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Effect of Bio-fertilizer on Different Barley (*Hordeum vulgare* L.) Varieties under Arjun (*Terminalia arjuna*) based Agroforestry System

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A B S T R A C T

An experiment was conducted during rabi season in factorial randomized block design at Organic Agriculture Research Farm, Karguaanji, Institute of Agricultural Sciences Bundelkhand University Jhansi to assess the effect of biofertilizers on different varieties of barley under Arjun based agro-forestry system with 3 treatments in main plot and 4 treatments in sub plot. The treatments were replicated three times. The main plot treatments consisted of three varieties of barley namely V_1- PL-58, V_2- PL-426 and V_3- Azad whereas subplot treatment consisted of biofertilizers B_0- Control, B_1– Azotobacter, B_2– P hosphorous Solubilizing Bacteria (PSB) and B_3 – Azotobacter + Phosphorous Solubilizing Bacteria (PSB). The growth, yield and yield parameters were studied.

***Key words*:** *Hordeum vulgare*, Biofertilizers, Agroforestry system, Harvest index, Yield parameters

Barley (*Hordeum vulgare* L.) (2n=14) is an important crop of rabi season in our country especially covering the northern plains of Uttar Pradesh, Haryana, Rajasthan, Punjab, Madhya Pradesh and Uttarakhand. It is mainly grown as a rainfed crop in problematic, marginal and resource poor soils except some malt barley under contract farming [1]. It is widely cultivated in states of Uttar Pradesh, Rajasthan and Bihar which accounts approximately 52, 18 and 11 percent of the total area, respectively. The major portion of grain produced is consumed as flour to prepare "Chapaties" or to make "Sattu" by roasting and grounding grains. It is also used to prepare malt for manufacturing beer and whisky and other products such as industrial alcohol and vinegar. The grains are also used for preparing pearl and powder products which generally form the diet of sick people. Surplus grains are used as cattle feed. Straw is also fed to cattle. The crop needs less water and is more tolerant to salinity and alkali condition than other winter cereals. It requires cool weather during early growth and warm and dry weather at maturity. The crop possesses very high tolerance to drought and salt.

Agroforestry is a farming system indicating crop and livestock with trees and shrubs in order to obtain economic, environmental, ecological and cultural benefits [2]. Particularly interactions among different components of agroforestry provides multiple benefits i.e., diversified farm income, increased biological production, better water quality and improved habitat for both humans and wildlife. An efficient agroforestry system would aim at systematically developing integrated land use systems and practices were the positive in tractions between trees and crop are encouraged and maximized. Agroforestry systems are designed for beneficial interactions of the crop plants and to reduce unfavorable interaction, these are designed to reduce the risks associated with agriculture whether on small scale or large as well as to attain sustainability. Therefore, there is a great need to identify the suitable agricultural and horticultural crops, which can grow well along with tree species with limited solar energy underneath the trees [3].

The cultured microorganisms packed in some carrier material for easy application in the field are called biofertilizers. Bio-fertilizers are living microorganisms of bacterial, fungal and algae origin [4]. Usage of these organisms in agriculture sector is incessantly increasing because it serves as a very effectual medium as a substitute of pesticides and chemical fertilizers [5]. Azotobacter is a non-symbiotic bacteria capable of fixing atmospheric nitrogen by living within the rhizosphere. Phosphate solubilizing bacteria are beneficial bacteria capable of solubilizing phosphorus from insoluble compounds as most of the soils are deficient in phosphorus due to its fixation. It has ability to solubilize the bound phosphate in the soil and increase its ability to the plant.

The application of biofertilizer in the soil helps in increasing the fertility of the soils as well as ameliorating physical condition including its water holding capacity.

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Biofertilizers, which were perhaps the major sources of plant nutrients in traditional agriculture, received less emphasis with the advent of high analysis chemical fertilizers. Without detracting from the fact that chemical fertilizer will continue to be main instrument for quickening the pace for agricultural production the recent researches indicate that a judicious use of biofertilizer can better maintain the long-term soil fertility and sustain high levels of productivity. Therefore, use of biofertilizer in appropriate proportion, assume special significance as complementary and supplementary to each other in crop production. Hence, the present study was undertaken to study the effect of bio-fertilizer on growth and yield attributes of barley varieties under arjun based agroforestry system.

