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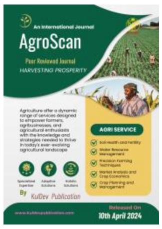

Research Article

The impact of biofertilizer on several varieties of barley (*Hordeum vulgare* L.) in an agroforestry system based on Arjun (*Terminalia arjuna*)

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ABSTRACT

At the Organic Agriculture Research Farm, Karguanji, Institute of Agricultural Sciences, Bundelkhand University Jhansi, a factorial randomized block design experiment was carried out during the rabi season to evaluate the impact of biofertilizers on various barley varieties under an Arjun-based agro-forestry system, with three treatments in the main plot and four treatments in the sub plot. Three duplicates of each treatment were conducted. Three different kinds of barley—V1-PL-58, V2-PL-426 and V3-Azad—were used in the main plot treatments, while biofertilizers B0-Control, B1-Azotobacter, B2-Phosphorous Solubilizing Bacteria (PSB) and B3-Azotobacter + Phosphorous Solubilizing Bacteria (PSB) made up the subplot treatments. Study was done on the growth, yield, and yield factors.

Introduction

An major crop grown during the rabi season in our nation is barley (Hordeum vulgare L.) (2n=14), which is mostly grown in the northern plains of Uttar Pradesh, Haryana, Rajasthan, Punjab, Madhya Pradesh, and Uttarakhand. With the exception of certain malt barley produced under contract farming, it is mostly planted as a rainfed crop on difficult, marginal, and resource-poor soils [1]. It is extensively grown in the states of Rajasthan, Bihar, and Uttar Pradesh, which together make up 52, 18, and 11 percent of the total area, respectively. The majority of the grain produced is used as flour to grind and roast grains to create "Sattu" or to make "Chapaties." Additionally, it is used to prepare malt for the production of vinegar, industrial alcohol, beer, and whiskey, among other goods. Additionally, the grains are used to make pearl and powder products, which are often included in the diets of the ill. Grain surpluses are fed to cattle. Cattle are also fed straw.

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Compared to other winter cereals, this crop requires less water and may withstand saline and alkali conditions better. As it is young, it needs chilly weather, and as it reaches maturity, it needs warm, dry weather. The crop has a very high resistance to salt and drought. An agricultural method known as agroforestry pairs crops and cattle with trees and shrubs to provide advantages for the economy, ecology, and culture [2]. Multiple advantages, including varied farm revenue, greater biological output, improved water quality, and enhanced habitat for both people and animals, are provided by the interactions between the various components of agroforestry. The goal of an effective agroforestry system would be to methodically create integrated land use practices and systems where the benefits of the relationship between crops and trees are maximized. In addition to reducing undesirable interactions between crop plants, agroforestry systems aim to achieve sustainability and lower the risks related to agriculture, regardless of the size of the operation. Finding appropriate agricultural and horticultural crops that can coexist peacefully with tree species that get less sun radiation underneath them is thus crucial [3].

Biofertilizers are microorganisms that have been cultivated and are packaged in a carrier substance for convenient field application. Living microorganisms of bacterial, fungal, and algal origin are known as bio-fertilizers [4]. Because these organisms are a very effective medium that may replace chemical fertilizers and pesticides, their usage in the agricultural sector is constantly growing [5]. Living in the rhizosphere, Azotobacter is a non-symbiotic bacterium that fixes nitrogen from the atmosphere. Because phosphorus is fixated in most soils, phosphate solubilizing bacteria are helpful bacteria that can dissolve phosphorus from insoluble substances. It has the power to release bound phosphate from the soil and give plants more of it. Applying biofertilizer to the soil improves its physical characteristics, particularly its ability to store water, and increases the soil's fertility.

