sub>P<sub>40</sub> level was 15.81 per cent over application of fertilizers at N<sub>40</sub>P<sub>20</sub> level.

### 3.2.7 Available NPK in soil after harvest

The data given in (Table 4) indicate that progressive increase in available N, P and K in soil after harvest was recorded with increase in vermicompost level from 1.5 and 3.0 t ha<sup>-1</sup>. Available N, P and K in soil were recorded maximum with vermicompost @ 3.0 t ha<sup>-1</sup> recorded 13.87, 15.03 and 9.16 per cent higher over vermicompost @ 1.5 t ha<sup>-1</sup>, respectively.

The irrigation method failed to produce significant variation in relation to available N, P and K in soil after harvest. Fertilizer application at N<sub>80</sub>P<sub>40</sub> recorded 6.62, 15.20 and 2.78 per cent higher available N, P, K content in soil after harvest of the crop over N<sub>40</sub>P<sub>20</sub>, respectively which

was remained at par with fertilizer at N<sub>60</sub>P<sub>30</sub>.

### 3.2.8 Economics

Data given in (Table 3) revealed that increasing vermicompost levels increased gross returns and net returns progressively. Among different vermicompost levels, maximum gross returns and net returns (148582 and 78274 ₹/ha) was recorded with application of vermicompost @ 3.0 t ha<sup>-1</sup>, which was 9.33 and 10.93 per cent higher over vermicompost @ 1.5 t ha<sup>-1</sup>. Among different treatments, maximum gross returns and net returns (129376 and 63068 ₹/ha) recorded with every furrow irrigation, which was 15.52 and 25.66 per cent higher, respectively over alternate furrow irrigation method. Among different fertilizer levels, maximum gross returns and net returns (148566 and 80418 ₹/ha) recorded with application of fertilizer at N<sub>40</sub>P<sub>20</sub> level, which was 13.72 and 24.49 per cent higher, respectively over fertilizer at N<sub>40</sub>P<sub>20</sub>.

## 4. DISCUSSION

The nutrient-rich composition of vermicompost, which enhances soil fertility and provides essential nutrients for plant growth [7,8]. He increased availability of nutrients, particularly

nitrogen, promotes tillering in cereals like barley. Similarly, the every furrow irrigation method resulted in higher tiller counts compared to alternate furrow irrigation. Adequate soil moisture availability facilitated by frequent irrigation favors tiller production and survival [9]. The increased availability of nutrients, especially nitrogen and phosphorus, from vermicompost and optimal soil moisture conditions under every furrow irrigation contributed to better spike development and grain formation [7-9]. Vermicompost application significantly increased soil organic matter content, microbial biomass, and nutrient availability, leading to improved barley growth parameters such as plant height, tiller count, and grain yield. Furthermore, vermicompost-amended plots exhibited enhanced nutrient uptake, particularly nitrogen, phosphorus, and potassium, resulting in higher grain quality in terms of protein content and nutrient composition [10]. The performance of furrow and alternate furrow irrigation techniques on barley growth and yield under semi-arid conditions. The furrow irrigation, especially every furrow irrigation, promoted better soil moisture distribution, root development, and nutrient uptake compared to alternate furrow irrigation. Consequently, barley plants subjected to every furrow irrigation exhibited superior growth attributes, increased tillering, and ultimately higher grain yield. The authors attributed these results to more efficient water and nutrient delivery to the root zone, minimizing water stress and optimizing physiological processes throughout the crop growth stages [11]. The response of barley to varying levels of nitrogen, phosphorus, and potassium fertilizers under rainfed conditions. Balanced fertilization, particularly at higher NPK levels ( $N_{80}P_{40}$ ), significantly enhanced barley growth parameters, yield components, and nutrient uptake efficiency compared to lower fertilizer doses ( $N_{40}P_{20}$ ). The importance of nutrient management in optimizing barley productivity and maximizing resource use efficiency, particularly in rainfed agricultural systems characterized by variable soil fertility and moisture availability [12]. The slow release of nutrients from vermicompost, which provides a steady supply throughout the crop growth period [8]. The long-term effects of vermicompost application on soil fertility dynamics and barley productivity in a rainfed agroecosystem. Continuous vermicompost supplementation improved soil structure, water retention capacity, and nutrient cycling, leading to sustained improvements in barley yield and quality over multiple cropping cycles. Moreover,

vermicompost-amended soils exhibited enhanced biological activity, including higher microbial diversity and enzyme activity, contributing to overall soil health and ecosystem resilience in the face of environmental stresses [13]. An economic analysis of different nutrient management practices in barley cultivation to assess their profitability and sustainability. The integrated nutrient management strategies, incorporating vermicompost application, optimized irrigation techniques, and balanced fertilizer doses, resulted in higher gross returns and net profits compared to conventional practices. The economic viability of sustainable nutrient management practices was underscored by their potential to mitigate production risks, improve resource use efficiency, and enhance farmer livelihoods in rainfed barley production systems [14]. The increased grain yield and reduced input costs associated with the use of vermicompost as an organic fertilizer [9].

## 5. CONCLUSION

Based on the study, it was found that vermicompost level, method of irrigation and fertilizer level has significant effect on no. of tillers, available N P K content in soil, yield attributes, yield, harvest and economics of barley. Among the vermicompost levels vermicompost at  $3.0 \text{ t ha}^{-1}$  recorded significantly higher N P K content in soil, no. of tillers, yield attributes, yield, harvest and economics than vermicompost at  $1.5 \text{ t ha}^{-1}$ . Methods of irrigation, every furrow irrigation recorded higher in N P K content in soil, no. of tillers, yield attributes, yield, harvest and economics than alternate furrow irrigation. Among fertilizer level, application of  $N_{80}P_{40}$  recorded significantly higher N P K content in soil, no. of tillers, yield attributes, yield, harvest and economics.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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