MATERIALS AND METHODS

The present investigation entitled was carried out at Organic Agriculture Research Farm, Karguaanji, Institute of Agriculture Sciences, Bundelkhand University, Jhansi (UP) which is geographically situated at 25°44' N latitude and 78°61' E longitude and at an altitude of 205 meters above mean sea level in semi-arid tract of central India. The site has sub-tropical climate characterized by hot dry summers and cool dry winter. The average maximum temperature during the month of May- June varies between 45.0°C to 48.0°C, while the average minimum temperature varies between 4 to 10°C during December-January, which is the coldest period of the year. The present experiment was conducted in factorial randomized block design (FRBD) with 3 treatments in main plot and 4 treatments in sub plot. The treatments were replicated three times. The main plot treatments consisted of three varieties V_1- PL-58, V_2- PL-426 and V_3- Azad whereas subplot treatment consisted of biofertilizers B_0- Control, B_1- Azotobacter, B_2- Phosphorous Solubilizing Bacteria (PSB) and B_3- Azotobacter + Phosphorous Solubilizing Bacteria (PSB). Thus, total number of plots were 36. The experimental field was prepared in between the rows of Arjun trees by ploughing with moldboard plough followed by cress-cross cultivator operation and finally pulverized by the rotavator. Then the field was divided into 36 plots in 3 replication keeping provision for irrigation channels path and distance to mark different replications as well as plots. Biofertilizer was mixed with FYM and applied in soil as per recommended dose in treatment plan. Seeds were sown and irrigated immediately. Two hand weeding were done at 21 and 60 days after transplanting to keep the crop free from weeds. The crop was harvested at maturity at 120 days after sowing, as the plants turned yellowish with necrotic leaf tips coupled with neck fall in more than 50% plants. Harvesting was done manually. For recording of observations, the technique of representative sampling from each plot was adopted with random selection of five plants then, mean values were calculated for plant height, number of tillers, number of leaves and fresh and dry weight of leaves.

Yield attributing parameters

Length of ear (cm): Five panicles randomly selected from the net plot area were harvested separately. The length of panicles were measured in centimeter from the neck node to its tip and finally the average length of panicle was worked out.

Number of grain ear^{-1}: Number of grains per panicle was calculated by subtracting the chaffy grains from total number of grains.

1000 seed weight (g): Handful seed were taken from the bulk of each plot and well dried in sun. The weight of 500 counted grains were taken in g and the value is doubled to get 1000-grain weight.

Grain yield (q ha^{-1}): Harvested bundles of barley plants from each net plot were threshed and winnowed separately. After winnowing the grain was dried plot wise and then their weight was recorded. The grain yield obtained from net plot was finally converted into quintal per hectare (q ha^{-1}).

Straw yield (q ha^{-1}): The sun-dried straw obtained from net plot area was weighted plot wise in kg and converted into quintal per hectare (q ha^{-1}) separately at 10 percent moisture level.

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

Biological yield = Grain yield + 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: Analysis of variance was done for partitioning the total variance into total variation due to the treatments and replications according to procedure of [6]. If the variance of F-calculated value of (MSS (T) / EMS) for treatment was greater than the F-table value at 5% and 1% level of significance, the variance between treatments was considered to be significant. If the F-calculated value is less than F-calculated value, the differences between treatments were considered to be non-significant. Statistical significance of variation due to treatments was tested by comparing calculated values to Table F values at the one per cent and five per cent level of probability.

RESULTS AND DISCUSSION

Plant height (cm)

