Growth, yield attributes and yield of barley under different levels of fertilizer and vermicompost grown underevery furrow and alternate furrow irrigation methods (*Hordeum vulgare* L.)

ABSTRACT

A field experiment was conducted during the *Rabi* season of 2021-22 at the Agronomy Research Farm of CCS Haryana Agricultural University,Hisarin a split-plot design with two vermicompost levels*i.e.*, vermicompost @ 1.5 t ha^{-1} and vermicompost @ 3.0 t ha^{-1}, two irrigation methods*i.e.*, every furrow irrigation and alternate furrow irrigation method as the main plot treatments and three fertilizer levels at $N_{40}P_{20}$, $N_{60}P_{30}$ and $N_{80}P_{40}$ $kgha^{-1}$ as subplot treatments and replicated three times.Among the vermicompost levels, vermicompost at 3.0 t ha^{-1} 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^{-1}. Among methods of irrigation, every furrow irrigation recorded significantly higher in no. of tillers,yield attributesi.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 $N_{80}P_{40}$ 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

Introduction :

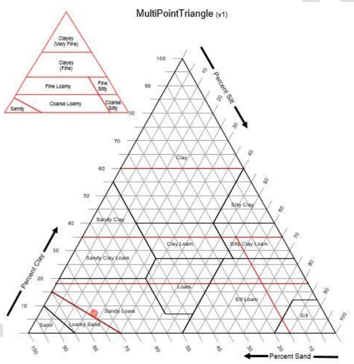
Barley (*Hordeum vulgare* L.) is an important cereal crop grown in *Rabi*season in northern plains as well as in Northern hills of India, mainly under rainfed or limited irrigation condition on poor to marginal soils. The crop is grown mostly because of its low input requirement and better adaptability to harsh environment like drought, salinity, alkalinity and marginal lands (Singh *et al*. 2016). 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^{-1} (Anonymous 2021). 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^{-1} (Anonymous 2021). The average productivity of barley in the state is far back to attainable yield of 45-50 q ha^{-1} due to water and nutritional stresses. 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 (Hussain *et al*., 2004; Wajid*et al.*, 2004). At the early growth stage, water stress has a negative impact on tillering, booting and heading.(Hossain and Akhtar (2013).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 us to save irrigation water with no grain yield reduction. AFI stimulates fine root growth and roots into deeper soil and increased root tip number and root activity surface area which increase root water uptake.

Vermicompost is an excellent soil amendment and a biocontrol agent which make it the best organic fertilizer and eco-friendly as compared to chemical fertilizers. Thus, integrated application of inorganic and organic fertilizer applied to the soil, it increases the porosity, nutrient content and helps the plant in proper nourishment. Therefore, keeping this in view, the present study entitled "Response of barley to vermicompost and fertlizer levels under alternate furrow irrigation method" was carried out under field conditions with objective to study the effect of vermicompost and fertilizer levels on plant water relation under alternate furrow irrigation method.

MATERIALS AND METHODS

The field experiment was conducted at the Agronomy Research Farm, CCS Haryana Agricultural University, Hisar which is located at 29° 10' N latitude and 75° 46' E longitude, at an elevation of 215.2 m above mean sea level in the subtropical region of Haryana in India. Hisar has a semi-arid climate, with very cold winters and hot, dry and desiccating summers. During the hot summer months of May and June, the maximum temperature is around 48°C, while the lowest temperature is around 3°C during the winter months of December and January. Area's average annual rainfall is roughly 400 mm. 70-80 per cent of which is obtained during the monsoon season from July to September. During the winter and spring, it is received in cyclic rain showers. Data revealed that 71 mm of rainfall was received during the crop growth season. The average weekly maximum and minimum temperatures vary from 14 to 41.1 ˚Celsius and 3.3 to 19.8 ˚Celsius, respectively. Morning and evening relative humidity ranged from 68 to 99 per cent and 17 to 79 per cent, respectively, on weekly basis. During the crop season, sunlight hours varied from 0.7 to 8.8 hours. Soil samples were taken from five separate locations in the experimental field, at depths of 0-15, 15-30, 30-45 and 45-60cm before sowing. Composite samples were made and analyzed for the physico-chemical characteristics of soil. Findings of the analysis along with the technique used.The soil texture of the soil under experiment was sandy loam texture (sand 75, silt 18, clay 7%) and estimated byInternational PipetteMethod (Piper,1966). The organic carbon was medium (0.43) estimated by Conductivitybridgemeter(Richards,1954). The pH of the soil is slightly alkaline (8.10) estimated by GlasselectrodepHmeter (Jackson, 1973). The EC of the soil was 0.25 dSm^{-1} (non-saline). The available N was low, P was medium and K was low and estimated by Alkalinepermanganate method(SubbiahandAsija,1956),Olsen'smethod(Olsen*etal*.,1954), Flamephotometricmethod(Richards,1954), respectively.