With the introduction of high analysis chemical fertilizers, biofertilizers—possibly the primary supply of plant nutrients in traditional agriculture—received less attention. Though recent research suggests that judicious use of biofertilizer can better maintain the long-term soil fertility and sustain high levels of productivity, chemical fertilizer will still be the main tool for accelerating agricultural production. Because of this, using biofertilizer in the right amounts has unique importance in crop production as a supplemental and additional practice. In order to better understand how biofertilizer affects the development and production characteristics of different barley types grown in an arjun-based agroforestry system, the current research was conducted.

RESOURCES AND TECHNIQUES

The current study was conducted at the Organic Agriculture Research Farm, Karguanji, Institute of Agriculture Sciences, Bundelkhand University, Jhansi (UP), which is located in a semi-arid region of central India at an altitude of 205 meters above mean sea level and is geographically situated at 25°44' N latitude and 78°61' E longitude. The area has hot, dry summers and chilly, dry winters due to its subtropical climate. In May and June, the average maximum temperature ranges from 45.0°C to 48.0°C, while in December and January, the coldest month of the year, the average minimum temperature ranges from 4 to 10°C. Factorial randomized block design (FRBD) was used to perform the current experiment, with three treatments in the main plot and four treatments in the subplot. Three duplicates of each treatment were conducted. Three types (V1-PL-58, V2-PL-426, and V3-Azad) made up the main plot treatments, while biofertilizers (B0-Control, B1-Azotobacter, B2-Phosphorous Solubilizing Bacteria (PSB), and B3-Azotobacter + Phosphorous Solubilizing Bacteria) made up the subplot treatments. Consequently, there were 36 plots in all. The moldboard plow was used to prepare the experimental field between the rows of Arjun trees.

A cress-cross cultivator was then used, and a rotavator was used to pulverize the ground. After that, the field was split up into 36 plots in 3 replications, with space set aside for irrigation channels, paths, and distances to identify the various replications and plots. FYM and biofertilizer were combined, and the soil was treated according to the treatment plan's suggested dosage. The seeds were immediately planted and watered. To keep weeds out of the crop, two manual weedings were performed 21 and 60 days following transplanting. After 120 days of seeding, the crop was taken at maturity as more than 50% of the plants had neck fall and the plants had become yellowish with necrotic leaf tips. Harvesting was done by hand. The method of representative sampling from each plot was used to record observations. Five plants were randomly chosen, and the mean values for plant height, tiller count, leaf count, and fresh and dried leaf weight were then computed.

Factors that attribute yield

Ear length (cm): From the net plot area, five panicles that were chosen at random were harvested one at a time. From the neck node to the tip of the panicle, the length was measured in centimeters, and the average length of the panicle was then calculated.

First grain ear number: By deducting the chaffy grains from the overall number of grains, the number of grains per panicle was determined.

1000 grams of seed weight: From most of each plot, a handful of seeds were removed and thoroughly dried in the sun. To determine the weight of 1000 grains, the weight of 500 counted grains was measured in grams and the amount was doubled.

Yield of grains (q ha-1): Each net plot's harvested bundles of barley plants underwent independent threshing and winnowing processes. Plot-wise drying was done on the grain after winnowing, and their weight was then noted. The ultimate conversion of the grain production from the net plot was to quintal per hectare (q ha-1).

Straw yield (q ha-1): The sun-dried straw from the net plot area was converted into quintal per hectare (q ha-1) at a moisture level of 10% after being plot-wise weighed in kilograms.

Biological yield (qha^{-1}): For obtaining biological yield the grain and straw yield is added.

$$\text{Biological yield} = \text{Grain yield} + \text{straw yield}$$

Harvest Index: After harvest of the crop the rain were thoroughly cured for 15 days and individual plot yields were recorded and same was converted into tones per hectare.

$$\text{Harvest index (\%)} = \frac{\text{Economical yield (Grain yield)}}{\text{Biological yield (Grain yield + Straw yield)}} \times 100$$

Statistical analysis:

Using the protocol of [6], analysis of variance was performed to divide the total variance into the total variation resulting from the treatments and replications. The difference between treatments was deemed significant if the variance of the F-calculated value of (MSS (T) / EMS) for treatment was higher than the F-table value at the 5% and 1% level of significance. It was determined that there was no significant difference between the treatments if the F-calculated value was smaller than the F-calculated value. Through a comparison of derived values with Table F values at the one percent and five percent probability levels, the statistical significance of variance caused by treatments was assessed.