The data on plant height is depicted in (Table 1). the effect of different varieties on increasing plant height at 30 DAS was found non- significant at 30 DAS and significant at later stages. Bio-fertilizer caused non-significant effect at 30 DAS whereas maximum height was recorded with B_3- Azotobacter + PSB (40.04cm) and V_2- PL-426 (40.17 cm). However, at 60 DAS maximum plant height was recorded with V_2- (71.21 cm) which was significantly superior over V_3- Azad (67.97 cm) while statistically at par with V_1- PL- 58 (38.31 cm). Biofertilizer showed maximum plant height with B_3- Azotobacter + PSB (71.46 cm) which was statistically at par with B_1- Azotobacter (69.21 cm) and B_2- PSB (70.23 cm) but significantly superior over B_0- control (67.46 cm). At 90 DAS V_2- PL – 426 (81.02 cm) recorded the maximum plant height while remaining statistically at par with V_1- PL- 58 (79.72 cm) and significantly superior over V_3- Azad (77.91cm). B_3- Azotobacter + PSB (40.04 cm) recorded maximum plant height at 90 DAS which was statistically at par with B_1- Azotobacter (79.08 cm) and B_2- PSB (80.27 cm) but significantly superior over B_0- Control (76.91cm). Maximum plant height was observed with V_2-PL-426, this might be due to better availability of nutrients [7]. Biofertilizer affected the plant height up to significant level at successive growth stages. Plant height increased with variation in biofertilizer. It may be due to availability of all essential nutrients from organic source [8].

Number of tillers m^{-1}

Observations of number of tiller $plant^{-1}$ as affected by different treatments recorded at 30, 60 and 90 days after sowing are presented in (Table 1). The effect of number of tiller $plant^{-1}$ on different varieties at 30 DAS were found non-significant and significant at later on stages. At 30 DAS maximum number of tiller $plant^{-1}$was recorded with V_2- PL- 426 (3.39). Bio-fertilizer caused non-significant effect at 30 DAS whereas maximum number of tiller $plant^{-1}$was recorded with B_3- Azotobacter + PSB (3.57). At 60 DAS maximum number of tiller $plant^{-1}$was recorded with V_2 - PL – 426 (5.96) and it was significantly superior over V_3 - Azad (4.37) while statistically at par with V_1-PL- 58 (5.40). Biofertilizer showed maximum number of tiller $plant^{-1}$ with B_3- Azotobacter + PSB (6.03) which was statistically at par with B_1– Azotobacter (4.044) and B_2- PSB (5.61) but significantly superior over B_0- Control (4.29). At 90 DAS V_2- PL – 426 (4.85) recorded the maximum number of tiller $plant^{-1}$ while remaining statistically at par with V_1- PL- 58 (4.22) and significantly superior over V_3- Azad (3.70). B_3-Azotobacter + PSB (4.91) recorded maximum plant height at 90 DAS which was statistically at par with B_1- Azotobacter (4.08) and B_2- PSB (4.59) but significantly superior over B_0-Control (3.44). Periodical observations on number of tillers $plant^{-1}$ revealed that tillers $plant^{-1}$ increase up to 60 DAS and there after declining trend was observed irrespective of treatments. Maximum tillers $plant^{-1}$ was recorded at 60 DAS with V_2- PL-426 and biofertilizer B_3- Azotobacter + PSB this may be due to better utilization of moisture, nutrient and bulkiness provided from the organic sources to the soil.

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

Number of leaves

The observations of number of leaves as affected by different treatments recorded at 30, 60 and 90 days after sowing (DAS) are presented in (Table 2). The effect of varieties on number of leaves was found non-significant at 30 DAS and significant at later on stages. At 30 DAS differences among number of leaves was showed non- significant effect however, highest leaf area index was calculated with V_2- PL– 426 (12.20). Bio-fertilizers also showed non-significant effect on number of leaves however, maximum values recorded with B_3-Azotobacter + PSB (12.85). An appraisal of mean data at 60 DAS showed significant effect, maximum values recorded with V_2- PL – 426 (19.54) which was statistically at par with V_1- PL-58 (18.68) while remain significantly superior over V_3- Azad (17.52). Effect of biofertilizer was recorded maximum with B_3-Azotobacter + PSB (18.95) which was significantly superior over rest of the treatments except B_2- PSB (17.96). The photosynthetic activity of the plant is well reflected in the number of leaves [9-10].

Fresh and dry weight of leaves at harvest

The observations of fresh and dry weight of leaves as affected by different treatments recorded at harvest are presented in (Table 2). The effect of varieties on fresh and dry weight of leaves was found significant. Among fresh weight of leaves sowed significant effect however, highest fresh weight of leaves was calculated with V_2- PL – 426 (67.45). Biofertilizers also showed significant effect on fresh weight of leaves however, maximum values recorded with B_3- Azotobacter + PSB (69.54). An appraisal of mean data of dry weight of leaves showed significant effect, maximum values recorded with V_2- PL – 426 (14.75) which was statistically at par with V_1- PL- 58 (12.85) while remain significantly superior over V_3- Azad (11.54). Effect of biofertilizer was recorded maximum with B_3- Azotobacter + PSB (14.65) which was significantly superior over rest of the treatments except B_2– PSB (13.54).