Fig 1 : Soil texture analysis



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

The experiment was laid in split plot design with three replications. The barley variety was BH 946. In the main plot (Vermicompost and Irrigation Methods) were taken where two levels of vermicompost levels were V1: 1.5 and V2: 3.0 t/ha. In the same plot two irrigation methods were also taken as I1: Every furrow irrigation (EFI) and I2: alternate furrow irrigation (AFI). In the sub-plot there were three levels of fertilizers were taken where F1: $N_{40}P_{20}$ kg/ha; F2: $N_{60}P_{30}$ kg/ha and F3: $N_{80}P_{40}$ kg/ha, respectively.

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^{-1}.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^{-1} 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 lengthat 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 $spike^{-1}$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 yieldafter harvesting and sun drying, the net harvested crop yield weighed in each plot was recorded and converted to kilograms per hectare (kg ha^{-1}).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^{-1}). For statistical purposes, mean values were taken

Economics(₹ ha^{-1}): The gross returns (₹ ha^{-1}) 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^{-1}) 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^{-1}).

Net returns=Grossreturns–cost ofcultivation

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

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

RESULTS AND DISCUSSION

Number of total tillers (no./m^2)

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^{-1} 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 $N_{80}P_{40}$ level was 10.14, 9.68 and 6.02 per cent at 45, 60, 90 DASover application of fertilizers at $N_{40}P_{20}$ level, respectively.

Yield attributes and yield

Number of effective tillers/m^2

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^{-1} progressively increased number of effective tillers. Vermicompost @ 3.0 t ha^{-1} recorded 12.88 per cent higher effective tillers over vermicompost @ 1.5 t ha^{-1} The increase in number of effective tillers due to every furrow irrigation was 13.68 per cent over alternate furrow irrigation.The increase innumber of effective tillers due to application of $N_{80}P_{40}$ level was 8.21 per cent over application of $N_{40}P_{20}$ level.

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^{-1} was 14.49 over vermicompost @ 1.5 t ha^{-1}. 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 $N_{80}P_{40}$ level was 21.21 per cent over application of fertilizers at $N_{40}P_{20}$ level.

Number of grains per spike

Data in (Table 2)further revealed that vermicompost @ 3.0 t ha^{-1} significantly influenced the number of grains per spike of barley by 13.85% over vermicompost @ 1.5 t ha^{-1}. 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 $N_{80}P_{40}$ level was 17.38 per cent over application of fertilizers at $N_{40}P_{20}$ level.

1000-grain weight (g)

Data in (Table 2)revealed that vermicompost @ 3.0 t $ha^{-1}$and every furrow irrigation method significantly influenced the 1000-grain weight of barley over vermicompost @ 1.5 t ha^{-1} and alternate furrow irrigation.The increase in 1000-grain weight due to application of vermicompost @ 3.0 t ha^{-1} was 10.57 per cent over application of vermicompost @ 1.5 t ha^{-1}. 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 $N_{80}P_{40}$ level was 10.92 per cent over application of fertilizers at $N_{40}P_{20}$ level.