END RESULTS AND TALK

Height of plant (cm)

Plant height data are included in (Table 1). It was discovered that although the influence of various kinds on plant height at 30 DAS was non-significant at that point, it became significant later on. At 30 DAS, biofertilizer had no discernible impact, but maximum heights of 40.04 cm and 40.17 cm were obtained with B3-Azotobacter + PSB and V2-PL-426, respectively. However, after 60 DAS, V2-recorded the highest plant height (71.21 cm), which was statistically equal to V1-PL-58 (38.31 cm) but substantially greater to V3-Azad (67.97 cm). With B3-Azotobacter + PSB, biofertilizer produced the highest plant height (71.46 cm), which was statistically comparable to B1-Azotobacter (69.21 cm) and B2-PSB (70.23 cm), but noticeably higher than B0-control (67.46 cm).

The greatest plant height was reported at 90 DAS by V2- PL-426 (81.02 cm), which was statistically comparable to V1- PL-58 (79.72 cm) and much better than V3- Azad (77.91 cm). The maximum plant height measured by B3-Azotobacter + PSB (40.04 cm) at 90 DAS was statistically comparable to that of B1-Azotobacter (79.08 cm) and B2-PSB (80.27 cm), although it was noticeably higher than that of B0-Control (76.91 cm). With V2-PL-426, the maximum plant height was recorded; this may be because to improved nutrients' accessibility [7]. Plant height was significantly impacted by biofertilizer at progressively higher development stages. Variations in the biofertilizer led to an increase in plant height. The availability of all necessary nutrients from organic sources might be the cause [8].

Table 1 Plant height (cm) and Number of tillers at different stages of growth as affected by different treatments

Treatments	Plant height (cm)			No. of tillers / meter		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Varieties						
V_1 – PL- 58	38.31	69.58	79.72	3.08	5.40	4.22
V_2 – PL - 426	40.17	71.21	81.02	3.39	5.96	4.85
V_3 – Azad	36.76	67.97	77.91	2.98	4.37	3.70
SEm ±	1.59	1.22	1.35	0.98	0.97	0.90
CD (p=0.05)	NS	3.46	3.58	NS	2.05	1.35
Bio-fertilizers						
B_0 – Control	36.95	67.46	76.91	2.75	4.29	3.44
B_1 – Azotobacter	37.56	69.21	79.08	2.98	5.04	4.08
B_2 – PSB	39.10	70.23	80.27	3.31	5.61	4.59
B_3 – Azotobacter + PSB	40.04	71.46	81.94	3.57	6.03	4.91
SEm ±	0.56	0.98	0.95	0.85	0.82	0.78
CD (p=0.05)	NS	2.28	2.94	NS	1.96	1.28

Table 2 Number of leaves at different stages of growth and fresh and dry weight of leaves as affected by different treatments

Treatments	30 DAS	60 DAS	90 DAS	Fresh weight of leaves	Dry weight of leaves
Varieties					
V_1 – PL- 58	10.01	18.68	30.58	10.01	18.68
V_2 – PL - 426	12.20	19.54	32.65	12.20	19.54
V_3 – Azad	09.86	17.52	28.45	09.86	17.52
SEm ±	0.06	0.58	0.74	0.06	0.58
CD (p=0.05)	NS	1.75	2.20	NS	1.75
Bio-fertilizers					
B_0 – Control	9.54	16.54	28.95	9.54	16.54
B_1 – Azotobacter	10.65	17.20	30.58	10.65	17.20
B_2 – PSB	11.50	17.96	31.62	11.50	17.96
B_3 – Azotobacter + PSB	12.85	18.95	32.98	12.85	18.95
SEm ±	0.04	0.45	0.51	0.04	0.45
CD (p=0.05)	NS	1.02	1.45	NS	1.02