Yield attributes

The mean data pertaining to yield attributes viz. length of ear (cm), Number of grain ear^{-1}, grain weight ear^{-1} and 1000 seed weight have been summarized and presented in (Table 3).

Length of ear (cm)

An appraisal of mean data indicated that different varieties have significant effect on length of ear (cm). Maximum length of ear was recorded with V_2- PL – 426 (6.70 cm) which was statistically at par with V_1- PL- 58 (6.21 cm) while remain significantly superior over V_3- Azad (5.25cm). Various Bio-fertilizers produces significant effect on length of ear (cm).

Number of grains ear^{-1}

The perusal of data regarding number of grain ear^{-1} gets significantly affected by different varieties. V_2- PL – 426 (63.93) recorded maximum number of grain ear^{-1} which was statistically at par with V_1- PL- 58 (6.52) while remain significantly superior over V_3- Azad (60.74). Bio-fertilizer indicated significant effect on number of grain ear^{-1}. Highest number of grain ear^{-1} was noted with B_3- Azotobacter + PSB (63.49) which was significantly superior over B_0 – Control (59.17) while statistically at par with B_1 – Azotobacter (61.41) andB_2 – PSB (62.52).

Grain weight ear^{-1} (g)

Citation of data regarding grain weight ear^{-1} reveled that different varieties differs significantly. Maximum grain weight ear^{-1} were weighted with V_2- PL – 426 (7.72 g) which was statistically at par with V_1- PL- 58 (7.20 g) while remain significantly superior over V_3- Azad (6.00 g). Among different bio-fertilizer sowed significant effect on grain weight ear^{-1}. Maximum grain weight ear^{-1} was noted with B_3- Azotobacter + PSB (7.89g) which was significantly superior over B_0 – Control (6.14 g) while statistically at par with B_1 – Azotobacter (6.92 g) andB_2 – PSB (7.46 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 seed weight (g)

An appraisal mean data on 1000 seed weight revealed significant effect on different varieties. Maximum 1000 seed weight was noted with V_2- PL – 426 (37.65 g) which was statistically at par with V_1- PL- 58 (35.98 g) while remain significantly superior over V_3 - Azad (34.96g). Bio-fertilizer indicated significant effect on 1000 seed weight. Highest 1000 seed weight was noted with B_3-Azotobacter + PSB (37.75 g) which was significantly superior over B_0- Control (34.62 g) while statistically at par with B_1 – Azotobacter (35.78 g) and B_2 – PSB (36.36 g). Yield attributing characters viz. length of ear, Number of grain ear^{-1}, grain weight ear^{-1} and 1000 seed weight reach to the level of significance due to different varieties. Maximum values of yield attributes were recorded under V_2-PL-426. This might be due to profused tillering and availability of space, nutrients and light [11]. Yield attributing characters were positively influenced by different biofertilizer during the year of experimentation. Maximum values of yield attributing characters were registered with B_3-Azotobacter + PSB. This might be due to steady supply of nutrient through bio-fertilizers. The nutrient absorbed by plant from tillering to ear initiation helps to increase the number of ears [12]. The number of grain ear^{-1}, grain weight ear^{-1} were generally associated with length of ear, which has been favorably affected in present study. Number of grain ear^{-1} and grain weight ear^{-1}depends upon on the efficient translocation of photosynthates from source (leaf) to sink (grains). Higher translocation of photosynthates more will number of grain ear^{-1} and grain weight ear^{-1}. Significance difference in length of ear, number of grain ear^{-1}, grain weight ear^{-1} has been registered. This might be due to slow and steady supply of nutrient to the plant. The adequate availability of nutrient during the growth stages increased the length of ear, number of grain ear^{-1}and grain weight ear^{-1} [13]. 1000 seed weight is a partially a genetic character however, nutrient status and physiological conditions may affect. Although, biofertilizers showed a tendency to increase 1000 seed weight significantly. This increase in 1000 seed weight may be due to better nutrition of spikelets with B_3-Azotobacter + PSB [14].