Grain yield (kgha^{-1})

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^{-1} progressively increased grain yield. Vermicompost @ 3.0 t ha^{-1} recorded 11.00 per cent higher grain yield over vermicompost @ 1.5 t ha^{-1}. The per cent increase due to every furrow irrigation was 17.15 over alternate furrow irrigation.Application of fertilizers at $N_{80}P_{40}$ level which was remained at par with application of fertilizers at $N_{60}P_{30}$ level, recorded significantly maximum grain yield as compared to application of fertilizers at $N_{40}P_{20}$ level. The increase in grain yield due to application of fertilizers at $N_{80}P_{40}$ level was 13.02 per cent over application of fertilizers at $N_{40}P_{20}$ level.

Biological yield (kgha^{-1})

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 biological yield was obtained with vermicompost @ 3.0 t ha^{-1} recorded 10.75 per cent higher biological yield over vermicompost @ 1.5 t ha^{-1}. 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 $N_{80}P_{40}$ level was 15.81 per cent over application of fertilizers at $N_{40}P_{20}$ level.

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^{-1}. Available N, P and K in soil were recorded maximum with vermicompost @ 3.0 t ha^{-1} recorded 13.87, 15.03 and 9.16 per cent higher over vermicompost @ 1.5 t ha^{-1}, respectively. The irrigation method failed to produce significant variation in relation to available N, P and K in soil after harvest. Fertilizer application at $N_{80}P_{40}$ recorded 6.62, 15.20 and 2.78 per cent higher available N, P, K content in soil after harvest of the crop over $N_{40}P_{20}$, respectively which was remained at par with fertilizer at $N_{60}P_{30}$.

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^{-1}, which was 9.33 and 10.93 per cent higher over vermicompost @ 1.5 t ha^{-1}. 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 $N_{40}P_{20}$ level, which was 13.72 and 24.49 per cent higher, respectively over fertilizer at $N_{40}P_{20}$.

The candidate manuscript does not have a robust scientific discussion, I suggest the authors incorporate the suggested paragraphs, in this way, it would improve the scientific quality of the manuscript:

The study delineates the pivotal role of soil quality in shaping barley growth and yield. Soil serves as the primary medium for nutrient uptake (Araya-Alman et al. 2020; Campos, 2023), root development (Olivares et al. 2022a), and water retention (Olivares et al. 2022b; Lobo et al. 2023), thereby exerting profound effects on crop performance (Olivares et al. 2022c; Olivares et al. 2021a; 2021b). Notably, the application of vermicompost, a rich source of organic matter and essential nutrients, significantly enhanced barley attributes and yield. Vermicompost amendments foster soil health by improving its physical structure, enhancing nutrient availability, and promoting microbial activity, thereby augmenting crop productivity (Calero et al. 2022).

Precipitation patterns and climatic fluctuations exert pronounced effects on barley cultivation (Campos-Olivares et al. 2018; Cortez et al. 2018). Barley, being a cool-season crop, exhibits sensitivity to temperature and moisture regimes (Olivares et al. 2012; Olivares et al. 2013; Cortez et al. 2016; Viloria et al. 2023). Variations in precipitation levels, timing, and distribution profoundly influence water availability, soil moisture content, and ultimately, crop growth and yield (Olivares and Zingaretti, 2018; Olivares, 2018). Moreover, climate change-induced alterations in temperature regimes, erratic rainfall patterns, and heightened occurrences of extreme weather events pose substantial challenges to barley production (Olivares et al. 2018). Sustainable adaptation strategies, such as efficient irrigation management and resilient crop varieties, are imperative to mitigate the adverse impacts of climate change on barley productivity (Zingaretti and Olivares, 2019;Rodriguez et al. 2015).

Agronomic practices play a pivotal role in optimizing barley productivity. The study elucidates the differential impacts of irrigation methods and fertilizer applications on crop performance (Hernandez and Olivares, 2020; Hernandez et al. 2018a). Every furrow irrigation emerges as a superior water management strategy, fostering enhanced tiller development, yield attributes, and overall productivity compared to alternate furrow irrigation (Hernandez et al. 2017; Hernandez and Olivares, 2019; Hernandez et al. 2018b). Furthermore, judicious fertilizer management, particularly the application of N80P40 levels, significantly enhances barley yield by promoting robust growth, improving nutrient uptake efficiency, and maximizing grain yield potential (Hernandez et al. 2020; Montenegro et al. 2021b).