Tiller count (m-1)

30 days, 60 days, and 90 days after planting, observations of the number of tiller plants-1 impacted by various treatments are shown in (Table 1). At 30 DAS, the impact of one tiller plant on several kinds was found to be non-significant at first, but substantial subsequently. With V2-PL-426, the greatest number of tiller plants-1 was reported at 30 DAS (3.39). At 30 DAS, biofertilizer had no discernible impact, however B3-Azotobacter + PSB produced the highest number of tiller plants per plant (3.57). 60 DAS

How many leaves there are

Table 2 displays the observations of the number of leaves impacted by various treatments at 30, 60, and 90 days after sowing (DAS). Varieties were shown to have a non-significant influence on leaf count at 30 DAS and a substantial effect later on. Variations in the number of leaves at 30 DAS did not seem to have a substantial impact; nevertheless, V2-PL-426 (12.20) produced the highest leaf area index. The number of leaves was not significantly affected by biofertilizers either, however the highest values were found with B3-Azotobacter + PSB (12.85). A review of the average results at 60 DAS revealed a considerable impact; the highest values were obtained with V2-PL-426 (19.54), which was statistically comparable to V1-PL-58 (18.68) but still much better than V3-Azad (17.52). With the exception of B2-PSB (17.96), the effect of the biofertilizer was most pronounced with B3-Azotobacter + PSB (18.95), which was much better than the other treatments. The number of leaves on the plant is a good indicator of its photosynthetic activity [9–10].

Weight of leaves during harvest, both fresh and dried

The fresh and dry weight observations of leaves as influenced by various treatments that were noted during harvest are shown in (Table 2). It was discovered that variations had a considerable impact on the fresh and dried leaf weight. Although there was a considerable influence on the fresh weight of the leaves, the maximum fresh weight of leaves was determined with V2- PL – 426 (67.45). Additionally, biofertilizers had a notable impact on the fresh weight of leaves, while B3-Azotobacter + PSB obtained highest values (69.54). An analysis of the dry weight mean data for leaves revealed a substantial impact; the greatest values were found with V2-PL-426 (14.75), which was statistically comparable to V1-PL-58 (12.85) but still much better than V3-Azad (11.54). With the exception of B2-PSB (13.54), the effect of the biofertilizer was most pronounced with B3-Azotobacter + PSB (14.65), outperforming the other treatments by a wide margin.

Yield characteristics

Table 3 presents a summary and presentation of the average data related to yield qualities, namely ear length (cm), number of grains ear-1, grain weight ear-1, and 1000 seed weight.

Ear length (cm)

The evaluation of average data showed that ear length (in centimetres) is significantly influenced by variety. The maximum ear length measured with V2-PL-426 (6.70 cm) was statistically comparable to V1-PL-58 (6.21 cm), however it was still much longer than V3-Azad (5.25 cm). Different biofertilizers have a noticeable impact on ear length (in centimetres).

Grain count: 1

The various kinds have a considerable impact on how statistics about the number of grain ears-1 are viewed. Maximum number of grain ear-1 was recorded by V2-PL-426 (63.93), which was statistically comparable to V1-PL-58 (6.52) but still much better than V3-Azad (60.74). The number of grain ears-1 was significantly impacted by biofertilizer. The B3-Azotobacter + PSB (63.49) had the highest number of grain ears per unit, and this was statistically comparable to B1-Azotobacter (61.41) and B2 - PSB (62.52). It was also substantially better than B0 - Control (59.17).