Yield and harvest index

Observations on yield and harvest index as influenced by different treatments were statistically analyzed and summarized in (Table 3).

Grain yield (qha^{-1}): A close scrutiny of data regarding grain yield reveled that different varieties produced significant effect. Maximum grain yield was recorded with V_2- PL – 426 (42.74 q ha^{-1}) which was statistically at par with V_1- PL- 58 (40.13 q ha^{-1}) while remain significantly superior over V_3- Azad (36.61 qha^{-1}). Bio-fertilizer indicated significant effect on grain yield. Highest grain yield was recorded with B_3- Azotobacter + PSB (42.33 q ha^{-1}) which was significantly superior over B_0- Control (36.62 q ha^{-1}) and B_1- Azotobacter (38.01 q ha^{-1}) while statistically at par with and B_2- PSB (39.81 q ha^{-1}).

Straw yield (qha^{-1}): A perusal of data regarding straw yield sowed significant effect on different varieties. Maximum straw yield were recorded with V_2- PL – 426 (60.56 q ha^{-1}) which was statistically at par with V_1- PL- 58 (57.37 q ha^{-1}) while remain significantly superior over V_3- Azad (54.03 qha^{-1}). Bio-fertilizer indicated significant effect on straw yield. Highest straw yield was recorded with B_3- Azotobacter + PSB (60.61 q ha^{-1}) which was significantly superior over B_0- Control (52.42 q ha^{-1}) and B_1- Azotobacter (54.06 q ha^{-1}) while statistically at par with andB_2- PSB (57.29 q ha^{-1}).

Biological yield (q ha^{-1}): A close scrutiny of data regarding biological yield reveled that different varieties produced significant effect. Maximum biological yield was recorded with V_2- PL – 426 (103.30 q ha^{-1}) which was statistically at par with V_1- PL- 58 (97.50 q ha^{-1}) while remain significantly superior over V_3- Azad (90.63 q ha^{-1}). Bio-fertilizer indicated significant effect on biological yield. Highest biological yield was recorded with B_3- Azotobacter + PSB (102.93 q ha^{-1}) which was significantly superior over B_0- Control (89.04 q ha^{-1}) and B_1- Azotobacter (92.07 q ha^{-1}) while statistically at par with and B_2- PSB (96.43 q ha^{-1}).

Harvest index (%): An appraisal mean data on harvest index revealed non-significant effect on different varieties. However, maximum harvest index weight was calculated with V_2- PL – 426 (42.45%). Bio-fertilizer indicated non-significant effect on harvest index. Maximum harvest index was calculated with B_3- Azotobacter + PSB (42.98%). The higher grain yield was recorded with PL-426 which was comparable to PL-58. This impact has made it possible to record more numbers of tillers plant^{-1} with heavier ears contributing to higher grain yield withPL-426. Application of Azotobacter along with PSB registered the higher grain yield, however it was at par with PSB separately. The increased availability of nutrients at distinct photosynthesis phases would have support for better assimilation of photosynthates towards grain and also due the favorable effect of accelerating the yield attributes [15]. From the fore going discussion, it become apparent that length of ear, Number of grain ear^{-1}, grain weight ear^{-1} and 1000 seed weight played an important role in deciding the grain yield of barley and their progressive response to various biofertilizers resulted in increased grain yield. Straw yield is the amount of photosynthates not converted in straw yield. Like grain yield, straw yield also differed significantly due to different varieties. PL-426 recorded the higher straw yield. This might be due to increased production of tillers plant^{-1}, plant height and length of ear. Which ultimately contribute to increased straw yield. In case of biofertilizer higher straw yield was recorded with the combination of azoctobactor and PSB and it was comparable to PSB due to its slowly and steady supply of nutrient up to late growth phases [16]. Biological yield is the total yield of grain and straw yield. The higher biological yield was recorded with PL-426 which was comparable to PL-58. This impact has made it possible to record more numbers of tillers plant^{-1} and plant height with heavier ears contributing to higher biological yield with PL- 426.

CONCLUSION

Considering the variability in existing soil, nutrient supply and dynamic crop nutrient demand along with competition at various growth stages, barley variety PL-426 and biofertilizer combination of Azotobacter with PSB shows best results in terms of growth and yield under arjun based agroforestry system.

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