~~Productivity:~~

Productivity outcomes underscore the synergistic effects of soil amendments, irrigation techniques, and fertilizer regimes on barley yield. Optimal vermicompost supplementation, coupled with every furrow irrigation and N80P40 fertilizer application, culminates in superior productivity metrics, including increased tiller numbers, spike length, grain yield, and economic returns. These findings underscore the importance of integrated agronomic approaches in maximizing barley productivity while ensuring sustainability and resilience in the face of evolving environmental challenges (Rodriguez et al. 2013; Montenegro et al. 2021a).

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 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 t ha^{-1}. Methods of irrigation, every furrow irrigation recordedhigher in N P K content in soil, no. of tillers, yield attributes, yield, harvestand 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.

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^2)**			
	45 DAS	**60 DAS**	**90 DAS**	**At harvest**
Main plot (Vermicompost levels × Irrigation Methods)				

Vermicompost levels				
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$\pm$	9.6	14.0	10.0	9.6
CD (P=0.05)	33.2	48.4	34.4	32.8
Irrigation methods				
Every furrow irrigation	556.0	569.2	596.8	574.8
Alternate furrow irrigation	511.6	517.6	560.8	540.8
SEm$\pm$	9.6	14.0	10.0	9.6
CD (P=0.05)	33.2	48.4	34.4	32.8
Sub plot				
Fertilizer levels (kg/ha)				
$N_{40}P_{20}$	501.2	512.4	558.0	527.6
$N_{60}P_{30}$	548.0	555.2	587.2	569.6
$N_{80}P_{40}$	552.0	562.0	591.6	576.4
SEm$\pm$	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^2	**Spike length (cm)**	**Number of grains per spike**	**1000-grain weight (g)**
Main plot (Vermicompost levels × Irrigation Methods)				

Vermicompost levels				
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
Irrigation methods				
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
Sub plot				
Fertilizer levels (kg/ha)				
$N_{40}P_{20}$	418.4	6.6	35.1	34.8
$N_{60}P_{30}$	462.0	7.7	39.5	37.2
$N_{80}P_{40}$	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

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)**
Main plot (Vermicompost levels × Irrigation Methods)					
Vermicompost levels					
Vermicompost @ 1.5 t/ha	4253	9709	64308	133939	69631
Vermicompost @ 3.0 t/ha	4721	10753	70308	148582	78274
SEm±	81	181	-	-	-
CD (P=0.05)	278	624	-	-	-

Irrigation methods					
Every furrow	4842	11248	68308	153145	84837
Alternate furrow	4133	9214	66308	129376	63068
SEm±	81	181	-	-	-
CD (P=0.05)	278	624	-	-	-
Sub plot					
Fertilizer levels (kg/ha)					
$N_{40}P_{20}$	4169	9334	66048	130647	64599
$N_{60}P_{30}$	4581	10549	67728	144568	76840
$N_{80}P_{40}$	4712	10810	68148	148566	80418
SEm±	80	157	-	-	-
CD (P=0.05)	239	468	-	-	-

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_2O_5**	**Available K_2O**
Main plot (Vermicompost levels × Irrigation Methods)			
Vermicompost levels			
Vermicompost @ 1.5 t/ha	129.8	17.3	247.9
Vermicompost @ 3.0 t/ha	147.8	19.9	270.6
SEm±	3.9	0.4	5.1
CD (P=0.05)	13.6	1.3	17.8
Irrigation methods			
Every furrow irrigation	141.5	18.9	261.9
Alternate furrow irrigation	136.1	18.2	256.6
SEm±	3.9	0.4	5.1
CD (P=0.05)	NS	NS	NS