Weight of grain, ear-1 (g)

Citing data on grain weight ear-1 showed that there are considerable differences across kinds. The highest grain weight recorded in ear-1 was V2-PL-426 (7.72 g), which was statistically comparable to V1-PL-58 (7.20 g) but still much better than V3-Azad (6.00 g). The impact of several biofertilizers on grain weight ear-1 was substantial. Maximum grain weight ear-1 was recorded with B3-Azotobacter + PSB (7.89g), which was statistically comparable to B1-Azotobacter (6.92 g) and B2 - PSB (7.46 g), and substantially better than B0 - Control (6.14 g).

Treatment	Length of ear (cm)	No. of grain ear^{-1}	Grain weight ear^{-1} (g)	1000 seed weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
V_1 – PL- 58	6.21	62.52	7.20	35.08	40.13	57.37	97.50	42.29
V_2 – PL - 426	6.70	63.93	7.72	37.65	42.74	60.56	103.30	42.45
V_3 – Azad	5.25	60.74	6.00	34.96	36.61	54.03	90.63	41.95
SEm ±	0.60	0.85	0.67	0.82	1.25	1.98	2.68	1.50
CD (p=0.05)	1.4	2.56	1.68	2.45	3.72	5.25	7.45	NS
Bio-fertilizer					37.05	52.42	89.04	41.85
B_0 - Control	5.50	59.17	6.14	34.62	38.01	54.06	92.07	42.22
B_1 - Azotobacter	5.85	61.41	6.92	35.78	39.81	57.29	96.43	42.18
B_2 – PSB	6.36	62.52	7.46	36.63	42.33	60.61	102.93	42.98
B_3 Azotobacter + PSB	6.58	63.49	7.89	37.75	0.91	1.60	2.11	1.01
SEm ±	0.50	0.72	0.53	0.79	0.91	1.60	2.11	1.01
CD (p=0.05)	1.2	2.08	1.56	2.01	2.70	4.80	6.32	NS

1000 grams of seed weight

A considerable influence on distinct types was shown by an analysis of the mean data on 1000 seed weight. Maximum weight of 1000 seeds was recorded for V2-PL-426 (37.65 g), which was statistically comparable to V1-PL-58 (35.98 g) but still much heavier than V3-Azad (34.96 g). Biofertilizer had a noteworthy impact on the weight of 1000 seeds. The B3-Azotobacter + PSB had the highest 1000 seed weight (37.75 g), which was statistically comparable to the B1-Azotobacter (35.78 g) and B2-PSB (36.36 g) but much better than the B0-Control (34.62 g). Because of the many types, yield-attributing parameters such as ear length, number of grains ear-1, grain weight ear-1, and 1000 seed weight become significant. Under V2-PL-426, the maximum values of the yield characteristics were noted. The abundance of tillering and the accessibility of room, nutrients, and light may be the cause of this [11].

Various biofertilizers had a good impact on yield-attributing features throughout the experimental year. With B3-Azotobacter + PSB, the maximum yield-attributing character values were recorded. This might be because biofertilizers provide a consistent supply of nutrients. The number of ears on a plant may be increased by the nutrients it absorbs from tillering to ear initiation [12]. The length of the ear, which has been positively impacted in the current research, was typically correlated with the number of grains ear-1 and grain weight ear-1. Grain weight and number of grains per ear rely on how well photosynthates are transferred from source (leaf) to sink (grains). Increased photosynthetic translocation will result in higher grain weight and number in ear-1. There has been a noted significant variation in ear length, grain weight, and number of grains per ear. This might be the result of the plant receiving nutrients gradually and steadily. The length of the ear, the number of grains ear-1, and the grain weight ear-1 increased when there were sufficient nutrients available throughout the development phases [13]. Although certain genetics have a role in 1000 seed weight, physiological factors and nutritional state may also have an impact. However, there was a tendency for biofertilizers to greatly increase the weight of 1000 seeds. The improved feeding of spikelets with B3-Azotobacter + PSB may be the cause of this rise in 1000 seed weight [14].