Sub plot			
Fertilizer levels (kg/ha)			
$N_{40}P_{20}$	128.9	17.1	255.0
$N_{60}P_{30}$	133.9	19.0	260.6
$N_{80}P_{40}$	137.5	19.7	262.1
SEm$\pm$	2.4	0.4	4.6
CD (P=0.05)	7.1	1.2	NS
Initial status	125.5	16.3	241.3

REFERENCES

- Anonymous2021.https://www.indiastat.com/table/agriculture/area-production-productivity-barley-india-b/1423785
- Araya-Alman, M., Olivares, B., Acevedo-Opazo, C. et al. (2020). Relationship Between Soil Properties and Banana Productivity in the Two Main Cultivation Areas in Venezuela. J Soil Sci Plant Nutr. 20 (3): 2512-2524. https://doi.org/10.1007/s42729-020-00317-8
- Campos, B. O. (2023). Banana Production in Venezuela: Novel Solutions to Productivity and Plant Health. Springer Nature. https://doi.org/10.1007/978-3-031-34475-6
- Campos-Olivares, B., Hernández, R; Coelho, R., Molina, JC., Pereira, Y. (2018). Análisis espacial del índice hídrico: un avance en la adopción de decisiones sostenibles en los territorios agrícolas de Carabobo, Venezuela. Revista Geográfica de América Central. 60 (1): 277-299. DOI: https://doi.org/10.15359/rgac.60-1.10
- Calero, J., Olivares, B.O., Rey, J.C., Lobo, D., Landa, B.B., Gómez, J. A. (2022). Correlation of banana productivity levels and soil morphological properties using regularized optimal scaling regression. Catena,; 208: 105718. https://doi.org/10.1016/j.catena.2021.105718
- Cortez, A., Olivares, B., Muñetones, A. y Casana, S. (2016). Strategic Elements of Organizational Knowledge Management for Innovation. Case: Agrometeorology

Formatted: Spanish (Spain, International Sort)

Formatted: Justified

Formatted: Portuguese (Brazil)

Formatted: Spanish (Spain, International Sort)

Formatted: Portuguese (Brazil)

Formatted: English (United States)

Formatted: Spanish (Spain, International Sort)

Formatted: Spanish (Spain, International Sort)

Formatted: Spanish (Spain, International Sort)

Formatted: English (United States)

Formatted: Spanish (Spain, International Sort)

Network. Revista Digital de Investigación en Docencia Universitaria. 10 (1): 68-81. http://dx.doi.org/10.19083/ridu.10.446

- Cortez, A., Olivares, B., Parra, R., Lobo, D., Rodríguez, M.F. y Rey, J.C. (2018). Description of meteorological drought events in localities of the central mountain range, Venezuela.Ciencia, Ingenierías y Aplicaciones. I (1):22-44. DOI: http://dx.doi.org/10.22206/cyap.2018.vlil.pp23-45.
- Guevara, E., Olivares, B., Oliveros, Y., López, L. Estimation of thermal comfort index as an indicator of heat stress in livestock production in the Guanipa plateau, Anzoátegui, Venezuela. Revista Zootecnia Tropical. 2013. 31 (3): 209-223. https://n9.cl/ovcu9
- Hernández, R., Olivares, B., (2020). Application of multivariate techniques in the agricultural land's aptitude in Carabobo, Venezuela. Tropical and Subtropical Agroecosystems, 23(2):1-12. https://n9.cl/zeedh
- Hernández, R; Olivares, B. Arias, A; Molina, JC., Pereira, Y. (2018a). Agroclimatic zoning of corn crop for sustainable agricultural production in Carabobo, Venezuela. Revista Universitaria de Geografía.,. 27 (2): 139-159. https://n9.cl/l2m83
- Hernandez, R., Olivares, B., Arias, A, Molina, JC., Pereira, Y. (2020). Eco-territorial adaptability of tomato crops for sustainable agricultural production in Carabobo, Venezuela. Idesia. 38(2):95-102. http://dx.doi.org/10.4067/S0718342920200002000095
- Hernández, R; Olivares, B., Arias, A; Molina, JC., Pereira, Y. (2018b). Identification of potential agroclimatic zones for the production of onion (Allium cepa L.) in Carabobo, Venezuela. Journal of the Selva Andina Biosphere., 6 (2): 70-82. http://www.scielo.org.bo/pdf/jsab/v6n2/v6n2_a03.pdf
- Hernández, R. Olivares, B. (2019). Ecoterritorial sectorization for the sustainable agricultural production of potato (Solanum tuberosum L.) in Carabobo, Venezuela. Agricultural Science and Technology. 20(2): 339-354. https://doi.org/10.21930/rcta.vol20_num2_art:1462
- Hernández, R; Pereira, Y; Molina, JC; Coelho, R; Olivares, B y Rodríguez, K. 2017. Calendario de siembra para las zonas agrícolas del estado Carabobo en la República Bolivariana de Venezuela. Sevilla, Spain, Editorial Universidad Internacional de Andalucía. 247 p. https://n9.cl/sjbvk
- Hussain A., Ghaudhry M.R., Wajad A., Ahmed A., Rafiq M., Ibrahim M. and Goheer A R 2004. Influence of water stress on growth, yield and radiation use efficiency of various wheat cultivars. *International Journal of Agriculture And Biology*. 6:1074-1079.

Formatted: Spanish (Spain, International Sort)

Formatted: Spanish (Spain, International Sort)

Formatted: English (United States)

Formatted: English (United States)

Formatted: Space Before: 0 pt, After: 10 pt, Line spacing: Multiple 1.15 li, Widow/Orphan control, Adjust space between Latin and Asian text, Adjust space between Asian text and numbers

Formatted: Font: (Default) Times New Roman, Font color: Black

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Field Code Changed

Formatted: Hyperlink, Font: (Default) Calibri, Font color: Auto, English (United States)

Formatted: Space Before: 0 pt, After: 8 pt, Widow/Orphan control, Adjust space between Latin and Asian text, Adjust space between Asian text and numbers

Formatted: Font: (Default) Times New Roman, 12 pt, Spanish (Spain, International Sort)

- Hossain and Akhtar 2013. Growth and yield of barley (*Hordeumvulgare* L.) as affected by irrigation, sowing method and phosphorus level.*Academia Journal of Agricultural Research* **2**(1): 030-035.
- Lobo, D; Olivares, B; Rey, J.C; Vega, A; Rueda-Calderón, A. (2023). Relationships between the Visual Evaluation of Soil Structure (VESS) and soil properties in agriculture: A meta-analysis. Scientia agropecuaria; 14 - 1, 67 - 78. https://doi.org/10.17268/sci.agropecu.2023.007
- Montenegro, E; Pitti, J; Olivares, B. 2021. Adaptation to climate change in indigenous food systems of the Teribe in Panama: a training based on CRISTAL 2.0. Luna Azul. 51 - 2, 182 – 197. https://n9.cl/qwvw
- Montenegro, E; Pitti, J; Olivares, B. 2021. Identification of the main subsistence crops of Teribe: a case study based on multivariate techniques. Idesia. 39 - 3, 83 - 94. http://dx.doi.org/10.4067/S0718-34292021000300083.
- Olivares, B., Torrealba, J. y Caraballo, L. (2013). Variability of the precipitation regime in the period 1990-2009 in the location of El Tigre, Anzoátegui state, Venezuela. Rev. Fac. Agron. (LUZ). 30 (1): 19-32. https://n9.cl/mic0l
- Olivares, B., Parra, R., Cortez, A. y Rodríguez, M.F. (2012). Patterns of rainfall homogeneity in climatic stations of the Anzoátegui state, Venezuela. Revista Multiciencias. 12 (Extraordinario): 11-17. https://n9.cl/xbslq
- Olivares, B. and Zingaretti, ML. (2018). Analysis of the meteorological drought in four agricultural locations of Venezuela by the combination of multivariate methods. UNED Research Journal. 10 (1):181-192. http://dx.doi.org/10.22458/urj.v10i1.2026
- Olivares, B. (2018). Tropical conditions of seasonal rain in the dry-land agriculture of Carabobo, Venezuela. La Granja: Journal of Life Sciences. 27(1):86-102. http://doi.org/10.17163/lgr.n27.2018.07
- Olivares, B., Hernández, R; Coelho, R., Molina, JC., Pereira, Y. (2018). Spatial analysis of the water index: advances in sustainable decision-making in Carabobo agricultural territories, Venezuela Revista Geográfica de América Central. 60 (1): 277-299. DOI: https://doi.org/10.15359/rgac.60-1.10
- Olivares, B.O.; Rey, J.C.; Perichi, G.; Lobo, D. (2022b). Relationship of Microbial Activity with Soil Properties in Banana Plantations in Venezuela. Sustainability 14, 13531. https://doi.org/10.3390/su142013531
- Olivares B, Rey JC, Lobo D, Navas-Cortés JA, Gómez JA, Landa BB. (2022a). Machine Learning and the New Sustainable Agriculture: Applications in Banana Production Systems of Venezuela. Agricultural Research Updates. 42, 133 - 157. Nova Science Publishers, Inc
- Olivares, B.O.; Vega, A.; Calderón, M.A.R.; Rey, J.C.; Lobo, D.; Gómez, J.A.; Landa, B.B. (2022c). Identification of Soil Properties Associated with the Incidence of Banana Wilt Using Supervised Methods. Plants 11, 2070. https://doi.org/10.3390/plants11152070
- Olivares B, Rey JC, Lobo D, Navas-Cortés JA, Gómez JA, Landa BB. (2021a). Fusarium Wilt of Bananas: A Review of Agro-Environmental Factors in the