Index of Harvest and Yield

The yield and harvest index observations as impacted by the various treatments were statistically examined and condensed in (Table 3).

Yield of grains (qha-1): A detailed examination of the grain yield data revealed that different types had a significant impact. The highest grain yield, V2-PL-426 (42.74 q ha-1), was statistically comparable to V1-PL-58 (40.13 q ha-1), although it was still substantially higher than V3-Azad (36.61 q ha-1). Bio-fertilizer had a notable impact on grain give in. The combination of B3-Azotobacter + PSB produced the highest grain yield (42.33 q ha-1), which was statistically comparable to that of B2-PSB (39.81 q ha-1) and much better than that of B0-Control (36.62 q ha-1) and B1-Azotobacter (38.01 q ha-1).

Qha-1 Straw Yield: A review of the straw yield statistics revealed a noteworthy impact on several kinds. The highest yield of straw was obtained with V2-PL-426 (60.56 q ha-1), which was statistically comparable to V1-PL-58 (57.37 q ha-1), but still substantially higher than V3-Azad (54.03 qha-1). The yield of straw was significantly impacted by biofertilizer. The B3-Azotobacter + PSB combination produced the highest straw yield (60.61 q ha-1), which was statistically comparable to the B2-PSB combination (57.29 q ha-1) and much better than the B0-Control (52.42 q ha-1) and B1-Azotobacter (54.06 q ha-1).

Yield biological (q ha-1): A detailed examination of the biological yield data revealed that various types had a significant impact. V2-PL-426 (103.30 q ha-1) had the highest biological output and was statistically comparable to V1-PL-58 (97.50 q ha-1), although it was still much higher than V3-Azad (90.63 q ha-1). The biological output was significantly impacted by biofertilizer. The B3-Azotobacter + PSB combination produced the highest biological yield (102.93 q ha-1), which was statistically comparable to that of B2-PSB (96.43 q ha-1) and much better than that of B0-Control (89.04 q ha-1) and B1-Azotobacter (92.07 q ha-1).

Harvest percentage (%): The harvest index assessment mean data showed a non-significant impact on several kinds. However, V2- PL-426 (42.45%) was used to determine the maximum harvest index weight. The harvest index was not significantly affected by biofertilizer. The formula for the maximum harvest index was B3-Azotobacter + PSB (42.98%). Comparable to PL-58, the increased grain production was seen with PL-426. Because of this influence, more tillers plant-1 with heavier ears have been recorded, which has increased grain output with PL-426. Grain yield was greater when Azotobacter and PSB were applied together, but it was comparable when PSB was applied alone. Better incorporation of photosynthates into grain would be supported by the enhanced nutrient availability at different stages of photosynthesis, which would also have the advantageous impact of speeding up the yield characteristics [15].

The previous discussion made it clear that the following factors affected barley's grain yield: ear length, number of grains ear-1, grain weight ear-1, and 1000 seed weight. Barley's progressive reaction to different biofertilizers also led to an increase in grain output. The quantity of photosynthates in straw yield that are not converted is known as straw yield. Similar to grain output, the yield of straw varied greatly depending on the variety. Straw output was greater in PL-426. This might be caused by a rise in plant height, ear length, and tillers plant-1 production. can eventually result in a higher production of straw. Because PSB supplies nutrients gradually and steadily until late development stages, a greater straw yield was seen when azoctobactor and PSB were combined in the case of biofertilizer [16]. The overall yield of grains and straw is known as the biological yield. Comparable to PL-58, the greater biological output was seen with PL-426. Because of this influence, it has been feasible to record larger plant heights with heavier earlobes and more tillers per plant-1, which has increased biological yield with PL-426.

FINAL VERDICT

With regard to growth and yield under an arjun-based agroforestry system, barley variety PL-426 and a biofertilizer combination of Azotobacter with PSB exhibit the best results, taking into account the variability in the current soil, nutrient supply and dynamic crop nutrient demand along with competition at different growth stages.

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