Formatted: Font: Times New Roman
Formatted: Portuguese (Brazil)
Formatted: Portuguese (Brazil)
Formatted: Line spacing: Multiple 1.15 li
Formatted: Font: Times New Roman
Formatted: Spanish (Spain, International Sort)
Formatted: Spanish (Spain, International Sort)
Formatted: Portuguese (Brazil)

Venezuelan Production System Affecting Its Development. Agronomy, 11(5):986. https://doi.org/10.3390/agronomy11050986
- Olivares, B., Paredes, F., Rey, J., Lobo, D., Galvis-Causil, S. (2021b). The relationship between the normalized difference vegetation index, rainfall, and potential evapotranspiration in a banana plantation of Venezuela. SAINS TANAH - Journal of Soil Science and Agroclimatology, 18(1), 58-64. http://dx.doi.org/10.20961/stjssa.v18i1.50379
- Rodríguez, M.F., Cortez, A., Olivares, B., Rey, J.C, Parra, R. y Lobo, D Análisis espacio temporal de la precipitación del estado Anzoátegui y sus alrededores. Agronomía Tropical 2013. 63 (1-2): 57-65. https://n9.cl/14iow
- Rodríguez, M.F, Olivares, B., Cortez, A., Rey, J.C., Lobo, D. Caracterización físico natural de la comunidad indígena de Kashaama con fines de manejo sostenible de la tierra. Acta Nova. 2015. 7 (2):143-164. https://n9.cl/hakdx
- Singh, B., Dhaka, A. K., and Kumar, M. 2016. Performance of dual purpose barley varieties under different nitrogen application schedules. *Forage Research*, **41**(4): 246-248.
- Viloria, J; Olivares, B. et al. 2023. Mapping Projected Variations of Temperature and Precipitation Due to Climate Change in Venezuela. Hydrology, 10, 96. https://doi.org/10.3390/hydrology10040096
- Wajid A., Hussain A., Ahmed A., Rafiq M., Goheer A.R. and Ibrahim M 2004. Effect of sowing date and plant density on growth, light interception and yield of wheat under semi arid condition. *International Journal of Agriculture And Biology*. 6:1119-1123.
- Zingaretti, M.L Olivares, B.2019. Application of multivariate methods for the characterization of periods of meteorological drought in Venezuela. Revista Luna Azul. 48, 172:192. http://dx.doi.org/10.17151/luaz.2019.48.10